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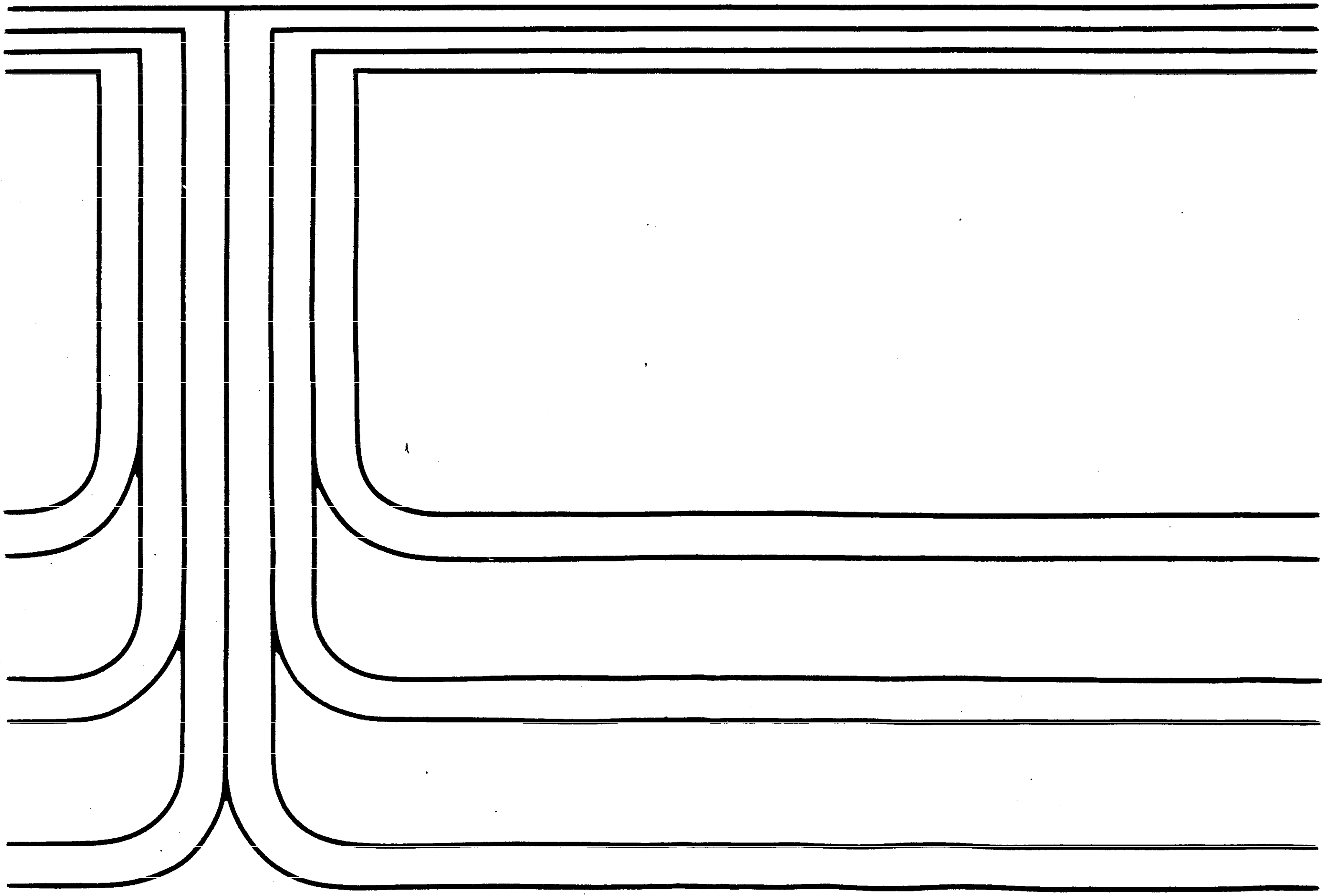
A Framework for Measuring the Economic Benefits of Ground Water



EPA 230-B-95-003

A FRAMEWORK FOR MEASURING THE ECONOMIC BENEFITS OF GROUND WATER[*]

October 1995

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[*] This report is the product of the EPA Interoffice Groundwater Valuation Workgroup that included two economists outside the Agency. Workgroup members are identified on the following page.

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I. INTRODUCTION

The primary goal of this report is to develop a framework for valuing ground water that is applicable to all offices within U.S. EPA (EPA hereafter) that consider the value of ground water resources when conducting Regulatory Impact Analyses (RIAs).[1] The precedent for this effort was set with the development of "A Guide for Cost-Effectiveness and Cost-Benefit Analysis of State and Local Ground Water Protection Programs" by EPA's Office of Water (United States Environmental Protection Agency, 1993). The guide provides a concise discussion of the processes for accomplishing these types of analyses, but does not provide specificity regarding the estimation of ground water values. It is the intent of this report to begin to develop the framework for a comparable guide for assessing the economic value of ground water. We use the term value in a generic sense such that the values associated with reductions in ground water quantity or quality may be considered losses and, conversely, increases are deemed benefits.

The objectives of this report are to:

1. Provide a conceptual framework for identifying and measuring the economic value of ground water.
2. Consider the extent to which the benefits of ground water protection, as suggested by the valuation framework, have been accounted for in previous RIAs; and
3. Provide guidelines for utilizing the valuation framework to consistently value ground water across EPA offices and policy issues within offices.

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[1] Although we limit our application of the valuation framework in this report to RIA's, the framework can also be applied to other ground water policies and programs.

The next section of this report describes the conceptual framework for identifying and measuring the economic value of ground water. The valuation framework links changes in physical characteristics of ground water to uses (services) provided by ground water and the economic effects of changes in ground water services. Almost all EPA program offices, in the course of their respective missions, develop policies or programs that can affect the condition of ground water resources. For example, issues relating to pesticides and resulting decisions by the Office of Pesticides can have implications for ground water quality in areas where pesticides are produced or in areas where the pesticides are applied. Similarly, actions by the Office of Solid Waste related to superfund sites can have implications for ground water quality. Having a consistent blue print for ground water valuation can serve to avoid duplication of effort, and can help to ensure consistency in ground water value assessments within and across offices.

Before moving to a discussion of how the ground water valuation framework applies to RIAs, we discuss studies that have investigated the value of ground water. We do this because RIAs are often dependent on data available in the literature and discussing existing studies helps to amplify issues raised in regard to the conceptual foundation for valuing ground water. The discussion of existing ground water valuation studies is presented in Section III and we focus on the commodity definitions as this issue is unique to ground water applications.

It was decided as part of the development of this report that the illustrative applications would focus on two recent RIAs. This was done because the field of environmental valuation is evolving rapidly and RIAs conducted five to ten years ago had limited access to much of the ground water valuation data currently available. It was also believed that the selected RIAs present the most comprehensive evaluations of ground water conducted by EPA for RIAs. The

RIAs examined are the "Class V Injection Well Regulatory Impact Analysis and Regulatory Flexibility Analysis" by the Office of Water (U.S. EPA, 1993) and "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units" by the Office of Solid Waste (Cadmus Group, 1993).

In the final section, Section V, we suggest initial guidelines for developing a common approach for valuing ground water across offices. These guidelines should be equally appropriate for the design of original studies as well as selecting available studies for transferring estimates to new applications in current RIAs.

II. FRAMEWORK FOR VALUING GROUND WATER

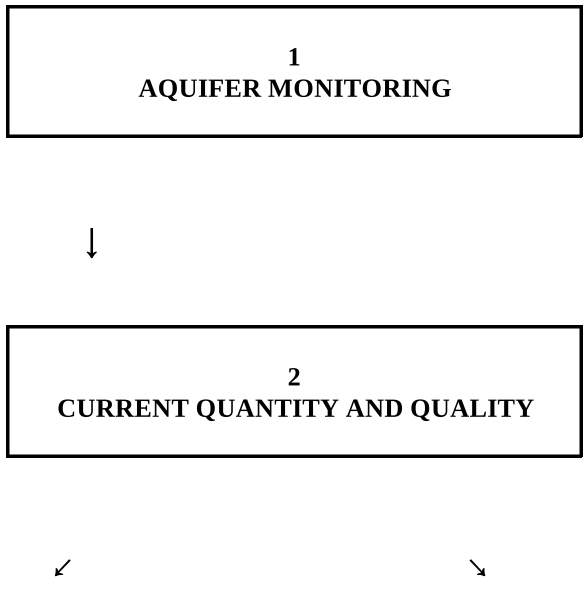
Any assessment of the effect of EPA programs or policies on the economic value of groundwater begins with the investigator making a number of decisions that define the conceptual and empirical domain of the investigation. These decisions are the direct consequence of explicit and implicit questions posed by the investigator(s) and to a large extent determine the outcome of the investigation. A fundamental issue is the definition of the change in the condition of a resource and the ensuing changes in services generated by the resource, i.e., commodity definition. This begins with an understanding of whether the change has occurred or is proposed. Given ex post or ex ante standing, the next step is to develop a technical definition of the reference condition of the resource and identify whether the increment of change is an enhancement or diminishment of the quantity and quality of the resource. For either enhancement of, or preventing harm to, the expected condition of the resource must be defined. Differences between the reference condition and expected condition define the change in the quantity and quality of a resource to be evaluated. Consideration should also be given as to whether the mechanism(s) employed to accomplish the change can achieve the proposed resource condition with certainty. It is also necessary to know the geographical extent of the changes to address the issue of whose values should count in the computation of aggregate benefits or costs. This information collectively constitutes the formal commodity definition for a resource being valued. These questions must be asked for original investigations of value as well for transfers of value estimates to unstudied sites.

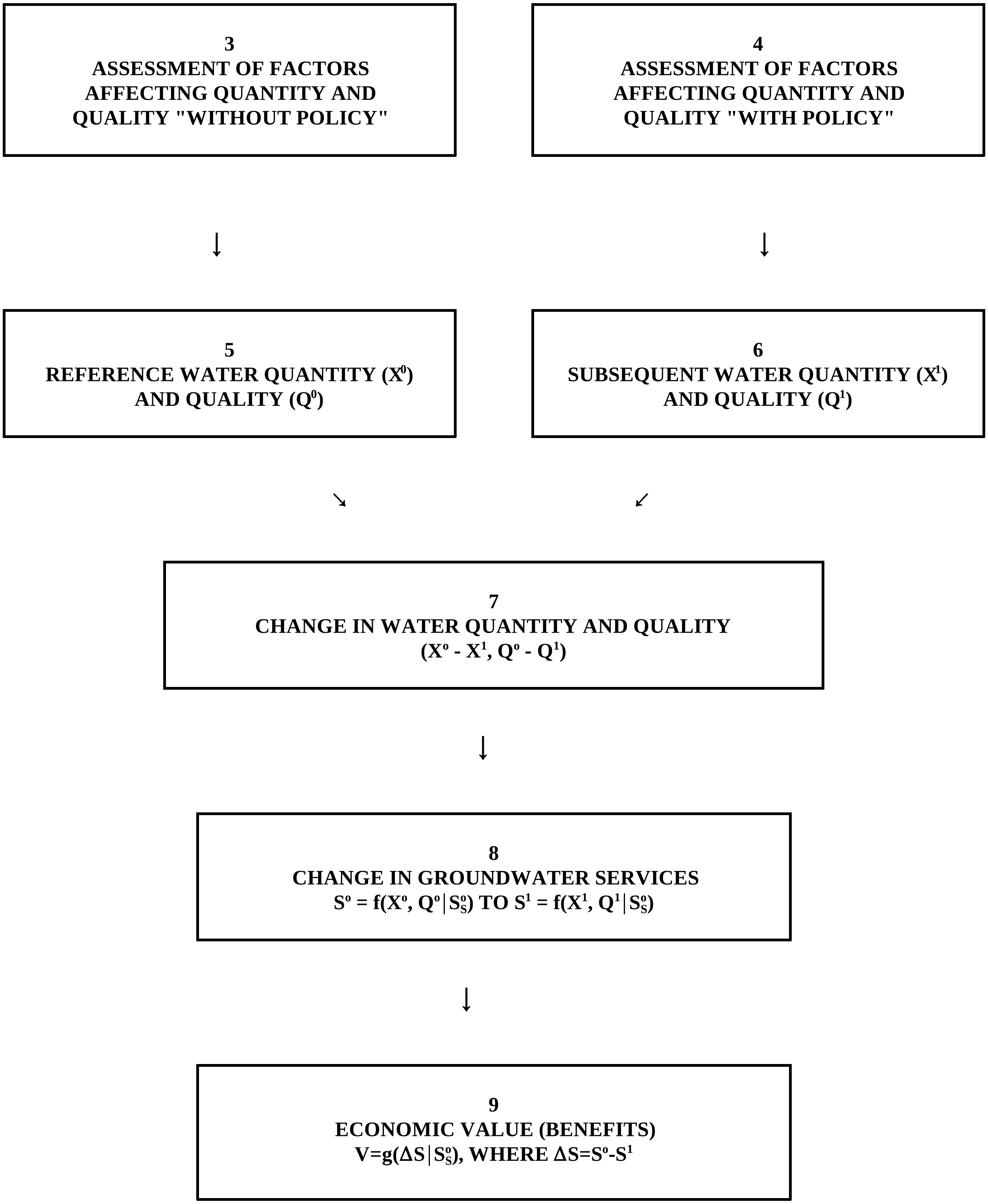
After the commodity definition is established, it is necessary to map changes in the resource condition into changes in the provision of services from which humans derive value. Accomplishing this step can be difficult regardless of whether an original investigation or transfer exercise is being performed. Benefit transfer practitioners have an added complication in that they must interpret value estimates at study sites and assess their transferability, conceptually and statistically, to the policy site. In turn, the increment of change being evaluated at the policy site must be carefully defined, not only for relevance to the current policy issue, but also to accomplish the transfer exercise itself.

Defining Ground Water Values

Valuing ground water requires a clear definition of the ground water "commodity" to be valued. Figure 1 summarizes the technical data required to define a ground water commodity. The first step is monitoring (Box 1) to assess the current or baseline aquifer condition in quantity and quality dimensions (Box 2). The next step is to assess how the current quantity and quality of ground water will change "with" and "without" the proposed regulation (Boxes 3 and 4). These factors include extraction rates, natural recharge and discharge, natural contamination (e.g., salt infiltration) and human-induced contamination (e.g., pesticide contamination, industrial chemical contamination), and public policies regarding the use and protection of ground water. The results of the assessments provide estimates of the reference (without policy) water quantity (X^0) and quality (Q^0), and the subsequent (with policy) water quantity (X^1) and quality (Q^1) (Boxes 5 and 6). Given estimates of the reference and subsequent ground water conditions, we define the change in water quantity and quality (X^o - X^1, Q^0 - Q^1) (Box 7). The steps and linkages illustrated by Boxes 1-7 primarily involve the work of hydrologists, geologists, engineers, ecologists, soil scientists, and other physical and biological scientists. Investigations of ground water conditions by these specialists must be sufficient to identify changes in ground water services linked to the prescribed policy in a manner that facilitates the estimation of economic values. Formally modeling the steps illustrated by Boxes 1-7 represents one of the greatest challenges that needs to be addressed to estimate economic values of ground water protection.

FIGURE 1. The Production of Benefits From Improved Ground Water Quality or Quantity




3
ASSESSMENT OF FACTORS AFFECTING QUANTITY AND QUALITY "WITHOUT POLICY"
4
ASSESSMENT OF FACTORS AFFECTING QUANTITY AND QUALITY "WITH POLICY"
5
REFERENCE WATER QUANTITY (X^0) AND QUALITY (Q^0)
6
SUBSEQUENT WATER QUANTITY (X^1) AND QUALITY (Q^1)
7
CHANGE IN WATER QUANTITY AND QUALITY
($X^o - X^1$, $Q^o - Q^1$)
8
CHANGE IN GROUNDWATER SERVICES
$S^o = f(X^o, Q^o | S^o_S)$ TO $S^1 = f(X^1, Q^1 | S^o_S)$
9
ECONOMIC VALUE (BENEFITS)
$V=g(\Delta S | S^o_S)$, WHERE $\Delta S=S^o-S^1$

Reference services (S^o) supported by ground water are determined by the without policy ground water quantity (X^o) and quality (Q^o) and subsequent services (S^1) are determined by the with policy ground water quantity (X^1) and quality (Q^1). Reference and subsequent ground water services are conditional upon given levels of substitute and complementary service flows (S_s^0) (Box 8). The interactions of scientists and policy analysts facilitate the mapping of changes in the condition of ground water to changes in service flows which affect economic activities. We can then estimate economic value (e.g., willingness-to-pay) as a function of the change in the ground water service flows, given the specified reference and subsequent ground water conditions, and service flows from substitutes and complements to the ground water resource (Box 9).

The steps and linkages illustrated by Boxes 8 and 9 involve the work of economists, building on the biophysical analyses developed for Boxes 1-7.[2] It is difficult to overemphasize this important point. When it comes to estimating economic values associated with natural resource service flows, the most complex and limiting step is often establishing clear linkages between changes in the biophysical condition of a natural resource and changes in natural resource policies or programs. Economic valuation of ground water therefore requires that progress be made on two fronts: establishing formal linkages between ground water protection policies and changes in the biophysical condition of ground water (Boxes 1-7), and developing these linkages in a manner that allows for the estimation of policy-relevant economic values (Boxes 8-9). Ideally, steps 1 through 9 involve interactions and cooperation between economists and other scientists to ensure a smooth and productive flow of data and models to develop policy-relevant ground water value estimates.

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[2] We use the term "biophysical" to indicate biological, ecological, hydrologic, chemical, and other physical factors.

<u>Ground Water Functions</u>

The linkages between biophysical changes in ground water quantity or quality (Box 7), changes in ground water services (Box 8) and changes in economic values (Box 9) can be better understood by considering aquifer <u>functions</u>. The biophysical dimensions of ground water quantity and quality determine two broad functions of any aquifer. The first function is storage of a water reserve or stock (Table 1). Ground water stored in an aquifer provides a reserve of water with given quantity and quality dimensions. The quantity dimension includes the amount of ground water available within a specific geographic region in a given time period, and the change in this quantity over time from recharge and extraction. Rates of natural recharge, natural discharge, and human-induced extraction must be considered. Quality includes both natural and human induced contaminants that may affect the services to which ground water can be applied in a given time period, and the change in quality over time due to natural filtration and the leaching of contaminants. The rates of human-induced contamination and natural sources of contamination must also be considered.

Table 1. FUNCTION: STORAGE OF WATER RESERVE (STOCK). Ground water stored in an aquifer provides a reserve (stock) of water which can be directly used to generate services. Potential service flows and effects of these services are listed below.

SERVICES		EFFECTS	VALUATION TECHNIQUES*
1	Provision of Drinking Water	Change in Welfare from Increase or Decrease in Availability of Drinking Water	Market Price/Demand Function Supply or Cost Function Producer/Consumer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
2	Provision of Water for Crop Irrigation	Change in Value of Crops or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
3	Provision of Water for Livestock	Change in Value of Livestock Products or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer

Table 1. Continued

4	Provision of Water for Food Product Processing	Change in Value of Food Products or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
5	Provision of Water for Other Manufacturing Processes	Change in Value of Manufactured Goods or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
6	Provision of Heated Water for Geothermal Power Plants	Change in Cost of Electricity Generation	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
7	Provision of Cooling Water for Other Power Plants	Change in Cost of Electricity Generation	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
8	Provision Water/Soil Support System for Preventing Land Subsidence	Change in Cost of Maintaining Public or Private Property	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
9	Provision of Erosion and Flood Control through Absorption of Surface Water Run-Off	Change in Cost of Maintaining Public or Private Property	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
10	Provision of Medium for Wastes and Other By-Products of Human Economic Activity	Change in Human Health or Health Risks Attributable to Change in Ground water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Ground water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer
		Change in Economic Output Attributable to Use of Ground water Resource as "Sink" for Wastes	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer

Table 1. Continued

11	Provision of Clean Water through Support of Living Organisms	Change in Human Health or Health Risks Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer
		Change in Value of Economic Output or Productions Costs Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
12	Provision of Passive or Non-Use Services (e.g., Existence or Bequest Motivations)	Change in Personal Utility	Contingent Valuation Benefits Transfer

*These valuation methods are described briefly in U.S. EPA, 1991 and in greater detail in Braden and Kolstad, 1991 and Freeman, 1993.

The second function is discharge to surface water (streams, lakes, and wetlands) (Table 2). In the Eastern U.S., for example, the base flow of many streams and rivers is supported by ground water discharge. Through discharge to surface water, ground water indirectly contributes to the services generated by surface waters and wetland ecosystems. Once again there are quantity and quality dimensions in terms of rates of discharge to surface waters and the quality of the discharge supply. It should also be noted that surface water may recharge ground water. In this case, a portion of the services provided under the water reserve or stock function should be attributed to surface water. To simplify exposition we focus on the flow of water from ground water to surface water. Similar logic can be applied to develop values for the effects of surface water flows to ground water.

The share of surface water services that can be legitimately credited to ground water is very difficult to quantify. The primary challenge is to model the physical interactions between ground water and surface water services such that the incremental (marginal) contributions of ground water discharge to surface water can be identified and measured. This task is necessary to avoid double-counting of service flows and, in turn, economic values (e.g., attributing the same service and associated value to both ground water and surface water). For example, assume an aquifer provides a major source of recharge water for a stream which is heavily used for recreational fishing. Assume also that normal land run-off also contributes substantially to the flow of the stream. Suppose two water quality protection policies are implemented during the same time period. One policy is targeted towards the recharge aquifer and the other is targeted towards land run-off.

Table 2. FUNCTION: DISCHARGE TO STREAMS/LAKES/WETLANDS. Ground water contributes to the flow or stock of water in streams, lakes, and wetlands. A portion of surface water and wetlands services are therefore attributable to the ground water resource. Potential service flows and effects of these services are listed below.

SERVICES		**EFFECTS**	**VALUATION TECHNIQUES**[*]
1	**Provision of Drinking Water through Surface Water Supplies**	**Change in Welfare from Increase or Decrease in the Availability of Drinking Water (Access Value)**	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
2	Provision of Water for Crop Irrigation through Surface Water Supplies	Change in Value of Crops or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
3	Provision of Water for Livestock through Surface Water Supplies	Change in Value of Livestock Products or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
4	Provision of Water for Food Product Processing through Surface Water Supplies	Change in Value of Food Products or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Property Value Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer

Table 2. Continued

5	Provision of Water for Other Manufacturing Processes through Surface Water Supplies	Change in Value of Manufactured Goods or Production Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
6	Provision of Cooling Water for Power Plants through Surface Water Supplies	Change in Cost of Electricity Generation	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
7	Provision of Erosion, Flood, and Storm Protection	Change in Cost of Maintaining Public or Private Property	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
		Change in Human Health or Health Risks through Personal Injury Protection	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Economic Output Attributable to Use of Surface Water Supplies for Disposing Wastes	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
8	Transport and Treatment of Wastes and Other By-Products of Human Economic Activity through Surface Water Supplies	Change in Human Health or Health Risks Attributable to Change in Surface Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Surface Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer
		Change in Economic Output Attributable to Use of Surface Water Supplies for Disposing Wastes	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer

Table 2. Continued

9	Support of Recreational Swimming, Boating, Fishing, Hunting, Trapping and Plant Gathering	Change in Quantity or Quality Recreational Activities	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Travel Cost Method Benefits Transfer
		Change in Human Health or Health Risks	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
10	Support of Commercial Fishing, Hunting, Trapping, Plant Gathering	Change in Value of Commercial Harvest or Costs	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
11	Support of On-Site Observation or Study of Fish, Wildlife, and Plants for Leisure, Educational, or Scientific Purposes	Change in Quantity or Quality of On-Site Observation or Study Activities	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Travel Cost Method Benefits Transfer
12	Support of Indirect, Off-Site Fish, Wildlife, and Plant Uses (e.g. viewing wildlife photos)	Change in Quantity or Quality of Indirect, Off-Site Activities	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Travel Cost Method Benefits Transfer
13	Provision of Clean Air through Support of Living Organisms	Change in Human Health or Health Risks Attributable to Change in Air Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Air Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer

Table 2. Continued

14	Provision of Clean Water through Support of Living Organisms	Change in Human Health or Health Risks Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer
		Change in Value of Economic Output or Productions Costs Attributable to Change in Water Quality	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
15	Regulation of Climate through Support of Plants	Change in Human Health or Health Risks Attributable to Change in Climate	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Hedonic Price/Wage Averting Behavior Benefits Transfer
		Change in Animal Health or Health Risks Attributable to Change in Climate	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Averting Behavior Benefits Transfer
		Change in Value of Economic Output or Production Costs Attributable to Change in Climate	Market Price/Demand Function Supply or Cost Function Consumer/Producer Cost Savings Contingent Valuation Benefits Transfer
16	Provision of Non-Use Services (e.g., Existence Services) Associated with Surface Water Body or Wetlands Environments or Ecosystems Supported by Ground water	Change in Personal Utility or Satisfaction	Contingent Valuation Benefits Transfer

*These valuation methods are described briefly in U.S. EPA, 1991 and in greater detail in Braden and Kolstad, 1991 and Freeman, 1993.

Assume the policies will collectively increase recreational fish catch by 50%. The economic value of this increase in fish catch cannot be attributed to both policies. In order to avoid double-counting, the total economic value of this increase in fish catch should be divided between the two policies based on the relative contribution of each policy to the 50% increase in fish catch.

Because of the interrelationships between ground water and surface water, surface water recharge to ground water and from ground water discharge to surface water, the aquifer functions listed in Tables 1 and 2 are not independent. Ground water recharge and discharge are both part of the water reserve or stock function because each affects the quantity and quality of water which exists in an aquifer in a given time period. Ground water recharge and discharge also are both part of the surface discharge function because both affect the quantity and quality of surface water. Because ground water discharge affects a different set of economic services supported by surface water quantity and quality, we include ground water discharge to surface water as a separate function (primarily for economic benefit accounting purposes). From a biophysical or ecologic perspective, however, it should be kept in mind that our two broad functions are highly interrelated. Interrelationships between these two functions need to be accounted for when modeling the linkages between policy changes, changes in ground water quantity or quality, and changes in economic values, as illustrated in Figure 1.

Ground Water Services

As with value, we use the term "service" in a neutral sense to imply that a service is neither inherently good nor bad. Services may have both positive and negative effects, depending upon the affected party's preferences or perspective. Services associated with the water reserve or stock function are listed in Table 1. A major service with this function is the provision of drinking water. In the United States, ground water accounts for about 35 percent of public water supplies and 80% of rural domestic supplies (American Institute of Professional Geologists, 1985). Overall, ground water supplies drinking water to 53 percent of the U.S. population (this figure includes private wells). Ground water is also extracted for use in irrigated agriculture, many industrial purposes, heated water for geothermal power plants, and cooling water for other power plants.

In some regions of the United States, ground water provides the service of supporting underground water/soil structure which acts to prevent land subsidence (sinkholes). The water storage function also helps to control flooding and erosion by providing a medium for absorbing surface water run-off. The underground water/soil structure of an aquifer also provides a medium for the absorption, transport, and dilution of wastes (e.g., sewage) and other by-products of human economic activity. Note that each of these services are jointly provided by soil structure and ground water in a given area. As with the services of the surface water discharge function, the incremental (marginal) contributions of ground water to these services must be quantified.

An aquifer may also generate non-use or passive use services (Bishop and Welsh, 1992; Freeman, Chap. 5, 1993). For example, these services may be attributable to the mere existence of an aquifer, independent of any current or future use. Alternatively, passive use services of providing potable drinking water to future generations may arise from bequest motivations on the part of the current generation.

Most major services provided by ground water under the water reserve or stock function are also included as indirect services associated with the surface water discharge function (Table 2). To the extent that ground water supports healthy and abundant surface waters, it also contributes to a variety of services generated by these environments. These services include recreational swimming, boating, fishing, hunting/trapping and plant gathering, and commercial fishing, hunting/trapping and plant gathering. Unless biophysical data are available to identify ground water's marginal contributions to these services, there is a high probability of double counting such that surface water values may be assigned to ground water or vice versa.

Effects of Changes in Ground Water Services

Moving towards the goal of estimating changes in economic values (Box 9, Figure 1), we need to identify the effects on (changes in) economic activities resulting from changes in ground water services. Examples of potential effects on economic activities are listed in the second columns of Tables 1 and 2. Under the "stock" function, for example, the potential effects of a change in the provision of drinking water include a change in utility from an increase or decrease in the availability of drinking water (access/quantity) and a change in human health or health risks (quality).

Defining changes in human health or health risks requires careful consideration of such issues as changes in mortality and morbidity, and cancerous and noncancerous health threats. Identification of the various types of health effects which can result from changes in ground water quality requires input from health professions. What is ultimately needed are dose-response models that link contaminant sources to changes in contaminants in ground water and then changes in human health. These dose-response models will facilitate defining the baseline and alternative service flows (S^o and S^1) and the estimation of policy-relevant values. Such linkages are essential for identifying changes in all service flows, not just human health effects.

Measuring Economic Values

Complete valuation of a change in the condition of ground water involves measuring the economic values for all relevant changes in ground water services associated with changes in the X and Q vectors. Economic values for ground water protection or remediation should capture the value for the total change in the ground water condition (X^1 - X^o, Q^1 - Q^o).[3] Thus, as suggested in the previous section, extensive knowledge of the ground water resource itself and its functions are crucial to defining the change in service flows, and the effects on economic activities of these changes in service flows.

Once changes in ground water services are identified and quantified (Box 8, Figure 1), the final step in the benefit estimation process is to assign monetary values to these service changes (Box 9, Figure 1). When measuring the economic value of environmental changes, theoretically appropriate measures of changes in consumer and producer welfare (or well-being) must be used. There is a consensus among economists that Hicksian compensating or equivalent welfare measures should be used (Freeman, Chaps. 3 and 4, 1993; Just, Hueth, and Schmitz,

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[3] See Boyle and Bishop (1987) for an application of total valuation to valuing endangered species.

1982; Varian, 1978). Because of problems with estimating willingness to accept, the most commonly applied measure of natural resource economic values is an individual's maximum willingness to pay (WTP). Hicksian WTP measures (compensating or equivalent) should reflect both the quantity and quality dimensions of the ground water resource being valued.

A number of empirical techniques are available for estimating changes in economic value associated with changes in ground water services. We do not attempt to define and explain each potential valuation technique in detail in this report. An overview of valuation techniques relevant to ground water quantity and quality is provided in U.S. EPA: Appendix A, (1983) and in Bergstrom, et al, (1996). More detailed descriptions of valuation techniques for environmental policies, including advantages and disadvantages of the various techniques, can be found in a number of references (e.g., Braden and Kolstad, 1991; Freeman,1993). We list potential valuation techniques for changes in ground water services in the last column of Tables 1 and 2. Although we advocated estimates of Hicksian welfare in the preceding paragraph, each of the techniques listed in the tables that utilize market, or choice, based data yield estimates of Marshallian surplus, i.e., income is held constant rather than utility. We do not intend to imply that estimates of Marshallian surplus are not appropriate for valuing ground water. Rather, these are not the conceptually desired measures.

Selection of a valuation technique for a particular policy application (e.g., RIA) involves many considerations. All else constant, techniques that measure maximum Hicksian WTP with minimal bias are preferred. Consumer/producer cost savings estimates, for example, may only provide minimum estimates of value because they do not reflect maximum WTP based on consumer preferences or producer production functions. Another major consideration is data availability. In many environmental valuation situations, revealed preference data (e.g., water market data) are not available. In contrast, contingent valuation relies on stated preference data (e.g., data on preferences obtained directly from people in a survey setting), measure Hicksian WTP directly, and can be applied to value a wide variety of the services listed in Tables 1 and 2. The largest distinctions between contingent valuation and revealed preference techniques is that contingent valuation measures Hicksian surplus and is the only methodology capable of measuring nonuse values. The application of contingent valuation to measuring nonuse values, however, is currently a subject of much debate (e.g., see Arrow et al, 1993).

Other important factors an analyst must consider when selecting a valuation technique include the time and expense involved in implementing the technique as compared to the timing of policy decisions for which the value estimates are needed and the available budget for the data collection and value estimation process. Related to the time and expense of implementing a valuation technique is the decision-makers desired levels of accuracy and reliability associated with value estimates. In general, increased accuracy and reliability (in a statistical sense) requires greater allocations of both time and money. For certain policy decisions, extremely high levels of accuracy and reliability may be required. For other policy decisions, decision-makers may be able to tolerate ("make do with") lower levels accuracy and reliability.

In a number of cases, the selection of a valuation technique, or techniques, is a fairly clear-cut decision (e.g., data availability may dictate the decision). In other cases, the decision may not be so clear. The final selection is likely to involve a "balancing" of all relevant considerations (e.g., theoretical consistency, data availability, estimation robustness, time constraints, budget constraints, acceptable accuracy and reliability).

Aggregation Issues

Once the economic value of ground water to an individual is determined, aggregate economic value is estimated by summing individual economic values (e.g., mean willingness-to-pays) over the total number of people in the "market area" of a particular aquifer who utilize water from the aquifer, and summing these values over time (Freeman, Chap. 7, 1993). For a given aquifer, there are likely to be different market areas associated with each of the services listed in Table 1. Determining the scope of these market areas is a complex process, involving careful study of the spatial distribution of consumers and producers who benefit from the services of ground water from a specific aquifer.

There is not, however, a clear consensus in the literature as to how to determine market size. Nearly all environmental economists agree that the market should include all individuals who are affected by a change in the condition of ground water resource, but this agreement breaks down when discussions move to who specifically is affected. This problem is exacerbated for nonuse values. In addition, physical data is often missing to develop direct links between changes in ground water and potentially affected populations, as we will note in the review of existing ground water valuation studies (the does-response function called for above).

Ground water policies also result in changes in the flow of ground water services over some time horizon (e.g., 50 years). The economic value of the policy in each time period (t) is the difference in the value of ground water quantity and quality with the policy in that time period (X_t^1,Q_t^1) and the value of what ground water quantity and quality would have been without the policy (X_t^0,Q_t^0). That is,

$$\Delta S_t = S_t^1(X_t^1,Q_t^1) - S_t^0(X_t^0,Q_t^0).$$

The total value of the ground water resource over the planning horizon (T) is the discounted sum of the values attributable to all individuals affected by the change in ground water services in each time period (ΔS_t).

Uncertainty in Ground Water Valuation

Because we have to deal with imperfect data regarding the quantity and quality of ground water, the actual changes in ground water services may be uncertain with associated probabilities of occurrence. This uncertainty may exist with respect to both the current level of services (S^o) projected into the future and the alternative level of services (S^1). Thus, we are dealing with expected, rather than deterministic, changes in services.

The expected changes in ground water service flows is a function of possible alternative changes in the baseline and future ground water conditions, and the probabilities of each one of these alternatives occurring. In some situations, there may be a number of possible alternative service flow changes, each having a different probability of occurring. In other situations, there may be only one service flow of interest with several competing policies for accomplishing the goal and each policy has a different probability of success.

When demand and (or) supply uncertainty are present, measures of economic value (e.g., willingness-to-pay) should reflect this uncertainty. The appropriate welfare measure is option price (Bishop, 1982; Smith, 1983; Freeman, Chap. 8, 1993). Option price is defined as a representative individual's maximum willingness-to-pay to obtain a specific ground water condition with certainty. Measurement of option prices is primarily accomplished using contingent valuation (Mitchell and Carson, 1989).

Intergenerational Issues

In many cases, the effects of ground water depletion and contamination may be long-term in nature, raising concerns related to intergenerational equity and irreversibility. The process of discounting benefits to calculate present values automatically downweights future benefits. Assuming the same monetized value of aggregate benefits in each time period, discounting results in an ever decreasing present value of benefits in each successive time period. After a certain point in the future (e.g. 50 years), the discounting process renders the present value of future benefits trivial. Thus, it is sometimes argued that the process of discounting or downweighting future benefits to calculate present values is "unfair" to future generations. Moreover, the benefits, costs and discount rate used in any analysis are solely representative of the preferences of the current generation.

Intergenerational equity or fairness concerns have resulted in debates over how best to (or not to) discount future benefits. These concerns have often focused discussion on the choice of a discount rate to use in calculations of net present values. Individuals and groups who desire to see more weight placed on future benefits, for example because of concern over the well-being of unborn generations, argue for lower discount rates. Individuals and groups who are more worried about the negative effects on the current economy of reducing current private consumption argue for higher discount rates (Sassone and Schaffer, Chap. 6, 1978).

The discount rate used in ground water policy analysis, or the analysis of any public program, is based on societies' marginal time preference for consumption. Since this concept is difficult to quantify, we believe the choice of a discount rate is fundamentally a normative decision. In the case of environmental policy analyses, this decision has been made by some branch or office of the federal government (Office of Management and Budget, 1992). That is, the discount rate which should be used to discount future ground water benefits (which reflects some subjective assessment of the preferences of future generations and weighting of their well-being) is "handed down" to policy analysts.[4] Although ground water policy analysts may be required to use a certain discount rate, the present value of future ground water benefits can be calculated using a variety of discount rates to assess the sensitivity of present-value calculations to the choice of a discount rate. Sensitivity analyses should not be used to identify a desired outcome, but to examine the effects of a number of plausible discount rates.

Concerns over the effects of current policy decisions on future generations intensify when suspected irreversibilities are present. For example, suppose a particular aquifer is threatened by contamination, purification of the aquifer would be extremely costly and natural filtration may take decades or longer. Also, suppose that the aquifer is not currently a significant source of water for human use. However, there is a chance, because of population growth, that the aquifer may become a major source of water for humans in the future. The uncertainty of future population growth combined with the discounting process may result in very low weights being placed on the possible future benefits of protecting the aquifer from contamination. Consequently, a policy to protect the aquifer from contamination may not pass a standard benefit-cost test.

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[4] Benefit estimates are based on the preferences of the current generation and the choice of a discount rate is based on the preferences of the current generation. Benefit-cost analyses, therefore, contain the implicit assumption that preferences do not change over time. Special concern for future generations only enter if nonuse values, based on bequest motivations perhaps, are included in the benefit assessment.

Whether or not these costs should be borne by future generations is largely a normative issue. The flip-side of the issue is that protecting the aquifer from contamination may impose major costs on the current generation. Paying these costs may reduce the well-being of the present generation, and could end up having little or no effect on future generations if future demand for water from the protected aquifer never materializes.

When uncertainty and irreversibility are major issues and benefits to future generations are of concern, the costs to the present generation of protecting ground water should be considered but may not comprise the definitive decision criteria. Although the economics of a safe minimum standard (Bishop, 1993) for resource protection are not clear (Ready and Bishop, 1991), decision makers may still want to consider protecting selected ground water resources if the costs to the present generation are not unreasonably high. In such cases, ground water managers may want to develop several policy scenarios for protecting ground water resources and then investigate the cost effectiveness of accomplishing the protection programs. The question remains whether the protection costs are unreasonably high since benefits no longer play a central role? This again is a normative decision which must eventually be made at some administrative level.

III. PREVIOUS GROUND WATER VALUATION STUDIES

Although we acknowledge service flows of ground water received by both private individuals and commercial interests, our exposition in this section focuses on ground water values held by individuals. The parameters of ground water valuations differ between applications to consumers and commercial interests, but we do not loose generality regarding the complexity of commodity specification by considering one group of users. Previous ground water valuation studies have used contingent valuation (Boyle, 1994; Boyle et al., 1994) avoided costs (Raucher, 1986) or avoidance expenditures (Abdalla et al, 1992; Abdalla, 1994) to estimate ground water benefits held by individuals.

To illustrate the scope of work involved with defining and measuring ground water values, we include a review here of the previous ground water studies which used contingent valuation. When applying contingent valuation to measure ground water values, it is necessary to explain the change in the condition of ground water (commodity definition) to survey respondents. The full complexity of the ground water valuation problem is encountered head-on when attempting to explain the ground water commodity to survey respondents in contingent valuation studies.

To our knowledge there have been nine contingent-valuation studies of ground water conducted to date; eight in the United States and one in the United Kingdom. We discuss the studies conducted in the U.S. (Table 3).[5] The first study was conducted by Edwards (1988) and estimated the benefits of reducing the probability of ground water contamination in the community of Falmouth, Massachusetts. Shultz (1989) also estimated the benefits of reducing the probability of ground water contamination, but in Dover, New Hampshire (see also Schultz and Lindsay, 1990). Sun (1990) estimated the benefits of protecting ground water in Dougherty County, Georgia such that contamination levels would be below U.S. EPA health advisory standards (see also Sun et al., 1992). Powell (1991) evaluated the protection of ground water in 15 communities located in Massachusetts (four), New York (four) and Pennsylvania (seven) (see

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[5] See Boyle (1994) for a more complete discussion of these studies.

also Powell and Allee, 1991). Caudill (1992) estimated the benefits of protecting groundwater in Michigan (see also Caudill and Hoehn, 1992). McClelland et al. (1992) estimated the national benefits of cleaning ground water contaminated by landfills. Jordan and Elnagheeb (1993), like Sun, estimated the benefits of protecting ground water so that contamination levels would be below health advisory levels, but for the entire state of Georgia. Finally, Poe (1993) estimated the benefits of protecting ground water so contamination levels would not exceed health advisory levels in Portage County, Wisconsin. In Table 3 we cite the most recent study first and then work backwards listing studies in reverse chronological order.

Despite their small number, these ground water valuation studies present a wide variety of applications. In the geographical dimension, for example, the applications range from individual communities (Powell, 1991; Shultz, 1989; and Edwards, 1988) to counties (Poe, 1992 and Sun, 1990) to states (Jordan and Elnagheeb, 1993; Caudill, 1992) to national estimates (McClelland et al., 1992). This diversity presents both advantages and disadvantages. The advantage is available value estimates potentially reflect a variety of ground water conditions at the study sites that enhance the potential for these studies to collectively provide the value data necessary for accomplishing a RIA. The disadvantage is there is very little depth to the value data pertaining to specific attributes of ground water conditions.

All eight studies focus on quality dimensions of the "stock" function of ground water. This focus is an artifact of the studies being primarily designed to value ground water as a source of drinking water. Although changes in the quality of ground water can affect the quality of surface waters, we suspect hydrologic data were not available to make these connections. All of the studies, except McClelland et al. (1992), employ the implicit assumption that the stock of ground water is currently sufficient to meet demand, but the quality of supply is threatened by contamination. McClelland et al. ask their survey respondents to assume that contamination will result in a shortfall of potable water.

In Table 3 we consider the condition of ground water in each of the study areas before presenting the studies' baseline and reference ground water commodity specifications. Four of the studies have information that indicates ground water in the study areas is contaminated (Poe, 1992; Caudill, 1992; McClelland, 1992; and Powell, 1991), and the other four implicitly assume the current condition is uncontaminated, or at least is below health advisory standards. The question marks beside the entries for these latter four indicate that we are unsure what survey respondents assumed regarding the current groundwater conditions when answering the valuation questions. Poe (1993) established contamination levels by mailing respondents water testing kits with which water samples were submitted for analysis. McClelland et al. (1992) asked respondents about their knowledge of ground water contamination in their community and selected one subsample in a location with a history of contamination. Powell (1991) selected communities for study based on whether they had a history of ground water contamination.

Three studies considered nitrate contamination (Poe, 1992; Jordan and Elnagheeb, 1993; and Edwards, 1988), while two studies considered concurrent nitrate and pesticide contamination (Caudill, 1992; Sun, 1990), one study considered chemical and diesel fuel contamination (Powell, 1991), and the type of contaminates were not specified in the McClelland et al. (1992) study. Respondents to the McClelland et al. (1992) survey were told contamination was from a landfill. We presume respondents employed subjective perceptions as to what contaminants were leaching into ground water.

Table 3. Ground Water Condition in Study Areas

Authors (Publication Dates)	Current Condition	Type of Contamination	Source of Drinking Water
Poe (1993)	18% of wells have nitrates in excess of safety standard	•Nitrates	•100% private wells (Question 1 in survey to screen out individuals on public supply)
Jordan and Elnagheeb (1993)	•Safe (?)	•Nitrates	•78% public systems •11% private wells
Caudill (1992); Caudill and Hoehn (1992)	•87% to 50% of wells above standards	•Nitrates and pesticides	•43% of Michigan's households rely on ground water
McClelland et al. (1992)	•From Version A of survey -56% knew of ground water contamination in community -13% said community draws water from contaminated wells or wells in danger of contamination	•Not specified	•From Version A of survey -51% said part of all of household's water comes from ground water
Powell (1991); Powell and Allee (19??)	•7 communities experienced contamination in past 10 years •8 communities had no history of contamination	•Trichlorethylene in 6 counties--MA (2), NY (2), PA (2) •Diesel fuel--NY (1)	•18% private wells •82% public water supply -communities draw water supply from ground water -percent of community on public supply ranges from 0% to 100%
Sun (1990)	•Safe (?)	•Agricultural fertilizers (nitrates) and pesticides	•Nearly 100% private wells
Shultz (1989)	•Safe (?)	•Not specified	•100% private wells
Edwards (1988)	•Safe (?)	•Nitrates	•89% public systems -communities draw water supply from ground water •11% private wells

Table 4 outlines the commodity descriptions used in each of the studies, and it is these descriptions that form the link between the physical data on ground water conditions at study sites, as discussed in Figure 1, and service flows provided by ground water within each study area (Tables 1 and 2). It is important to note that most of the studies asked respondents to evaluate more than one scenario of ground water contamination. In the discussion here we focus on selected scenarios that give the flavor of the commodity descriptions employed in the studies.

Having previously discussed the current ground water condition in the study areas, as presented in study publications, it is interesting to note the reference ("without policy") condition respondents were asked to assume when answering the contingent-valuation questions. Poe (1993), Jordan and Elnagheeb (1993) and McClelland (1992) provided information in the survey questionnaire which objectively defined the reference condition of drinking water services. Powell (1991), Sun (1990) and Edwards (1988) measured respondents' subjective perceptions of the reference condition of drinking water services in the study areas. In these studies, the investigators appear to have made a conscious decision to conduct the valuations based on respondents subjective perceptions of the reference condition. Caudill (1992) and Shultz (1989) did not establish either an objective or subjective reference conditions for their valuation exercises.

Table 4. Information Presented on Ground Water Commodity (Change in Services)

Author(s) (Publication dates)	Reference Condition	Subsequent Condition
Poe (1993)	• Stage I - respondents told 18% of wells above health standard • Stage II - well-specific test results provide	• Below health standards
Jordan and Elnagheeb (1993)	• Asked to assume level of nitrates exceed safety standard	• Reduce levels to below safety standard
McClelland et al. (1992)	• Asked to assume 40% of supply from ground water is contaminated	• Complete cleanup
Caudill (1992)	• Subjective perceptions measured	• Well water - eliminate health threat
Powell (1991)	• Respondents subjective rating of ground water condition (unsafe, somewhat safe, safe, or very safe)	• Very Safe - "I feel absolutely secure. I have no worries about the safety of the community water supply at present. I am certain the level of protection is excellent and I cannot foresee any contamination occurring in the future."
Sun (1990)	• Subjective perceptions measured	• Protect so below EPA health advisory levels for pesticides and fertilizers
Shultz (1989)	• Not specified objectively or subjectively	• Reduce potential of contamination (increment not specified)
Edwards (1988)	• Subjective perceptions measured	• Future contamination -in 5, 10, 20, or 40 years -0%, 25%, 50%, 75% or 100% probability of contamination

All eight studies specified the subsequent ("with policy") condition of services. Each study took a different approach to describing the change in services to be valued as defined by equation 1, some providing more complete definitions than others. Poe offered the most complete commodity definition. Poe conducted his study in two stages. In the first stage respondents water was tested for contaminants. In the second stage the well-specific test results were used to set the reference condition and the subsequent condition was below health standards. In contrast, Powell's respondents rated current conditions on a four point scale, ranging from "unsafe" to "very safe". In the valuation exercise, respondents' subjective rating of the current condition of drinking water services became the reference condition, and then stated a value for an increase in water quality to a rating of "very safe". This approach allowed respondents to translate the information presented and frame their own commodity definitions when responding to the contingent-valuation questions.

Studies attempting to completely (Poe, 1992; Jordan and Elnagheeb, 1993; and McClelland, 1992) or partially (Sun, 1990; Schultz, 1989; and Edwards, 1988) frame the change in ground water services have both strengths and weakness. The strength of completely specifying commodity descriptions is experimentally induced bias and variation in valuation responses may be reduced. The disadvantage is respondents may reject the objective information resulting in valuation responses that are based on subjective perceptions (Kask and Maani, 1992; and Lichtenstein, et al., 1978).[6] The Powell study meets this hurdle head on, but

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[6] The possibility of subjective editing of information points out the desirability of eliciting information about respondents' subjective assessments of the ground water valuation scenario so that these subjective assessments (e.g., subjective risk assessments) can be incorporated into value estimation, interpretation and application.

also raises questions. For instance, how can value estimates, based on subjective perceptions, be linked to actual changes in ground water conditions? These are fundamental issues in any environmental commodity valuation study. These questions must be addressed if ground water value estimates are to be useful for public-policy analyses.

A basic insight from this overview is that the library of ground water valuation studies measuring individual values is very thin in terms of the number of studies, and consequently, in terms of values for specific dimensions of ground water. For example, all eight studies account for only the direct provision of drinking water service (service row 1, Table 1). This implies a need for more primary data on values for other ground water services if the library of ground water value studies is going to be sufficient for RIAs (and other policy needs). Original valuation studies are needed for all of the potential service/effect flows of ground water identified in Tables 1 and 2.

Another basic insight from this overview is that to be useful for policy assessment, valuation studies must be very detailed and complete. For example, following the valuation framework summarized by Figure 1 and Tables 1 and 2, the basic ground water information required for policy analysis is changes in ground water service flows. Assessment of this change requires knowledge of the current (baseline), reference, and subsequent ground water conditions. In general, the descriptions of the current, reference, and subsequent ground water conditions are quite vague in the eight studies. This vagueness makes it difficult to establish the linkages between changes in ground water policies, ground water conditions, services provided, and estimated values. Of particular concern is the difficulty of ascertaining how the value estimates correspond to actual biophysical changes in ground water resources and the resulting change in service flows.

If valuation studies do not provide sufficient information for establishing the technical linkages illustrated in Figure 1 and Tables 1 and 2, the usefulness of valuation estimates for policy assessment is greatly reduced. Valuation studies need to measure values for changes in service flows that have clear linkages to biophysical changes in ground water resources. To complete the policy assessment process, clear linkages must also be established between changes in ground water policies and biophysical changes in ground water resources. Improvements are needed in the assessments conducted by physical scientists and economists, and these investigations need to work to enhance the interfaces between these analyses. The difficulties encountered when assessing changes in ground water policies are further illustrated by considering two policy assessment case studies in the next section.

IV. GROUND WATER VALUATION AND REGULATORY IMPACT ANALYSES

U.S. Presidential Executive Order 12866 issued in 1994 instructs government agencies to conduct regulatory impact analyses (RIAs) on all major regulations. RIAs are to include assessments of the benefits and costs of the full range of effects associated with a proposed regulation (USEPA, 1991). The full range of effects includes benefits and costs which can be quantified monetarily, and those which cannot be quantified monetarily.[7] The RIA guidelines were developed for evaluating any type of environmental regulation, e.g., air, surface water or ground water. Our focus is specifically on ground water. In the remainder of this section we will review two RIAs that dealt with ground water resources while complying with the overall RIA guidelines. Our general process for evaluating these RIAs is to consider how the benefit assessment components correspond to the framework we have proposed in this report.

Draft Class V Injection Well Regulatory Impact Analysis

The purpose of this RIA was to consider the benefits of regulating Class V industrial wells. Four types of industrial facilities operating Class V injection wells were considered as case studies: automotive repair, dry cleaning, metal fabrication and electroplating. Within each industry actual pollution incidents or events were considered.

Class V injection wells represent a case where groundwater is used as a medium to dispose of wastes (Row 10 in Table 1). In the current RIA, disposal is presumed to pose a human health threat so injections of waste are being proposed for regulation.

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[7] Although our focus is on potential benefits, the discussion also provides insight on potential costs of a proposed regulation since social costs are often foregone benefits (or opportunity costs).

Within the empirical section of this RIA, Chapter 4, a very specific perspective is taken regarding benefits. Detailed breakdowns of contaminants and contaminant concentrations were developed for the RIA. No discussion of the dispersion of the contaminants were provided and explicit consideration was not given to the multifaceted ground water services documented in Tables 1 and 2. Only human health risks were quantified, the quality component of Row 1 in Table 1. Although a larger domain of benefits may have been considered for inclusion in the analysis, we could not discern this from the available documentation.

Benefits were computed using breakeven analyses (contaminant concentration resulting in zero net benefits) and an averting behavior approach (avoidance cost). Health benefits for the breakeven analysis were computed using the number of statistical lives saved and a range of values from the literature were employed. Uncertainty was considered in the analyses by considering the expected efficiency of proposed regulations. Avoidance costs were based on the most cost efficient response to the contamination events and uncertainty was factored in by considering the probability that contamination would go undetected. Both of these approaches are likely to give minimum estimates of value because they do not reveal the public's maximum willingness to pay to avoid contaminated ground water.

The primary questions that arise when the analyses for this RIA are compared to the ground water valuation framework in Section II are:

- Were important benefit categories omitted?
- Were benefits of reducing health risks underestimated?

These issues may not be relevant for the RIA, but the available documentation does not allow us to answer these questions.

Draft RIA for Final Rulemaking on Corrective Action for Solid Waste Management Units

The purpose of this RIA was to present methodology to be used to estimate costs and benefits of site cleanup at hazardous waste facilities regulated under the Resource Conservation and Recovery Act. An application is included to provide an illustration of the methodology. We concentrate our discussion on the benefits component of the application.

Referring back to Figure 1, the RIA clearly defined the reference and subsequent ground water conditions and projected these conditions through time as we recommend in Section II. This work was done through interactions of environmental scientists, economists and engineers, an approach we also advocate to provide policy relevant value estimates. Notably, the RIA focus on the quality of ground water, thus ground water services listed in rows five through nine of Table 1 can be reasonably excluded because the physical stock of ground water would not appear to be affected by the action being evaluated.

The types of values estimated include human health benefits, ecological benefits, and nonuse values. Health benefits from protecting ground water arose from reducing three paths of exposure: ingesting contaminated drinking water, inhaling volatile compounds during household use of ground water, dermal uptake while showering. The pathways of contamination arise from drinking ground water and household uses of ground water (first row of Table 1). From the information provided in the RIA we can not discern whether other indirect pathways of human health effects, (rows two through four in Table 1) were not considered or were deemed to be minor or were not relevant.

The averted water use applied the cost of water treatment as a proxy for benefits, likely yielding an underestimate of benefits in this category. This component measures the access value of potable drinking water in Row 1 of Table 1. No mention is made of averting costs for commercial users of ground water, (rows two through seven of Table 1). If commercial users derive their water from municipal sources, then the benefits accruing to these users may have been counted. If commercial users derive ground water from private wells and invest in purification, benefits in this category are underestimated.

National nonuse benefits were estimated, addressing Row 12 of Table 1. Nonuse benefits were not estimated for the function of ground water discharging to surface water. For each of the benefit categories listed in Tables 1 and 2, data were developed for specific contamination sites. The RIA does not discuss how national averages of nonuse values should, or can, be adjusted for application to corrective actions at specific sites.

The property value analysis considered the effects on residential property values located near solid waste facilities. Although this is a valid method for estimating ground water values, property value effects may result in double counting with the use value measures. Precisely, is there double counting with the averted-cost and hedonic-price measures of benefits? Since an integrative framework for the various benefit components is not given and the component value estimates are implicitly assumed to be additive, it is difficult to ascertain if double-counting of benefits occurred.

The solid waste corrective action RIA appears to be consistent with the ground water valuation framework we proposed in Section II. Despite the general consistency of the approaches, issues that arise when comparing the RIA with our proposed ground water valuation framework are:

- Were some of the indirect effects of contaminated ground water inadvertently overlooked, e.g., health effects other than household consumption?
- Were use benefits underestimated due to use of averting expenditures and not considering commercial users of ground water?
- Does the lack of a conceptual framework for integrating the various benefits estimates lead to double counting of some benefit components?

As noted for the previous RIA, these issues do not necessarily imply problems in the RIA, but do imply an expanded scope of benefits needs to be considered in the design and reporting of RIAs.

Summing Up

The solid waste RIA appears to be much closer to the ground water valuation framework in Section II than is the injection well RIA. This difference may be due to reporting or the injection well RIA may indeed have taken too narrow of a scope when considering potential benefits of the action. Given the applications, we ask whether important benefit categories were omitted in both RIAs and whether values may have been underestimated for benefit categories considered. Both of these issues, if present, will lead to under estimates of total benefits vis a vis total costs of the implementing the regulations. No information is reported regarding what components of values were considered, but not analyzed for the RIAs.

The injection well RIA explicitly considered uncertainty and did implicit sensitivity analyses by considering different levels of regulation. No comparable analyses were reported for the solid waste RIA. Given the complexity of ground water resources and services, uncertainties regarding ground water conditions, and difficulties in measuring benefit categories, we strongly urge that all ground water RIAs should consider potential sources of uncertainty and conduct sensitivity analyses to investigate the robustness of assumptions employed in analyses.

Finally, neither analysis even opened the door for considerations of intergenerational equity issues. Although this is a very difficult issue, which we did not attempt to solve in Section II, consideration should be given to the fact that all benefits and costs arise from the preferences of the current generation given available technology. Simultaneously, either implementing or not implementing ground water policies can have substantial implications for ground water resources available to future generations.

There are several key points to consider when addressing the issues raised in our overview of the two RIAs and developing systematic ground water evaluations for future RIAs and other policy assessments. These key points are illustrated by our valuation framework summarized in Figure 1 and Tables 1 and 2. An RIA must first assess the biophysical condition of a ground water resource "with" and "without" the proposed policy change. It appears that the RIA addressed effects where biophysical data were available and did not report potential effects that could not be documented with available technology or data. More research is needed to develop data bases and models to assess the effects of ground water policies on biophysical changes in ground water resources (Boxes 1-7 in Figure 1). The next issue faced in conducting an RIA is to identify how the policy-induced changes in the biophysical condition of a ground water resource will change ground water service flows (Box 8, Figure 1). The two RIAs we reviewed only accounted for a portion of the service flows suggested in Tables 1 and 2. Future RIAs should identify potentially affected service flows that were considered and dismissed because no effect was identified, or the identified effect was quite small, or there was no data to quantify the effects. Both RIAs used several valuation methodologies (e.g., averting behavior, contingent valuation, hedonic price), but are weak because value estimates can not be clearly linked to specific biophysical changes in the ground water resources. The application of economic value estimates in RIAs can be improved by precisely defining changes in ground water service flows in terms that are relevant for economic analysis (using Figure 1, and Table 1 and 2 as a guide).

V. A STRUCTURE FOR CONSIDERING THE VALUE OF GROUND WATER

In this section, we discuss a general process or protocol for EPA offices to follow when incorporating the economic value of ground water in RIAs. The overall goal of this protocol is to generate and apply economic value estimates consistently across policy issues and offices within EPA. Our valuation framework begins to develop the protocol for this consistency. In addition, following the protocol may help EPA Offices to avoid duplication of efforts and potential double-counting of values. For example, concise summaries of previous RIAs would be available enabling future RIAs to explicitly build on the knowledge developed and experience gained in conducting previous RIAs. This effort may be particularly fruitful for transferring knowledge and information through time, across policy issues within EPA Offices, and across offices within EPA.

Another useful application of our protocol is that it will provide information for building EPA's Regulatory Impact Analysis (RIA) Benefit-Cost Database. Our protocol is different from the RIA Benefit-Cost Database in that it provides guidelines for conducting and reporting benefit assessments in RIAs. The RIA Benefit-Cost Database is a general reporting of all information contained in RIAs. It probably is not practical to include all of the detailed information about procedures used to assess ground water values in the RIA Benefit-Cost Database. We recommend, however, that all of the information generated by our protocol be available to supplement the RIA Benefit-Cost Database, and the Database include information about where more detailed information regarding valuation procedures can be obtained.

Protocol Components

The first component of our protocol is for the RIA analyst to record answers to the following important questions.

- Name of Proposed action? ____________________

- What is the current ground water condition?

____ Contaminated --->

What are the contaminants?

Contaminant	**Concentration**	**Geographic Extent**
______	_______	_______
______	_______	_______

____ Uncontaminated --->

What are the potential contaminants?

Geographic
Contaminant Concentration

____Unknown

- What is the proposed action?

____Protection --->

What are the proposed policies or rules
____

____Remediation --->

What are the proposed policies or rules?
____

- What are the sources of contamination?

____Known --->

List of sources:

Source	**Contaminant**
______	_______
______	_______

____Unknown

- What would the ground water condition be over the study time frame without any action (reference condition)?

	Quantity	Quality
Year 1	______	_______
Year 2	______	_______
Year 3	______	_______

Etc. ______ ________

- What would the ground water condition be over the study period with action (subsequent condition)?

	Quantity	Quality
Year 1	______	________
Year 2	______	________
Year 3	______	________
Etc.	______	________

Answers to these questions relate to Boxes 1 - 7 in Figure 1 and comprise the technical data necessary for estimation of benefits, Boxes 8 - 9.

The next component of the protocol is to identify affected services that give rise to benefit estimates. This issue relates to both the stock and surface water discharge functions (Tables 1 and 2). Assessment of potential changes in services can be facilitated by completing matrices such as those shown in Tables 5 and 6. These tables are partially filled out for a hypothetical regulation. The first step in completing the tables is to assess the reference condition for the services listed under each function in Tables 1 and 2. For example, affected services for the stock function are documented in Table 5. The "Reference Conditions" indicate that the aquifer provides an adequate supply of drinking water through public or private wells and is uncontaminated. These quantity and quality dimensions are known with certainty. The aquifer is not directly utilized for crop irrigation, livestock watering, or food processing services, as indicated by the "no" entries in the second column of Table 5. To clarify interpretation of the table all other entries for these services are left blank. Thus, the body of the table only documents affected services. Completing the first column indicates that a service was considered and purposely excluded. The information in the first column also briefly notes why a potential service is excluded.

The entries for the discharge function in Table 6 indicate that the aquifer indirectly provides water for crop irrigation and livestock watering, but surface water is not used for human consumption. Again, quantity is assumed to be adequate, but the quality is threatened by contaminated ground water. The extent and timing of the potential contamination is unknown.

Table 5. Changes in Ground Water Services - Stock Function

Service	Reference Conditions					Subsequent Conditions						
	Affected by Proposed Rule (If no, why?)	Quantity	Quality		Uncertainty	Quantity			Quality			Uncertainty
			Contamination	Concentration		Increase	Decrease	No Change	Increase	Decrease	No Change	
Drinking Water	Yes	Adequate for Current Demand	None	N/A	None			X		Potential Decrease		Extent and timing of contamination
Crop Irrigation	No (No known or anticipated use)											
Livestock Watering	No (No known or anticipated use)											
Food Product Processing	No (No known or anticipated use)											
etc.												

Table 6. Changes in Ground Water Services - Discharge Function

Service	Reference Conditions					Subsequent Conditions						
	Affected by Proposed Rule (If no, why?)	Quantity	Quality		Uncertainty	Quantity			Quality			Uncertainty
			Contamination	Concentration		Increase	Decrease	No Change	Increase	Decrease	No Change	
Drinking Water	No (No known or anticipated use)											
Crop Irrigation	Yes	Adequate for current demand	None	N/A	None			X		Potential Decrease		Extent and timing of contamination
Livestock Watering	Yes	Adequate for current demand	None	N/A	None			X		Potential Decrease		Extent and timing of contamination
Food Product Processing	No											
etc.												

A starting point for assigning monetary values to changes in ground water services is an assessment of available valuation data, e.g., the studies reported in Table 3. Available value estimates would be graded as to their suitability for transfer to the current ground water valuation issue. For discussions of criteria for selecting value estimates see the special issue of Water Resources Research (Vol. 28, No. 3, 1992) dealing with benefits transfer. We do not envision this process as being purely qualitative (e.g., good, average or poor), but dealing with specific issues of how the available value estimates relate to the current situation being evaluated in the RIA at hand. For example, are the same contaminants involved? Are the magnitudes of contamination comparable? Were the valuation studies conducted adequately, e.g., are estimates biased or have large variances?

As an example, suppose there is a potential decrease in the quality of drinking water provided directly by the aquifer. This change is represented by an increase in the concentration of Chemical Z of 30 ppb. As indicated in Table 7a, the proposed regulation will not affect the quantity of ground water available for human consumption, and the aquifer is not directly used for the other services listed in Table 5. The "Increment Evaluated" under "Quantity Changes" is listed as "no effect" in Table 7a. The value columns for the quantity change, therefore, are left blank to facilitate interpretation of the table. The increment of contamination to be evaluated is documented under the"Quality Changes" heading in Table 7a. We assume that the water can be made safe for drinking, but expenditures must be made on water purification. For our hypothetical example we assume value data are not available to assign initial values to the reduction in quality.[8]

Table 7a. Available Data for Valuing Changes in Ground Water Services - Stock Function

	Quantity Changes			Quality Changes		
Services	Increment Evaluated	Value Estimate(s)	Valuation Method	Increment Evaluated	Value Estimate(s)	Valuation Method
Drinking Water	No effect			30 ppb Reduction	None Available	N/A
Crop Irrigation	No effect			No effect		
Livestock Watering	No effect			No effect		
Food Product Processing	No effect			No effect		
Etc.						

After assessing available data, additional data needs are identified. This covers services for which available value estimates are not appropriate and services for which value estimates do not exist. Continuing with the example, value estimates are only needed for a reduction in water quality for

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[8] A number of Meta analyses of environmental values are being developed. These studies could, if developed for ground water valuation (Boyle et al., 1994), can be a source of initial value estimates for RIAs (Smith and Huang, 1993; Smith and Kaoru, 1990; Smith and Osborne, 1993; and Walsh et al., 1988).

human consumption under the stock function. We identify averting cost as a minimum estimate and contingent valuation as a procedure for estimating the full value the public places on avoiding potential contamination . Values included in contingent valuation estimates, but excluded from averting costs, include disutility from having to invest and maintain filtering systems for private wells and potential nonuse values. The question mark in Table 7b indicates that the values remain to be estimated. After the study is completed, the question mark would be replaced by the estimate(s).

Tables similar to 7a and 7b can be developed for the ground water recharge. We omit this step here for expositional convenience.

The final step is to identify services that will not be monetized including the reasons for not monetizing them (Table 8). In this simplistic example, we assume a 50% chance of a 30 ppb level of contamination. We further assume that all effects are monetorized. The expected change can be monetorized in some instances using appropriate measures of economic value under uncertainty (e.g., option price described previously).

Table 7b. Needed Data for Valuing Changes in Ground Water Services - Stock Function

Service	Quantity Changes			Quality Changes		
	Increment Evaluated	Desired Valuation Method	Value Estimates	Increment Evaluated	Desired Valuation Method	Value Estimates
Drinking Water	No effect			30 ppb Reduction	Contingent valuation or averted cost	?
Crop Irrigation	No effect			No effect		
Livestock Watering	No effect			No effect		
Food Product Processing	No effect			No effect		

Table 8. Other Valuation Considerations for Changes in Ground Water Services - Stock Function

Services	Nonmonetorized Effects (Reason Why)	Treatment of Uncertainty	Sensitivity Analyses
Drinking Water	None	50% chance of contamination	Geographical extent of contamination
Crop Irrigation	None		
Livestock Watering	None		
Food Product Processing	None		

However, in some cases this will not be possible. In such instances, sensitivity analyses conducted with plausible value estimates can be utilized to consider the effect of the uncertainty on the outcome of the entire benefit-cost or cost-effectiveness analysis. Another source of uncertainty in the current example is the geographical extent of the contamination. It is assumed that this factor is not known and can not be accurately predicted. Thus, several scenarios of damages might be investigated to consider the impact on aggregate value estimates.

VI. CONCLUDING COMMENTS

Preparing an RIA that adequately considers the full range of effects of a proposed ground water regulation is a major undertaking. Benefit estimation can be facilitated by carefully identifying, measuring, and documenting the linkages and "chain of events" shown in Figure 1, using Tables 1 and 2 as guides for tracing specific linkages between policies, changes in ground water services and value estimates. These tables guide identification and quantification of linkages between a proposed regulation, changes in services provided by ground water functions, and the effects of service changes on economic activities and values. This information reveals the gainers and losers of a proposed regulation, over both time and geographic space. Using Table 5, 6, 7a, 7b and 8 will facilitate clear and concise documentation of valuation analyses for RIAs. This documentation will report service effects valued as well as those dismissed as not relevant. It will also insure all RIAs considering ground water values begin at the same starting point, consider the same issues and provide uniform reporting. Establishing structure and consistency within and across EPA offices is important for producing accurate benefit estimates, avoiding double-counting problems, and eliminating duplication of ground water valuation efforts.

We envision these tables as comprising a concise form for reporting all benefit analyses conducted for RIAs. The list of questions would comprise a cover sheet to identify the RIA and ground water issue. Each of the tables would then follow to complete the documentation. This reporting framework would provide a systematic way of documenting and reviewing RIA benefit analyses. It may also be helpful to document studies used as secondary sources of value data as has been done by Boyle (1994) for ground water contingent-valuation studies, and we abbreviated in Tables 3 and 4.

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