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A Guide for Cost-Effectiveness and Cost-Benefit Analysis of State and Local Ground Water Protection Programs

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Preface

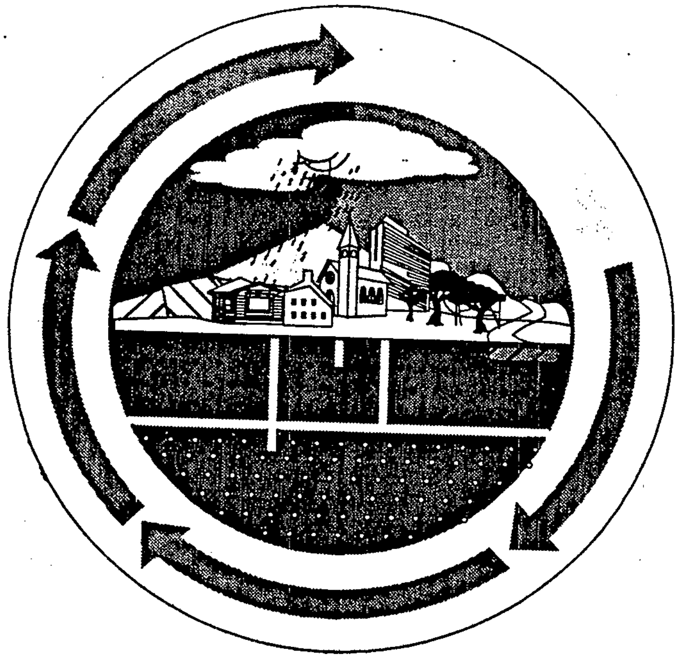
This *Guide for Cost-Effectiveness and Cost-Benefit Analysis of State and Local Ground Water Protection Programs* is one of the first in a series of assistance documents that EPA will release in support of Comprehensive State Ground Water Protection Programs (CSGWPPs). The Final Comprehensive State Ground Water Protection Program Guidance was released in January 1993. This guide will assist states in developing Strategic Activity #2 of the CSGWPP Guidance, "Establishing Priorities." States will need to establish priorities for both prevention and remediation activities under a CSGWPP.

A CSGWPP will efficiently allocate resources according to the state's priorities in ground water protection through the coordination of federal, state, and local ground water programs. Economics can be used as a tool for effective decision-making in this effort by allowing the ground water program manager to consider a program's full range of costs and benefits to the community. It can also be used to justify ground water protection decisions to the public, the state legislature, or the federal government.

This guide will familiarize state and local ground water program managers with the tools of economic analysis. It will also show how these tools can be used to evaluate ground water programs through cost-effectiveness or cost-benefit analysis. Case studies show the practical application of cost analysis, cost-effectiveness analysis, and cost-benefit analysis. A bibliography is included if a program manager needs further information on any of these subjects.

Ground water protection decisions are made based on political, environmental, and social factors. Economics is a way to help choose among options, or to determine the cost or benefit of a certain option, but protection decisions cannot be based solely on a cost-benefit analysis. State and local governments know that their citizens demand ground water protection. The laws that they pass give program managers a stewardship responsibility to protect ground water beyond simple economic analyses. In addition, program managers must take into account societal equity in distributing the expenses and advantages of environmental protection. This includes protecting the resource for future generations.

Economic analysis is a tool for decision-making. As long as it is used with the other decision-making tools, it can prove very useful for ground water protection decisions.



1. Introduction

Any action that a community or state takes to protect its ground water resources will have consequences for the people living in the area, for business and industry, and for state and local governments. These consequences can be environmental, economic, social, or political. They can also be negative ("costs") or positive ("benefits"), and are often inter-related. For example, a local government may enact a stringent regulation to improve the quality of ground water as a source of drinking water. This action may impose economic hardship on a local industry, thus threatening its viability. On the other hand, the same regulation may attract new industries that depend on a source of clean ground water.

To make the best use of resources and to have the greatest impact on the environment, a program manager needs to prioritize his or her actions based on these consequences. When designing a new ground water protection program or action, a program manager must consider all of the possible consequences and incorporate them into the decision making process. This will allow for a more accurate assessment of a program's broad impact.

Several tools exist to evaluate the consequences of ground water protection programs, including economic, environmental, political, and sociological impact analyses. ***Economic analysis*** is a decision-making tool that planners can use to identify, measure and quantify the economic impacts of existing and planned programs, to compare the impacts across programs, and to estimate their importance. This guidebook shows you how to assess these costs and then how to use two methods that formally incorporate economic considerations into ground water protection decisions: cost-effectiveness analysis and cost-benefit analysis.

- ☐ ***Cost assessment*** is the tool that is used as the basis for the more detailed cost-effectiveness and cost-benefit analyses. It allows you to identify the costs associated with a program, select the most appropriate ones to include in the assessment, and estimate the program's costs.

- ☐ ***Cost-effectiveness analysis*** is most often used to compare actions with the same objective and decide which of them will have the most effect for the funds expended. It is also used to evaluate a single option's ability to attain a quality standard or given amount of pollution prevention under a fixed budget.

- ☐ ***Cost-benefit analysis*** is simply a comparison of a program's costs and benefits, which can be expressed as a ratio or as net benefits (by subtracting costs from benefits). This form of analysis is generally used to determine the value of a particular program.

Why Use Economic Analysis?

One of the indispensable tools ground water protection managers use to make difficult program decisions is environmental analysis, which examines how actions affect the physical environment. Economic analysis provides a different perspective by analyzing the monetary effects of programs.

Developing estimates of the costs, benefits, and cost-effectiveness of ground water protection programs (or obtaining a better understanding of the estimates of others) provides ground water program managers with several advantages:

- ☐ *Efficient Decision-Making*

  Economic analysis allows you to make decisions that consider the full range of costs and benefits to your community or state. These include both the program's direct impacts (e.g., the amount by which pollution levels are reduced per dollar spent) and indirect impacts (e.g., the loss of tax revenue due to the relocation of businesses or higher property value because of the desirability of living near a clean ground water source).

- ☐ *Efficient Use of Resources*

  Your program can make the most efficient use of limited financial resources by using economic analysis. This tool can help you to choose among options for reaching a ground water protection goal on the basis of cost-effectiveness. Without this analysis, the goal may still be achieved, but at greater expense than necessary. By placing resources where they can have their greatest impact, valuable funds can be used for other programs. This tool also helps minimize the economic consequences for your community or state.

- *Priority Setting*

  Economic analysis helps you to set priorities for your community or state's ground water protection actions. EPA's Ground Water Protection Strategy recognizes the importance of this, stating that prioritization actions should consider the use, value, and vulnerability of a resource, as well as its social and economic values. Priority setting is also one of the six strategic activities of a Comprehensive State Ground Water Protection Program, which will coordinate federal, state, and local ground water protection efforts.

- *Program Justification*

  When ground water protection programs are being proposed, they have the potential to affect a great many interests, including the community's residents, businesses, developers, industries, other government agencies, and environmental groups. Economic analysis can help you justify your program to these parties by providing an objective and consistent evaluation of the costs and benefits involved.

What Expertise Do I Need to Conduct These Analyses?

You do not need to be an economist to use this guidebook. The information provided here is intended to familiarize you with the concepts of economic analysis. It also gives you the information necessary to determine the type and level of analysis that will be most useful for your area's ground water protection program. Some users of this guidebook will feel it is too detailed; others may want more detail. This guidebook can help users with more basic or simple analyses by giving them a framework, setting aside details that may not be important to their level of analysis. For those users wanting more detail, references are provided.

This guidebook describes a few important and frequently used tools that you can apply to help answer a basic question: What should I do to protect my area's ground water supply? Although many of the terms introduced here may be unfamiliar to you, you will recognize that many of the actions they represent are already part of your office's activities. The case studies that accompany Chapters 4 through 6 are examples of economic analyses that have already been conducted by ground water protection offices throughout the United States.

1. Introduction

Because of the large number of technical and non-technical issues that are involved in economic analyses of ground water protection programs, you may also want to seek assistance from your state Superfund, RCRA, or other programs on such technical matters as selecting a remediation approach. The bibliography at the end of this guidebook provides a list of the papers and books published on a wide variety of technical and non-technical matters related to ground water protection and economic analysis.

Will I Need to Hire Consultants?

As an economic analysis becomes more precise, it also becomes more complex. If you find that the level of analysis required is beyond the analytical capabilities of your office, it may be desirable to bring in expert assistance. The decision to retain a consultant is subjective and depends largely on the method and level of analysis selected, the degree of precision desired, the availability of information and data, and the specializations and numbers of professionals within your office.

Regardless of the extent to which you use consultants--from estimating specific costs to conducting the entire analysis--it will be advantageous to become familiar with the concepts presented in this guidebook. At a minimum, the method of analysis you select should suit your program's needs. The more familiar you are with the economic analysis process, the more actively you can participate and contribute valuable information. A collaborative effort between your office and its consultants will ultimately produce the most accurate results and ensure that they are used well.

How Should I Use This Guidebook?

This guidebook addresses a series of steps in economic analysis. Each chapter represents a step in the process, beginning with preparing for an economic analysis and ending with conducting cost-effectiveness and cost-benefit analyses. (Although the cost-effectiveness and cost-benefit chapters are comprehensive in their outline of important analysis steps, they do not devote weighty attention to the steps covered in detail in previous chapters. They do, however, make it clear when and where you should refer for more information.)

This guidebook is designed to be read as a whole. If you are fairly familiar with economic concepts and elect to read only a particular section or chapter, you should be able to do so with reasonable comprehension. However, you may have to refer to other chapters when directed to do so, in order to fully understand a step or concept, and how it fits into the framework of the analysis. The general theme of each chapter and the major issues it addresses are described below.

- *Chapter 2: Preparing for the Economic Analysis*

  This chapter helps you set clear goals and objectives for your ground water protection program and then to develop a program or program options. These, in turn, will help you select the most appropriate method of analysis for your program. This chapter also presents some useful pointers for achieving a balanced and consistent analysis.

- *Chapter 3: Establishing the Baseline*

  Before initiating a new ground water protection program, it is necessary to carefully analyze the present and future ground water situation in your area under current levels of protection. This step is useful for determining a program's costs, benefits, or effectiveness.

- *Chapter 4: Assessing the Costs*

  Cost assessment is a necessary element for both cost-effectiveness and cost-benefit analysis. The decisions made on a ground water protection program will depend, to some extent, on its costs to the program office, industry, and community. This chapter describes the different types of costs associated with ground water protection programs, the appropriate costs to include in the analysis, and the appropriate estimation techniques used to measure costs.

- *Chapter 5: Analyzing Cost-Effectiveness*

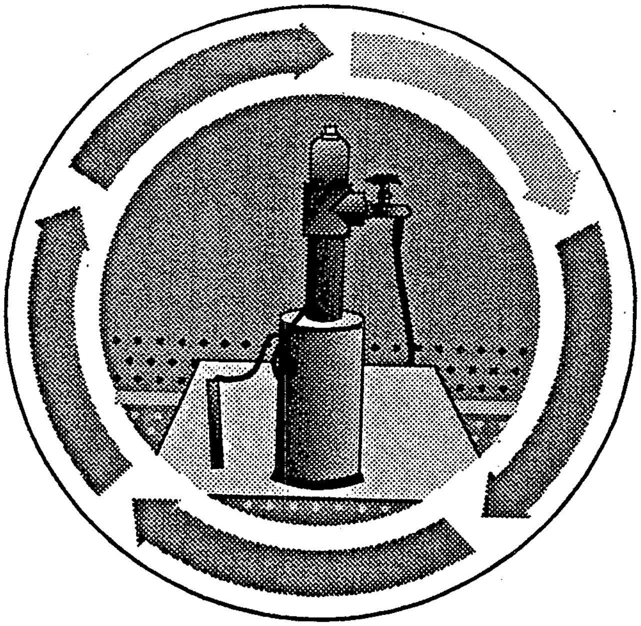
  This chapter addresses the uses and limitations of cost-effectiveness analysis, and the various ways it can be expressed in the context of ground water protection programs. A step-by-step guide to cost-effectiveness analysis is also provided.

- ☐ *Chapter 6: Analyzing Cost-Benefits*

  This chapter discusses the appropriate use of cost-benefit analysis. It also describes several types of benefits that result from protecting ground water resources.

Following Chapter 6, glossary is provided for the technical terms used in this guidebook. The bibliography at the end of the guidebook will point you to some useful sources of more detailed information on a given subject.

Last, it is important to stress that this guidebook does not present any hard and fast rules for conducting an economic analysis, nor does it dictate your choice of a specific type of analysis. Rather, once you have become familiar with the concepts presented here, you will be able to choose the best type of analysis based on the circumstances of your program and community, and the resources of your ground water protection office.



2. *Preparing for the Economic Analysis*

Economic analysis allows you to quantify the impacts of a program or action in terms of dollars or some other measure (e.g., parts per billion of contamination). Once the impacts are quantified, you can then compare them with the impacts of alternative programs or evaluate the effects of policy changes across programs. Using economic analysis, you can examine a program with regard to how its value is being defined and by whom, who will pay the costs of protection, who will benefit from protection efforts, and on whose behalf your ground water protection office is acting.

In order to use economic analysis effectively, it is first necessary to set clear goals and objectives for your program, and then to develop a program or a number of program options. The goal, objectives, and program options should, at the very least, reflect a comprehensive understanding of the current and reasonably expected uses of ground water, the ground water protection problem your community or state is facing, and the potential impacts of the program (this can be done through Strategic Activity #2 of the Comprehensive State Ground Water Protection Program). Once these are well established, you can select the most appropriate type(s) of economic analysis to conduct.

A hypothetical example of the steps taken in preparing for the economic analysis is given at the end of this chapter. To help illustrate the concepts presented in this guidebook, this example is carried through each of the remaining chapters.

Define the Ground Water Protection Program

Set a Goal

The first step in defining your ground water protection program is to set its *goal*, which is simply a statement of what the program hopes to accomplish. It generally declares for whom or for what purpose the ground water is being protected (e.g., community health, industrial processes), and may also identify the sources of contamination the program intends to protect against (such as pesticides or leaking underground storage tanks).

A program goal may be specific, such as "ensuring county residents of an adequate and safe water supply through the year 2000," or far broader, such as "implementing ground water protection measures in an effort to avoid future contamination problems." The specificity of a program goal will most likely reflect a community's perception about a potential threat to its ground water supply.

Set Objectives

The second step is to set the program's *objectives*, which are statements of what your ground water protection actions intend to accomplish. These are often specific and are expressed as quantities, such as the units or levels of pollution prevention achieved per dollar spent, the dollar cost per unit of pollution prevention achieved, or a program that generates maximum benefits as a percentage of total cost. The objectives can also be more general, such as establishing a county-wide program to ensure safe drinking water to private wells, or protection from a specific contaminant for a specific cost.

Establishing quantified objectives serves two main purposes. First, they strengthen and lend legitimacy to program decisions. When program managers must justify their programs to state and local officials, public interest groups, or other private entities, objectives help explain what will be achieved when the program is implemented. Second, objectives help managers to limit the number of program options to be evaluated, thus saving time and effort. For example, establishing a minimum ground water quality standard may eliminate some protection program options from consideration based on their ineffectiveness.

Define Options

The third step is to define the program's *options*, which are the alternative actions (or components) that could be undertaken to meet the program's goal and objectives. These include, for example, permit requirements to restrict aquifer discharges, underground storage tank safety measures, ground water monitoring, zoning, administration, and enforcement. Options can include both different components and different levels of implementation for similar components. The feasibility of each option will depend on who the program will affect and how severely, and a number of legal, social, and political considerations in addition to its economic impacts.

Identify Impacts

The final step before undertaking an economic analysis of a ground water protection program's options is to identify all of the economic and non-economic impacts of each component. This does not require extensive research or knowledge in each discipline, only a thoughtful evaluation of the component. Program managers should carefully think through the implications of each component, and the program options as a whole, to ensure that they have a clear understanding of what their impacts will be. The questions below will help you explore all of the impacts that might accrue to various parties:

- ☐ How does the proposed ground water protection program or component affect the severity or extent of potential ground water contamination?

- ☐ Does the proposed program or component directly address the potential for adverse effects resulting from ground water contamination?

- ☐ Who or what does the proposed program or component directly affect, including the surface water ecosystem? Who does it indirectly affect? Asking these questions specifically may uncover costs and benefits that were not immediately obvious.

- ☐ What is the timing of the impacts that will result from the program or component? Because timing differences can significantly affect the value of the costs and benefits of a ground water protection program, program mangers should think of both its long- and short-term effects.

All of these factors must be considered for all components or options within a single, finite time frame, such as 20 or 30 years. This will allow you to compare each option from the same beginning point and over the same period, and make the evaluation of costs, benefits and effects easier and more consistent.

Choose the Appropriate Method of Analysis

Economic analysis is only one among many decision tools; others include environmental, political, and sociological impact analysis. However, because economic analysis allows the impacts of a program to be more easily quantified than these other, inter-related types of analysis, it is often the preferred method of assessing the value of a protection program to the community.

For example, evaluating the compliance costs of a program in relation to the effectiveness or benefits of various options will foster the design of a program that will achieve a desired environmental impact with the least amount of adverse economic impact.

2. *Preparing for the Economic Analysis*

Economic analysis is useful in helping managers to improve their program decisions. From the perspective of the ground water program itself, such analysis will help managers make the best use of their limited resources. From a broader perspective, it will minimize the economic impact on the community affected, and presumably reduce the associated political and sociological impacts. And finally, economic analysis will provide additional information to help managers justify their program.

Within economic analysis are several techniques that have been widely employed or have gained acceptance as providing useful information to the decision process. Three of these techniques are examined in this guidebook: cost assessment, cost-effectiveness analysis, and cost-benefit analysis.

Cost assessment can be used alone or in conjunction with the other two techniques. The value of cost-benefit and cost-effectiveness analyses lies in their comparison of costs to other critical factors. The appropriate method depends on an evaluation of the information available to the program manager and an assessment of the needs and resources of the community or state.

Cost Assessment

Cost assessment can be of value when it is used independently. This technique is most useful as a preliminary analysis in situations where program managers know what party or parties will be expected to pay for the ground water protection program, and when the costs to those parties are expected to be excessive. Under such circumstances, it may be helpful to begin with a cost assessment in order to narrow the range of program options, or to dismiss a program based on its excessive cost. Once this has been accomplished, the effects or benefits of the remaining options can be assessed using cost-effectiveness or cost-benefit analysis.

Cost-Effectiveness Analysis

This type of analysis is appropriate when a program manager wants to compare alternative program options that address the same objective in order to determine which of them will have the greatest effect for the funds expended. Cost-effectiveness analysis is also useful in evaluating a single program option for its ability to attain a quality standard or threshold of pollution prevention given a fixed budget. The cost-effectiveness of protection programs can be expressed in a number of ways, including:

- ☐ units (or levels) of pollution prevention achieved per dollar spent
- ☐ units (or levels) of pollution prevention achieved for programs of equal cost
- ☐ dollar cost per unit (or level) of pollution prevention achieved
- ☐ dollar cost of programs that prevent equal units (or levels) of pollution.

Cost-Benefit Analysis

This technique is appropriate when the decision maker wants to determine the value of a particular program; it is typically employed when it is necessary to decide whether to implement a ground water protection program or one of its components. In the context of cost-benefit analysis, value is represented in one of two ways:

- ☐ the ratio of benefits to costs
- ☐ net benefits, which are calculated by subtracting costs from benefits.

Define the Scope of the Analysis

Before you conduct an economic analysis, it is necessary to define its scope (i.e., identify who and what should be included in the analysis and who and what should be excluded). Without a clear definition of scope, the analysis may become too complex or will overlook important considerations.

For example, suppose a community's ground water protection program results in companies relocating to that community to take advantage of its "guaranteed" source of clean ground water. Clearly, there will be some costs and benefits for the community if the companies move there. But what about the communities from which the companies relocated? Should they be included in the analysis? What if they relocated from another state or another country? It is easy to see how the analysis might become too complicated if program managers try to incorporate too many effects into their economic analysis. Conversely, a poorly defined scope might lead managers to exclude costs and benefits that realistically should be included in the analysis.

A clearly defined scope will ensure that all potentially affected or interested parties are properly addressed, that the analysis covers the correct geographic area, and that all appropriate effects (e.g., costs) are included. The scope of the program will be influenced by a number of issues that are of concern to program managers, either by choice or as a consequence of public policy. These include:

- ☐ the constituency for whom the analysis is being undertaken
- ☐ the budget constraints of the program office
- ☐ the extent to which the program may affect an industry or community disproportionately
- ☐ the economic stability of an industry or community potentially affected by a program
- ☐ the geographic boundaries within which a program will be implemented
- ☐ the severity of an environmental threat in the absence of a protection program.

Hypothetical Example

The following pages contain a hypothetical example that illustrates how a ground water protection program is defined and how to choose an appropriate level of economic analysis. This example is then carried through Chapters 3 through 6 to assist you in conducting each of the three types of economic analysis described in this guidebook.

The example concerns the fictional Fairhomes County (population 500,000), which is located in the northwest part of the state. The county relies almost entirely on ground water for its water supply, although it contains numerous lakes and several small streams that support recreational use. At present, there are 200 public water supply wells and about 25,000 private wells in use in the county. Seventy-five percent of the County's water is provided for residential use, 18 percent for commercial and industrial use, and 7 percent for agricultural and other uses.

The County has experienced considerable residential and industrial growth in the last decade. Its ground water contamination, although currently limited to shallow private wells, is a concern given the likelihood of future growth as well as the County's reliance on ground water resources. In 1991, the County began developing a comprehensive ground water management plan. The exhibit on the next page summarizes how the County went about defining the plan and the way in which it analyzed alternatives for implementing it.

At present, there is one area of approximately 50 homes that is affected by the acute ground water contamination of private wells. The contamination originated from a leak in an above-ground tank at a petroleum tank farm. The leaking tank has been drained, but the existing contamination of the ground water will likely remain for some time.

Hypothetical Example: Preparing for the Economic Analysis

Defining a Ground Water Protection Program

☐ ***Goal:*** To ensure a safe and adequate supply of ground water for all existing and future needs in the County.

☐ ***Objectives:*** Establish a County-wide ground water protection program that ensures adequate and safe supplies in a manner that is cost-effective and/or results in the maximum net benefits for the County as a whole.

☐ ***Options:***

Protection Program #1:	Increased ground water monitoring efforts, especially near public water supply wells. Additional emphasis on inspections and enforcement. Remediation of water supplies that become contaminated.
Protection Program #2	New zoning restrictions, primarily affecting public supply well and recharge areas, but also limiting industrial/commercial development in residential areas. Additional standards and requirements for current businesses. Outreach and technology transfer programs aimed at businesses. Industrial property transfer approvals.

☐ ***Impacts:***

The program manager identified the impacts of the two alternative protection strategies to address possible future contamination. These impacts are as follows:

Protection Program #1

In the event that contamination does threaten the County's water supplies, the program should eliminate or reduce substantially the actual contamination that occurs. Other impacts are:

Defining a Ground Water Protection Program

- County residents, through higher taxes and direct assessments, pay for administrative, monitoring, enforcement, and if appropriate, remediation costs.
- Businesses may face increased fines and other complaince costs.
- Property values would change.

Protection Program #2

The program should decrease or eliminate the threat of contamination, particularly with respect to the public supply wells, where the zoning and technical standards will have the greatest impact. The impacts are:

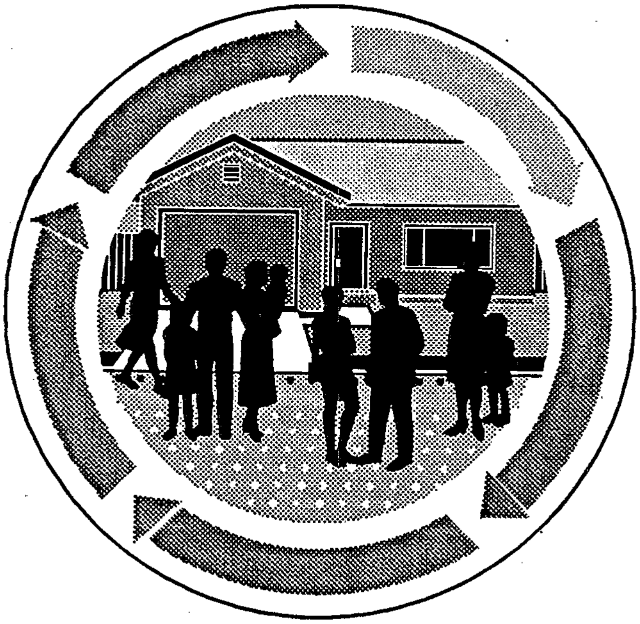
- Businesses face higher compliance costs and some business relocation may occur due to zoning restrictions.
- County residents pay for the costs of administering zoning, technological studies, and outreach programs.
- Property values may change.

Choosing the Appropriate Method of Analysis

☐ ***Cost Assessment:*** This method will be used to determine the costs of all potential program components.

☐ ***Cost-Effectiveness Analysis:*** The County will conduct a cost-effectiveness analysis of the two alternative programs.

☐ ***Cost-Benefit Analysis:*** The County will also conduct a cost/benefit analysis of the two alternative protection programs.



3. *Establishing the Baseline*

The baseline is a starting point for an economic analysis of a ground water protection program. It is necessary so that the analyses of all options start from the same position. The baseline is defined as an assessment of the ground water resource situation with no additional protection programs or program elements.

The baseline calculation includes the costs as well as the effects (e.g., incremental level of contaminants) that result from the current program as it responds to contamination. The purpose of the baseline is to ensure that you include only the incremental (additional) impacts of the proposed program in your analysis.

Establishing the baseline involves defining or predicting:

- ☐ the present condition of the ground water resource
- ☐ the future condition in the absence of any additional program elements
- ☐ the action that will be taken in response to the future condition under the existing program
- ☐ the condition of the ground water after the action has been completed.

These tasks require that the manager make assumptions about what might occur in the absence of any additional ground water protection efforts. In doing so, it is often useful to develop several scenarios with different assumptions, and then estimate the baseline in terms of best- and worst-case scenarios.

3. Establishing the Baseline

Four steps are involved in establishing the baseline. These are:

- ☐ Step 1: Define the baseline
- ☐ Step 2: Quantify the baseline
- ☐ Step 3: Consider factors that increase or decrease baseline estimations
- ☐ Step 4: Incorporate probability into the baseline calculation.

Step 1: Define the Baseline

No Action Scenario

The baseline can be defined under two scenarios. In the first, it is assumed that no action will be taken in response to future contamination. For example, suppose that a community is facing the likelihood that the quality of its ground water will diminish to the point that it will be unsafe for drinking in 20 years. Under this scenario, the baseline must include the costs of having unsafe drinking water (e.g., increased costs for individuals to buy bottled water, lost property tax revenues, business relocation, increased health risks). While this is considered to be a true "do nothing approach," it may inaccurately estimate the baseline because few communities are likely to ignore such future contamination. In other words, a community is unlikely to allow people to consume contaminated drinking water indefinitely.

Action Scenario

Because the true "no action" scenario is unlikely, a program manger will probably choose to use the second, or "action" scenario, for the baseline calculation. In this scenario, the baseline is defined assuming that some action would be taken under the existing program in response to contamination. The baseline under this scenario would include the total costs of responding to the contamination, plus any costs associated with the contamination occurring before the response action is taken. If, for example, several public water supply wells are forced to close due to contamination from abandoned drums of hazardous waste, the baseline should incorporate the costs associated with losing the wells in addition to the costs of removing the buried drums.

If you assume that the response to contamination is not entirely successful (that is, some additional contamination occurs in spite of the remedial action taken), you should also include these costs in the baseline. In the previous example, if after removing the drums and any contaminated soils, another public supply well becomes contaminated, the costs associated with the newly contaminated well must be included in the baseline.

The Time Frame

Baseline estimates must be calculated over a defined period of time that coincides with the life of the proposed ground water protection program. The Office of Management and Budget recommends that federal programs be evaluated on a 30-year basis. State and local ground water program managers may choose another period of time to accommodate their circumstances and the information available to them.

Step 2: Quantify the Baseline

Quantifying the baseline refers to estimating its impacts. The baseline can be quantified in two respects: its costs and its effectiveness.

Baseline Costs

Baseline costs include the total costs of responding to contamination and the costs of contamination (if any) that occur in spite of the response. The most common elements of these baseline costs are:

- ☐ treatment costs (i.e., the cost of remediating ground water contamination)
- ☐ replacement costs (i.e., the cost of providing safe drinking water)
- ☐ damage costs (i.e., the cost of contamination effects).

It is important when calculating the baseline that these costs not be double counted. For example, if you include the estimated cost of remediation in the baseline, you should include the only cost of contamination for the period before the remediation is completed. Similarly, the baseline cost cannot include the cost of contamination *and* the cost of providing safe water, unless there will be a time lag between the detection of the contamination and the provision of safe drinking water. These are discussed in more detail below.

Treatment Costs

The costs associated with remediating contaminated ground water can be large, and depend on the type of remedy selected. They include the cost of obtaining and maintaining the remediation equipment and staff necessary to conduct the remediation.

3. Establishing the Baseline

There are two general types of remedial activities. The first is *active restoration*, which includes such measures as extraction and treatment, and in-situ treatment. It is favored in cases where the contaminants present are mobile, there are moderate to high hydraulic conductivities in the contaminated aquifer, and effective treatment technologies are available. This type of activity includes physical, chemical, and biological treatment methods.

The second type is *containment through hydraulic control*, which relies on measures to physically prevent or control the spread of contaminants by installing pumping wells, subsurface drains, slurry walls, and the like. Containment is favored when the ground water is naturally unsuitable for consumption, when there is low projected future demand for the water, contaminants are of low mobility or concentrations, there is a low potential for exposure, or the aquifer has low transmissivity. These actions are generally less expensive than active restoration.

Because the selection of a remediation approach is a complex process, you may wish to involve staff from the Superfund or RCRA programs to help develop remediation scenarios. There are also numerous documents that contain information on remediation technologies and their costs (see the bibliography for examples).

Replacement Costs

As an alternative to responding to contamination via treatment, your program may call for simply replacing contaminated ground water supplies. In such a case, the costs of replacement must be included in the baseline. You must also decide whether the likely method for replacement will include hooking up to an existing alternative supply, drilling new wells, or providing water from another source (e.g., bottled water).

It is possible that your baseline will include both replacement and treatment costs. For example, if you supply bottled water to individuals affected by contamination before treatment systems are installed, these costs must be included in the baseline. You may want to rely on staff from your state or community health and environmental protection agencies to help you develop plausible assumptions about the costs of providing safe drinking water until remediation, if undertaken, would allow a return to the original source.

Damage Costs

Damage costs are incurred by affected parties as a result of ground water contamination and might include the following:

- *Adverse Health Effects.* Quantifying these effects is a complex task. Although it may not be possible to quantify them precisely, it is necessary to identify these effects and factor them into the baseline. This can be done using a risk assessment, which is discussed in detail in Chapter 6.

- *Aesthetic, Environmental, and Property Damages.* Although techniques for estimating these costs have not been fully developed, both the contingent valuation and hedonic property value methods are useful; these are presented in Chapter 6.

- *Economic Dislocation.* If the contamination of ground water would cause an industry to relocate, then the lost jobs and tax revenue that result are considered to be costs. For example, if the contamination of a wellfield means that three companies will relocate, the number of jobs these companies provide must be multiplied by their salaries and then by the tax rate to yield the income tax revenues lost.

- *Litigation Expense.* Any of the above effects may lead to litigation against a state or community. To estimate litigation expenses, it is necessary to make assumptions about the likelihood of liability suits and multiply this probability by an average figure for damages awarded in similar suits.

To calculate the baseline under the action scenario, you must make certain to include only those damage costs that are incurred in spite of the response taken to address contamination; otherwise, you will over-estimate the baseline. For example, suppose that a community estimates the total cost of ground water contamination in terms of health effects, lost jobs, lower property values, etc., to be $20 millon under the no action scenario. The ground water protection manager, believes, however, that under the action scenario, existing monitoring and remediation programs will respond to the contamination long before it reaches such dramatic proportions. The program manager estimates that these remedial actions will decrease the extent of contamination, resulting in fewer adverse health effects and less economic displacement, thereby reducing the cost of these changes to $5 million. Adding these damage costs of responding to contamination yields the baseline costs under the action scenario.

3. *Establishing the Baseline*

Baseline Effectiveness

In the context of ground water protection, effectiveness refers to the impact that a program (or no program) has on the quality of the resource. Effectiveness can be quantified in several ways, including the occurrence of pollution in absolute terms, units (or level) of pollution (e.g., ppb), or units (or level) of pollution prevented.

In quantifying the baseline effectiveness, the program manager predicts the occurrence or level of pollution that is likely to result in the absence of any additional program. This prediction will be based largely on professional judgment and experience in monitoring ground water resources. By quantifying the effectiveness of the baseline, the ground water protection manager can ensure that when conducting a cost-effectiveness analysis of a program, only the incremental effects of the program are considered.

For example, if a program manager estimates that existing treatment systems would result in concentrations of 50 ppb of a particular hazardous constituent in groundwater, this concentration serves as a baseline from which to measure the effectiveness of an alternate treatment strategy or protection program.

Step 3: Consider Factors that Increase or Decrease Baseline Estimations

Factors Affecting Baseline Costs

The ability to estimate the costs of remediating contaminated ground water, providing safe drinking water, and contamination effects depends on a knowledge of local factors, as well as assumptions about the extent and severity of local contamination, and the parties affected.

- ☐ *Extent of Contamination.* As a rule of thumb, the more widespread the contamination might be, the more expensive the remedial actions will be. In estimating the likely extent of either the "no action" or the "action" contamination baseline, you may use a single worst-case scenario or several scenarios ranging from mild to severe. The choice of scenarios will depend on the program options being considered. For example, in a small community served by three or four public water supply wells and numerous private wells, a worst-case scenario might involve the loss of all wells. On a state level, however, it is unlikely that all water wells would be lost. A worst-case scenario in this case might assume that the state would be forced to establish new sources of drinking water within its borders.

- *Severity of Contamination.* This will affect the level, and thus the costs, of the response required. For example, so long as contaminants in drinking water do not reach concentrations above the maximum contaminant levels (MCLs), the water might still be used for drinking and the remedial actions required might include only intensified monitoring and limiting certain activities in the wellhead area. However, when contamination exceeds MCLs, more costly remedial actions might be required. Thus, the assumptions made about the short-and long-term severity of contamination scenarios will have an impact on the baseline cost estimates.

- *Affected Parties.* The individuals who incur costs because of ground water contamination are called the "affected parties." Determining which parties should be included in a contamination cost estimate can be a thorny issue and will have a direct impact on the estimate. For example, if the contamination of a wellfield might prompt a local manufacturing firm to leave the community, the cost of contamination would be under-estimated if this possibility is ignored. At the state level, however, it is safe to ignore if the industry simply moves from one city to another within the state.

  The identification of affected parties raises both equity and fairness issues. Such issues may make it more or less reasonable for a particular group of people to bear the costs of a program or program component, or the costs if a program is not implemented. However, the debate of such issues is largely a political matter; economic analysis can only provide additional information to assist in evaluating the impacts of political decisions.

Factors that Influence Baseline Effectiveness

Accurately quantifying baseline effectiveness will depend largely on the program manager's knowledge and experience with similar ground water resource conditions.

- *Physical Characteristics.* The hydrology, geology, topography, and climate of the ground water resource and its surrounding area should be considered.

3. *Establishing the Baseline*

- ☐ *Extent of Existing Program.* The age, expected life, and quality of an existing ground water program's physical capital assets must be considered when estimating baseline effectiveness and benefits. You may assume the shortest life expectancy of the physical assets or a probable range given that some upgrades will be made at marginal cost. It is also necessary to factor in the probability of having enough future budget appropriations to satisfy the financial needs of an existing program.

- ☐ *Future Trends.* To the extent that changes in population and industry growth can be forecast, they should be considered in quantifying future contamination. However, it should not necessarily be assumed that growth in an area will result in increased ground water contamination. For example, if your area will experience commercial, rather than industrial growth, ground water contamination may be expected to decline, depending on the rate of change and volume of new development.

Step 4: Incorporate Probability into the Baseline Calculation

Once you have estimates of baseline costs and/or effectiveness, it is still possible that the baseline is biased. This is because it is not possible to be certain that ground water contamination will occur, or reach a predicted level, in the absence of an additional protection program. Intuitively, this fact will lead to overstating baseline costs and understating baseline effectiveness. These exaggerated impacts can be accounted for by incorporating probabilities into the calculation.

Program managers should realize that even with detailed data, estimating the likelihood of future events is not a precise science. In addition, it may not be possible or practical to obtain data that can assist in making probability calculations. To overcome these problems, you may elect to make a simple uniform assumption of 100 percent probability of contamination. Such an assumption can be interpreted as a worst-case scenario.

Incorporating Probability in Baseline Cost

To incorporate probability into the baseline cost calculation, you must multiply the cost of contamination by the probability of contamination (or a level of contamination) occurring. The result of this calculation is called the "***expected cost.***" The higher the probability of contamination occurring or reaching a predicted level, the higher the expected cost.

For example, if the cost of contamination is $1 million, but it has a 50 percent probability of occurring, the expected cost would be $500,000. But if the probability is 90 percent, then the expected cost is $900,000. Note that while the expected cost changes as the likelihood of contamination changes, the full cost of contamination remains at $1 million. (It is necessary to assign a probability of contamination that is greater than zero; otherwise, the full cost of contamination would be $0.)

Incorporating Probability in Baseline Effectiveness

The probability that contamination (or a level of contamination) will occur in the absence of an additional program will vary based on the assumptions you make about the factors that increase or decrease effectiveness. As is the case with baseline costs, multiplying the estimated measure of baseline effectiveness (e.g., the level or concentration of a contaminant or group of contaminants) by the probability of contamination yields the expected baseline effectiveness.

Calculating Probabilities of Contamination

Alternatively, you may elect to assume different probabilities that contamination will occur and examine their effects on the baseline cost and effectiveness calculation. This is called ***sensitivity analysis***.

A sensitivity analysis should begin by making assumptions about the factors that increase or decrease the baseline costs or effectiveness. Then, the probability of contamination or contamination level should be determined based on these assumptions. For example, based on assumptions about an aquifer's physical characteristics, the condition and extent of the existing program, and future population trends, you might conclude that there is a 90 percent chance that 10 percent of your community's wells will become contaminated. The next step is to change some of the initial assumptions and determine a new probability accordingly.

Incorporating probability into the baseline can have a dramatic impact on both the costs and effectiveness of the baseline, and thus, on the cost-benefit and cost-effectiveness analyses of ground water protection programs. Therefore, you should try to base these probability estimates on historical or empirical evidence (e.g., studies of past contamination incidents) to the maximum extent possible. For example, detailed hydrogeological surveys of the extent and rate of migration of a contamination plume may allow you to predict with greater certainty, the likelihood that certain wells will be affected.

*Hypothetical Example: Establishing the Baseline**

For Baseline Costs

Step 1: Define the Baseline

☐ ***Scenario:*** The action scenario was chosen for the baseline. The actions to be taken in response to contamination include replacing water supplies in areas with private wells affected by contamination and installing treatment systems at several public water supply wells.

☐ ***Time Frame:*** 30 years.

Step 2: Quantify the Baseline

Samples taken from private water supply wells in the County indicate that approximately 200 private wells in one community could be threatened by rising contamination levels. To address this contamination, the County would choose to replace the ground water, first by providing bottled water and eventually by constructing extensions from public supply systems. The costs are as follows.

One-Time Costs:

Transmission main extensions: 20 miles of extensions x $275,000/mile	$5,500,000
Piping, pumps, and hookups to 200 houses: Average distance of 3,750 ft x $50/ft x 200 houses	$37,500,000
Bottled water until construction is completed (1 year): 200 homes x 4 people/ home = 800 people Each person consumes 2 liters of water/day = 1,600 liters/day or 584,000 liters in a year x $.60/liter	$350,000
Estimated 5% decline in property values of 200 homes valued at $100,000 each	$1,000,000
Total	$44,350,000

For Baseline Costs (cont.)

Step 2: Quantify the Baseline (cont.)

Well sampling data also indicate that several public supply wells may be threatened by contamination from industrial sources. Because of the importance of these wells to the County's overall water use, the County would install treatment systems to keep these wells in operation rather than shutting them down. The costs of these treatment systems are as follows:

One-Time Costs:

Installation of treatment systems: $1,700,000 per system x 20 wells	$34,000,000

In addition to these one-time capital costs, the program manager estimates that the County will incur some additional annual costs. These costs include:

Annual Costs:

Property tax revenue loss: 4.5% per year x total decline in property values of $1,000,000	$45,000/year
Additional County staff resources (e.g., hydrogeologists, enforcement personnel, engineers) and equipment costs	$2,300,000/year
Total one-time costs:	$78,350,000
Total annual costs:	$4,345,000 per year

For Baseline Costs (cont.)

Step 3: Consider Factors that Increase or Decrease Baseline Estimations

The program manager evaluated the potential extent and severity of contamination, as well as the affected parties, to consider how these factors might change the baseline.

☐ ***Extent of Contamination:*** If the extent of contamination increases (i.e., more wells are contaminated) with respect to either public or private wells, the baseline will increase. Conversely, if the extent is less, both elements of the baseline costs will decrease.

☐ ***Severity of Contamination:*** Assuming that the contamination of the private wells does occur, the severity of this contamination will have little effect on these costs because the water supplies will be replaced regardless of the level of contamination. However, changes in the severity could increase or decrease treatment costs at public supply wells if cheaper/more expensive treatment technologies are required or if less/more operations and maintenance costs are incurred.

☐ ***Affected Parties:*** Currently, the program manager has not accounted for business relocation and lost jobs due to contamination, primarily because there are few potentially affected businesses in the proximity of the private wells, and because firms using the public supply system will still have access to clean ground water from other wells. If the businesses become major affected parties (e.g., if the costs of obtaining water from the public supply system go high enough to force some companies to relocate or go out of business), baseline costs could rise.

The program manager believed that the severity and affected parties could have only a marginal effect on costs in either direction. And because in deriving the initial baseline cost estimates, the program manager relied on consultation with expert staff, engineering cost estimates, professional experience, and available ground water data, the program manager was reasonably confident about the accuracy of the estimates.

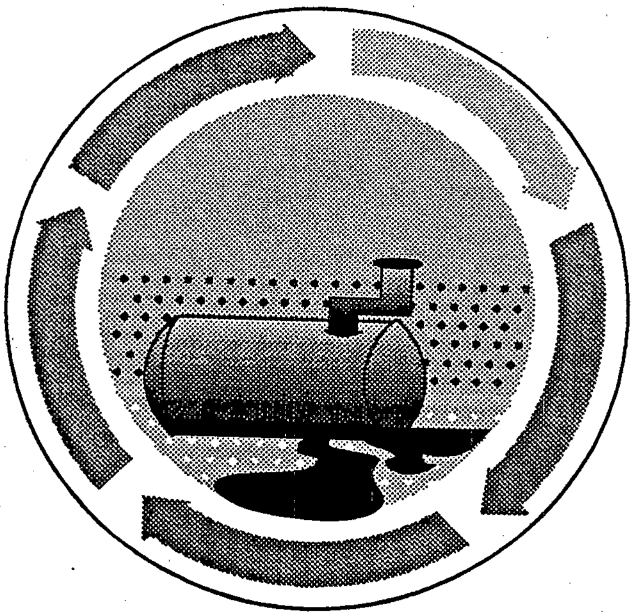
Step 4: Incorporate Probability into the Analysis

To simplify the analysis, the program manager decided to take a conservative approach and assume a 100% probability of contamination (i.e., a worst-case scenario)

3. *Establishing the Baseline*

For Baseline Effectiveness
Step 1: Define the Baseline
☐ ***Scenario:*** As before, the action scenario was chosen for the baseline.
☐ ***Time Frame:*** 30 years
Step 2: Quantify the Baseline
The County's ground water protection manager decided to evaluate the cost-effectiveness of the two programs on a per capita basis (i.e., how many people are protected and at what cost). To ensure that only the incremental effects of the programs are measured, the program manager established a baseline number of people affected by contamination. As was the case in the baseline cost calculation, the program manager assumes that 800 people could be affected by the contamination of private wells. If each private well is assumed to service one household of 4 people, the County's private wells serve 100,000 people, leaving its remaining 400,000 residents being served by public wells. Assuming, as before, that 20 public wells (10 percent) are likely candidates for contamination and that on average, each public well supplies about the same number of people, then 10 percent of the population served by public supply wells, or 400,000 people are likely to be affected by the contamination of 10 percent of the public wells.
Step 3: Consider Factors that Increase or Decrease Baseline Effectiveness
The program manger believes that the zoning program places more emphasis on private wells (i.e., through restrictions on development near residential areas) than does the monitoring/remediation program. Therefore, changes to the baseline effectiveness relating to private wells could have a slightly larger impact on the relative cost-effectiveness of the zoning program. However, because the number of private well users (800) potentially affected by contamination under the baseline is so small relative to the number of public supply well users (400,000), the program manager elects to disregard the likely minor impact that such changes to baseline effectiveness might have.
Step 4: Incorporate Probability into the Analysis
As before, the probability of contamination is assumed to be 100%.

* In this hypothetical example, some of the costs are presented as one-time costs, while others are expressed on an annual basis. In conducting an economic analysis, it is necessary to express all costs as either one-time or annual costs. Chapters 4 and 6 discuss "amortization" and "present value" concepts that can be used to convert costs into either annual or one-time costs.



4. *Assessing the Costs*

An important factor that affects a decision to protect ground water is the costs that a protection program imposes on the community, local industry, and the ground water program office. Assessing these costs is a fundamental step in determining the program's potential effectiveness and in comparing its costs and benefits.

The cost assessment process entails three steps: selecting the costs to include in the analysis, selecting the cost estimation technique, and estimating the costs. This chapter provides a framework that will allow you to identify the costs associated with a ground water protection program, determine which of them are appropriate to include in the assessment, and to estimate the costs using a variety of methods.

Step 1: Select the Costs

The costs of a ground water protection program cover the program's entire spectrum, from the costs of setting up the program, to the costs involved in complying with its components. These costs fall into two broad groups: direct and indirect costs.

The first step in the cost assessment is to classify each of the costs for a program into one of these two groups, which makes it easier to identify all of the relevant costs. A more detailed discussion of direct and indirect costs, as well as some useful sub-categories of these costs, is provided below.

Classifying the Costs

The distinction between direct and indirect costs is determined by how closely they are correlated to the protection program.

4. *Assessing the Costs*

Direct Costs

Direct costs are paid by governments, firms and individuals who are directly affected by a program or policy. These costs, which are often fairly easy to define and quantify, are incurred by those who design, implement, and enforce a program, as well as by those who must comply with the program's requirements. Examples of these types of costs are:

- ☐ salaries for state or local officials who are involved in preparing regulations, ordinances, technical guidance, and information materials related to a protection program
- ☐ the cost a manufacturer incurs to install new spill control measures or leak detection systems in order to comply with the program.

Indirect Costs

Indirect costs represent the costs that are "passed on" to others by those initially responsible for the program or those who incur the program's direct costs. Because they are passed on, indirect costs are more likely to be overlooked, and are more difficult to estimate. Nonetheless, it is necessary to include these costs in an economic analysis because they can impose a large burden on the parties who will bear them.

Indirect costs can be classified in terms of how closely they are correlated to direct costs. For example, if manufacturers are required to purchase pollution control equipment to comply with a program (a direct cost), they may pass those costs on to consumers by charging higher prices for the goods they sell (an indirect cost). Such indirect costs are closely correlated to the direct costs. Other indirect costs may be more loosely correlated, such as a decreased demand for manufactured goods, which in turn might lead to layoffs and decreased tax revenues if people relocate.

To help you in identifying the costs associated with a ground water protection program, it is useful to break down both direct and indirect costs into subcategories based on the form in which they are incurred (program or compliance costs) and on who incurs them (public or private costs). By thinking about program costs in terms of these sub-categories, you can avoid overlooking any critical costs.

Program costs include the costs of designing, implementing, and administering a ground water protection program. Examples of these costs, which are usually direct costs, include:

- ☐ cost of equipment
- ☐ administrative and technical salaries
- ☐ legal fees for research
- ☐ public participation costs
- ☐ other costs specific to a program's design and implementation (e.g., consultant design fees, travel).

To ensure that all program costs are identified, it will be necessary to consult with all of the parties who would potentially be involved with the ground water protection program's design, implementation, and administration.

> *Double Counting*
>
> A common error in identifying and estimating both direct and indirect costs is double counting. For direct costs, double counting may occur when the distinctions among administrative, design, and operation costs are somewhat imprecise and are later counted again as some other type of program or implementation cost. Double counting is also a problem when assessing indirect costs. For example, if a manufacturer's full cost of purchasing pollution control equipment is included in the cost assessment as a direct cost, then such indirect costs as higher product prices cannot be included. To avoid overestimating costs by double counting, it is important to evaluate costs carefully.

Compliance costs are incurred by the public and private entities whose activities are regulated by a ground water protection program. Some examples of direct compliance costs include:

- ☐ additional capital expenditures associated with meeting the requirements of the ground water protection program
- ☐ equipment or process costs to meet new operating requirements
- ☐ permit fees.

The State of Washington case study at the end of this chapter gives an example of how a community estimated the direct compliance costs for a ground water protection program.

Other costs may result from the program's indirect economic effects and are thus considered indirect compliance costs. These costs might include:

- ☐ decreased property values because manufacturing practices are restricted by new zoning ordinances

- ☐ higher prices for the goods and services provided by a regulated industry

- ☐ increased utility rates and lower tax rates caused by a loss of economic activity that results from ground water protection regulations.

Public costs are those borne by the state or local government. For example, the salary for a new hydrologist in the Department of Water is a public cost.

Private costs are those absorbed by a private entity such as a local business or manufacturing plant. For example, the capital improvements a private utility must make to comply with a ground water protection program are considered private costs.

The distinction between public and private costs may become obscured when they are passed on. The direct cost of zoning restrictions, for example, may first fall on the private sector. Later, when property values fall in the rezoned area, the public sector will also bear a cost in the form of decreased tax revenues. Recognizing the distinction between these two types of costs will allow you to be thorough in your cost estimations by looking past the initial incidence of costs and determining if additional costs are passed on to other entities.

In addition to these costs, any ground water protection program may have primary and secondary effects. ***Primary effects*** are felt by individuals, firms, or agencies as a result of changes (e.g., new fees, clean ground water) brought about by a program. ***Secondary or "spillover" effects***, in contrast, are the result of actions taken by agents whose activities are not affected by a program, but are affected by changes made by individuals, firms, or agencies that incur primary effects.

To illustrate these types of cost, suppose that a local government hires a new inspector for its program -- this is a direct program cost. Firms incur costs to comply with the inspector's findings -- these are direct compliance costs. The firm then passes a portion of these costs on to consumers in the form of higher prices -- these are indirect compliance costs. All of these costs are primary costs. Now suppose that consumers facing the higher prices that have been passed on to them have less money to spend on videos, and a video store goes out of business as a result. This is a secondary effect, as are the costs associated with it. Because of the immense potential complexity of estimating secondary effects, this guidebook discusses only primary effects (i.e., costs and benefits) and the techniques for estimating them.

Choosing a Level of Analysis

Once you have identified and classified the costs of your ground water protection program, you are ready to select the costs you will include in the analysis. It is essential that none of these costs is double counted.

Conventional economic analyses require that an evaluator assess all of the possible costs, and if appropriate, the benefits associated with a program. However, ground water protection program managers often do not have the resources necessary to conduct such an in-depth analysis. Recognizing this, three levels of analysis are presented in this section:

- ☐ direct program costs
- ☐ direct compliance costs
- ☐ indirect costs.

These levels offer a framework to suit various perspectives that can be adopted, beginning with a level that requires the least amount of detail and ending with the most in-depth analysis.

Direct Program Costs

Analyzing a ground water protection program solely from the perspective of a program office involves measuring direct costs, excluding compliance costs. These costs are incurred by the program office for the design, implementation, operation, and enforcement of the program. This narrow perspective is only suitable for a cost-effectiveness analysis that will be used within a ground water protection office to compare program alternatives. Because it is pointless to measure benefits in a commensurately narrow scope, all cost-benefit analyses will require the estimation of more types of costs.

The most common technique for estimating direct program costs is comparative accounting (this method is discussed in the next section). This involves breaking a program down into its constituent activities and then assigning a cost to each activity based upon experience with similar types of programs or activities. The South Dakota case study at the end of this chapter provides an example of direct program costs.

Program managers who want to know the direct economic impact of their program on the regulated community may elect to include direct compliance costs in their analysis. However, to support a cost-benefit analysis, direct compliance costs must be combined with

Direct Compliance Costs

direct program costs. Simply measuring the direct compliance costs will not provide a sufficiently broad perspective to balance an estimation of benefits.

The technique used to estimate direct compliance costs depends on the nature of the program, that is, the entities and activities it regulates or restricts. The two techniques typically used to estimate these costs--modeling or systems engineering techniques and surveys--are discussed below.

Indirect Costs

Indirect cost estimation is used when large portions of the economic impacts of a program will be passed on to others. Maintaining a consistent and balanced approach is essential in assessing these costs.

For example, in *cost-effectiveness analysis,* suppose that you are comparing two programs to determine which of them will achieve a threshold level of pollution prevention at the least possible cost. You may find that an indirect compliance cost of one program (decreased land values to community residents due to a new zoning ordinance) is likely to be so significant that it must be incorporated into the cost assessment. To be consistent, if its competing program has any impact on community residents (increased property taxes to fund an extensive monitoring program), it must also be included in the cost assessment of the competing program.

In *cost-benefit analysis,* it is important to balance the inclusion of corresponding costs and benefits. In the previous example, a program manager should only include indirect costs to community residents in a cost-benefit analysis if the benefits to residents are also included.

It is important not to count what are called ***pure resource transfers*** as costs, especially of such indirect compliance costs as lost jobs, decreased property values, and declining tax revenues. For example, if a ground water protection program causes an industry to move out of a certain area because of a decline in property values but another industry moves in and replaces the lost jobs, a pure resource transfer has occurred. Resource transfers are not always pure, however. If, for example, decreases in property values are not completely offset by corresponding increases elsewhere in the community, a portion of the decreased values should be considered costs. Likewise, if an influx of jobs more than offsets jobs lost as a result of the imposition of zoning restrictions, this would be counted as an indirect net benefit to the community.

Step 2: Select the Cost Estimation Technique

The specific techniques for estimating ground water protection program costs are fairly straightforward. This section present four techniques that are useful in estimating the cost components of various programs in cost-effectiveness or cost-benefit analysis. They are:

- ☐ comparative accounting
- ☐ modelling or systems engineering techniques
- ☐ surveys
- ☐ combined approach.

Comparative Accounting

Comparative accounting involves breaking a program down into its constituent activities and assigning a cost to each based upon experience with similar types of programs or activities. It is perhaps the most frequently used cost estimating techniques for ground water protection and other public programs. The South Dakota case study at the end of this chapter illustrates the use of comparative accounting techniques to estimate direct program costs including program design, operation, and administrative costs.

The first step in preparing a cost estimate using this technique would be to break the program down into activities or components that could be readily priced. These include staff time, legal costs, meeting expenses, postage, and public information materials. It is important to make precise distinctions among each type of cost (e.g., administration, design) to avoid double counting. Prices for these components would be dictated by the market or derived from professional judgment and experience. In the second step, the total cost of the individual components is calculated by multiplying their price by the quantity. Last, the total cost for the entire program is derived by simply summing these individual costs.

Application. Comparative accounting is most useful when quantifiable data for a specific activity are not abundant, but where cost figures for components of that activity or similar activities exist elsewhere. Because ground water protection program managers are likely to have access to information relating to general program administration costs, comparative accounting is most appropriate for estimating such direct costs as program design and operation costs. To the extent that data are available, however, this technique can also be used to estimate compliance costs.

Modeling or Systems Engineering Techniques

Modeling or systems engineering techniques use models or designed systems of standard or reasonably expected processes (e.g., zoning changes) or projects (e.g., buildings, parks) to which cost data can be applied. The applicability of these techniques is limited primarily to programs that require capital expenditures on physical structures, plant and equipment, machinery, etc. In a ground water protection program, these techniques might be used to estimate the cost of ground water monitoring, well drilling, installation, and maintenance.

The first step in preparing a cost estimate using these techniques is to list all of the structures, plant, and equipment that are anticipated to be needed under a program. In the second step, cost data are applied to each of these items. Reference materials such as *Means Average Construction Cost Data* and other documents listed in the bibliography to this guidebook can be useful in estimating the costs of these and other engineered structures. In the third step, the data for each item are totalled.

Application. Modeling and systems engineering techniques are most appropriate for engineered systems (e.g., structures, buildings, construction projects). Obviously, the limited applicability of these techniques is their principal shortcoming. Their advantage is that they are based on well established data, and as a result, are fairly accurate within their limited application range.

Surveys

Surveys allow a program manager to access information about the costs of a ground water protection program that are otherwise difficult to obtain. Surveys can be used to obtain data on the cost of compliance from private firms and households. The Dover, New Hampshire case study at the end of Chapter 6 shows how a survey can be designed. Dover's survey was used to determine residents' willingness to pay for clean ground water (this type of benefit will be discussed in Chapter 6). To be effective, surveys must be carefully designed and executed. Technical references such as those listed in the bibliography can assist you in using surveys to estimate the costs of ground water protection programs.

Application. Surveys are most useful in obtaining data that are not readily accessible to ground water program managers from parties that either have or can access such information. Because of the generally complex design requirements, however, conducting a statistically valid survey can be expensive. In addition, in responding to surveys, people often have an incentive to over- or under-state costs. These incentives can introduce a bias into the survey, which will in turn influence the accuracy of the survey's cost estimates.

A Combined Approach

The modeling or systems engineering techniques and the survey have a number of weaknesses that may discourage program managers from using them independently. To compensate for the shortcomings of each of these techniques, you may opt for a combination of the two approaches in estimating compliance costs. The survey approach would be used to collect information on possible program options, as well as the special circumstances faced by the entities who would be affected by the program requirements. The engineering approach would then be used to derive the actual costs of the technologies needed for the program, given the circumstances of the people and businesses surveyed. This combined approach will balance information that is best supplied by the potentially regulated entities with that information best derived from standard cost sources.

Step 3: Estimate the Costs

Once program costs have been identified and classified, the level(s) of analysis has been chosen, and the cost estimation technique(s) has been selected, you are ready to estimate the costs of the ground water protection program. Three factors must be considered in your estimation:

- ☐ the period of time over which the program or program options will be in effect
- ☐ the time value of money
- ☐ incremental costs.

Time Period

Chapter 2 of this guidebook discussed the need for defining a period of time over which the ground water protection program will be in effect. If you are considering more than one program option, each must be evaluated over a single, finite period of time (costs, benefits, and effects cannot be estimated over an infinite period of time). This period must be the same period of time that you have selected for the baseline (Chapter 3).

Time Value of Money

To evaluate costs that are incurred over time, it is necessary to make adjustments to reflect the "time value of money." Because of inflation and other factors, the dollar value of a cost realized today is higher than if it is to be realized at some point in the future. In order compare future costs with the costs incurred today, they are translated into what is called ***"present value"*** terms using an adjustment figure called the ***"discount rate."*** The discount rate is based on a number of assumptions, including the inflation rate, the degree of risk that is perceived for a project, and the ***opportunity cost*** (what the money intended for a program could earn if it were invested or used for something else.

To see why present value is important, consider the following example. Suppose you have a choice between receiving $50 today or $100 two years from now; which is the better choice? To compare the alternatives, it is necessary to express them in comparable terms.

One way is to see how much money you would have in two years if you invested the $50 today. Assuming a 10 percent rate of interest, a $50 investment would yield the following:

Opportunity Cost

The use of program resources carries a hidden, or "opportunity cost." This cost is the equivalent of the highest-value activity foregone as a consequence of the activity undertaken. Suppose a town passes a regulation that limits the number of new homes per acre in order to reduce the number of septic tanks within its borders. As a result, a developer who planned to put five houses on a 2-acre lot can now build only four. The opportunity cost to the developer is thus the revenue he forgoes by building one less house; to the city, it is the tax revenues it loses from that house.

The concept of opportunity cost is important for two reasons. First, it is useful in identifying costs. In the example above, if you fail to consider opportunity cost, you might not view the program as imposing any costs on the developer; after all, four houses were built. However, before the program, the developer could have built five houses. Thus, the opportunity cost to build a house is a cost to the developer of the program. Second, opportunity cost is the basis for the discount rate for present value calculations (see the example above). If you have the choice of spending $50 on a program or investing it, the rate of return that you could receive is the opportunity cost of spending the money today.

Today	Year 1	Year 2
\$50	\$50 (1.1) = \$55	\$55 (1.1) = \$60.50

Thus, in two years, your \$50 would be worth \$60.50. Obviously, the \$100 you would be offered two years from now is worth much more, so it is the better alternative. This technique is called calculating the ***future value.***

Alternatively, you could calculate how much \$100 in two years would be worth today. This is called calculating the ***present value***. To calculate this, you use the same interest rate (now termed the ***discount rate***) and apply the following formula:

Today	Year 1		Year 2
PV=	\$0 (1/1.1)	+	\$100 $(1/(1.1)^2)$
PV =	0	+	82.64

Either way, the \$100 in two years is the better choice. To understand how present value might have implications for ground water protection programs, suppose Program A and Program B each cost \$500,000, but that the costs for Program A are incurred today, whereas Program B's costs are incurred two years from now. Using present value, Program B is clearly less expensive.

Amortization is another way to apply the time value of money concept to express costs in terms of the same time frame. Amortization is useful if you would like to compare costs to benefits or calculate cost-effectiveness on an annual basis.

The difference between discounting/present value calculations and amortization is simple. While calculating present values involves discounting a stream of future payments into today's dollars, amortization allows you to allocate present-day, one-time costs (e.g., capital expenses) uniformly over a given period into the future.

An example of amortization is provided in the hypothetical case study in this chapter and in Chapter 6.

4. *Assessing the Costs*

Incremental Costs

The last factor to consider in estimating the costs of a ground water protection program is incremental costs. These are the costs of a program over and above the baseline costs (the costs incurred if an additional program is not implemented, as discussed in Chapter 3).

The incremental costs of a program can be assessed by estimating *all* of the costs associated with ground water and ground water protection assuming the additional program is implemented, and then subtracting from them the estimated baseline costs. Another way of arriving at these costs might be to isolate the incremental costs associated with an additional protection program and estimate them accordingly.

Hypothetical Example: Assessing the Costs

Step 1: Select the Cost Estimation Technique	
The ground water program manager elects to use several techniques to estimate the costs of the program, including comparative accounting and modelling techniques (primarily to assess program costs) and survey techniques (to estimate direct and indirect compliance costs).	
Step 2: Estimate the Costs	
Costs of Protection Program #1:	
2 additional senior staff at $75,000	$150,000
12 additional technical staff at $45,000	540,000
20 additional inspectors at $38,000	760,000
5 clerical/administrative staff at $17,000	85,000
Total	$1,535,000
The installation of 100 monitoring wells at $270,000 per well = $27,000,000	
Amortized at 10% for 30 years	$2,860,000 per year
Operating and sampling costs of 100 wells at $2,000 per well	$200,000 per year
Increased average compliance cost (inspections and enforcement for firms:	
500 firms at $2,000 per firm	$1,000,000 per year

Costs of Protection Program #2:	
1 additional senior staff member at $75,000	$75,000
1 legal staff member at $70,000	70,000
5 additional technical staff at $45,000	225,000
10 policy staff at $40,000	400,000
4 outreach specialists at $35,000	140,000
10 clerical/administrative staff at $17,000	170,000
Total	$1,080,000
Compliance costs for firms:	
1,000 firms at an average cost of $1,750 per firm per year to institute new procedures:	$1,750,000 per year
One-time expenses for new equipment: 100 firms at $20,000 = $2,000,000 total amortized at 10% for 30 years	$210,000 per year

Note: Amortization is used to express one-time costs, typically capital costs, in terms of annual expenses, and is based upon the following present value formula:

$$PV = x/r\ [\ 1 - (1/1 + r)^n]$$

To amortize, you solve for x, so the formula becomes:

$$x = PV\ (r)/1 - (1/1+r)^n$$

where: x is the annual cost
PV is the value of the one-time capital expenditure
r is the interest rate
n is the number of years in the period of analysis

Case Study: State of Washington

The State of Washington proposed regulations to limit the discharge of certain industrial contaminants to its ground water. The regulations were to apply to all ground water in the state occurring in soils and fully saturated geologic formations, and were prevention oriented (they did not specifically address remedial action). Under the proposed regulations, affected businesses would be required to apply for a waste discharge permit, adjust their processing technologies to meet the new standards, and engage in a variety of monitoring, evaluation, and reporting activities.

Example of Estimating Direct Compliance Costs

In accordance with Washington's Regulatory Fairness Act of 1982, the Washington State Department of Ecology commissioned the preparation of a Small Business Economic Impact Statement to evaluate the effect of the regulations on small businesses. In addition, the Department commissioned a cost-of-compliance study to be conducted as part of a larger cost-benefit analysis. This second study was to concentrate on industries dominated by larger firms (i.e., those with more than 50 employees).

Small Business Compliance Cost Study Methodology

To calculate the costs of compliance for small firms, the Department of Ecology first needed to identify those small businesses that would be affected by the regulations. It determined that only those business that *did not* have to comply with the State's present waste discharge standards would be affected. Thus, the first task was to identify businesses that *were* subject to such standards and eliminate them from further consideration. The Department identified four types of businesses that fell into this category:

- ☐ firms allowed to discharge to surface waters through the National Pollutant Discharge Elimination System (NPDES) permit system
- ☐ firms discharging into wastewater treatment facilities which, in turn, are permitted under NPDES
- ☐ firms managing hazardous waste and permitted under the Resource Conservation and Recovery Act (RCRA) as administered by the State

- ☐ agricultural interests using best management practices and already in compliance with Department of Agriculture regulations.

The Department of Ecology also eliminated interests that were dominated by larger firms and thus, by definition, were excluded from consideration in a small business compliance study. These large firms included mining and mineral processing, petroleum refining, pulp and paper mills, and plywood mills.

The Department divided the remaining firms according to their Standard Industrial Classification (SIC) codes. Based on EPA documents, state records and reference materials, and interviews with businesses, it identified the waste streams likely to be generated by small firms within theses SIC codes, as well as the actions and types of treatment technologies required to comply with the regulations. The general types of businesses identified included:

- ☐ feedlots
- ☐ fruit and vegetable packers
- ☐ meat processors
- ☐ diary products
- ☐ fruit and vegetable processors
- ☐ sanitation services.

The Department estimated that these industries comprised 525 small firms in the State.

To analyze the compliance costs for such a diverse group of industries, the Department made the following simplifying assumptions: 1) enforcement levels for the various hazardous constituents covered under the regulations would be consistent across facilities, rather than permit-specific, 2) representative waste streams and treatment technologies could be generalized for each SIC code, and 3) all hazardous constituents present in a hazardous waste stream would, if they reached ground water, remain at their original concentrations. These assumptions, although simplified, allowed the Department to conduct a consistent analysis of compliance costs for the businesses in question.

The Department recognized, however, that there were firm- and site-specific factors that should be taken into account in order for the analysis to be meaningful. It thus divided these firms into four levels (I-IV) based on several factors, including:

Level I:	complexity and toxicity of the waste stream
Level II:	required level of treatment technology
Level III:	susceptibility of local ground water to contamination
Level IV:	location of other beneficial uses of ground water.

The costs of each compliance activity for each level of firm were estimated through interviews with consultants and State records. These costs are presented below.

Large Firm Compliance Cost Study Methodology

The State estimated the cost of compliance for industries dominated by large firms by using a questionnaire distributed to representative firms in the oil refining, pulp and paper, and plywood industries (representatives of the mining and mineral processing industry could not formulate cost estimates within the time allotted for the study, and are not presented below). The questionnaire asked firms to estimate the cost or a range of costs to carry out activities (e.g., ground water monitoring) necessary to comply with the regulations on a per-activity or per-facility basis. Additional information obtained from the questionnaire and State records on the number of activities required for each facility allowed the Department of Ecology to derive annual cost-of-compliance estimates simply by multiplying the estimated cost per activity (i.e., price) by the number of activities undertaken (i.e., quantity).

Summary of Compliance Cost Study Results

The small business compliance cost study derived cost estimates for the initial year and for the four levels of firms as follows:

Level I:	$ 1,600	Level III:	$45,000
Level II:	$ 14,300	Level IV:	$197,500

The large business compliance cost study derived the following non-discounted annual cost estimates:

Plywood:	$5,500/mill/year for ground water assessments
Pulp & Paper:	$148,560 - $336,600/mill/year for ground water monitoring
Oil Refining:	$2 - $5 million/refinery/year for ground water evaluation program
	$5 - $10 million/refinery/year for forced closure of hazardous waste sites.

The Department concluded that small businesses would be disproportionately affected by the proposed standards due to the substantial economies of scale associated with various treatment technology costs, and the fairly uniform cost of preparing a permit application for all firm sizes.

Case Study:
East Dakota Water Development District, South Dakota

> Example of Estimating Program Costs

The Big Sioux Aquifer is a shallow glacial outwash aquifer located in eastern South Dakota. It underlies about 1,000 square miles of prime agricultural land in 13 counties, 11 of which are members of the East Dakota Water Development District and/or the First District Association of Local Governments, which cooperates with the East Dakota District on ground water protection efforts. The aquifer is the sole source of water for most of the District's residents. The area is farmed intensively and irrigation is widespread. The rapid migration of surface water into the Big Sioux Aquifer makes it especially susceptible to contamination from both agricultural and industrial sources.

Estimation Approach

To address the growing concerns over ground water contamination, the District decided that a comprehensive ground water protection program was necessary. The first steps toward implementing the program were identifying the issues of primary concern and devising program components to address them effectively. The objective of the program was to prevent ground water resources, particularly a shallow sole-source aquifer located largely under agricultural land, from being contaminated by agricultural practices. The District decided on a ground water protection program that contained the following components:

- ☐ a ground water task force
- ☐ a comprehensive ground water information system
- ☐ a ground water monitoring system
- ☐ county and municipal model ordinances
- ☐ developmental ground water demonstration projects
- ☐ a public awareness and outreach strategy.

The next step was to estimate the cost of these individual components. Because the two pieces of information needed to estimate each component's cost--price and quantity--were not always available, the District broke down each component, whenever possible, into individual activities. Many of these activities, in turn, could be divided further into more discrete units. The ultimate objective of this process was to define the program in terms of individual elements or activities for which prices and quantities were more readily available. In some instances, however, when the means of implementing a component had not been determined, the District was not able to define it adequately in terms of individual elements. In these cases, or when costs could not reasonably be assessed for a specific activity (e.g., utilities, overhead, other administrative expenses), the District allocated costs according to some "reasonable" fixed percentage.

The District derived prices from a variety of sources. In some instances, these were known with certainty, while in others, prices were based on past experience with similar projects and tasks or consultation with experts. Similarly, the District knew in some cases the quantity (e.g., 10 maps) or range (5-15 town meetings to develop a local zoning ordinance) of activities required. The fixed percentages used to estimate overhead expenses and the costs of less well-defined programs were based upon professional judgment and experience.

Program Cost Estimates

The cost estimates for the components of the East Dakota Water Development District's Ground Water Protection Program are shown below. This section also describes the assumptions relevant to these cost estimates, and when possible, the methodologies used to derive the cost estimates.

Organizing a Ground Water Task Force: $100. The Task Force was to act as a reviewer and expert consultant throughout the program's implementation. The individual activities involved in its organization consisted primarily of staff time and the materials (e.g., envelopes, postage) necessary to notify potential Task Force members. No cost estimates for meetings were included in this component. The District determined that one workday of staff time would be necessary at a cost of about $10/hour, while the cost of materials was estimated at slightly less than $20. These estimates were based upon the experience with a similar task force formed for a community wellhead protection program in Brookings, South Dakota.

Developing a Comprehensive Ground Water Information System: $97,170. To derive a cost estimate for developing an information system, the District broke down this component into four activities. The first would involve gathering and plotting data on public water supply (PWS) wells by location, construction, drillers' logs, permitted withdrawals, and water levels in the surrounding areas. Because gathering information on the District's 42 PWS wellfields would require collecting data from existing sources rather than new research, the District estimated that only a modest level of staff time was required (approximately 2 hours per wellfield at a price of $10 per hour). Overhead expenses (phone calls, paper, etc.)

were estimated at 20 percent of salary expenses, or $80. The total cost estimate for this activity was approximately $500.

The second activity was the preparation of county-wide aquifer maps at a total cost of $20,000. The District arrived at this figure by assuming that 11 maps would be prepared by the South Dakota Geological Survey (SDGS) at a cost of slightly less than $2,000 per county. This price estimate was based on a consultation with the SDGS, who also stated that the price could have been as high as $200,000 per county, but could be reduced because SDGS had already conducted much of the extensive hydrogeologic mapping required.

The third activity was a delineation of wellhead protection areas around existing PWS wellfields. The District wanted to use the most sophisticated method of delineation given the existing data (in this case, a uniform flow analytical model with a 10-year time of travel). The total cost for the delineations was estimated at $60,000. Of this, nearly $50,000 was devoted to salaries (assuming 10-11 staff weeks per county at approximately $10 per hour). An additional 20 percent of salaries was included as overhead and a nominal $400 was budgeted for travel. (Again, the cost would have been higher if the SDGS had not already conducted extensive hydrogeologic mapping.)

The last element of the information system was a geographic information system demonstration project covering 30 square miles, at an estimated total cost of $16,670. Most of the administrative work on this task was donated by a retired State University faculty member for a nominal fee of about $6,000. The remaining costs would be for salaries (for graduate student labor) and administrative expenses. Aerial photography would be provided by a local firm at no cost. This estimate was based almost entirely upon discussions with the project administrator.

Installing a Ground Water Monitoring System: $25,000. To estimate the cost of this system, the District assumed that the SDGS would install 3 to 7 monitoring wells around 8 to 10 selected shallow wellfields within the District. About 50 wells would be drilled and constructed using 2" PVC pipe, 10' screens, and an average well depth of 24'. The price was estimated at $450 per well ($23,000 total). All installation cost assumptions were based upon consultation with SDGS staff. The District also assumed that an additional four weeks of staff time (roughly $1,600) would be required for administrative oversight, as well as the standard 20 percent of salaries ($330) for overhead expenses.

Developing and Implementing Model Ordinances: $115,000. The District divided this program component into two elements: ordinance development and ordinance implementation. It further determined that it would need to develop both a country and municipal ordinance that would be incorporated into existing local zoning regulations. The goal of these model ordinances was to make it easier for local communities and counties to adopt ground water protection regulations. The District also wanted the ordinances to be simple, easy to understand, and free from complex legal terminology. As a result, the District did not incur any legal fees. The cost of developing a county ordinance was estimated at $5,000, based primarily on previous experience with a similar ordinance passed in Brookings County, South Dakota. Because there was less experience in developing community ordinances, the District felt more effort would be required for this element, and estimated its cost at $10,000. The total cost for developing the two ordinances was estimated at 30 staff weeks at $10 per hour, plus 20 percent administrative expenses and $500 for travel expenses.

Implementing the ordinances was by far the most expensive single component of the District's program. This effort called for one-on-one technical assistance with local communities. The District estimated the total cost of the implementation effort at slightly over $9,000 per county for 11 counties ($100,000). Because of the many meetings required, travel costs were significant ($4,000). Staffing costs amounted to roughly $7,000 per county, or almost 18 staff weeks per county. Standard administrative expenses totaled almost $20,000.

Developing Ground Water Demonstration Projects: $55,000. This program component consisted of several individual projects to encourage best management practices on issues ranging from protecting deep public water supply wells to promoting alternative land use in agricultural areas. Because of their development nature, the estimated costs of these projects were somewhat speculative. The District tended to assign a dollar amount to a project, and then used fixed percentages to allocate costs within this estimate. It also adjusted these percentages slightly if, for example, one activity called for more travel-related expenses.

For example, one project would entail cursory field checks of deep wellfield areas to evaluate well construction, elevation, local drainage, and nearby contamination sources. Travel costs for this effort would be substantial, and were estimated at $4,000. An additional $5,000 in staff time was allocated for inspection of the 38 deep wellfield areas in the District, plus $1,000 in overhead. Two technical assistance projects designed to reduce the contamination of rural domestic wells and promote alternative land use in critical wellhead protection areas were estimated to cost $5,000 each. For these two projects, approximately 80 percent of the cost was allocated to salaries, with an additional 20 percent split between overhead and travel costs. A fourth demonstration project would involve promoting the development of contingency plans to address spills of hazardous or toxic materials within or along streams upgradient of wellhead protection areas, at a cost of

$15,000. The allocation of costs within this project was similar to that of the two previous demonstration projects.

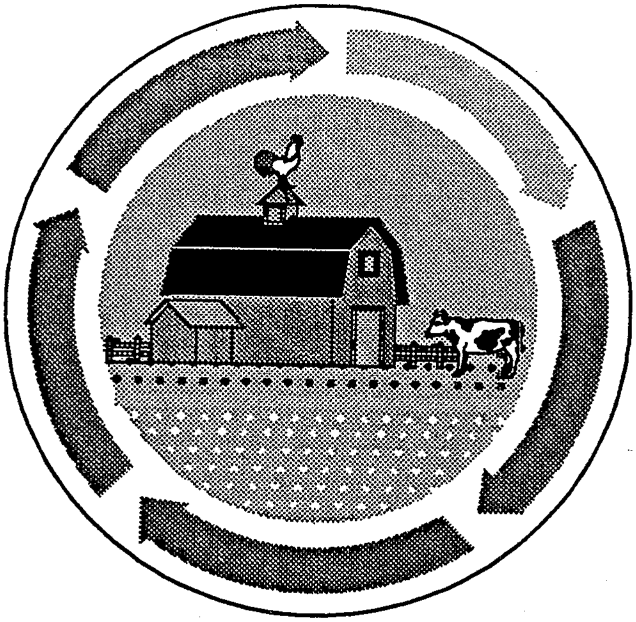
Developing a Public Awareness and Outreach Strategy: $35,000. This final component called for the State Department of Transportation to install educational and caution signs where major roads intersect wellhead protection areas. The signs were assumed to be 2' x 4' and cost $100 per sign. Eighty signs would be installed, and 20 additional signs would be held in reserve as replacements, for a total cost of $10,000. Installation costs were estimated at $4,000, and oversight and administrative costs were estimated at $800 and $200, respectively.

Another element of the strategy consisted of a training course on ground water protection issues, brochures, videos, slides, and articles for publication. The video would be contracted out at an estimated cost of $4,000. Travel expenses associated with the training courses were estimated at $2,000. The outreach and educational materials were to be prepared in-house at a cost of about $12,000 (30 staff weeks) and slightly more than $2,000 in overhead expenses. The total cost of this element was estimated at $20,000.

Summary of Total Costs

The total estimated cost of the East Dakota Water Development District's ground water protection program was $198,270.

Program Components	
Organize task force	$100
Develop information system	97,170
Install monitoring system	25,000
Develop and implement model ordinances	115,000
Develop demonstration projects	55,000
Develop public awareness and outreach strategy	35,000
Total cost of program	$198,270



5. *Analyzing Cost-Effectiveness*

Cost-effectiveness analysis is useful in evaluating the various options for carrying out a ground water protection program, particularly if the program's budget is fixed. For example, when a given quality standard or certain level of protection must be met, cost-effectiveness analysis is often used to arrive at the least-cost method of achieving that goal. Alternatively, this technique is useful in determining a quality standard or level of protection that can be achieved for a given amount of money.

Cost-effectiveness analysis is also useful in determining the value of incremental changes in programs (adding or subtracting one component) in terms of the amount of protection they afford per dollar spent. For example, suppose that a community is considering eliminating one of its three program components for budgetary reasons. The first two components cost $40,000 and reduce aquifer contamination by 70 percent (a 0.00175 percent contamination reduction per dollar spent). The third component costs $5,000 and raises the level of protection to 95 percent (a 0.0021 percent reduction per dollar spent). In this case, the third component, which has an incremental cost of 12 percent, will likely be regarded as worthwhile because it provides a 26 percent increase in protection.

The cost-effectiveness of protection programs can be expressed in several ways, including:

- ☐ units of pollution prevention achieved per dollar spent
- ☐ units of pollution prevention achieved for programs of equal cost
- ☐ dollar cost per unit of pollution prevention achieved
- ☐ dollar cost of programs that prevent equal units of pollution.

5. Analyzing Cost-Effectiveness

Cost-effectiveness analysis can be employed to compare program options that encompass:

- ☐ different types of protection methods (e.g., zoning versus permitting)
- ☐ combinations of protection methods (e.g., monitoring, permitting, and enforcement systems versus monitoring, education, and zoning)
- ☐ similar methods at different levels of implementation (e.g., one zone versus four zones).

The Importance of Comparable Units

To evaluate the effectiveness of ground water protection program options, it is therefore necessary to measure the expected results of each option in comparable units. Establishing a ***standardized measure of pollution prevention*** will allow you to compare the effectiveness of different program options. The measures of pollution prevention may include:

- ☐ level of contaminant reduction in the aquifer (ppb)
- ☐ percent reduction of contaminant in the aquifer
- ☐ probability that a contamination incident will occur
- ☐ units of contaminant prevented from reaching the aquifer
- ☐ percentage of contaminant prevented from reaching the aquifer
- ☐ probability that a contamination incident will be prevented.

Because accurate measures of pollution prevention are often impossible to obtain unless sophisticated aquifer monitoring and mapping have already been conducted, it may be necessary to develop estimates or proxy measures of program effectiveness. A common proxy or estimate of the effectiveness of a zoning program, for example, would be the quantity or units of a contaminant prevented from reaching the aquifer as a result of the contaminant's prohibition. In the State of Wisconsin case study at the end of this chapter, pollution prevention is measured in terms of the pounds per year of atrazine active ingredient prevented from potentially contaminating the aquifer.

It is also possible to use engineering texts and other technical studies to obtain potential measures of pollution prevention. For example, if a program manager wishes to evaluate the effectiveness of different treatment technologies, these technical references could provide specific data on the amount of each contaminant removed by each treatment technology (e.g., granular activated carbon filters versus aeration). Alternatively, he could consult experienced technical staff (e.g., staff hydrogeologists, engineering firm personnel, academics) to obtain these data.

This chapter presents a step-by-step guide for conducting a cost-effectiveness analysis. As shown in the box below, three of these steps (defining a program, establishing the baseline, and assessing the costs) were covered in previous chapters and are not repeated here. Please refer to these chapters, when appropriate, for more detailed discussions.

Steps in a Cost-Effectiveness Analysis

Define a Ground Water Protection Program (Chapter 2)

- set a goal
- set objectives
- define options
- identify impacts

Establish the Baseline (Chapter 3)

- define the baseline
- quantify the baseline
- consider factors that increase or decrease baseline estimations
- consider the probability of baseline bias

Estimate the Effectiveness of Program Options

Assess the Costs (Chapter 4)

- select costs
- select the cost estimation technique
- estimate costs

Evaluate Cost-Effectiveness

Estimate the Effectiveness of Program Options

Using the standardized measure of prevention you selected, you can estimate the effectiveness of a program option and compare it with the effectiveness of other options.

Comparing Program Options to the Baseline

When selecting the program's goal and objectives, the program manager determines the level of effectiveness he or she wishes to achieve. Program options can then be removed from consideration if they do not meet this level.

To realize a program's true effectiveness, you must take into account the baseline calculation (see Chapter 3). This involves subtracting the baseline from the effectiveness of a program option to yield the incremental or marginal effectiveness of the program. Thus, it is important that the baseline and the programs being evaluated are both expressed in comparable units. The hypothetical example at the end of this chapter illustrates one use of the baseline in a cost-effectiveness analysis.

Timing Factors

In addition to measuring the effectiveness of the program options in comparable units and taking the baseline into account, you should also consider timing factors. For example, suppose Program A protects 2,000 people annually for three years, while Program B protects 1,000 people annually for ten years. On a unit (per person) basis, Program A is more effective. However, accounting for the duration of the two programs, Program B is more effective.

Factors Affecting the Estimation of Effectiveness

Limiting Factors

Two factors limit or complicate the conduct of a cost-effectiveness analysis. The first is the presence of ***multiple contributing factors*** (e.g., more than one contaminant or source of contamination for an aquifer), which make the determination of a standard measure of effectiveness more difficult. To address this situation, one approach is to assume that all contaminants are of equal importance. Thus, a program that reduces the concentration of contaminant A by 5 percent is as effective as a program that reduces contaminant B's concentration by 5 percent. Alternatively, when several contaminants are present, it is also feasible to develop a prioritizing scale on which all contaminants can be placed relative to one another. The scale will likely be based on the relative risk each contaminant poses, or on some other criterion developed by the program manager. If contaminant A poses a greater threat and is therefore a higher priority than contaminant B, a program reducing the concentration of contaminant A is more effective than one that reduces contaminant B's concentration by 5 percent.

The second is ***disparate program options.*** This factor limits cost-effectiveness analysis because of the difficulty involved in finding standardized measures with which to compare the options. For example, suppose that zoning and public education are two options being considered for a ground water protection program. Both have the same ultimate objective of reducing the amount of contamination that reaches the aquifer, but the methods for measuring their effectiveness differ. The measurement of zoning's effectiveness will likely be based on the expected reduction of contaminants in the zone, while the measurement of public education's effectiveness is usually based on the number of people who receive information. Because it may not be possible to develop a suitable measure of effectiveness that is common to both of these options, you may not be able to compare their cost-effectiveness.

Evaluate Cost-Effectiveness

Each program option that meets the quantified effectiveness objective and is within the program office's budgetary means should be evaluated for its cost-effectiveness. Cost-effectiveness options can be compared using two basic approaches:

When the program office is under budgetary constraints or when specific levels of pollution prevention are to be achieved, use:

- ☐ dollar cost of programs that prevent equal units (or levels) of pollution or
- ☐ units (or levels) or pollution prevention achieved for programs of equal cost.

When seeking the option that will maximize pollution prevention per dollar spent, use:

- ☐ units (or levels) of pollution prevention achieved per dollar spent or
- ☐ dollar cost per unit (or level) of pollution prevention achieved.

The hypothetical example below illustrates the evaluation of cost-effectiveness.

5. *Analyzing Cost-Effectiveness*

Sensitivity Analysis

Sensitivity analysis is the testing of results due to changes in assumptions. In developing the estimates of effectiveness and costs, it is likely that, where precise data are not available, a number of assumptions were made to complete the analysis. Varying the assumptions will highlight weaknesses in the analysis that are important to decision making.

Testing the sensitivity of the final results to a particular assumption is merely a matter of altering the assumption, re-calculating cost-effectiveness according to new assumptions, and noting the changes in the final results for the options being compared. If the change is significant, more data may be necessary to fully understand the impact of the change.

Hypothetical Example: Analyzing Cost-Effectiveness

Comparing the Program Options to the Baseline

Recall from Chapter 3 that the ground water program manager from Fairhomes County estimated the number of people affected by contamination under the baseline to be:

Private well users:	800 people
Public well users:	40,000 people

Two alternative protection programs to be evaluated using cost-effectiveness analysis are: 1) zoning restrictions and new standards for businesses, and 2) monitoring, enforcement, and remediation.

For simplicity, the program manager estimates that both programs will protect 100 percent of the public well users from contamination. However, only the zoning program will protect the 800 private well users. Thus, the total number of people protected under the two programs are:

Program #1: 40,000
Program #2: 40,800.

Evaluating Cost-Effectiveness

To complete the cost-effectiveness analysis in Fairhomes County, the program manager takes the cost of each program option developed from Chapter 4 and divides by the number of people protected. The results of this calculation are shown below:

Program #1: 5,575,000/year ÷ 40,000 = $139 per person/year

Program #2: 3,040,000/year ÷ 40,800 = $74 per person/year.

Thus, Program #2 is more cost-effective on a per-person basis.

Case Study: State of Wisconsin

Ground water monitoring initiatives in Wisconsin discovered that atrazine (a herbicide commonly used in corn crop production to reduce weeds) contamination was more widespread than originally thought. Consequently, the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) proposed amendments to the 1991 Atrazine Rule, to be implemented in 1992.

Example of Establishing Standard Measures of Prevention

Although the DATCP did not undertake a formal cost-effectiveness analysis to compare alternative programs, their approach encompassed many of the steps necessary to develop a case study. Information not reported in their Environmental Impact Statement, but necessary to complete the cost-effectiveness analysis case study, was obtained by contacting the DATCP for further estimations.

Proposed 1992 Amendments

The 1992 proposed amendments were developed with the same objective as that of the original Atrazine Rule: "to minimize the level of atrazine in ground water to the extent that is technically and economically feasible." The amendments call for the establishment of five atrazine management areas (AMAs) and eight prohibition areas (PAs). These areas would be in addition to one AMA and six PAs established under the original Atrazine Rule. The additional AMAs would be subjected to stricter maximum atrazine application rules based on the type of soil in which crops are planted.

Estimated Effects of Proposed Amendments. The effects of the proposed amendments were estimated in terms of the anticipated reduction of atrazine active ingredient applied to corn crops in pounds per year (ppy). To estimate this reduction, it was necessary to incorporate estimations on present atrazine use, soil characteristics, and types of corn produced in the delineated AMAs and PAs. The general estimations for AMA and PA conditions included the following:

	Total Acreage	Acres Dedicated to Corn Production	Acres Dedicated to Corn Production to which Atrazine is Applied**
AMAs*	700,000	350,000 (50%)	175,000 (50%), of which 157,500 (90%) are planted in fine to medium soil and 17,500 (10%) are in course soil
PAs*	24,000	18,000 (50%)	9,000 (50%)

* 12,000 AMA acres (2 percent) are overlapped by PAs

** The average application rate of atrazine to corn crops is 1.4 pounds active ingredient per year, based on survey results.

Estimated Atrazine Reduction in AMAs: The present average application of atrazine to corn crops (1.4 ppy), multiplied by the estimated AMA corn acres to which atrazine is applied (175,000), equals the amount of atrazine active ingredient currently applied in AMAs (245,000 ppy). Subtracting from this figure the maximum amount of atrazine active ingredient that could possibly be applied under the proposed rates (170,626 ppy), resulted in the estimated reduction of atrazine active ingredient in the AMAs under the proposed amendments (74,374 ppy).

Estimated Atrazine Reduction in PAs: The present average application of atrazine to corn crops (1.4 ppy), multiplied by the estimated PA corn acres to which atrazine is applied (9,000), equals the amount of atrazine active ingredient currently applied in PAs (12,600 ppy). This figure is also the estimated reduction of atrazine active ingredient in the PAs under the proposed amendments.

Total Estimated Atrazine Reduction: The sum of estimated atrazine reduction in the additional AMAs and PAs (86,974 ppy) needed to be adjusted slightly to account for the 12,000 acres of AMAs that are overlapped by PAs. Subtracting approximately 1,490 ppy (or 2 percent) from the sum resulted in a total reduction estimate of 85,484 ppy atrazine active ingredient.

Estimated Program Costs of Proposed Amendments. The DATCP estimated the incremental program costs of implementing the proposed amendments in terms of the additional monitoring and enforcement staff and equipment necessary. Annual program costs were estimated at $103,900, while one-time equipment costs would amount to approximately $18,800. Assuming that equipment costs are amortized over an indefinite period at 10%, the total program costs were estimated at $105,780 per year.

Estimated Compliance Costs of Proposed Amendments. Compliance costs were estimated in terms of the increased cost per acre of corn production as a result of the partial or total substitution of other herbicides for atrazine, or the implementation of alternative weed reduction measures.

Estimated Compliance Costs in AMAs: The AMA acres to which atrazine is applied to sweet and seed corn crops at rates exceeding those proposed (20,396), multiplied by the average cost increase of reducing atrazine in sweet and seed corn production ($7.5 per acre), equals the cost of reducing atrazine application to these crops in the AMAs ($152,972).

The AMA acres to which atrazine is applied to field corn crop production at rates exceeding those proposed (96,154), multiplied by the average cost increase of reducing atrazine in field corn production ($5 per acre), equals the cost of reducing atrazine application to field corn crops in the AMAs ($480,769).

The total compliance cost of reducing atrazine maximum application rates to all corn crops in the AMAs was thus estimated to be $633,741.

Estimated Compliance Costs in PAs: The PA acres to which atrazine is applied to sweet and seed corn crops (1,350), multiplied by the average cost increase due to the elimination of atrazine application in sweet and seed corn production ($10 per acre), equals the cost of eliminating atrazine application to these crops in the PAs ($13,500).

The PA acres to which atrazine is applied to field corn crops (7,650), multiplied by the average cost increase due to the elimination of atrazine in field corn production ($7.5 per acre), equals the cost of eliminating atrazine application in field corn crop production in the PAs ($57,375).

The total compliance cost of eliminating atrazine application practices in corn crop production in the PAs was thus estimated to be $70,875.

Total Estimated Compliance Costs: Based on the above estimates, the total compliance cost of the proposed 1992 amendments would be an increase in the cost of corn production of $704,616, less $12,675 (to account for the approximately 2 percent of the AMAs that are overlapped by PAs), or $691,941.

Alternative Option

An alternative option to the proposed amendments was evaluated by the DATCP. Under this alternative program, atrazine application would be prohibited in the AMA established under the 1991 Atrazine Rule, as well as the additional AMAs and PAs delineated by the 1992 proposed amendments.

Estimated Effects of Alternative Option. The effects and compliance costs of this option were calculated in exactly the same way as those for the proposed 1992 amendments.

Estimated Atrazine Reduction in Existing AMA: The AMA established under the 1991 Atrazine Rule consists of 25,000 acres, 6,250 of which are applied with atrazine in corn production. The maximum application rate for this AMA was set under the alternative option at .75 ppy, limiting the total amount to 4,688 ppy of atrazine active ingredient.

Estimated Atrazine Reduction in New AMAs: The AMAs delineated under the 1992 proposed amendments would essentially be prohibition areas under the alternative option.. Returning to the discussion above on the estimated atrazine reduction under the proposed amendments, the amount of atrazine active ingredient currently applied in the AMAs was estimated to be 245,000 ppy, all of which would be prohibited under the alternative option.

Estimated Atrazine Reduction in New PAs: The eight PAs proposed under the 1992 amendments are also included in the alternative option. The total reduction of atrazine active ingredient in the PAs was already estimated to be 12,600 ppy.

Total Estimated Atrazine Reduction: The reduction of atrazine active ingredient due to the prohibition of its use in the existing and new AMAs, and the new PAs was estimated to be 262,288 ppy, less 4,496 ppy (to account for the approximately 2 percent of AMAs that overlap PAs), or 257,792 ppy.

Estimated Program Costs of Alternative Option. The DATCP estimated the annual program costs of the proposed 1992 amendments at $103,900, with $10,500 of this attributed to support work to administer the program. Estimating that the demand for support work would be reduced by 30 percent if the prohibition of atrazine was adopted (as opposed to maximum application limits), the annual program costs of the alternative option were estimated at $100,750. One-time equipment costs would be the same, approximately $18,800. Assuming equipment costs are amortized over an indefinite period at 10%, total annual program costs were estimated at $102,630.

Estimated Compliance Costs of Alternative Option. Compliance costs were again estimated in terms of the increased cost per acre of corn production due to the substitution other herbicides for atrazine, or the implementation of alternative weed reduction measures. The following estimations were made with respect to increased production costs:

- ☐ the average cost per acre of eliminating atrazine, in any type of corn production, in areas currently subject to AMA maximum application rates would be $2.5

- ☐ the average cost per acre of eliminating atrazine in the production of corn in areas now subject to state maximum application rates would be $10 for sweet and seed corn, and $7.5 for field corn.

Estimated Compliance Costs in Existing AMA: Of the 6,250 acres in the existing AMA to which atrazine is applied in corn production, approximately 938 are dedicated to sweet and seed corn, and 5,312 to field corn. Multiplying each of these amounts by the average increased cost of eliminating atrazine use from the existing AMA maximum application rate ($2.5 per acre) resulted in estimated increased costs of $2,345 for the production of sweet and seed corn and $13,280 for field corn. The total estimated compliance costs in the existing AMA were thus estimated at $15,625.

Estimated Compliance Costs in Additional AMAs: The AMA acres to which atrazine is applied to sweet and seed corn crops (30,625), multiplied by the average cost increase of reducing atrazine in sweet and seed corn production ($10 per acre), equals the cost of reducing atrazine application to these crops in the AMAs ($306,250).

The AMA acres to which atrazine is applied to field corn crop production (144,375), multiplied by the average cost increase of reducing atrazine in field corn production ($7.5 per acre), equals the cost of reducing atrazine application to these crops in the AMAs ($1,082,813).

The total compliance costs of reducing atrazine maximum application rates to all corn crops in the AMAs were thus estimated to be $1,389,063.

Estimated Compliance Costs in PAs: The PA acres to which atrazine is applied to sweet and seed corn crops (1,350), multiplied by the average cost increase due to the elimination of atrazine application in sweet and seed corn production ($10 per acre), equals the cost of eliminating atrazine application in sweet and seed corn crop production in the PAs ($13,500).

The PA acres to which atrazine is applied to field corn crops (7,650), multiplied by the average cost increase due to the elimination of atrazine in field corn production ($7.5 per acre), equals the cost of eliminating atrazine application in field corn crop production in the PAs ($57,375).

The total compliance cost of eliminating atrazine application practices in corn crop production in the PAs was thus estimated to be $70,875.

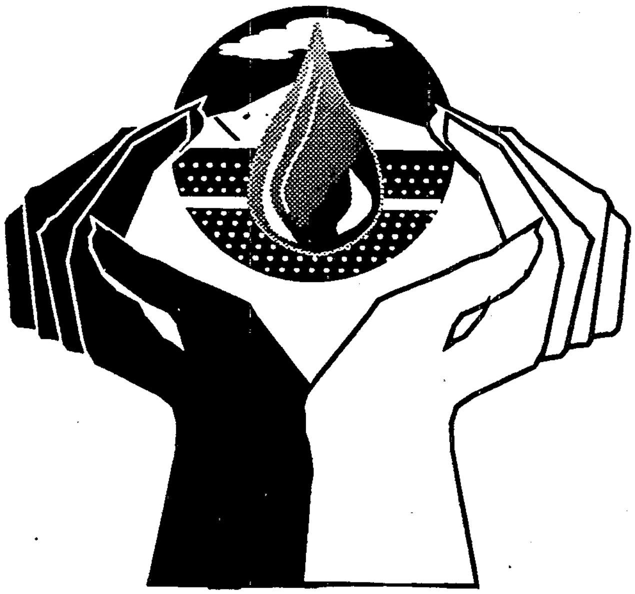
Total Estimated Compliance Costs: Based on the above estimates, the total compliance cost of the alternative option would be an increase in the cost of corn production of $1,475,563, less $25,295 (to account for the approximately 2 percent of the AMAs that are overlapped by PAs), or $1,450,268.

Cost-Effectiveness

The cost-effectiveness of the proposed amendment plan and alternative plan was estimated by dividing the reduction of atrazine active ingredient by the cost of implementing each option.

	Proposed Plan	Alternative Plan
Program Costs Only	.81 ppy/dollar (85,484 ppy/$105,780)	2.5 ppy/dollar (257,792 ppy/$102,630)
Program and Compliance Costs	.11 ppy/dollar (85,484 ppy/ ($105,780 + $691,941))	.17 ppy/dollar (257,792 ppy/ ($102,630 + $1,450,268))

The alternative plan, although slightly more cost-effective, failed to meet the "economic feasibility" requirement of the State's legislation; therefore, the original plan was proposed in the 1992 amendments.



6. *Analyzing Costs and Benefits*

Cost-benefit analysis is a comparison of benefits to costs. This type of economic analysis is most often employed in determining the merits of a particular program and when deciding whether to implement a program or one of its components.

The results of a cost-benefit analysis can be expressed in one of two ways. The first is as a ***ratio of benefits to costs***. The second is as ***net benefits***, which are calculated by subtracting costs from benefits.

Evaluations of the costs and benefits of ground water protection programs are based on the premise that both the costs and benefits are measurable and can be compared to each other. In this regard, a balanced perspective is essential. A balanced cost-benefit analysis will include estimations of all of a program's associated costs and benefits (e.g., both the compliance costs an industry incurs as the result of a ground water protection program and the benefits it gains from having a source of clean ground water).

This chapter presents an introductory discussion of the types of benefits that are estimated for ground water protection programs, and then presents the steps to be taken in conducting a cost-benefit analysis. As shown in the box on the next page, several of these steps have been covered in previous chapters, and are not repeated here.

Identify the Types of Benefits

The benefits associated with a ground water protection program take one of two forms that derive from the ground water's use as a commodity or as a resource. These types of benefits are discussed below in more detail.

Steps in a Cost-Benefit Analysis

Define a Ground Water Protection Program (Chapter 2)

- set a goal
- set objectives
- define options
- identify impacts

Establish the Baseline (Chapter 3)

- define the baseline
- quantify the baseline
- consider factors that increase or decrease baseline estimations
- consider the probability of baseline bias

Assess the Costs (Chapter 4)

- select costs
- select the cost estimation technique
- estimate the costs

Identify the Types of Benefits

Estimate the Benefits

Evaluate Cost-Benefits

Commodity and Resource Benefits

Commodity Benefits

Ground water benefits can take two forms. The first is the benefit accruing from the use of ground water as a *commodity* for:

- ☐ drinking water (individual use)
- ☐ agricultural uses
- ☐ industrial applications.

Because markets usually exist for these uses of water (people will pay for them), these benefits of water are given a price. This price represents a measure of the commodity value of ground water. Ground water can also be viewed as a commodity through its interaction with surface waters. Its commodity value is based on the value of the surface water ecosystem.

Resource Benefits

The second form of benefit is *resource* benefits. These include:

- the benefit of being able to use the ground water as a resource at some time in the future (generally termed "***option values***")

- the benefit of having a source of clean water for future generations (the "***bequest value***")

- the benefit of knowing the ground water is uncontaminated, even if there is no expectation that it will have to be used ("***existence values***").

Other types of resource benefits, such as recreation value, are frequently measured for such water resources as lakes, wetlands and streams, but have not been applied to ground water.

Because markets generally do not exist for resource benefits, they are usually not priced. Instead, they are captured by what is called "***consumer surplus,***" a term used to measure benefits to individuals and businesses that consume ground water (see the box on the next page).

When you are considering the potential benefits of your ground water protection program, it is useful to think of them in terms of direct and indirect and primary and secondary benefits, just as you did for costs in Chapter 4.

- ***Direct benefits*** are the benefits realized by governments, firms, and individuals who are directly affected by the program. An example of a direct benefit is avoiding the costs of having to develop an alternative supply of ground water.

- ***Indirect benefits*** are the benefits passed on to others. An example would be a firm's decision to expand as a result of protection measures that ensure water quality.

Consumer Surplus

To capture all of the benefits that consumers gain from a clean source of water, it is necessary to estimate their willingness to pay for uncontaminated ground water, in terms of both its commodity and resource values. A partial measure of the benefits of water is a ***"commodity value,"*** which is simply the total expenditures made for ground water. But for any commodity, including ground water, different consumers will be willing to pay different prices for the commodity. Taken together, their willingness to pay represents the total demand for water (or the ***demand curve***). Because consumers generally face a single price for water in the marketplace, there will be consumers who would have been willing to pay more for water than the market price. Summing these consumers' excess willingness to pay and subtracting from it what they actually do pay yields the ***"consumer surplus."***

The amount that consumers are willing to pay will reflect three different types of values:

- ☐ the commodity value and consumer surplus associated with consuming clean drinking water, which reflect the amount of water people feel they need and the value they associate with not being exposed to health risks through their water supply
- ☐ the consumer surplus associated with knowing that water is available for use in the future or for future generations (option and bequest values; these values have no price and thus no commodity value)
- ☐ the consumer surplus associated with knowing that ground water is clean, even if there is no intent of using it in the future (the existence value).

"Producers" of ground water (e.g., water utilities) also receive benefits in that they receive a payment for providing water to consumers. However, if you calculate the amount consumers pay for ground water ***and*** include it as a portion of the benefits consumers receive (i.e., its commodity value), then you cannot also count the payment received by the producer as a benefit. This would be double counting.

- ***Primary benefits*** are felt by an individual, firm, or industry as a result of changes brought about by a program. Clean drinking water is an example of a primary benefit.

- ***Secondary benefits*** are the benefits of a program that "spill over" from those who incur primary benefits to the rest of the economy. For example, if a large manufacturing firm relocates into a community to take advantage of a protected source of ground water (a primary direct benefit), the additional jobs resulting from the firm's relocation are primary indirect benefits. However, if the demand for goods and services created by these new jobs causes additional firms to start up or relocate into the community, these new jobs are secondary benefits. Because secondary benefits are very complex to estimate, they are not discussed further in this guidebook. However, if your program office decides to calculate secondary benefits, it should also calculate secondary costs.

Estimate the Benefits

Estimating benefits presents the greatest challenge in conducting a cost-benefit analysis. A program's resource benefits (such as the value of knowing that ground water is clean), for example, may be difficult to quantify because they are intangible. However, resource benefits are no less important than commodity benefits (such as the value of using uncontaminated water for agricultural crop production), and should be evaluated in a commensurate way if possible. Cost-benefit analysis provides a framework for making this comparison.

Because it may not always be practical or even possible to measure benefits directly, a commonly used method is to estimate the program's costs, and then estimate the losses in well-being that are avoided by implementing a program that improves or maintains the quality of ground water relative to the baseline (see Chapter 3).[1] This practical technique allows the estimation of the benefits that derive from the avoided costs of treatment, alternative ground water supplies, and the damages associated with contamination.

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[1] It is important to remember that protection initiatives such as the Wellhead Protection Program, while not actually improving the quality of ground water, can yield real benefits by monitoring the current quality of the resource. Assuming that the baseline calculation incorporates the likelihood and cost of potential contamination, these avoided baseline costs of a protection program represent the benefits of the protection program.

6. *Analyzing Costs and Benefits*

The remainder of this chapter discusses the four techniques used for estimating benefits to individuals and businesses. These are:

- ☐ *Avoided cost.* This method estimates the costs that individuals or businesses would incur (e.g., for water treatment, alternative supplies) in the absence of a ground water protection program as the "benefits" of the program.

- ☐ *Health risk assessment.* This subset of the avoided cost technique measures the benefit to individuals of avoiding increased illness or risk of cancer by protecting ground water from future contamination. In other words, it substitutes the risk of disease for monetary costs as a measurement of avoided costs.

- ☐ *Contingent valuation.* This survey method is used for measuring the total willingness to pay for the various attributes of ground water.

- ☐ *Hedonic pricing.* This technique uses property values to determine the value of one attribute of property, such as ground water quality.

The Avoided Cost Method

An important technique for estimating the commodity benefits that individuals and businesses will realize from ground water protection programs is the avoided cost method. This technique estimates the costs that would be incurred in the absence of a ground water protection program. Because a ground water protection program is designed to detect, respond to, or treat contamination, it avoids these costs, which are treated as "benefits" of the program and are called ***avoided-cost benefits***. Looking at costs in order to reveal benefits may seem counter-intuitive, but it is actually a common way of justifying actions to prevent an unwanted event from occurring. For example, the benefit of changing the oil in a car can be characterized as the avoided cost of major engine repairs.

Avoided cost is a frequently used benefit estimation technique, both because it is a common sense approach and because the information necessary to estimate avoided costs is often readily obtainable. Ground water managers are generally familiar with the specific types of treatment processes required for different types of contamination, and many communities have undertaken detailed analyses of the costs of treating contamination events that they have experienced.

The use of the avoided cost technique is premised on ***response*** costs. If a ground water resource faces the risk of contamination, communities and others that rely on that water can expect, at some point, to incur costs associated with responding to contamination. The expected value of these costs depends on:

- the cost of actions taken in response to contamination, which generally include remediating or treating the water, or in cases of severe contamination, developing alternative water supplies

- the costs of damages that result from the contamination, such as losses in agricultural crop production or increased industrial production costs (health damages are discussed separately below in the section on risk assessment)

- the likelihood of contamination.

An effective ground water protection program will significantly reduce the likelihood of contamination, thereby reducing the expected cost value of contamination response and damages once a program is implemented. If the costs associated with responding to contamination can be avoided by implementing a ground water protection program, the avoidance of these costs is regarded as a quantifiable benefit. Some guidelines on developing these cost estimates are given below.

It is important to note that the total avoided costs of a response program may *not* provide a basis for comparing the benefits of protection programs. This is because a protection program will often have several components, each designed to protect different areas from contamination threats that are specific to each area. For example, it is not appropriate to use the costs of responding to all types of contamination of a public well as the basis for analyzing the benefits of a protection program component that is designed to control a single type of pollution (e.g., nitrate pollution). The costs for response and protection should be broken down by contaminant and into comparable units, such as the cost per well, per gallon, or per consumer. Because contamination response cost estimates are the foundation for avoided cost estimations of benefits, whenever possible, they should be developed with this use in mind.

In the Suffolk County, New York case study presented at the end of this chapter, the County estimated the cost of treating a specified number of wells for two classes of contaminants in order to select the most cost-efficient treatment methods of both existing and future contamination events. These estimates can be used to derive estimates of some of the avoided cost benefits of Suffolk Country's proposed protection measures.

Estimating Avoided-Cost Benefits

The estimation of avoided-cost benefits has three components:

- ☐ the cost of damages incurred if a contamination event was not noticed, or if action was not taken (the baseline costs)
- ☐ the probability that the contamination would be detected and an effective response taken to prevent contamination before the ground water was used (the probability of the program working)
- ☐ the costs to detect, respond, and comply with the program designed to address a contamination event (direct and indirect program and compliance costs).

These three components are represented in the following simplified equation for calculating avoided-cost benefits:

(Baseline Costs x Probability of Program Working) - Direct and Indirect Program and Compliance Costs = Avoided-Cost Benefits

The process of calculating avoided-cost benefits entails four steps. These should be repeated for each type of protection method being considered in a ground water protection program.

Step 1: Calculate baseline costs. As discussed in Chapter 3, the baseline represents the effects of doing nothing more than the existing program. The types of costs that would be incurred include:

- ☐ ***Treatment costs:*** the costs to treat the types of contaminants anticipated. These costs should be estimated separately according to the treatment methods used, which will depend on such factors as the type of contaminant and the characteristics of the well (e.g., location, size, volume of production, population serviced).

- ☐ ***Replacement costs:*** The costs to replace the volume of water that would be lost to consumption if a contamination event occurred. These costs would be based on the volumes of water consumed from wells in the area and the period of time that an alternative supply would be needed.

- ☐ ***Damage costs:*** the value of the damages that would be experienced.

It is important to remember not to double count these costs. Thus, during the same period, for the same water supply, the costs of both replacement and treatment should not be included in the estimate. If the response to contamination is staged (e.g., replacement bottled water is provided until a treatment facility is in place), however, both types of costs would be included for the periods in which they would be incurred.

If possible, it is also helpful to assign to any given well or area probabilities that it will experience a contamination event, and preferably separate out the probabilities according to the types of sources and/or types of contaminants. Otherwise, one assumes a "worst case" and a 100 percent probability of contamination occurring.

Next, present and future costs should be ***aggregated.*** This can be done in one of two ways:

- ☐ Calculate the present value of all future costs and add these costs to those one-time costs incurred during the present period (e.g., capital expenditures).

- ☐ If you want to compare programs on an annual basis and assuming that you estimate annual costs in "constant" dollars (i.e., taking inflation into account), you can amortize all one-time present costs and add these costs to your annual expenses (see the Suffolk County case study at the end of this chapter for an example of amortization).

Last, you may elect to incorporate into the baseline calculation the probability that contamination will occur. If you do not, you are essentially assuming a 100 percent probability of contamination, at least for the purpose of calculating the avoided costs of a program. If you assume that contamination is only, say, 75 percent likely, then you will multiply the baseline by this possibility. Note that this has the effect of lowering the potential avoided costs, and hence the benefits, of a program. You may also elect to use a range of probabilities and use the results to derive a range of avoided-cost benefits.

Step 2: Determine the probability that the program will work. This step involves estimating the likelihood that the proposed ground water protection program will detect and effectively respond to a contamination event and thus prevent contamination-related costs. The effect of this probability on baseline costs, and thus, the coincident benefits of a program, may be dramatic. Therefore, you should be careful to base your probability estimates on available data to the greatest extent possible. For example, maps showing the location of public supply wells in relation to potential contamination sources, hydrogeologic studies, well samples, plans for residential and commercial development, etc. may assist you in making accurate probability estimates.

In general, the more intensive the monitoring component of a program, the higher the probability of detection. Because the likelihood of detecting contamination in the absence of monitoring cannot be predicted, a range of probabilities is useful.

Next, you should estimate the probability of the program being effective. The most simple assumption is that the program will be 100 percent effective; however, you may wish to use a range of probabilities. Assuming that contamination occurs, multiplying these two probabilities will yield the overall probability that the program will both detect and effectively address the contamination. For example, suppose you assume that the probability of the detection is 90 percent and that the probability of the program being effective ranges from 100 percent to 50 percent. Therefore, the probability that the program will both detect and address a contamination incident will range from 90 to 45 percent.

Step 3: Multiply the baseline costs by the probability that the program will work to yield the costs of contamination that could be avoided. Note that if the probability of the program working was zero, the potential avoided costs will also be zero (that is, the program can have no benefit because it does not work).

Step 4: Subtract the program costs from the potential cost of contamination to yield the expected avoided-cost benefits of the program.[2] The hypothetical example at the end of this chapter illustrates this process.

Depending upon the structure of the program or programs being considered, you may need to adjust your costs for events that are uncertain. To illustrate this concept, consider the following example. If a program's costs are certain to be incurred (e.g., monitoring wells will be installed, new staff will be hired, new standards for businesses will be enacted), the full amount of these costs should be subtracted from the total potential costs of contamination. However, if the cost elements of a program are contingent upon other events (e.g., remediation will not occur unless contamination is detected), you will need to multiply the amount of these costs by the probability that they will be incurred.

The Uses and Limitations of the Avoided Cost Method

Although estimating benefits using the avoided-cost method is fairly straightforward, it underestimates program benefits because it does not include the consumer surplus associated with avoiding increased costs for clean water and because it excludes the resource values associated with clean ground water.

Despite these concerns, avoided costs are likely to be the most useful and accessible benefits that are calculated for ground water protection programs. Thus, the results of an avoided-cost benefit estimation should be reported as a *partial* estimate of benefits.

[2] At first glance, the relationship between the local government expenditures in response to ground water contamination and the estimates of consumer well-being are not obvious. To see this relationship, it is necessary to assume that ultimately, individuals pay for local government expenditures (either directly through fees or indirectly through taxes or changes in the services governments provide). Increases in the price of water as a result of contamination will have two effects on consumers: 1) their total expenditures on water would increase (by paying a higher price for the quantity consumed) and 2) their consumer surplus would decrease (that is, the difference between what they actually pay for water and what they would be willing to pay for additional water will decrease when prices are higher).

Risk Assessment

An important and complex subset of avoided costs is the benefit of avoiding increased illness or risk of cancer by protecting ground water from future contamination. One of the primary motivations for protecting ground water is the protection of public health, which makes estimating the health benefits of different protection options very meaningful to policy makers and program managers.

However, the number of assumptions needed to estimate the potential for illness or death in the absence of protection programs makes this benefit extremely difficult to estimate. It should only be evaluated if it can be assumed that there is a probability that contamination would go undetected, exposing the population to health risks.

As with other types of economic analysis, the avoided costs of treatment and alternative supply should not be double counted with avoided health risks, unless health damages would be incurred even with detection.

The issues to be addressed in using the results of a risk assessment to calculate the benefits of ground water protection include:

- ☐ what assumptions are made about the "value" of avoiding a cancer case or the number of cases that result in "premature death" and
- ☐ how to ascribe a value to avoiding non-cancer health risks.

The approach to risk assessment suggested in this guidebook follows, in part, EPA's approach to conducting regulatory impact analyses of proposed drinking water regulations (see U.S. EPA *Guidelines for Performing Regulatory Impact Analysis*, December 1983 (reprinted in March 1991), particularly "Appendix A: Analysis of Benefits," March 1988). The details about the process of health risk assessment, including the sources of information needed to conduct such an assessment, are presented in the text box on the next page. The remainder of this section is limited to a discussion of how to monetize health benefits.

Measuring Health Costs

In a regulatory impact analysis, the number of excess cancer cases and the ***hazard ratio*** (the ratio of exposure to a substance to the toxicity of the substance) that are derived from the risk assessment are used to provide a range of estimates of the value of avoiding these risks. There is a standard way to value these effects:

Risk Assessment

To measure the benefits of avoided health-related costs resulting from a ground water protection program, it would be ideal if a local government were in a position to develop detailed and precise estimates of the risks of exposure to ground water contaminants. If this is not possible, the steps outlined below indicate the types of information that need to be compiled or the types of assumptions that must be made to develop a range of possible health risks resulting from ground water contamination. There are three basic stages in conducting a risk assessment of potential ground water contaminants.

Step 1. Assess the potential for exposure. To determine exposure potential, the potential sources of contamination, the physical characteristics of potential exposure sites, potentially exposed populations, and potential types of releases must be identified. Then, ground water transport calculations or models may be used to determine the potential concentrations of contaminants that a population may be exposed to from different types of contamination events. Finally, the potential intake of contaminants must be estimated for all of the ways in which drinking water might expose residents to contaminants.

Step 2. Determine the potential toxicity of contaminants. After intake is estimated, the toxicity of contaminants must be determined. Because toxicity data are being updated continuously, the best source of information on the potential toxicity of ground water contaminants is an EPA data base called the Integrated Risk Information System (IRIS). The purpose of this step is to determine at what dose a contaminant becomes a health threat, or for carcinogens, the dose-response relationship.

Step 3. Develop measures of potential risks. After data on exposure and toxicity for potential ground water contaminants have been gathered, the risk of adverse health effects is characterized in terms of 1) the increase in the number of potential additional cancer cases for carcinogens, and 2) a hazard quotient of exposure to harmful doses for non-carcinogenic health effects.

For more detailed information on conducting risk assessments, see U.S. EPA, *Risk Assessment Guidance for Superfund,* volume 1, December 1989 and U.S. EPA, *Superfund Exposure Assessment Manual,* 1988.

- ***Increased cancer risks.*** In this case, a range of values of reducing risks to life is estimated and then applied to the number of lives that would be saved if the cancer risks are avoided. This range reflects methodological and other differences in studies estimating what society is willing to pay for small reductions in life-threatening risks. This range is between $1.5 million and $8.5 million (constant 1986 dollars) per "statistical" life.[3] For example, if the risk of death from exposure to ground water contaminants is 1 in 1 million, and the population of the community adopting protection measures is 2 million, the protection measures (assuming they remove all probability of contamination) would result in 2 "statistical" lives saved, for a benefit of between $3 million and $17 million.

- ***Increased non-cancer health risks.*** Here, a value is estimated in terms of financial losses (medical costs and lost wages). Estimating the value of non-fatal illnesses avoided is much more difficult because these costs will vary considerably for different types of contaminant-induced illness and for different individuals. The hazard quotient derived from the risk assessment for non-cancer effects indicates whether a population's exposure to a toxic contaminant exceeds the threshold level that results in some level of health impact. In other words, if the hazard quotient is over 1, the exposure is over the minimum exposure that results in some type of health impact. This quotient only indicates the minimum contaminant dosage required for some type of health effect; other health effects may manifest at higher dosages. If the hazard quotient is greater than 1, the population is at risk for some negative health impact.

  The procedure for determining exactly what illnesses are likely to develop is called segregation of hazard indices. It is used to ascertain the mechanism for the contaminant's action on the human body. This analysis generally requires a trained toxicologist to determine the types of illnesses that are likely to result from potential exposures. Once this is determined, the costs of treating specified illnesses can be used, in conjunction with estimates of lost wages and length of illness, to determine the potential economic impact of exposure to ground water contaminants.

[3] Fisher, Ann, "The Value of Reducing Risks of Death: A Note on New Evidence," *Journal of Policy Analysis and Management,* vol. 8, no. 1, Winter 1989, pp. 88-100.

Because of the large number of assumptions involved in a health risk assessment, it is best to estimate a range of possible exposures. The range of values associated with health risks should then be applied to each possible level of exposure.

For non-fatal health impacts, the calculation of potential medical expenditures and foregone earnings gives a lower-bound estimate in determining the benefits of avoiding exposure to health-threatening contaminants. It estimates the expenses that individuals would incur, but does not take into account changes in their overall welfare (e.g., individuals may feel sick but not spend money on treatment).

The Uses and Limitations of Risk Assessment

Despite its difficulty, this is an important approach to estimating the costs and benefits of ground water protection programs. Combined with the avoided costs of treatment, alternative supply, and non-health damages, this approach will provide a measure of benefits that may represent the bulk of a program's benefits, although it would exclude the resource benefits of ground water protection.

Contingent Valuation[4]

This economic analysis technique estimates a good's full benefits to individuals by estimating their total demand for that good. For most commodities, demand can be estimated from data on the amounts of a commodity that are purchased at different prices. Ground water, however, does not have a price if it is obtained from private wells, and may not be priced at "market price" if it is obtained from public wells. It is thus called a non-market good. For this reason, the data available on the volumes of ground water consumed at different prices will not be sufficient to derive a demand curve for ground water, and without a demand curve, it is not possible to estimate changes in consumer surplus. Similarly, there are no data at all on how people value the resource benefits (option, bequest, and existence values) of ground water because there is no market for these benefits.

The contingent valuation method is used to estimate the demand for non-market goods by determining the amount of money people would be willing to pay for different quantities of those goods. In essence, it creates a hypothetical market (a sort of "what if" situation)

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[4] EPA is currently developing a major contingent valuation study in support of RCRA's Corrective Action Rule. Interested persons should contact the Office of Solid Waste for further information.

and asks individuals to place a value on the good in this market. This willingness to pay is obtained through in-person, telephone, or mail surveys that are carefully structured to 1) present a scenario establishing a hypothetical market in which the good can be bought, in terms that the respondent is comfortable with, 2) accurately elicit the respondent's willingness to pay for the good, 3) reveal the characteristics of the respondent that are likely to influence the value placed on the good in question, and 4) avoid biasing the responses.

Contingent valuation is the officially approved method for valuing non-market goods by the U.S. Water Resources Council and for valuing natural resources under the Department of Interior's CERCLA regulations.[5] This method is also approved by the U.S. Environmental Protection Agency, the U.S. Forest Service, and the U.S. Army Corps of Engineers. However, this is a very detailed and costly method to undertake in evaluating benefits.

EPA's Office of Policy, Planning and Evaluation has recently completed a major study exploring the use of the contingent valuation method for valuing ground water. This study, entitled *Methods for Measuring Non-Use Values: A Contingent Valuation Study of Groundwater Cleanup*, discusses methodological issues in measuring non-use values for ground water cleanup. The study also determined that citizens will pay an average of $7 per person per month for non-use values of ground water. This is a significant amount when added over a city or state.

Measuring Willingness to Pay

Contingent valuation surveys require careful attention to two factors: the survey questionnaire and the sample population that is selected for surveying.

The Survey. The first step in a contingent valuation study of ground water protection is to determine what attributes of ground water need to be characterized in order to elicit people's willingness to pay for it. In developing the survey, it is essential to develop a detailed scenario explaining:

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[5] U.S. Water Resources Council, *Economic and Environmental Principles for Water and Related Land Resource Implementation Studies*, Washington, DC: U.S. GPO, 1983; and U.S. Department of the Interior, "The Final Rule for Natural Resource Damage Assessments Under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980," *Federal Register*, vol. 50, no. 245, 1986.

- ☐ the characteristics of the ground water (e.g., healthfulness, uses)

- ☐ the baseline level at which the ground water is being provided (e.g., the volume of ground water currently being pumped)

- ☐ the changes in the amount of ground water provided or its characteristics under different protection options.

Then, individuals are asked to determine the amount they would be willing to pay to avoid a decrease in quality or quantity, or to improve current levels. The scenario must also include a realistic method of payment (e.g., tax increases or user fees) and a description of any available substitutes (e.g., other water sources).

In conducting the survey, there are several different ways to approach asking people to provide a value. The basic options are:

- ☐ A *single-value question,* either *open-ended* (e.g., how much would you be willing to pay for ____?) or a *take-it-or-leave it value* (would you pay $____ for ___?). The Dover, New Hampshire case study at the end of this chapter used a take-it-or-leave-it question: "Would you be willing to pay $___ per year in extra property taxes for such a ground water protection plan in Dover"? This method requires a large survey population to ensure meaningful results.

- ☐ *Iterative questions* (are you willing to pay $____ for ? If not, would you pay $____ less?). One type of iterative approach is a bidding game. Here, respondents are asked if they will pay a certain price for clean ground water and the price is raised if they answer yes or lowered if they answer no until their equilibrium price is reached. An alternative to the bidding game is a single-question payment card, which provides a range of optional prices (including any value in between). As an aid to the respondent, it may provide examples of the amount that is spent on non-related public goods such as road repairs.

The survey may also try to assist people in the difficult task of putting dollar values on something they do not usually think of in those terms, either by providing visual aids or by specifying a range of values from which to choose.

The contingent valuation method assumes that the hypothetical market can be described in such a way that the respondents will react in the same way as they would in a real market. This helps to encourage realistic and valid responses and to avoid potential bias (where the sample willingness-to-pay estimates will systematically diverge from the respondents' "true" willingness to pay). Most bias can be alleviated or eliminated with careful survey design. Six potential sources of bias pertain to contingent valuation surveys:

- ☐ *hypothetical bias:* the respondents cannot or will not treat the hypothetical market as they would a real situation

- ☐ *strategic bias:* the perceived consequences of the experiment influence the respondents' stated values

- ☐ *permanent vehicle bias:* where the method of payment used in a survey elicits emotional or protest responses from the participants (e.g., people who do not want to see their taxes raised give a $0 value to their water)

- ☐ *starting point bias:* in a bidding approach, where the starting bid implies a value for the good that influences the price ultimately chosen (e.g., if an individual reconsiders his or her valuation of a good because it seems too extreme relative to the starting bid)

- ☐ *information bias:* the respondents are influenced by the amount and detail of information given to them

- ☐ *interviewer bias:* interviewers consciously or unconsciously influence respondents' decisions or valuations.

The Sample. Contingent valuation surveys are costly and their samples must be large enough to obtain meaningful data. A sample that is too small will result in statistically biased values for the average willingness to pay. Some of the contingent valuation methods used to gain unbiased estimates demand a very large sample size, such as the take-it-or-leave-it-type surveys, because each individual is giving only one value that may or may not reflect their highest value. If the sample is large enough, the highest and lowest acceptable values can be determined over the entire sample. In general, contingent valuation studies need more respondents than most types of survey research because there is a greater potential for people to refuse to participate (the questions require much effort on the respondent's part to go through a very unfamiliar exercise) and because a large difference between willingness-to-pay values is expected. Sample sizes of 600 to 1,500 completed, useable surveys are recommended, although a sample size this large is not common in contingent valuation surveys.[6]

The sample must also be representative of the characteristics of the general community. To ensure that a sample is representative, the people to be interviewed must be randomly selected and then evaluated statistically to see if they reflect the overall population. If the evaluation reveals that the sample of respondents is not representative, the results of the willingness-to-pay questions must be weighted statistically to reflect the overall population.

Aggregate Willingness to Pay. After the survey is conducted and the willingness-to-pay responses are weighted to reflect the characteristics of the larger population, the "average willingness to pay" (either mean or median) for different ground water protection options is obtained directly from the survey results. The average individual response is then multiplied by the total population to derive the aggregate willingness to pay for the good, with the aggregate willingness-to-pay values calculated for each ground water protection scenario in the survey. This method provides an estimate of the total area under the demand curve of aggregate social willingness to pay for protecting ground water resources.

The Uses and Limitations of Contingent Valuation

If it is feasible to use contingent valuation to estimate the benefits of a proposed ground water protection program, this method will provide the most thorough estimate of the program's total economic benefits. Two considerations must be taken into account with this method, however. 1) Great care must be taken in designing a contingent valuation study or an incorrect specification of what is being valued will render the results essentially meaningless. 2) It is very difficult to use this method in conjunction with any other household benefit estimation methods because of the potential for double counting. Because contingent valuation is most likely to measure the total willingness to pay for the attributes of ground water (quantity and quality), measuring the benefits related to any of the individual attributes used in the contingent valuation scenario may result in double counting benefits. One of the primary areas of overlap is health risk assessment: the value used in estimating the benefits from avoiding small increments of fatal health risks is a total willingness-to-pay measure, just like that obtained through contingent valuation. It would be difficult to design a scenario for a contingent valuation survey that did not include health risks as part of the changes in ground

[6] Mitchell, R.C. and R.T. Carson, *Using Surveys to Value Public Goods*, Washington, DC: Resources For the Future, 1989, p. 228. Additional survey references are noted in the bibliography.

water attributes. Thus, the avoidance of these risks would be double counted if both methods were used. In general, if a contingent valuation approach is used to value the benefits of a ground water protection program, the survey should elicit all of the relevant values people place on ground water; no other benefit estimate should be used for benefits derived from drinking water commodity use and resource values. Avoided cost estimates of benefits to businesses, however, would not be double counted under estimates derived from a contingent valuation study.

Hedonic Pricing

Whether a household gets its water from a private well or a public drinking water system, it is unusual for the water to be priced at levels that reflect its cost of production or its commodity value. Usually, water is either free or a nominal fee is charged. One way to try to determine the demand for water (how much people are willing to pay for different amounts) when there is no real market is to look at the market for another good (such as housing values) whose price is affected by the quality of water. In this kind of indirect approach, the effect of different levels of water quality on housing prices can indicate the value placed on the quality of ground water itself.

Hedonic pricing is a method that uses property values to determine other values (for example, the difference in price between two "identical" houses located one mile and ten miles, respectively, from a park is a partial measure of the value of the park). Housing is traded in a well-defined market, and the price of a house is defined largely in terms of relative attributes offered by different types of houses within the same market. This method estimates the implicit price of each attribute associated with housing prices. Among the attributes that affect the price of housing (e.g., the number of rooms or the proximity to public transportation), environmental quality (specifically air quality) has been shown to be a relevant factor.[7]

Although hedonic pricing models have been applied to estimate the change in property values associated with proximity to things that might have an effect on ground water quality

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[7] For example, see Freeman, A.M. III, *The Benefits of Environmental Improvement: Theory and Practice,* Baltimore: Johns Hopkins Press for RFF, 1979, pp. 152-162, and Brookshire, D.S., R.C. d'Arge, W.D. Schulze, and M.A. Thayer, "Experiments in Valuing Nonmarket Goods: A Case Study of Alternative Benefit Measures of Air Pollution Control in the South Cost Air Basin," *Methods for Assessing Air Pollution Control Benefits,* vol. 2, Washington, DC: U.S. EPA, 1979.

(i.e., a hazardous waste site),[8] this technique has not been applied exclusively to ground water quality to date. Although academic researchers may be interested in applying this method to ground water, several methodological questions need to be resolved to be sure that the study correctly values ground water protection efforts. Because hedonic pricing has not yet been adapted for use in estimating the benefits of ground water protection efforts, it is not covered in detail in this guidebook. The references section lists a number of studies on hedonic pricing.

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[8] See Michaels, R. Gregory and V. Kerry Smith. "Market Segmentation and Valuing Amenities with Hedonic Models: The Case of Hazardous Waste Sites," *Journal of Urban Economics*, vol. 28, September 1990.

Hypothetical Example: Assessing Costs and Benefits

To estimate the avoided-cost benefits of the two ground water protection program options being considered in Fairhomes County, the program manager begins with the baseline calculated in Chapter 3.

The total estimated one-time costs are $78,350,000. Amortizing over a 30-year period at a 10% rate of interest yields annual costs of approximately $8,300,000. Adding these amortized costs to the estimated annual costs of $2,345,000 yields total baseline costs of $10,645,000.

The program manager assumes a worst-case scenario and estimates that the likelihood of such a contamination event occurring is 100%. Therefore, the total potential avoided costs are $10,645,000.

Next, the program manager estimates the probability that the two programs will each detect and effectively address the ground water contamination. Because Program #1 places a greater emphasis on monitoring, the program manager assumes a 100% probability of detection, while Program #2 only receives an 80% probability of detection. For simplicity, both programs are assumed to be 100% effective.

Multiplying these probabilities by $10,645,000 yields the following potential costs that could be avoided:

Program #1	$10,645,000 x (1)(1)	=	$10,645,000
Program #2	$10,645,500 x (.8)(1)	=	$8,516,000

Next, the program manager subtracts the direct and indirect costs of the two programs (from Chapter 4), which in this case are assumed to be certain to be incurred, to derive the total avoided-cost benefits:

Program #1	$10,645,000 - $5,595,000	=	$5,050,000/year
Program #2	$8,516,000 - $3,040,000	=	$5,476,000/year

Thus, the annual avoided-cost benefits of Program #2 are higher.

Case Study: Suffolk County, New York

Example of Estimating Avoided Costs

The 885 square miles that make up Suffolk County contain 10 towns, 29 villages, and 73 school districts. The County has eight hydrogeologic zones and seven water management areas that are based on geographic considerations.

The County's ground water reservoir holds over 70 trillion gallons of water and is composed of three vertically layered aquifers. There are about 561 public supply wells in the County: 318 in its glacial aquifer, 238 in its Magothy aquifer, and 5 in its Lloyd aquifer. In addition, an estimated 77,800 private wells serve 1.3 million County year-round and seasonal residents (1980 Census). Sixty-five percent of its water is provided for residential use, 21 percent for commercial/industrial uses, and 7 percent for agricultural uses.

Most of the County's ground-water contamination affects the uppermost aquifer, although some wells in the deepest aquifer are also contaminated. The principal sources of ground water contamination in the County are organic solvents from consumer products and commercial/industrial facilities, pesticides from currently prohibited agricultural practices, and nitrates from cesspools and fertilizers. Nearly 1,000 private wells and 25 public supply wells have been found to exceed organic contamination limits, while 4 public and over 2,700 private wells have exceeded pesticide contamination limits.

Suffolk County has experienced substantial residential, commercial, and industrial growth since the mid-1960s, which is projected to continue over the next 40 years. Consequently, ground water quality management has been a predominant environmental concern. Before developing a Comprehensive Water Management Plan in 1987, the Suffolk County Sanitary Code already contained several new provisions for the protection of ground water resources addressing water supply (Article 4), realty subdivision (Article 6), water pollution (Article 7), and hazardous materials storage (Article 12).

Extent of Ground Water Contamination

As of 1987, contamination by synthetic organic chemicals was the greatest overall threat to the County's water supply. This contamination originated from a number of residential and industrial sources, but the principal chemicals were halocarbons (from solvents and degreasers) and aromatic hydrocarbons (from fuel components). Future organic chemicals contamination in new industrial and residential developments was addressed by instituting new controls in the Suffolk County Sanitary Code.

About 30 percent of the private wells in County farming areas showed signs of pesticide contamination. The major pesticides found in the ground water were no longer used, but remnants of them were carried by natural vertical flow into deeper portions of the aquifer. The County felt that stricter federal and state regulations might be needed for the adequate protection of supplies from other agricultural pesticides in the farming regions.

Nitrate contamination was also widespread, with the principal sources being lawn fertilizers and on-site commercial and residential wastewater disposal sites. More than one sample with marginal or poor water quality due to nitrate contamination was found in 22 percent of the County's public wells.

The Comprehensive Water Resources Management Plan, as summarized below, recommended a combination of regulatory measures and public education efforts to reduce significantly the threat of nitrates and other sources of ground water contamination.

Comprehensive Water Resources Management Plan

Suffolk County produced its Comprehensive Water Resources Management Plan in 1987. Its objective was to ensure County residents of an adequate and safe water supply through the year 2020. The Plan examined:

- ☐ Structural program options to address existing ground water *contamination* (e.g., the construction of new water supply systems and treatment facilities for contaminated water).

- ☐ A non-structural ground water *protection* program to prevent further contamination. The program's more than dozen components included planning functions, regulatory controls, land acquisitions, and taxation.

A cost-benefit analysis of the ground water protection program provided a valuable overview of its merits. The cost to the County of each program component was estimated individually and reported in the Plan. The County did not, however, evaluate the benefits of the program or compare them to its costs. Therefore, for the purposes of developing this case study, benefits were estimated in terms of the avoided costs of treating contaminated wells in the future if the program was not implemented. Avoided costs were based on data developed for the County's management plan for contaminated ground water.

Protection Program Costs

Although it was not specified in the Plan, it appears that cost estimates for most components were derived using a modified comparative accounting technique. For example, the County's cost estimates were often a function of the number of additional professionals necessary (and the salaries those positions would demand) or the anticipated rate at which various program components could be subcontracted. The modeling approach was also applied in circumstances where capital expenditures would be necessary for the implementation of a component. The primary components encompassed in the County's non-structural ground water protection program included:

- ☐ monitoring and enforcement activities
- ☐ wastewater collection planning
- ☐ chemical spill response and compensation
- ☐ pesticide, stream corridor recharge, and saltwater interface investigations
- ☐ public information programs
- ☐ wellhead protection
- ☐ toxic household waste disposal control
- ☐ water conservation
- ☐ industrial property transfer approval.

The total annual operating costs of these program components were estimated at about $1,350,000 a year. In addition, it was estimated that Suffolk County would incur a one-time expenditure of $1.5 million from their capital budget to support the program. Assuming a 20-year amortization period at a 12 percent rate of interest yields an annual capital cost of approximately $180,000. This translates to a total annual cost of $1,530,000. Assuming that measures would be uniformly applied across the County, and that costs could be distributed equally across the approximately 541 public supply wells in the County that did not need treatment, the annual program cost per well was approximately $2,830.

Treatment Costs. The County estimated that 20 public water supply wells would have to install treatments systems for organics or pesticides in the near future as a result of contamination. According to the Plan, aeration and granular activated carbon absorption were the most likely treatment technologies the County could use to meet these standards. The average annual capital and operating costs for treating wells using these two technologies are summarized below for two production rates (0.1 and 3.0 million gallons per day (mgd)).

Estimated Annual Treatment Costs (in 1985 dollars)

Treatment Technology	Aeration		Granular Activated Carbon	
Production Rate	0.1 mgd	3.0 mgd	0.1 mgd	3.0 mgd
Capital Costs	$92,000	$540,000	$150,000	$950,000
Annual Operating Costs	$4,300	$63,000	$40,000	$360,000
Total Annual Treatment Costs*	$16,000	$130,000	$60,000	$480,000

* Based on amortization of capital costs over 20 years at 12 percent interest (annualization factor = .13) plus annual operating costs.

Based upon the County's estimates and depending upon the "size" of the well, the lower bound for the value of ground water ranged from about $15,000 per well per year for "small" wells to nearly $500,000 per well per year for "large" wells. Note that these treatment cost estimates were based on only two classes of contaminants (VOCs and pesticides). These cost estimates, and hence the measure of the value of ground water, could have been quite different if it had been possible to obtain data for other types of contaminants.

Alternative Supply Costs. Suffolk County also estimated that it would cost over $43 million (in 1985 dollars) to construct transmission and distribution water main extensions to service the 68 communities that had contaminated wells. However, the County did not include additional costs for the construction and distribution of water mains in six regions. Therefore, it is not possible to calculate the full avoided costs of obtaining alternative supplies for these communities.

Comparison of Costs and Benefits

Suffolk County did not actually compare the value of clean ground water (i.e., the benefits) to the costs of its proposed ground water protection program. However, it is possible to use the results from the avoided-cost calculation above, together with data from the Water Resources Management Plan, to make such a comparison.

A comparison of the costs per well of the protection program and the estimated avoided treatment costs reveals that the value of ground water may exceed the costs of the protection program by an amount ranging from approximately $470,000 per well per year to slightly less than $13,000 per well per year. This range assumes, however, that the program will be 100 percent successful in preventing ground water contamination. If the program did not prevent all contamination, the difference between the value of ground water and the costs would decrease substantially.

Case Study: Dover, New Hampshire

Example of Using Surveys

The water supplies for Dover are pumped directly from ground water resources stored in aquifers. In 1988, many of Dover's neighboring towns experienced ground water contamination problems caused primarily by the leaching of chemicals and toxic wastes from underground storage tanks. Although Dover itself had not experienced any serious ground water pollution problems, despite two wells closed for benzene contamination, the town decided to take proactive measures and draft a ground water protection ordinance.

1988 Ground Water Protection Ordinance

Hazardous wastes, pesticides, development, and urban runoff posed the major threat to Dover's ground water resources. The objective of the 1988 ordinance was "to promote public health, safety, and general welfare by protecting and preserving the quality of existing and future ground water supplies from adverse or detrimental land use, development, or activities."

The ordinance required the identification of important and sensitive recharge areas, and the re-zoning of activities in these areas. Zones were delineated by three circular layers (primary, secondary, and tertiary) around wellhead areas. In the primary zone, development is not allowed. In the secondary zone, pesticide application and the storage of hazardous waste are illegal. In the tertiary (recharge) zone, development densities of greater than 20 percent coverage are prohibited. These zoning laws formed the backbone of Dover's ground water protection program.

6. *Analyzing Costs and Benefits*

Dover considered many alternative land strategies employed in similar New England towns, including public acquisition or land overlying sensitive recharge areas. They decided upon zoning as the best means of meeting their specific needs and cost constraints.

Costs

The annual operating costs of Dover's zoning ordinance have been minimal: only one person is responsible for responding to complaints in this area, which is a small part of his daily routine. The real cost of the program has been hydrogeologic surveys of the basins, the identification of recharge areas, zone delineation, and administrative procedures. Since 1988, the town and the EPA have spent an estimated $250,000 on these activities (for an average cost of $80,000 per year over a three-year period). These were one-time costs needed to design the ground water protection program.

Benefits

As the Dover Planning Council was developing its zoning ordinance, two independent researchers from the University of New Hampshire (Steven Schultz and Bruce Lindsay) were performing an independent analysis to determine the value of ground water protection to the residents of Dover.[9] They felt this information would assist public officials and policy makers in assessing the political and economic viability of specific ground water protection plans. Although there is no indication that their study influenced the policies adopted by the Council, valuable information can be extrapolated from their method of estimation (the contingent valuation survey).

Under this methodology, a simulated market is created in which the "quantity" is represented by the provision of ground water protection services and the "price" is represented by the residents' willingness to pay for a change (i.e., an increase) in the provision of these services. The mechanism for creating this "market" is a survey in which respondents are asked how much more in property taxes they are willing to bear to enact a ground water protection program.

Schultz and Lindsay wanted to determine how much Dover residents were willing to pay for ground water protection programs. They employed a dichotomous choice contingent

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[9] Schultz, Steven D. and Bruce E. Lindsay, "The Willingness to Pay for Groundwater Protection," *Water Resources Research,* vol. 26, no. 9, 1990, pp. 1869-1875.

valuation experiment to determine resident's willingness to pay (WTP) for ground water protection.

First, they conducted a pre-test survey with an open-ended valuation question to establish a range of reasonable responses. The results of this survey indicated that the maximum WTP would be $500. Next, they mailed a contingent valuation survey to 600 Dover property owners. The survey described a possible protection program of acquisitions, zoning ordinances, hiring personnel, and other strategies. It then asked:

> Would you be willing to pay $__ per year in extra property taxes for such a groundwater protection plan in Dover?

Each survey distributed to a household had a specific dollar amount included in the above question, ranging from $1 to $500 in $25 increments. The survey also included questions about the socioeconomic characteristics of the respondents. Property owners were selected because the researchers assumed that they would pay for protection programs through higher property taxes.

A total of 346 usable surveys were returned along with 14 refusals. After adjusting for the 10 sampled property owners who had died or moved away, the response rate for the survey was calculated to be 59.3 percent. From the responses, Schultz and Lindsay were able to determine the maximum and minimum WTP of property owners. They decided to use the median estimates of the respondents' WTP instead of mean estimates to ensure that the results would not be statistically affected by outlier (very high/low) values. All of the non-respondents to the survey were assigned a WTP value of zero, a very conservative assumption. From the survey responses, they were also able to determine what socioeconomic variables had an effect on respondents' preferences (no socioeconomic traits were found that differentiated respondents from non-respondents).

Schultz and Lindsay estimated the median WTP for ground water protection in Dover to be $40. The mean WTP value was more than three times the median value because a few residents placed a value on ground water protection that was well outside the range of likely responses. Also, the 40.7 percent of those surveyed who did not respond were assigned a WTP value of zero. After multiplying the median WTP value of $40 by the number of property owners (2,938), they estimated that the residents of Dover were willing to pay $117,520 annually to protect their ground water resources.

The estimates of annual WTP values for the survey are very conservative for three reasons:

- ☐ median values for WTP were used instead of mean values
- ☐ non-respondents were not assumed to value ground water protection in the same way respondents did in the survey
- ☐ only property owners (not renters) were surveyed.

If the non-respondents were assumed to place the same value on ground water protection as did respondents, the median value would increase, and the annual WTP value for Dover would be $199,200 ($67.80 x 2,938). Furthermore, if the mean WTP estimate was used to calculate WTP, this amount would increase approximately six-fold, to $642,420. In addition, these values do not account for the rental population of Dover, which relies on these same ground water resources.

Costs Versus Benefits

The design and implementation cost of the zoning ordinance for ground water protection in Dover averaged just over $80,000 per year over a three-year period. These were one-time costs, supplemented by continuing minimal operating costs. Under Schultz and Lindsay's most conservative assumptions, the residents of Dover were willing to pay $117,520 a year for a ground water protection program. In fact, their estimates indicated that residents' WTP for ground water protection could reach almost $200,000 a year, based on the assumption that survey non-respondents had the same average WTP as respondents.

A comparison of the actual costs of the ordinance with the Schultz and Lindsay survey results reveals two important conclusions. First, the benefits of a ground water program, as represented in terms of residents' WTP, exceeded the costs significantly, thus indicating that the program was worthwhile. Second, the study results indicate that if Dover needs to undertake additional protection measures in the future, the benefits appear to justify the additional expenditures. Because the survey payment vehicle was a tax, policy makers should expect that residents will support higher taxes to meet these needs if they arise.

Other Considerations

The estimated $80,000 annual cost incorporated only program costs. The estimation and inclusion of the compliance costs associated with the zoning ordinance would have reduced the benefit-cost margin, or the net benefits. Compliance costs might have been assessed by estimating the decreased value of the zoned areas due to restrictions on development and pesticide use.

Glossary

Avoided cost benefits	The benefits of not incurring costs that would have to be paid in the absence of a ground water protection program (e.g., remediation and alternative supply costs).
Avoided health-related cost benefits	The value of lives saved and non-fatal illness avoided due to a ground water protection program.
Commodity benefits	The benefits resulting from the use of ground water as a commodity, such as for drinking water, agricultural uses, and industrial applications. These benefits will depend on the quality and volume of ground water, and they frequently can be estimated using market prices for ground water or goods and services produced.
Comparative accounting cost estimation	A cost estimation technique that involves breaking a new program into its constituent activities and assigning a cost to each activity based on experience with other types of programs.
Compliance costs	The costs that arise as a result of public and private activities to comply with ground water protection requirements.
Consumer surplus	The difference between what consumers actually pay and what they would be willing to pay for additional units of a good or service.
Contingent valuation	A survey method for measuring the total willingness to pay for the various attributes of ground water.

Deadweight loss	The term for a decrease in economic well-being that results when costs or production increase (i.e., the supply curve shifts up). Deadweight loss results from decreased demand due to increased prices, and is not captured by estimates of consumer surplus.
Direct costs	The costs paid by entities that are directly affected by a program or policy.
Discounting	The process of adjusting for the time value of money. If a cost or benefit is realized today, its dollar value is higher than if it is realized at some point in the future. The factor used to make this adjustment is the discount rate, which is applied to future costs or benefits to translate them into present-value terms.
Existence value	The benefit of knowing that a ground water resource is uncontaminated, even if there is no expectation that it will be used.
Expected costs	The cost of an event multiplied by the likelihood of the event occurring.
Hazard quotient	The ratio of exposure to a substance to the toxicity of the substance, indicting the maximum dosage required for the substance to result in some type of health effect.
Hedonic pricing	A benefit estimation technique that uses property values to determine the value of one attribute of property, such as ground water quality.
Hydraulic conductivity	The rate at which a fluid can move through a permeable medium. It is a function of both the medium and of the fluid flowing through it.
Implementation costs	The costs of designing, building, and operating a ground water protection program for the public sector.

Indirect costs	The costs passed on to others by those initially responsible for payment, such as higher utility fees for customers or lost tax revenues for the government.
Marginal costs	The cost of producing each additional unit of output. This is the same as the supply curve for a firm or an industry.
Maximum contaminant level (MCL)	A numeric criterion established under the Safe Drinking Water Act that sets a ceiling on the permitted concentration of contaminants in drinking water. MCLs are set at the level at which no known or anticipated health effects occur and that allows an adequate margin of safety.
Modeling or engineering cost estimation	A cost estimation technique that uses standard cost curves and unit cost data derived from engineering text to determine program costs.
Net benefits	The total discounted benefits of a ground water protection program minus the total discounted costs.
Opportunity cost	The value of the next-best use for a resource (such as labor or other inputs), usually measured by the market price of the resource. More generally, the opportunity cost of an activity is the value of any foregone alternative.
Option value	The benefit of being able to use a ground water resource at some time in the future. This benefit includes use by future generations, sometimes termed "bequest" value.
Primary costs	The costs associated with changes in a firm's operation or in government programs that result in changes in the goods and services used or produced.
Resource benefits	This term incorporates both option, bequest, and existence values, which are not priced by the market.

Secondary costs	Ripple effects in the economy that result from changes in the demand for goods and services due to the implementation of a ground water protection program and compliance with it.
Statistical life	An estimate of the number of deaths that might result from exposure to a carcinogen, calculated by multiplying the community population by the number of excess cancer deaths per unit of population (usually 100,000), and dividing by the unit of population (i.e., 100,000). This estimate does not reflect any projection of individual deaths.
Survey value cost estimation	Gathering relevant cost data from ground water protection program managers, private entities, and others to determine the total costs of a program.
Wellhead protection	Protecting the surface and subsurface area surrounding a water well or wellfield, which either recharges or influences the well or wellfield.
Willingness to pay	A measure of the maximum amount that an individual is willing to pay for each unit of a good or service, as measured by the area under the demand curve for the good or service.

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