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Abstract

Nitrates in drinking water, which may come from nitrogen fertilizers applied to crops, are a potential health risk. This report evaluates the potential benefits of reducing human exposure to nitrates in the drinking water supply. In a survey, respondents were asked a series of questions about their willingness to pay for a hypothetical water filter, which would reduce their risk of nitrate exposure. If nitrates in the respondent's drinking water were to exceed the EPA minimum safety standard, they would be willing to pay $45 to $60, per household, per month, to reduce nitrates in their drinking water to the minimum safety standard. There are 2.9 million households in the four regions studied (White River area of Indiana, Central Nebraska, Lower Susquehanna, and Mid-Columbia Basin in Washington). If all households potentially at risk were protected from excessive nitrates in drinking water the estimated benefits would be $350 million.

Keywords: Water quality, drinking water, nitrates, benefits, contingent valuation

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Summary

Consumers would be willing to pay $45 to $60 per household per month for a filter that reduced nitrates in drinking water to levels considered safe, if their drinking water exceeded the EPA minimum safety standard. Additional findings from a survey conducted in four regions of the United States showed that respondents would pay from $45 to $70 per month for a filter that would render their drinking water totally nitrate-free.

Ground water is an important source of drinking water, especially in rural areas. During the past 15 years, considerable public interest has arisen about the quality of the Nation's ground water resources. This is especially true for agricultural chemical residuals, which may potentially degrade ground water quality. Concern about agricultural sources of ground water contamination is driven by fears that exposure to agricultural chemicals in drinking water may pose human health risks.

The objective of this report is to use applied microeconomic models to evaluate the potential benefits of reducing or eliminating nitrates from drinking water. The more than 800 persons surveyed in 1994 lived in four regions: the White River area of Indiana, Central Nebraska, the Lower Susquehanna River Valley, and the Mid-Columbia Basin in Washington.

After being given a description about possible nitrate risks, and being asked to assume that their water supply contained nitrates above levels considered safe, respondents were asked if they would pay a randomly selected dollar amount for a water filter to lower nitrates to safe levels. Then they were asked if they would pay a higher dollar amount for a filter that would eliminate all nitrates from their drinking water.

Potential benefits for the 2.9 million households in the four study regions were estimated at $350 million, if households potentially at risk were protected from excessive nitrates in the drinking water.

Discovery of nitrates and pesticides in ground water during the 1970's and early 1980's dispelled the commonly held view that ground water was protected from these chemicals by layers of rock, soil, and clay. In 1990, the U.S. Environmental Protection Agency (EPA) released results from a survey showing that, while at least half of the Nation's drinking water wells contained detectable amounts of nitrates, only about 1.2 percent of community water systems and 2.4 percent of rural wells contained nitrates at levels higher than EPA recommendations (10 mg/liter).

The Environmental Working Group estimates that 2 million people drank water from systems that violated the EPA nitrate standard at least once between 1986 and 1995. An additional 3.8 million people drank water from private wells with nitrates above the 10 mg/liter standard.

The extent to which drinking water contamination from agricultural chemicals poses a risk to human health is unclear. A well-documented nitrate contamination concern is infant methemoglobinemia, in which nitrates impair the ability of an infant's blood to carry oxygen. Nitrates in water and foods (such as hot dogs) have also been suggested as possible sources of cancer. However, the health risk of water containing traces of nitrates at levels below those that possibly endanger humans is poorly understood.

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Introduction

Ground water is an important source of the Nation's drinking water, especially in rural areas. Concern about agricultural sources of ground water contamination is driven by fears that exposure to agricultural chemicals in drinking water may pose human health risks. Over the past 15 years, a considerable amount of public interest has arisen about the quality of the Nation's ground water resources. This is especially true for agricultural chemical residuals, which may potentially degrade ground water quality.

Discovery of nitrates and pesticides in ground water during the late 1970's and early 1980's dispelled the commonly held view that ground water was protected from these chemicals by layers of rock, soil, and clay. In 1990, the Environmental Protection Agency (U.S. EPA, 1990) released results from a nationwide survey of drinking water wells. Conducted over a 5-year period, the survey evaluated the presence of nitrates in both community and private drinking water wells. The survey showed that while at least half of the Nation's drinking water wells contained detectable amounts of nitrate, only about 1.2 percent of community water systems and 2.4 percent of rural wells contained nitrates at levels higher than EPA recommendations (10 mg/liter). The Environmental Working Group estimates that 2 million people drank water from systems that violated the EPA nitrate standard at least once between 1986 and 1995. An additional 3.8 million people drank water from private wells with nitrate levels above the 10 mg/liter standard (Environmental Working Group, 1996).

The extent to which drinking water contamination from agricultural chemicals poses a risk to human health is unclear. A well-documented nitrate contamination concern is infant methemoglobinemia, in which nitrates impair the ability of an infant's blood to carry oxygen (USDA, 1991). Nitrates in water and foods, such as hot dogs, have also been suggested as possible sources of cancer risk (Environmental Working Group, 1996; National Research Council, 1995). However, the health risk of water containing traces of nitrates at levels below those that possibly endanger human health is poorly understood (Conservation Foundation, 1987). Consumers, faced with uncertainty about the danger posed by drinking water containing low levels of nitrates, may be willing to pay for drinking water supplies with nitrate levels even lower than those considered acceptable by EPA.

The objective of this report is to use applied microeconomic models to evaluate the potential benefits of reducing or eliminating nitrates from drinking water. Over 800 individuals in four regions of the United States were asked in 1994 how much they would be willing to pay for a water filter that would reduce nitrates in their water supply to levels considered safe, and, in addition, how much they would be willing to pay for a filter that completely eliminated nitrates from their drinking water. From the survey responses, we estimated the average willingness to pay for safer drinking water. These benefits were then extrapolated to create regional estimates of nitrate reduction benefits for the four distinct geographic regions (White River area of Indiana, Central Nebraska, Lower Susquehanna, and Mid-Columbia Basin in Washington).

Measuring Economic Benefits of Reducing Nitrates in Drinking Water

The water supply in the United States is generally considered healthy and safe. However, modern water supply systems can have bacteria or parasites that may pose a human health risk. Irregular occurrences of chemicals in the raw water supplies make it difficult to anticipate adequate treatments. Finally, residuals from crop fertilizers can end up in drinking water supplies, requiring additional treatment for removal or exposing consumers to a risk of dietary exposure to levels that exceed the legal standard.

Consumers make choices about the food and drink they consume, based on a number of factors. In addition to the price of the product, such factors as appearance, convenience, texture, smell, and perceived quality all influence the choices made in the marketplace. In an ideal world, consumers make consumption decisions with full information about product attributes and choose food products that maximize their well-being.

In the real world, however, information problems complicate the consumer's decision. Drinking water can have some attributes that give an indication of its quality, such as cloudiness or unpleasant odor. In other cases, bacteria or chemicals in a consumer's drinking water are not readily observed. Consumers then do not see the risk since these impurities are invisible to the naked eye.

The potential for drinking water contamination is greater for rural consumers who depend upon private wells. Municipal water supplies must pass certain quality standards under the Safe Drinking Water Act. Those relying on private wells are protected only by such local requirements as well testing as a condition of property sale or transfer. Even then, testing requirements generally cover bacterial contaminants, not nitrate levels.

Consumers' lack of information about drinking water leads to a case of market failure. The workings of a non-regulated market may yield greater than optimal levels of nitrates in the water supply; residuals that people would be willing to pay to reduce, if they knew of their existence. On the other hand, nitrogen fertilizer users have no direct incentive to reduce fertilizer use to enhance or protect drinking water quality.

The economic issue is how best to ensure that the regulations to prevent or reduce nitrate levels in drinking water maximize the net benefits of reducing health risks while minimizing the costs these regulations impose on producers and consumers. It may be to society's overall benefit to encourage reductions in chemical use, if the benefits of safer drinking water exceed the costs of chemical residue reduction. Although regulations governing the use of nitrogen fertilizers may increase the cost to farmers of producing crops, the increased safety of the drinking water supply and other non-market benefits of reduced agricultural chemical use could exceed those costs. A critical element is how the benefits of safer drinking water are defined and measured.

Economic Benefits Defined as "Willingness To Pay"

The economic value of any resource, whether marketed or non-marketed, is defined as the user's willingness to pay (WTP) to receive benefits from the resource. This measure has been accepted as the standard when conducting benefit-cost studies of non-marketed resources (U.S. Department of the Interior, 1986; U.S. Water Resource Council, 1979, 1983; Sassone and Schaffer, 1978; Just, et al., 1982). WTP is a measure of the economic value in terms of income or other goods a person is willing and able to forgo to gain or maintain a resource, good, or service. Net WTP, which is the difference between WTP and actual price of the good, is usually estimated in a cost-benefit analysis. Whether this WTP is actually collected as cash is largely irrelevant from the standpoint of economic efficiency. While it may be important for political reasons to transfer a portion of the user's WTP to actual cash flow, any financial returns are just a transfer of benefits from user to recipient. The total economic value received by society does not change, only the distribution among members of society.

The benefits attributable to natural resources (such as ground water) can be divided into two general categories: use values and nonuse values. Use values consist of both consumptive uses, such as drinking water or irrigation supply, and nonconsumptive uses, such as water supply for estuaries and wetlands, which support wildlife. The distinction between consumptive and nonconsumptive values may sometimes be hazy.

Nonuse values include option, existence, and bequest values. Option value is the value someone places on preserving the right to be able to use a good sometime in the future. Existence value is the value someone places on a good just for knowing that it exists, even if that person may never use or see the good. That this value actually exists is demonstrated by the fact that people pay wildlife organizations to help protect animal species such as African elephants or Humpback whales even though they will probably never see one (in the wild) in their lifetime. Bequest value is the value someone places on a good to protect it for use by friends, relatives, or future generations. (For a discussion of nonuse values in the context of ground water resources, see Crutchfield, 1993.)

Nonmarket Valuation Techniques Used To Estimate Willingness To Pay for Safer Drinking Water

With nonmarket goods, no price exists, so one cannot directly obtain demand functions for these goods. Estimating the benefits or costs of changes in drinking water quality involves analytic techniques to elicit the values people place on clean water. Many different estimation procedures have been used to develop valuation functions for changes in environmental quality. These procedures use two basically different approaches. The first relies on indirect methods, where choices individuals make when using or consuming water are examined to obtain a measure of how these services are valued. For example, travel cost as an approximation for the value of water-based recreation or bottled water expense in lieu of potentially contaminated tap water. The second approach uses structured conversations directly to elicit the values the respondent places on these services, referred to as contingent valuation (Smith, 1993).

Indirect approaches are based on the premise that the values people place on goods and services are revealed by the choices they make in purchasing or consuming them. Under certain assumptions, these values can be retrieved using information on consumer choices about marketed goods and services that are complementary to the nonmarketed good or resource service in question.[1] The most commonly used indirect approach to valuing changes in water quality is the travel cost model, where travel expenditures used as a proxy for the price of enjoying recreational uses of water (as influenced by changes in water quality) are taken to measure the value of those uses. These are, of course, not applicable to the issue of valuing changes in drinking water quality. Other revealed-preference approaches have been used, however, to value water quality changes, including:

> **Averting expenditures models** -- where the value of clean drinking water is measured by expenditures on less risky substitutes such as bottled water (Nielsen and Lee, 1987, Abdalla et al., 1992).
>
> **Hedonic property analysis** -- where the variation in property values across sites with differing water quality provides a measure of the value of clean water. For an example of how hedonic property analysis can be used to value ground water quality, see Michaels (1993).

Direct approaches to valuing water quality benefits identify the values people place on water quality from survey responses. The most widely used technique is the contingent valuation method (CVM), where respondents are presented with information about water quality and relationships between water quality and usability of the resource. Respondents are then asked to tell the researcher how much a given change in water quality would be worth to them. Numerous examples of using CVM to value water quality changes are available, although they primarily deal with valuing recreational use of surface water.

CVM uses surveys in which people are asked how much they are willing to pay for a change in the level or condition of some nonmarketed good. The basic notion underlying CVM is that a realistic, but hypothetical, market for buying (or selling) use and/or preservation of a non-marketed good can be described to an individual. Then, individuals are asked to participate in this hypothetical market, responding to questions about whether or not they would choose to pay for some good or service.

Key features of the hypothetical market include the following:

> 1) A description of the good or service being valued. For example, a CVM survey might start with a description of an endangered species, or of the possible health effects of exposure to a hazardous substance. The baseline level of provision of the good, as well as the change in the quality of the good should be clearly stated. Plus, the researcher should ensure that the respondents are perceiving the correct good.
>
> 2) A description of the means by which the respondent would pay for a good or service. This is often called the "payment vehicle." Examples include contribution to a fund to protect endangered species, fees for a hunting or fishing license, or a surcharge on a person's utility bill or property taxes. The payment vehicle should be realistic and emotionally neutral to the respondent, and appropriate to the good and the hypothetical market.
>
> 3) The procedure to obtain dollar values from the respondent. The respondent may be asked for an actual dollar amount, such as, "How much would you be willing to pay to a fund to preserve the Spotted Owl?" A more recent approach is to offer respondents a randomly chosen value, and ask them to indicate whether they would be willing to pay this amount, "Would you be willing to pay $20 to a fund to preserve the Spotted Owl?" This technique is called the "referendum," or "dichotomous choice" approach, since it calls for a yes or no response. The expected willingness to pay in this hypothetical market is then estimated statistically from survey responses (as discussed below).

CVM has been shown to be reliable, especially for estimating use values. For example, Loomis (1992) found that CVM is reliable in retesting. When survey respondents were asked the same CVM questions approximately 9 months after the first survey, the new WTP estimates were found to be statistically the same as the old estimates. At least for familiar goods and services, such as drinking water, CVM typically has been shown to compare very favorably with other nonmarket resource valuation techniques, such as travel cost, hedonic, simulated market results, and the outcome of actual referenda (Mitchell and Carson, 1989; Cummings et al., 1986). However, CVM has been controversial for estimating nonuse values. Largely due to complaints by Exxon and the American Petroleum Institute on the high economic damage estimates estimated with CVM for the

[1] These restrictions have to do with weak complementarity of the marketed goods with environmental quality (see Ribaudo and Hellerstein, 1992).

Exxon Valdez oil spill, the National Oceanic and Atmospheric Administration formed a Blue Ribbon panel (co-chaired by Kenneth Arrow and Richard Solow) to assess the validity of using CVM for natural resource damage assessment. The panel has approved of the applicability of CVM for this type of assessment, as long as certain guidelines are followed (U.S. Department of Commerce, 1993).

One criticism of CVM is that this approach requires consumers to make only hypothetical decisions about hypothetical purchases. As an alternative, researchers have constructed experiments where respondents are given cash and asked to allocate it across goods with varying attributes. For example, Fox et al. (1993) created experimental auction markets where participants were given money and asked to purchase sandwiches of different levels of food safety. The objective was to derive willingness-to-pay measures that were based on actual, revealed preferences rather than on hypothetical responses.

Benefits Transfer as an Alternative Valuation Method

Another approach to valuing water quality changes uses benefits estimates derived in one location to value water quality changes in another. This procedure, termed "benefits transfer," makes determinations about economic value or tradeoffs in one context using information (price elasticities, demand parameters, and so on) obtained in another. For example, if an analyst were asked to assess the benefits of preventing ground water pollution in a particular setting, the analyst could commission a new study (averting expenditures or CVM). However, doing so would take time and money.

As an alternative, suppose a valuation study had been undertaken that related the willingness to pay for improved water quality to variables such as income, demographic characteristics, knowledge about and severity of the environmental problem, and so forth. Then, in a different region with a similar valuation issue one could potentially use the measures of willingness to pay from the first study to approximate willingness to pay for improved water quality in the second region. If one could assume that the underlying preferences for water quality were similar in the two regions, then the analyst could transfer the benefits estimates from the original site to obtain benefit measures at the new site -- hence the term "benefits transfer."

There are two ways to apply willingness-to-pay estimates derived from a valuation study in one area to another. If one assumes that the individuals in the original transfer area have the same underlying preferences for drinking water quality and have the same demographic characteristics as residents in the policy area, then we can simply multiply the mean willingness to pay for safer water developed in the transfer area by the number of households in the policy area. This procedure is called "point transfer," since one transfers the point estimates of mean willingness to pay to a new site. A weaker assumption is that the preferences of the survey respondents in the transfer area are the same as for the population in the policy area, but the demographic characteristics of the two populations can differ. In this case, one could still estimate the overall willingness to pay using what is called "function transfer": using the estimated willingness-to-pay functions from a CVM or other valuation study to estimate willingness to pay for the policy area, controlling for variations in demographic characteristics such as income, education, age, and so forth.

The general preference among economists is to use function transfer (Loomis, 1992). In essence, this means applying new values for independent variables in the policy area to the valuation function taken from the transfer area study. If values for these variables were available for everyone in the policy area, then estimating the aggregate willingness to pay for safer water would be straightforward. Lacking such information, the analyst can use data at an aggregate grouping, such as average household income, age of household head, and percentage of males at the county level. The analyst could then substitute the group means for the independent variables in the willingness-to-pay calculation and sum over the number of households in the policy area.

The process of benefits transfer introduces another layer of uncertainty and imprecision because measurement error implicit in the original case study can be compounded when applying benefits measures (per household willingness to pay) or valuation functions (travel cost or CVM equations) in the new situation. The appeal of this process, though, is that it allows the analyst to obtain some insight into the magnitude of environmental benefits and costs without the time and expense required for a new study.

In this report, we use the CVM approach to estimate the value of safer drinking water, combined with a benefits transfer approach to estimating the regional benefits of preventing or reducing nitrate contamination in drinking water supplies.

Estimating Willingness To Pay for Safer Drinking Water

Consumers are faced with several potential sources of health risk in drinking water: bacterial contamination, industrial chemical residues, agricultural chemical residues. In this report, we focus on one specific

Table 1--Estimates of ground water protection benefits
(Listed in order of increasing resource value)

Study	"Good" being valued	Estimated willingness to pay (WTP)	Description of valuation procedure
Caudill, 1992, and Caudill and Hoehn, 1992	Protection of ground water subject to pesticides and nitrates	Rural: $43-$46/hh/year[1]. Urban: $34-$69/hh/year	Open questions in CVM
Powell, 1991	Ground water subject to contamination by toxic chemicals and diesel fuel	All data: $61.55/hh/year Respondents with a history of contamination: $81.66/hh/year Respondents with no contamination: $55.79/hh/year	Method of computation not specified. WTP for private well users exceeds WTP for public water supply users by $14.04
McClelland and others, 1992	Ground water, type of contaminant not specified	Complete sample: $84/hh/year	Predictions from Box-Cox model
Shultz, 1989, and Shultz and Lindsay, 1990	Ground water, type of contaminant not specified	Mean WTP: $129/hh/year	Computed from logit model
Jordan and Elnagheeb, 1993	Drinking water subject to contamination by nitrates	Public water systems: $146/hh/year. Private wells: $169/hh/year	Averages computed at midpoints from CVM payment card
Poe, 1993, and Poe and Bishop, 1992	Drinking water subject to contamination by nitrates	$168-$708/hh/year	Computed from logit models. WTP estimates vary depending on water quality information given respondent
Edwards, 1988	Ground water subject to contamination by nitrates and pesticides	$286-$1,130/hh/year	Derived from figure 2 published in the journal article by Edwards
Sun, 1990, and Sun, Bergstrom, and Dorfman. 1992	Ground water subject to contamination by agricultural fertilizers, nitrates and pesticides	Mean WTP: $641/hh/year, ranges from $165-$1,452/hh/year	Computed from logit model

[1]hh = household
Source: Economic Research Service

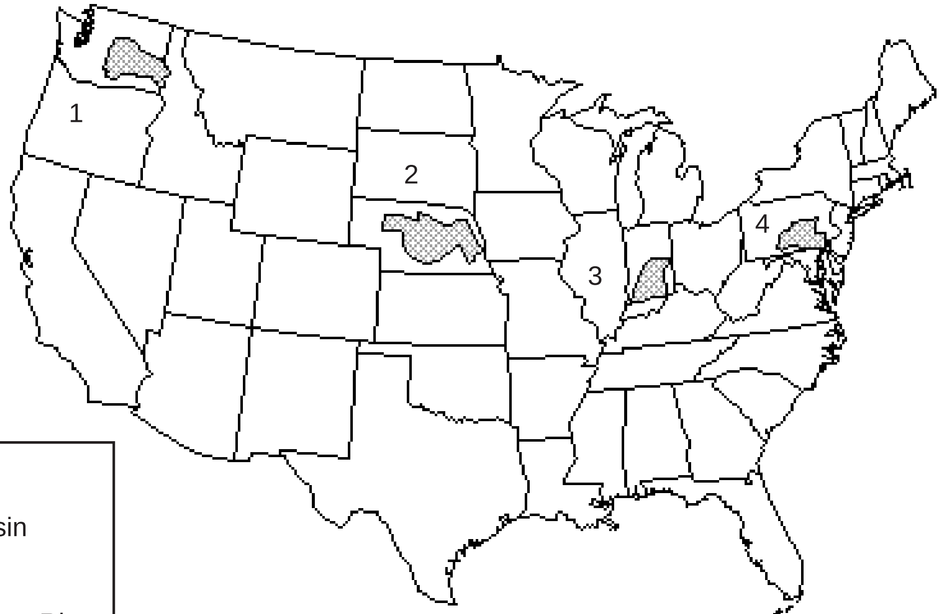
chemical residue that may be linked to agricultural chemical use: nitrates in ground water resources that serve as drinking water.

Table 1 summarizes the literature on willingness-to-pay for reduction of agricultural chemical residuals or prevention of ground water pollution. Three studies (Jordan and Elnagheeb, 1993; Poe, 1993; and Poe and Bishop, 1992) covered the issue examined here, the benefits of reducing nitrate levels in drinking water. We also present several other studies which, though they do not address the issue of drinking water directly, provide an assessment of people's willingness to pay for protection of ground water resources in general. We summarize these studies to provide context within which to evaluate our own estimation results. The estimated benefits vary widely, as might be expected, given the variety of procedures used and differences in the way the studies were conducted. The CVM estimates of ground water protection benefits range from about $40 per household per year (Caudill and Hoehn, 1992) to over $1,000 per household per year (Edwards, 1988; Sun et al., 1992).

Estimation of Willingness To Pay

The CVM questions and the explanatory variables used here were part of the National Survey of Recreation and the Environment, which was administered by the Survey Research Institute at the University of Georgia. This survey was conducted by telephone in two waves in

Figure 1--USDA willingness to pay survey sites, 1994



Legend:

1 - Mid-Columbia Basin
2 - Central Nebraska
3 - White River Basin
4 - Lower Susquehanna River

1994. The survey response rate was approximately 50 percent. The four geographic areas covered were the White River region of Indiana, Central Nebraska, Lower Susquehanna, and Mid-Columbia Basin in Washington State (see fig. 1). The questions regarding drinking water quality appeared in the middle of the survey, after a set of questions on water-based recreational activities. The survey was pre-tested on employees of the USDA's Economic Research Service and on nonemployees.

The survey gathered a set of demographic and other characteristics for each respondent. Our working hypothesis was that the willingness to pay for nitrate-free drinking water would depend on such factors as the respondent's age, income, education, sex, location (rural or urban), knowledge of nitrate contamination, and whether or not they used bottled water, were connected to a municipal water supply system, or used a water treatment system. Variable definitions and summary statistics by region are included in table 2 on page 9.

One issue in CVM surveys is how the question is formulated. Both the nature of the underlying risk and the commodity to be valued must be believable to the respondent. Accordingly, we defined the good being valued as a filter to be installed on the respondent's drinking water tap which would reduce or eliminate nitrates. Respondents were given background information on the nature of the health risks from nitrates in drinking water, and then given the choice of purchasing a water filter at a given price to reduce or eliminate these risks. To avoid alarming respondents or inducing so-called panic responses to the CVM questions, the discussion of the potential risks avoided the uses of trigger words such as "cancer." Instead, we told respondents that "nitrates are chemical substances hazardous to human health if taken in large quantities."

Another concern in CVM analysis is that respondents might have difficulty evaluating marginal changes in risk, especially if the risks are small, ill-defined, or involve health risks such as cancer. For example, respondents to a CVM survey may be unable to evaluate a water filter that reduced nitrate levels from, say, 15 milligrams per liter (considered unsafe) to 10 milligrams (considered safe) if the question were formulated in terms of reduction of milligrams of nitrate per liter of water. To address this concern, we formulated the question to elicit two levels of consumer WTP: a) willingness to pay to have nitrate levels in their drinking water reduced to safe levels (as determined by scientists), and b) willingness to pay to completely eliminate nitrates in their drinking water.

Both CVM questions on nitrate contamination reductions were asked. The questions were formulated in what is called a referendum, or dichotomous choice, manner. This method, in particular, is asserted to reveal accurate statements of value because the format provides reasonable incentives for value formulation and reliable value statements (Hoehn and Randall, 1991; U.S. Department of Commerce, 1993). The dichotomous aspect is that the respondent was prompted to provide a yes or no response (or vote, hence the term "referendum") to a dollar bid amount contained in the valuation question. The bid amount (that is, the amount of money to be paid for the water filter) varied across the respondents.[2] While this is the basic and most common referendum approach, variations on this approach do exist.[3] First, the respondents were asked to consider a hypothetical situation where they were told that their tap water contained nitrates at a level 50 percent greater than EPA maximum standards (numbers corresponded to the questions in the larger survey):

387 Now we would like to ask you a question. Suppose your home tap water is contaminated by nitrates to a level that exceeds the EPA's minimum standard by 50%. However, assume that the local water agency could install and maintain a filter in your home that can lower nitrates to the minimum safety standards set by the EPA. (If the respondent asks, the safety standard is 10 milligrams of nitrates per liter of water.) Note that if you chose not to have this filter installed, the nitrates will be present in your tap water at the original levels. If this filter cost $*** per month, would you purchase it? (The amount $*** varied randomly across respondents)

1. YES
2. NO go to 389
3. Refused — go to 391
4. Don't know, Not Ascertained go to 391

388 If the filter cost was $*** per month, would you (still) buy it?

1. YES
2. NO
3. Refused
4. Don't know, Not Ascertained

389 If the filter cost was lowered to $*** per month, would you buy it?

1. YES -- go to 391
2. NO
3. Refused — go to 391
4. Don't know, Not Ascertained go to 391

390 Why did you answer NO to this question. I will read a list of 6 reasons, please choose the most appropriate (*if none match, choose OTHER).*

1) I do not expect to receive enough benefits from the proposed filter system.
2) I cannot afford higher water treatment costs at this time.
3) Clean water is my right and it is unfair to ask me to pay. (go to 391)
4) The government should pay for this, even if it means higher taxes.
5) I do not believe in the government water quality standards.
6) I would rather buy bottled water than install this filter. (go to 391)
7) Other (go to 391)
8) Refused
9) Don't know, Not Ascertained

Then, the respondents were given a chance to pay a certain dollar amount to have a filter installed that would reduce nitrate levels to EPA maximum standards. In a second CVM question, respondents were asked whether they would pay a given dollar value for a more powerful filter that would completely eliminate nitrates from the home's tap water:

391 Now, let's consider an alternative water filter system with one difference from the one described in the previous scenario.

First, suppose again that the local water agency could still install and maintain the filter system in your home. However, due to technological advances, instead of only partially eliminating nitrates, this system can completely eliminate nitrates from your tap water. If this filter cost your household $*** per month, would you purchase it?

1. YES
2. NO — go to 393
3 Refused — go to 399
4. Don't know, Not Ascertained go to 399

392 If this filter cost $*** per month, would you still buy it?

1. YES
2. NO
3. Refused — go to 399
4. Don't know, Not Ascertained

393 If this filter cost was lowered to $*** per month, would you buy it?

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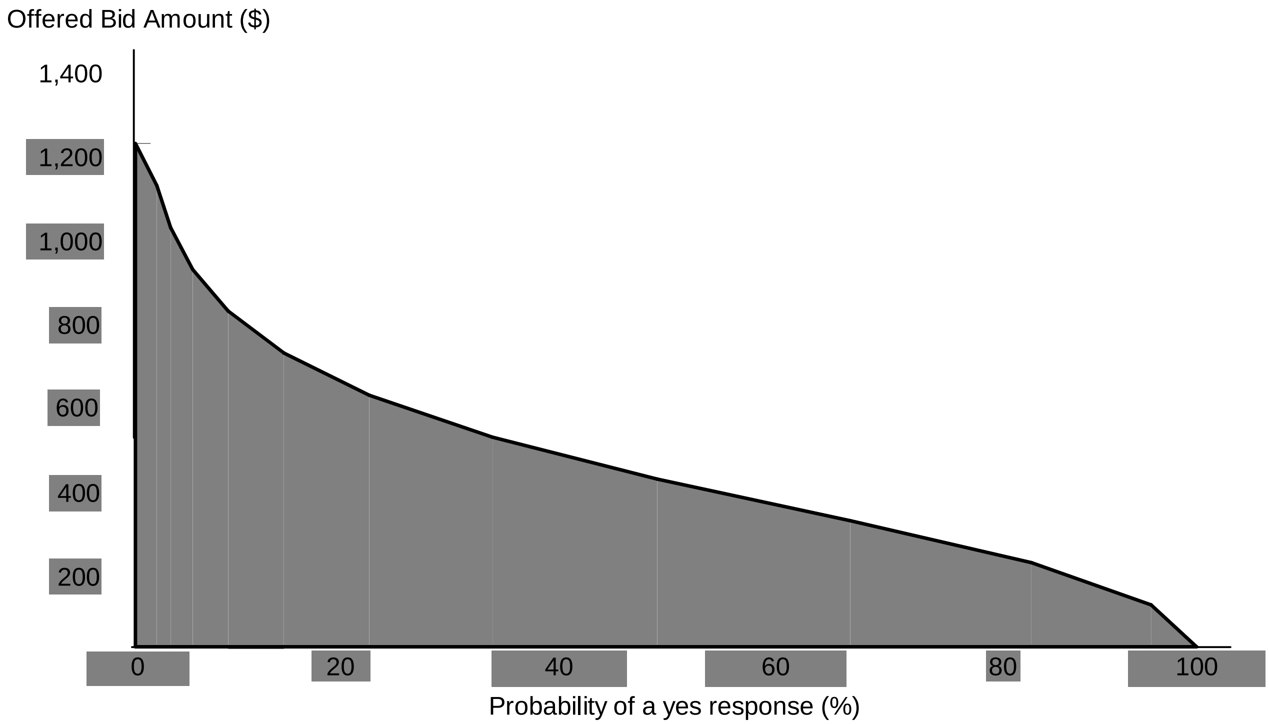
[2] Cooper (1993) presents a method for determining the appropriate range of bids to include in the surveys.

[3] One modification is to ask a second referendum question. If the respondent answered yes (no) to the bid value in the first question, the respondent is prompted to answer a followup question in which the offered bid value is higher (lower) than the bid amount in the first question (Hanemann, Loomis, and Kanninen, 1991). This double-bounded version, which should give a more precise estimate of the welfare benefit, has the same utility theoretic properties as the single-bounded approach. It is most useful in personal interview instruments, and is not practical for mail surveys.

Figure 2--Response curve for a willingness-to-pay question



1. YES — go to 395
2. NO
3. Refused — go to 399
4. Don't know, Not Ascertained go to 399

394 Why did you answer NO to this question. I will read a list of 4 reasons, please choose the most appropriate (*if none match, write down OTHER).*

1) I do not expect to receive enough benefits from the proposed filter system.
2) I cannot afford higher water treatment costs at this time.
3) The government should pay for this, even if it means higher taxes.
4) I would rather buy bottled water than install this filter. (go to 400)
5) Other
6) Refused go to 400
7) Don't know, Not Ascertained, go to 400

400: Continues the survey....

How is it possible to derive a net benefit estimate from a set of yes or no responses to a set of bid values? One concern is that the respondent agreed to pay the $50 bid that was offered, but also would have paid $125 if asked. Given that all we have is a set of yes or no answers, how can we estimate maximum WTP? The answer is that the researcher can statistically infer maximum WTP from these responses to the different bids.

Figure 2 shows the relationship between the probability of a yes response to a hypothetical willingness-to-pay question, based on the offered bid amount. For very high filter prices, the probability that a respondent would indicate that he/she would be willing to pay this amount would be low. On the other hand, as the bid value for the water filter decreases, the probability that the respondent would be willing to pay the amount increases. We can estimate this relationship by using a qualitative dependent variable regression (for example, logit, probit, or weibill) on the data.

The functional relationship in figure 2 is estimated using responses from the CVM survey. From the survey, we have both the bid amounts given to the respondent, and the yes or no responses showing whether or not they would be willing to pay that bid amount. The curve in the figure shows the value 1 - Prob(WTP $\leq$ $bid), which equals, "Yes, I would pay," to the offered bid amounts. In the figure, the curve shows that a predicted 100 percent of the respondents would be willing to pay $0, and 0 percent would be willing to pay $1,200. The area under the curve is the net benefit; in this hypothetical example, this area is approximately $435. For a complete discussion of the derivation of the referendum CVM benefit measure, see Cooper (1995).

Table 2--Variables used in the regressions, definitions, and mean values by region

Variable	Definition	White River	Central Nebraska	Lower Susquehanna	Mid-Columbia Basin
CONSTANT	Constant term	1	1	1	1
BID	The offered $ bid value	$30.32	$27.8	$28.71	$28.52
PERSINC	Personal annual income	$25,080	$24,550	$33,860	$44,700
EXTRAINC	Household income minus personal income	$19,540	$15,410	$12,190	$16,260
HEARD	Respondent heard about nitrate contamination (1=yes, 0=no)	0.1726	0.53	0.2074	0.2291
MUN	Respondent's home connected to municipal water supply (1=yes, 0=no)	0.7259	0.685	0.5319	0.7401
TREAT	Respondent uses a water treatment system (1=yes, 0=no)	0.264	0.2	0.2872	0.1586
BOTLEW	Respondent purchases bottled water (1=yes, 0=no)	0.2792	0.16	0.2766	0.1982
YRSZIP	Years respondent has lived at same zip code (1= < 1 year, 2 = 1-2 years, 3=2-5 years, 4= > 5 years)	3.34	3.445	3.58	3.348
RURAL	Respondent lives in rural area (1=yes, 0=no)	0.3096	0.33	0.3298	0.2203
AGE	Age (in years) of respondent	38.95	41.94	38.95	39.18
SEX	Sex of the respondent (1=male, 0=female)	0.3503	0.42	0.4947	0.4361
EDUCATE	Respondent's years of education (1=< 8, 2=9-11, 3=HS diploma, 4=some college, 5=college degree, 6=post graduate education)	3.76	4.015	3.75	3.96

Source: Economic Research Service

The starting bids for the WTP questions were determined using a simplified version of the sample design program from Cooper (1993), given information on the mean and variance of WTP from an open-ended version of the survey questions that was done with a focus group. For simplicity, the number of unique bid sets was 10. Since no standard exists for setting the follow-up bids, the lower bound bids were one-half the starting bid, and the upper bound bids were one and one-half times the starting bid. Based on the pre-test results, the bid sets (bid, lower bound, upper bound) ranged from ($5,$3,$8) for bid set one to ($63,$32,$95) for bid set ten. Each respondent received a bid set chosen at random from this set of 10 bids.

To identify and remove protest responses from the final regression data sets, respondents who answered no to both the initial bid and the follow-up lower bound were asked the reason why they would not pay the lowest bid amount. Of these, those respondents who choose anything except the first two choices were excluded from the regressions. Protest bidders turned out to be only several percent of those who answered no to the lower bid. Variables were excluded from the final regressions if they had insufficient variation or had low response rates. The likelihood functions were maximized using the Gauss maximum likelihood function with analytic first derivatives (Greene, 1990). The results presented in table 3 are from a bivariate probit estimation.[4] Usable responses totaled 819.

In the regression over all the data, the bid, the coefficient for personal income, and the coefficient for extra income are of the expected sign and significant to at least the 1-percent level. The coefficient for years lived in the zip code was positive and significant at the 5-percent level. This positive sign may suggest that the longer someone lives in a community, the more aware he or she becomes of the water quality in that community. On the other hand, the coefficient for age is negative and significant at the 1-percent level. In contrast to the sign of years in the zip code (the correlation between years in the zip code and age is 0.24), the negative sign on age suggests that the older someone is, the less concerned with water quality. In the region-specific regressions, age was significant and negative in all four regions (at the 5-percent level). Years in the zip code was significant and positive. The income variables were also not universally significant in the region-specific regressions. The rest of the explanatory variables in table 2 were not significant.

[4]See Cooper and Crutchfield (1996) for a presentation of WTP estimates derived with double bound and single bound estimation procedures.

Table 3--Regression results[1]

	White River	Central Nebraska	Lower Susquehanna	Mid-Columbia Basin	All Regions[2]
Question 1: Willingness to pay for safer drinking water					
Constant term	1.044907	-0.242602	1.164382	1.121732	0.771594
Bid value	-0.020693	-0.016528	-0.014884	-0.024085	-0.018360
Personal income	0.000007	0.000008	0.000004	-0.000000	0.000000
Extra income	0.000006	0.000004	-0.000002	0.000004	0.000002
Heard about nitrate contamination	-0.133383	0.087773	0.214476	0.077777	0.086234
Connected to a municipal water system	0.182692	0.081183	0.042466	-0.132924	0.016667
Uses water treatment system	0.426762	0.286686	-0.167360	-0.305657	0.046512
Uses bottled water	-0.047124	0.198056	-0.248084	0.089862	-0.039424
Years living at current zip code	0.012753	0.250502	-0.046614	0.097674	0.069358
Respondent lives in rural area	-0.008405	0.130285	0.228704	0.251104	0.143868
Respondent's age	-0.020660	-0.014379	-0.010717	-0.014442	-0.014651
Respondent's sex	-0.199404	-0.084918	-0.131950	0.409802	0.060738
Repondent's years of education	0.065188	0.092577	0.063515	0.067758	0.104807
Rho parameter in regression	0.104296	0.314760	0.233481	0.051109	0.231248
Question 2: Willingness to pay for nitrate-free drinking water					
Constant term	0.760970	0.394574	0.501684	0.868969	0.622807
Bid value	-0.011764	-0.017234	-0.011507	-0.012168	-0.013034
Personal income	0.000007	0.000009	0.000007	0.000011	0.000009
Extra income	0.000008	0.000009	0.000010	0.000003	0.000006
Heard about nitrate contamination	-0.081894	0.010481	0.237994	0.184145	0.124045
Connected to a municipal water system	0.130404	0.053592	-0.093516	-0.113749	-0.016923
Uses water treatment system	0.478118	0.127457	-0.113074	-0.077745	0.069284
Uses bottled water	0.071005	0.061793	0.138606	0.148328	0.102525
Years living at current zip code	0.048357	0.139612	0.024207	0.049538	0.062309
Respondent lives in rural area	-0.129400	0.342839	0.305265	-0.038083	0.122478
Respondent's age	-0.019182	-0.015376	-0.010847	-0.013886	-0.014589
Respondent's sex	-0.079919	-0.190880	0.070376	0.205292	0.008786
Repondent's years of education	-0.023679	0.035048	0.011859	-0.027860	0.007561
Rho parameter in regression	-0.165550	0.446497	0.124714	-0.161880	0.101137

[1]Details and key statistics from the regressions are available from the authors upon request.
[2]Based on a pooled regression over all data.
Source: Economic Research Service

Table 4 -- Willingness to pay estimates

Region	Drinking Water Quality: Safer	Nitrate-free	Difference
	Dollars per month		
White River	45.42	48.26	2.84
Central Nebraska	51.39	56.66	5.27
Lower Susquehanna	60.76	60.85	0.09
Mid-Columbia Basin	55.16	65.11	9.95
All Regions	52.89	54.50	1.61

Source: Economic Research Service

Results: Expected Mean Willingness To Pay for Nitrate Reduction

Given the regression results presented in table 3, it is possible to estimate the expected willingness to pay for nitrate reduction (table 4).

The estimated willingness to pay for a water filter that reduced nitrates to safe levels ranged from $45.42 per month to $60.76 per month, for an average of about $53 for all four regions taken together. As expected, the estimated willingness to pay for a filter that removed *all* nitrates was higher than for the first filter, but not by much. For all regions, respondents would pay more for the increased protection. For the four regions taken together, the premium placed on the more effective filter came to about 3 percent over the standard filter, or about $1.61 per month. Multiplying the monthly willingness-to-pay estimates by 12 gives an estimate of the annual willingness to pay -- from $540 to $780 per year.

Comparison with Existing Studies

In comparing the results of the current study with those done earlier, many WTP estimates were lower in the previous studies (table 1). Part of this disparity can be explained by the nature of the goods respondents were asked to value. In some cases, survey respondents placed a value on ground water as a general resource rather than drinking water per se. Only Jordan and Elnagheeb (1993), Poe (1993), Poe and Bishop (1992), and Sun et al. (1992) specifically addressed the issue of drinking water quality. Our survey dealt with drinking water, and stressed the potential health implications of nitrates. This may explain why our willingness-to-pay estimates are higher than those obtained when the respondent was asked to value ground water. Our results are reasonably consistent with those of the Sun et al. average WTP of $641 per year.

Regional Estimates of Benefits of Safer Drinking Water

The estimates of willingness to pay for safer drinking water can be used to estimate the benefits of protecting drinking water quality in the four study areas. To do this, a benefits transfer procedure is used to apply the values for safer drinking water obtained from our survey to the entire population in the four regions.

Using available data from published sources, we obtained averages for the following variables for each county in the four regions of our analysis: household income, percent of households living in rural areas, sex, and average age of household head.[5] A problem arises, however, because (as is typically the case in non-market valuation studies) the survey asked, and willingness to pay was assumed to depend upon, attitudinal and issue-specific information which varied from one respondent to another. In this case, the willingness to pay for safer drinking water was assumed to depend upon whether a person knew about nitrate contamination, whether his/her water came from a municipal water supply, whether he/she used a water treatment system or bottled water, and so forth. Furthermore, the question on education levels was phrased in such a way that we could not obtain equivalent information on that variable at the county level. For the remaining variables in our valuation function, we then followed the suggested procedures and used the mean values for these variables (on a region-specific basis) obtained from our survey.

In summary, the aggregation procedure was as follows. For each county in the four regions, we estimated a value for willingness to pay per household by applying mean values (either from published data or from our survey) for each independent variable to the corresponding estimated parameters from our regressions. The per-household estimates of willingness to pay were then multiplied by the number of households in each county, and then summed across the four regions.

However, this procedure may overstate the benefits of drinking water protection. The original survey questionnaire asked people to assume that their drinking water contained nitrates at levels above EPA-recommended levels. Applying a per-household willingness-to-pay estimate to all households in each region could overstate the total benefits of safer drinking water, because it would imply that all households in each region had excessive levels of nitrates in their water. It is probably the case that a considerable number of households in the four study regions do not have nitrates at levels considered unsafe.

An alternative approach to estimating the regional benefits would be to assume that households without excessive levels would have zero willingness to pay for nitrate reduction. Unfortunately, we do not have data on nitrate levels in drinking water for the four study regions. We do, however, have information on the potential for ground water contamination in the four areas studied.

An analysis of farm chemical use and soil data has ranked the cropland in the four area studies regions on the basis of expected potential for farm chemicals (including nitrates) to leach into ground water (Crutchfield et al. 1995). Cropland was characterized as being hazardous, risky, slightly risky, or safe from potential farm chemical leaching (in some cases, no farm chemicals were applied). In order to account for the differing levels of risk of nitrate contamination across the four study areas, we multiplied the total willingness to pay in each region by the percentage of cropland considered hazardous or risky to farm chemical leaching. This, then, assigns a willingness to pay of zero to a portion of the households in the region -- those not likely to have nitrates in their drinking water supplies.

Table 5 presents the regional benefits estimates, both mean willingness to pay per household and total benefits of safe or safer drinking water. The average per-

[5]Data were created using the “Zipfip” program, a data product produced by ERS which creates aggregate, county-level data from a variety of sources, including the Bureau of the Census and the Census of Agriculture. See Hellerstein et al. (1993) for details.

Table 5 - Regional willingness to pay and total benefits estimates

Region	Mean per household: Safer drinking water	Mean per household: Nitrate-free water	Share of land at-risk for leaching[1]	Total benefits: Safer drinking water	Total benefits: Nitrate-free free water	Households
	$/mo	$/mo	Percent	$1,000/yr	$1,000/yr	Number
White River	50.31	58.14	19	105,821	122,280	922,516
Central Nebraska	58.71	64.69	16	55,065	60.670	488,481
Lower Susquehanna	66.57	70.97	12	122,908	131,034	1,282,305
Mid-Columbia Basin	60.93	74.57	23	30,107	38,850	216,727
Total	n/a	n/a	n/a	313,900	350,834	2,909,929

[1]Percent of cropland rated as hazardous or risky, from Crutchfield et al., 1995
n/a = not applicable

Source: Economic Research Service

household WTP estimated via benefits transfer was somewhat higher than for the original studies. In part, this is due to differences in the mean values of the independent variables between the aggregate values and the means from the survey. In addition, there is the possibility that non-linearity in the benefit valuation functions derived from the survey could have led to an upward bias in the regional estimates (Downing and Ozuna, 1996). The total benefits are the sum of individual household willingness-to-pay estimates, multiplied by the percentage of land considered at-risk for contamination of groundwater supplies.

Comparison with an Earlier Benefits Transfer Exercise

Because site-specific data on WTP to reduce nitrate contamination in these four regions were not available prior to the current study, Crutchfield (1994) and Crutchfield et al. (1995), in an effort to estimate WTP for this issue, applied a benefits transfer exercise to the same four regions. The authors surveyed the then-existing literature on CVM evaluation of the value of protecting ground water from agricultural chemicals. Two approaches were taken: (1) transfer of the mean WTP from the eight studies referenced to measure aggregate WTP in the four regions, and (2) transfer of the original valuation functions from the referenced studies where sufficiently similarly independent variables could be obtained in the four regions. Survey data from USDA's Area Studies program and other sources were used to provide information on average values of the independent variables (income, age, and so forth).

Table 6 compares the mean WTP from this CVM study with the benefits transfer estimates from the earlier studies. Comparisons across studies should be done with caution, however. The three studies used in the earlier benefits transfer exercise posed the CVM questions differently. Shultz and Lindsay (1990) asked about WTP to prevent ground water contamination of an undetermined nature. Sun et al. (1992) asked respondents to value prevention of ground water contamination by agricultural fertilizers and pesticides as well as nitrates.

The closest comparable study to ours is that by Jordan and Elnagheeb (1993), which asked specifically for willingness to pay to prevent nitrate contamination in drinking water. The benefits transfer exercise using information from Jordan and Elnagheeb yielded a benefits transfer estimate of $238, while our estimate was $635 for the safer drinking water question, and $654 for the nitrate-free drinking water question. Transfer of the Schultz and Lindsay demand equation produced an overall estimate of $128 and the Sun et al. produced an estimate of $638. Thus, our results, while higher than WTP values from other studies, are consistent with the Sun et al. study. One key difference is that the earlier benefits transfer exercise from Crutchfield et al. considered only the rural population, whereas this study measured aggregate WTP for all households.

Conclusions

This study has demonstrated how applied micro-economics can develop estimates of the benefits of reducing potential health risks from nitrates in drinking water. Our results indicate that, at least for the population in our survey, consumers would be willing to pay from $45 to $60 per month to be assured that their drinking water contained no nitrates in excess of safe levels, and up to $10 per month more for assurance that their drinking

Table 6--Comparison of benefits transfer results: Willingness to pay in four study areas

Study	White River	Central Nebraska	Lower Susquehanna	Mid-Columbia Basin	All regions
			Dollars per household per year		
1995 study: Transfer of Shultz and Lindsay WTP	198	111	210	157	128
1995 study: Transfer of Jordan and Elnagheeb WTP	353	236	188	313	233
1995 study: Transfer of Sun, Bergstrom. and Dorfman WTP	943	597	641	905	639
Current study: Safer drinking water	604	705	799	731	716
Current study: Nitrate-free drinking water	698	776	862	899	793

Source: Economic Research Service

water supplies were totally nitrate-free. Our estimates, while higher than some studies that measured the benefits of ground water or drinking water protection, are within the range of values in the existing literature of CVM studies of these benefits.

Like all CVM studies, this one is subject to some cautionary notes. We were somewhat surprised by the relatively small difference in values between the safer drinking water and nitrate-free drinking water questions. Other studies have shown a greater willingness to pay for marginal changes in risk. For example, Ready et al. (1996) conducted a CVM study of willingness to pay for fruit with two different levels of pesticide residues: one with a 50-percent reduction in residue-related health risk (achieved by switching to fruit treated with a safer chemical), and one with a 99+ percent reduction in health risk. They found an increase in WTP of up to 22 percent for the 99+ percent risk reduction scenario, compared with 50-percent reduction in risk. (Note: these questions were asked of two different groups of respondents.)

Two explanations are possible. First, our respondents could have truly felt that safe levels of nitrates were acceptable, and that there was little reason to pay more for a water filter that completely eliminated nitrates. Also, respondents may have overstated their willingness to pay on the first question. Ordering of questions is important in multi-stage CVM experiments, and perhaps splitting the survey to ask *either* WTP for partial nitrate reduction *or* total elimination, but not both, would have yielded different results.

Still, the conclusions of our study remain: consumers do appear to prefer reducing the perceived health risks from agricultural chemicals in their drinking water, and would be willing to pay for risk reduction. These results could be used in an overall assessment of the economic implications of alternative strategies to reduce agricultural chemical use, by providing an assessment of the nonmarket benefits of safer drinking water.

References

Abdalla, C. W., B. Roach, and D. J. Epp. “Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Ground Water Contamination.” *Land Economics*, Vol. 68, No. 2. May 1992, pp. 163-9.

Caudill, J. D. “The Valuation of Groundwater Pollution Policies: The Differential Impacts of Prevention and Remediation.” Ph.D. dissertation, Dept. of Agri. Econ., Michigan State University, 1992.

_____, and J.P. Hoehn. “The Economic Valuation of Groundwater Pollution Policies: The Role of Subjective Risk Perceptions.” Staff Paper No. 92-11, Dept. of Agri. Econ., Michigan State University, 1992.

Conservation Foundation. *Groundwater Protection*. Washington, DC, 1987.

Cooper, J. C. “Optimal Bid Selection for Dichotomous Choice Contingent Valuation Surveys.” *Journal of Environmental Economics and Management*, Vol. 24, 1993, pp. 25-40.

Cooper, J. C. “Application of Nonmarket Valuation Techniques to Agricultural Issues.” Staff Paper No. 9503. U.S. Dept. Agr., Econ. Res. Serv., 1995.

Cooper. J. C. “A Comparison of Approaches to Calculating Confidence Intervals for Benefit Measures from Dichotomous Choice Contingent Valuation Surveys.” *Land Economics*, Vol. 70, No . 1, Jan. 1994, pp. 111-122.

Cooper, J. C., and S. R. Crutchfield. “A Benefits Transfer Test of the Benefits of Reducing Nitrate Contamination of Drinking Water." Selected Paper, American Agricultural Economics Association Meeting, San Antonio, July 31, 1996.

Crutchfield, S. R. "Estimating the Value of Ground Water Protection: An Application of Benefits Transfer." Selected Paper, American Agricultural Economics Association Meeting, San Diego, Aug. 7-10, 1994.

Crutchfield, S. R. "Issues in Measurement of the Non-Use Value of Ground Water." *Clean Water and the American Economy. Proceedings: Ground Water Volume 2.* U.S. Environmental Protection Agency, EPA 800-R-93-001b, Mar. 1993, pp. GW4-17 - GW4-27.

Crutchfield, S. R., P.M. Feather, and D. Hellerstein. *The Benefits of Protecting Rural Water Quality: An Empirical Analysis.* U.S. Dept. Agr., Econ. Res. Serv., AER-701, Feb. 1995.

Cummings, R., D. Brookshire, and W. Schultze. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* New Jersey: Rowm and Allanheld. 1986.

Downing, M., and T. Ozuna. "Testing the Reliability of the Benefit Function Transfer Approach." *Journal of Environmental Economics and Management*, Vol. 30, 1996, pp. 316-322.

Edwards, S. F. "Option Prices for Groundwater Protection." *Journal of Environmental Economics and Management*, Vol. 15, 1988, pp. 465-87.

Environmental Working Group. *Pouring it On: Nitrate Contamination of Drinking Water*. Washington, DC, Feb. 1996.

Feather, P. M., and D. Hellerstein. "Calibrating Benefit Function Transfer to Assess the Conservation Reserve Program." Unpublished. U.S. Dept. Agr., Econ. Res. Serv. 1996.

Fox, J. A., D. J. Hayes, J. B. Kliebenstein, D. G. Olsen, and J. F. Shogren. "The Acceptability of Irradiated Pork." *Swine Research Report*, Iowa State University, Ames. 1993.

Greene, W. *Econometric Analysis*. New York: MacMillan Publishing Company, 1990.

Hanemann, W. M., J. Loomis, and B. Kanninen. "Statistical Efficiency of Double-Bound Dichotomous Choice Contingent Valuation." *American Journal of Agricultural Economics*, Vol. 73, No. 4, Nov. 1991, pp. 1255-1263.

Hellerstein, D., D. Woo, D. McCollum, D. Donnelly. "ZIPFIP: A Zip and FIPS Database Users Manual." U.S. Dept. Agr., Econ. Res. Serv. 1993.

Hoehn, J., and A. Randall. "A Satisfactory Benefit Cost Estimator from Contingent Valuation." *Journal of Environmental Economics and Management*, Vol. 73, No. 3, Sept. 1991, pp. 860-66.

Jordan, J. L., and A. H. Elnagheeb. "Willingness To Pay for Improvements in Drinking Water Quality." *Water Resources Research*, Vol. 29, No. 2, Feb. 1993, pp. 237-45.

Just, R., D. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy*. Englewood Cliffs, NJ: Prentice-Hall. 1982.

Loomis, J. "The Evolution of a More Rigorous Approach to Benefit Transfer: Benefit Function Transfer." *Water Resources Research*, Vol. 28, No. 3, Mar. 1992, pp. 701-705.

McClelland, G. H., and others. "Methods for Measuring Nonuse Values: A Contingent Valuation Study of Groundwater Cleanup." Final report, Office of Policy, Planning, and Evaluation, Environmental Protection Agency, Cooperative Agreement #CR-815183, 1992.

Michaels, R. G. "When Home Is No Longer a Castle: Inferring the Economic Value of Ground Water Contamination From Residential Property Sales." *Clean Water and the American Economy. Proceedings: Ground Water Volume 2.* U.S. Environmental Protection Agency, EPA-800-R-93-001b, Mar. 1993, pp. GW2-34 - GW2-42.

Mitchell, R., and R. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington, DC: Resources for the Future. 1989.

National Research Council. "Nitrate and Nitrite in Drinking Water." Washington, DC: National Academy Press. 1995.

Nielsen, E. G., and L. K. Lee. *The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals.* AER-576, U.S. Dept. Agr., Econ. Res. Serv., Oct. 1987.

Poe, G. L. "Information, Risk Perceptions, and Contingent Values: The Case of Nitrates in Groundwater." Ph.D. dissertation, Dept. Agr. Econ., University of Wisconsin-Madison. 1993.

_____, and R. C. Bishop. "Prior Information, General Information, and Specific Information in the Contingent

Valuation of Environmental Risks: The Case of Nitrates in Groundwater." Staff Paper 93-11, Department of Agr. Econ., Cornell University, July 1992.

Powell, J. R. "The Value of Groundwater Protection: Measurement of Willingness To Pay Information and Its Utilization by Local Government Decision Makers." Master's thesis, Cornell University, 1991.

Ready, R. C., J. C. Buzby, and D. Hu. "Differences between Continuous and Discrete Contingent Valuation Estimates." *Land Economics*, Vol. 72, No. 3, Aug. 1996. pp. 397-411.

Ribaudo, M. O., and D. Hellerstein. *Estimating Water Quality Benefits: Theoretical and Methodological Issues*. TB-1808, U.S. Dept. Agr., Econ. Res. Serv., Sept. 1992.

Sassone, P., and W. Schaffer. *Cost Benefit Analysis: A Handbook*. New York: Academic Press, 1978.

Shultz, S. "Willingness To Pay for Groundwater Protection in Dover, NH: A Contingent Valuation Approach." Master's thesis, University of New Hampshire, 1989.

_____, and B. Lindsay. "The Willingness To Pay for Groundwater Protection." *Water Resources Research* Vol. 26, 1990, pp. 1869-1875.

Smith, V. K. "Nonmarket Valuation of Environmental Resources: An Interpretive Appraisal." *Land Economics*, Vol. 69, No. 1, Feb. 1993, pp. 1-26.

Sun, J. "Economic Analysis of Groundwater Pollution by Agricultural Chemicals." Master's thesis, Dept. of Agri. and Applied Econ., University of Georgia, 1990.

Sun, H., J.C. Bergstrom, and J.R. Dorfman. "Estimating the Benefits of Ground Water Contamination Protection." *Southern Journal of Agricultural Economics*, Vol. 19, No. 4, Dec. 1992, pp. 63-71.

U.S. Department of Agriculture, Working Group on Water Quality. "Nitrate Occurrence in U.S. Waters (and Related Questions)." Sept. 1991.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. "Proposed Rules: National Resource Damage Assessment." *Federal Register,* Vol. 58, No. 10, 15 CFR, Chapter IX, pp. 4601 - 4614. 1993.

U.S. Department of the Interior. "Natural Resource Damage Assessments: Final Rule." *Federal Register*, Vol. 51, No. 148, pp. 27,674 - 27,753. 1986.

U.S. Environmental Protection Agency. *National Pesticide Survey - Phase 1 Report.* EPA-570-90-003, Sept. 1990.

U.S. Water Resource Council. "Economic Principles and Guidelines for Water and Related Land Resources." Mar. 10, 1983.

______________. "Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resource Planning (level C)." *Federal Register*, Vol. 44, No. 243, pp. 72,892 - 72,976. 1979.