Methods for Valuing the Benefits of the Safe Drinking Water Act:

Review and Assessment

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Abstract. In this paper we review the valuation methodologies that are capable of providing estimates of economic benefits for safe drinking water quality. The most commonly used are the averting behavior and contingent valuation methods. Reviews of the applied valuation literature reveals a wide range of willingness to pay estimates for protection of drinking water quality. We provide a brief assessment of this literature, including a discussion of the validity of the studies and the potential for transferring these estimates for use in policy analysis. In general, benefits transfer is feasible but questions remain regarding the accuracy of these transfers. Comparative research with revealed and stated preference approaches with benefit transfer applications is needed.

I. Introduction

Recently, the 1996 Amendments to the Safe Drinking Water Act were signed. These amendments require an active role for economic analysis. For example, for all future drinking water standards, the EPA must conduct a thorough benefit-cost analysis and use "state of the art" economic analysis when setting standards. The requirement to balance the benefits and costs was included in the amendments to address the concern that the health protection benefits of the standards might not be worth their costs. The purpose of this paper is to assess the current "state of the art" of the methodologies for measurement of the economic benefits of safe drinking water.

Much research has been conducted focusing on the benefits of safe drinking water, in particular, the benefits of groundwater protection has received considerable attention. Crocker, Forster, and Shogren (1991) provide a theoretical framework for valuing the ex ante benefits of preventing groundwater contamination. They also explore the effects of the risk and location of contamination, the exposed population, and risk perceptions on WTP. Bergstrom, et al. (1996) provide a conceptual model which describes the linkages between changes in groundwater quality and the services that are received by households. With this model they propose a protocol for benefits estimation that would avoid missing and/or double counting values in the economic benefits measurement. Abdalla (1994) and Boyle, Poe, and Bergstrom (1992) provide focused reviews of the empirical literature in groundwater valuation.

In this paper we review the valuation techniques currently used to estimate the economic benefits associated with safe drinking water. When changes in drinking water quality can be modeled as changes in prices for marketed goods (i.e. bottled water), welfare effects can be estimated using traditional market models and changes in consumer and producer surplus (Walker and Hoehn, 1990). However, many environmentally related welfare effects cannot be directly traced through the market system; therefore, other methods have been developed to assess them. These can be grouped into two categories: revealed preference and stated preference approaches.

II. Valuation Methods

Revealed preference approaches can be categorized as indirect market methods because they focus on the household production of drinking water-related goods and the markets that are related to it. Indirect market methods include the cost of illness approach, the averting behavior approach, and the hedonic pricing method. Welfare effects of changes in drinking water quality are measured indirectly through markets for related goods. In general, the advantage of revealed preference approaches is that they rely on historical, ex-post data by which economic values are revealed by people's behavior. The disadvantage of this reliance is that it is oftentimes difficult to conduct benefits analysis of proposed policies or policy that would place individuals beyond the bounds of their historical experience. In this case, forecasting errors can occur on the part of the analyst.

Stated preference approaches can be categorized as direct market methods because they rely on hypothetical behavior in contingent scenarios to estimate welfare effects of changes in drinking water quality directly. Stated preference methods include contingent valuation, contingent (averting) behavior, and conjoint analysis. Each of these rely on ex-ante, data, individual forecasts of their behavior. In general, the disadvantage of stated preference approaches is that they rely on behavioral intentions and not revealed behavior. In this case, individuals may make their own forecast errors (not the analyst). The primary advantage of stated preference approaches is that the contingent scenarios can be designed to analyze policy that is unfamiliar to respondents or beyond their range of experience.

Another approach to valuing safe drinking water quality is to use primary data collected for other locations, time periods, and water contamination episodes by either revealed or stated preference approaches. The results from these primary studies can be pulled "off the shelf" and transferred to the study site and time. Benefits transfer is a cost-effective approach to benefits estimation, however, its primary limitation is the difficulty in finding primary studies which match the conditions of the study site.

The economic value of safe drinking water includes changes in expenditures and well-being including medical costs, lost earnings, lost production in the home, lost leisure time, third party expenditures (i.e. medical insurance), defensive expenditures, pain and suffering, and altruism toward others. Each of the available valuation methods are able to place dollar values on most of these categories that affect individual well-being (Table 1). For more extensive discussion of these methods, see Freeman (1993) or Braden and Kolstad (1991).

Revealed Preference Approaches

The averting behavior method, which sums the costs of actions taken to avoid a pollutant, is the most popular revealed preference approach to valuing safe drinking water. The averting behavior method is able to more accurately estimate the WTP values that economists prefer for welfare analysis relative to the cost of illness and hedonic price methods. Also, the hedonic price method, which measures the effects of water pollution on property values, is difficult to implement in the safe drinking water context because drinking water is often not a location-specific good such as climate or the location of hazardous waste disposal sites.

Cost of Illness. Cost of illness (COI) studies measure the foregone income and the costs of all forms of medical treatment and adds them together to calculate the expenses of a drinking water related illness. The COI method is straightforward because it uses market data on wages, hours worked, prices and quantities that are revealed through changes in behavior in labor and health care markets. It has the advantages of (1) being relatively simple to employ, (2) involving little subjective judgment or interpretation on the part of the analyst and (3) being easy to understand by non-economists. Moreover, it has less burdensome statistical demands than do other methods discussed below. One complication in many health risk studies is that third parties may bear some of the costs associated with illness through institutions such as insurance, entitlement programs, or paid sick leave, and these may represent as much as two-thirds of all personal care expenses. In these cases, the social costs exceed the private costs of illness. The cost of illness approach is often able to capture these expenditures.

Unfortunately, the COI technique has several limitations. First, for those not participating in the labor market it is difficult to accurately value the lost home production of goods and services for which there are no market prices. For those in the labor market, it ignores the disutility of foregone leisure, the costs of defensive expenditures, and the pain and suffering associated with the illness. According to most interpretations, COI studies will underestimate WTP but can at least yield accurate lower bounds due to the exclusion of the components of economic damages discussed above.

Averting Behavior. Averting behavior, or defensive expenditures, studies begin with the assumption that people make choices in order to maximize their level of well-being when faced with increased health risks associated with exposure to unsafe drinking water. Averting behavior and drinking water quality can be conceptualized as substitutes in the household production of health. The cost of averting or mitigating behavior that would be needed to exactly counteract the harmful effects of a decline in drinking water quality, holding the realized health state constant, is a theoretically correct measure of WTP to avoid the decline in drinking water quality. Unfortunately, in practice this approach is difficult to implement because observed changes in averting behavior in reaction to changes in actual drinking water quality will not necessarily restore an individual to her original realized health state. Also, in order to measure theoretically correct estimates of WTP the knowledge that households have about techniques for averting health risks must be known. If other behavior and purchases change in reaction to a change in drinking water quality, such as reductions in restaurant meals, averting behavior costs by themselves do not fully reflect the economic damages of a reduction in drinking water quality. However, even with these caveats, upper and lower bounds on WTP can be estimated with estimates of defensive expenditures (Bartik, 1988).

In order to use information on averting behavior and costs to estimate bounds on WTP for improved health, one must have information about behavioral changes and costs as well as about individual-specific characteristics. Cropper and Freeman (1991) identify categories of data necessary for an averting-behavior study: information on symptom severity, frequency, and duration; levels of ambient pollution exposure for each individual; information on possible averting and mitigating behaviors and their costs; and relevant demographic information. Even with this information it may be difficult to infer the desired bounds. Costs may be difficult to measure because some averting behaviors, such as increased time spent boiling water or hauling it from safe sources, may not involve time spent in the labor market and the value of time must be estimated. Also, some defensive actions involve the purchase of durable goods, such as water purifiers, which may yield enjoyment that is independent of health benefits, such as improved taste. The fractions of the observed cost attributable to an improvement in health or a reduction in health risk must be known to infer accurate bounds on WTP.

Hedonic Pricing. Hedonic property value models can be used to estimate property owners' WTP for changes in various attributes of a good by the preferences they reveal in land or housing markets. In the case of drinking water quality, property possessing higher levels of quality should command higher prices than those with lower levels, all else equal. The hedonic pricing approach essentially assumes that the commodity in question can be fully characterized by its set of attributes. In the case of a house this would include such things as its age, the number of rooms it has, neighborhood characteristics, and perhaps some measure of local drinking water quality (i.e. ambient concentrations of groundwater pollutants). Furthermore, it assumes that each of these attributes has an implicit price associated with it, and therefore the market price of the property is equal to the sum of the implicit prices per unit multiplied by measures of the quantity of the attribute. Empirically, by regressing housing prices on the corresponding set of attributes, it is possible to estimate the implicit prices. Therefore, the implicit price of a variable measuring ambient groundwater quality is equal to its marginal WTP.

While, the hedonic property approach has the advantage of relying on data revealed through actual behavior, there are several disadvantages. First, the data requirements for an hedonic study are large. Second, only WTP values for small changes in water quality can be accurately estimated from the hedonic price models. In order to calculate the theoretically correct

WTP values for large changes in water quality, other data requirements are necessary, such as spatially distinct hedonic markets (Palmquist, 1984).

Stated Preferences Approaches

Rather than relying on observed behavior of individuals to reveal their preferences, the stated preference methods use survey techniques that ask individuals for their willingness to pay for some specified policy or project that is related to drinking water quality. The contingent valuation (CV) method has become the most popular approach to valuing safe drinking water. The CV method is a survey approach which asks people for their WTP for safe drinking water, contingent on being faced with the same choice when purchasing the good in a market or voting in a policy referendum. Other survey methods exist that are similar to CV in that they ask individuals to express their preferences when presented with hypothetical scenarios. Those methods include the contingent behavior and conjoint analysis methods. These may be more appropriate in certain circumstances and, when combined with CV, may help to improve the validity of CV responses. Contingent behavior and conjoint analysis are fundamentally similar to CV and equally hypothetical in nature (see Table 1).

Contingent Valuation. A contingent market contains several elements which are required to elicit theoretically valid measures of WTP during a household survey (Mitchell and Carson, 1989). . The survey instrument must lead respondents through a valuation exercise describing the source of drinking water, the goods and services that safe drinking water provide (i.e. reduced health risks), and the proposed policy or project and how it would change drinking water quality. The contingent market must make clear an incentive compatible payment vehicle and policy implementation rule. Payment vehicles could include higher taxes, higher prices on goods, or voluntary contributions to a "safe drinking water fund." An incentive compatible payment vehicle would link the hypothetical payment to access to the safe drinking water. An incentive compatible policy implementation rule might include majority rule, where the respondent would have little reason to not tell the truth about preferences for safe drinking water. Finally, a valuation question is presented which elicits statements of behavioral intentions about WTP. Valuation questions can be open-ended, closed-ended, or some combination of the two (i.e. payment cards).

In the context of passive use values for natural resource damages, the NOAA Panel on Contingent Valuation provided a number of guidelines in order for a CV study to be reliable (Arrow, et al., 1993). Several of the guidelines are similar to guidelines presented in Mitchell and Carson including use of the dichotomous choice WTP format (relative to willingness to accept questions), full reporting of data and questionnaires, debriefing questions, describing preserved substitute environmental goods, and analysis of the data for internal consistency. On the other hand, many of these guidelines have generated much controversy because they would significantly raise the cost of a CV study, for example, use of face-to-face interviews, sample sizes exceeding 1000 (for dichotomous choice questions), extensive pretesting and pilot surveys, and averaging of temporally varying value estimates. Many of these recommendations are currently being examined in forthcoming and ongoing research in order to determine whether they are necessary for reliable damage assessment and benefit cost analysis.[1] While following these recommendations is almost certain to produce a high quality CV study, it must be realized that the requirements of a study for a court case with many millions of dollars are necessarily more

[1] See recent issues of the Journal of Environmental Economics and Management, Land Economics, and the American Journal of Agricultural Economics.

stringent than a benefit-cost analysis of a policy proposal. Indeed, none of the CV studies that we review later would pass the NOAA Panel's requirements for reliability of damage assessment.

The clear advantage of the CV approach for valuing safe drinking water is that it allows the researcher to better control the valuation scenario to measure ex-ante WTP under uncertainty about health outcomes. Contingent markets can be constructed to place respondents in the same circumstances they would face with a proposed project. It eliminates many of the inevitable confounding factors that are involved with measuring WTP ex-post in revealed preference studies. Furthermore, it may be the only viable valuation alternative in situations where there are no related markets or observable behavior from which to infer individuals' values. For this reason, CV is the only valuation technique for measuring altruism toward the health of others and other passive use values related to drinking water quality.

There are several limitations to the CV method. First, the validity of individuals' answers can be tainted by strategic bias, in which case individuals may intentionally understate or overstate their WTP if they perceive that they can favorably influence the policy outcome by doing so. However, experiments with different payment vehicles have found little evidence of strategic behavior among CV respondents (Milon, 1989). Second, responses can vary due to the type of valuation question that is presented. It has been found that responses to CV questions can be very sensitive to the way in which a question is framed. One example of this is that answers to closed-ended WTP questions, where the interviewer asks the individuals to simply state whether they are willing to pay a specific amount, tend to generate value estimates that are larger than when questions are open-ended, where the interviewer asks individuals to specify their maximum willingness to pay (Boyle, Poe, and Bergstrom, 1994). These problems are not intractable and can often be controlled for through appropriate survey techniques. See also Diamond and Hausman (1992).

Third, the inherent hypothetical nature of CV questions has called into question the reliability of the values they generate. Cummings and Harrison (1994) have found that in private goods markets presented in an experimental setting, closed-ended hypothetical WTP values overstate true WTP values. Stated behavioral intentions may not be fully realized once the respondent is placed in the identical (non-hypothetical) situation, especially if unexpected constraints on behavior arise. On the other hand, Carson, et al., (1996) find that WTP values for a wide range of environmental commodities that provide use value do not overstate WTP when compared to estimates derived from revealed preference studies. Nevertheless, in cases where related markets do not exist for the commodity being valued and respondents are unfamiliar with the good, individuals may not be able to formulate and express values because they have little or no tangible experiences to draw from (Whitehead, et al., 1995). Unfortunately, these are precisely the situations in which economists must rely on the CV method because there are few viable alternatives.

<u>Contingent Behavior</u>. The contingent behavior method is an ex-ante, hypothetical version of the ex-post averting behavior approach in which respondents are asked about their potential actions if faced with unsafe drinking water. Contingent behavior studies present individuals with scenarios in which they are asked about what they would do if they were faced with a drinking water contamination episode. Contingent defensive expenditures after the hypothetical episode are measured. In an ex-ante framework, these averting behaviors can be used to place a value on changes in health risks under uncertainty about health outcomes. The advantages of the

contingent behavior approach, relative to contingent valuation, is that the hypothetical response desired from survey responses is set in a more familiar context (i.e. purchasing bottled water). The disadvantages of the contingent behavior approach are similar to the averting behavior approach; WTP can not be fully estimated, instead the contingent defensive expenditures place a lower bound on WTP. Also, the stated behavioral intentions may not be realized as actual behavior when the respondent is placed in the same situation.

Conjoint Analysis. Conjoint analysis is an marketing technique that can be used to analyze contingent choices for safe drinking water. Conjoint analysis data is elicited, often during computer assisted on-site interviews or group meetings, by presenting survey respondents with situations for which they supply ratings or rankings of preferences for the paired comparisons (Viscusi, Magat, and Huber, 1991). The advantages of conjoint analysis are that it allows a wider range of tradeoffs relataive to the CV method or contingent behavior, such as risk-risk or risk-cost tradeoffs. Advocates of conjoint analysis purport that it is an alternative to CV that places respondents in a more market like setting by presenting them with a series of choice options with varying characteristics, including price which improves the validity of stated preferences. The limitations of conjoint analysis are similar to those of the CV method (Roe, Boyle, and Teisl, 1996). Also, conjoint analysis scenarios are cognitively challenging to respondents, especially as the number of characteristics in the scenarios increase, limiting the applicability of the approach.

III. Valuation Studies

In this section we provide a detailed review of revealed and stated preference studies which value changes in safe drinking water . We limit our review to studies which provide dollar estimates of damages from contamination or benefits of protection of drinking water. All values are converted to 1996 dollars by the consumer price index (see appendix). To our knowledge, only one study (Harrington, Krupnick, and Spofford, 1989; 1991) has used the COI approach and this study also measured averting expenditures. Several studies, mostly in Pennsylvania, have estimated defensive expenditures associated with drinking water contamination episodes (Table 2). A brief review of the groundwater contamination averting behavior studies can be found in Abdalla (1994). Hedonic price studies of the effects of contaminated drinking water on property values are scarce due, perhaps, to the lack of statistically significant effects of drinking water quality on property values or, alternatively, the difficulty in obtaining spatially differentiated measures of groundwater quality. Two studies, both in Wisconsin, have considered property value effects although neither found evidence of lost residential property values due to unsafe drinking water (Malone and Barrows, 1990; Page and Rabinowitz, 1993). By far, the greatest number of valuation studies related to drinking water quality have been conducted using the CV method (Table 3). Boyle, Poe, and Bergstrom (1994) conducted a meta-analysis of the groundwater quality valuation studies and summarized many of the key findings. At least one study has compared the averting behavior and CV methods (Laughland, et al., 1996) and one study (Barrett, Stevens, and Willis, undated) has compared CV with conjoint analysis. To our knowledge no one to date has conducted a contingent behavior study of defensive expenditures related to drinking water quality.

Revealed Preferences

Averting Behavior Studies. Harrington, Krupnick, and Spofford (1989) conduct a telephone survey of 50 Pennsylvania households (148 individuals) following the 1983 Pennsylvania giardiasis outbreak in order to determine defensive actions and costs. Ninety-eight percent of the sample reported changes in their water consumption including combinations of hauling water, boiling water, and/or purchasing bottled water. No household installed a water treatment system. Based on different assumptions about the jointness of the averting behavior and wage rates, which ranged from leisure time valued at $0 to the after tax wage rate, they estimate that averting expenditures range $153 - $483 per month based on the averages of the ranges of values.

Harrington, Krupnick, and Spofford (1989) also estimate the cost of illness in a mail survey of 370 Pennsylvania individuals who actually experienced giardiasis. Three different wage rate scenarios are used: the implicit after-tax wages of those not in the labor market is equal to the average wage of those in the labor market, the minimum wage, and zero. Under each scenario, the out-of-pocket medical care costs ($384) are a small fraction of the total cost of illness which is $1296-$1895 for the 176 individuals that were included in the study. Time costs for medical care were small. The value of lost wages, subjective work productivity, and value of leisure time are each large components of the total cost of illness.

Abdalla (1990) examined the actions taken by 1045 households in College Township, Pennsylvania in response to detection of percholoroethylene (PCE) in their well. The data was collected with a mail survey instrument (70% response rate). Seventy-six percent of those households purchased bottled water, installed water treatment systems, hauled water from clean sources, and/or boiled water in response to PCE contamination. For each household which engaged in defensive behavior during the 6 month episode, bottled water costs rose by $98, transportation costs rose by $240, the value of lost leisure time fell between $36-$88 for water hauling and $80-$99 for water boiling, energy costs rose by over $5.50, and the cost of using home water treatment systems was $386 for 52 households (1987 dollars). The low (high) estimates of the value of time are calculated assuming that the value of leisure time is equal to the minimum (average household) wage. With the total usage cost of the water treatment systems included in the defensive expenditures, the total household cost of defensive behavior averaged $26-$32 per month over the six month period.

In a study similar to Abdalla (1990), Abdalla, Roach, and Epp (1992) examine the actions taken by 761 households of the borough of Perkasie, Pennsylvania in response to detection of trichloroethylene (TCE) in one of their wells. The data was collected with a mail survey instrument (46.9% response rate). One-hundred thirty-three households (37%) purchased bottled water, installed water treatment systems, hauled water from clean sources, and/or boiled water in response to TCE contamination. Of those households which engaged in averting behavior, the average weekly averting expenditure per household was between $4 and $9 per week depending on wage rate assumptions. This amounts to costs of $366 to $785 over the 88 week episode.[2] The low (high) estimates are calculated assuming that the value of leisure time is equal to the minimum (average household) wage. Only 17% of the purchase costs of the water treatment systems are included to account for depreciation. Households were more likely to take defensive actions of they knew about TCE, if they perceived that the risk of cancer increased as a result of TCE, and if they had children in the household. In an empirical model of those who engaged in defensive actions, expenditures increased if young children (under 3) were present in the household.

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[2] However, Abdalla, Roach, and Epp state that the costs were $.51/week for those engaging in defensive behavior. We calculate the dollar values in the text based on their response rate and total cost calculations.

Collins and Steinback (1993) examined the actions taken by 299 households in rural West Virginia in response to tests which revealed bacteria, minerals, and organic compounds in their water supplies, most of which were from wells. The data was collected with a combination of mail survey and telephone survey techniques. The mail survey was sent to 878 households who had tested for unsafe water (43% response rate). Of those, 86% engaged in some type of averting behavior. Of the 86% who agreed to participate in a phone survey, 59% provided data used to collect detailed information about specific defensive actions and expenditures associated with each type of contaminant. The most common type of action was to clean and/or repair the water system followed by hauling water, installing treatment systems, boiling water, using a new water source, and correcting the contamination source. In computing defensive expenditures, the value of leisure time is assumed equal to the after tax household wage for adults and the after tax minimum wage for children. Capital costs of installation of water treatment systems are annualized based on the expected lifetime of the system. Combining the mail and telephone survey results, the weighted average of the total household cost of defensive behavior averaged \$32 and \$36 per month for bacterial and mineral contaminants. The total household cost related to organic contaminants was \$109 per month.

Laughland, Musser, Musser, and Shortle (1993) estimate averting expenditures for 800 households in Milesburg and Boggs Township, Pennsylvania who experience a surface water contamination episode. Telephone surveys were used to obtain complete information from 226 households (61% response rate). During the almost three month boil water advisory most (91%) of the respondents boiled, hauled, or purchased water. Those who did not engage in averting behavior tended to have more education and income (although these differences were not statistically significant) and attended more public meetings about the episode than others. However, it is not clear whether these households had water treatment systems installed before or during the episode. Based on high and low estimates for the value of time, the average monthly household defensive expenditures ranged between $16 and $35. Based on regression models found in Laughland, et al. (1996), these expenditures were positively related to the subjective notion of the convenience of the averting behavior.

Stated Preferences Studies

Contingent Valuation Studies. Boyle, Poe, and Bergstrom (1994) present a meta-analysis of CV studies that measure the benefits of groundwater protection. Annual WTP for groundwater protection ranged from $65-$1291 for a variety of protection programs. They find that much of the variance in WTP is related to the differences in the CV studies. Based on a conceptual model of groundwater value under uncertainty, WTP varies in the expected direction with (expected sign in parentheses), the magnitude of the change in probability of contamination for the nitrate studies (+), the costs of substitute sources of drinking water (-), income (+), whether the policy was simply to contain the contamination (-), whether use values were the focus of the study (-), and with a reduction in the drinking water supply relative to seeking other sources of drinking water (+). Also, annual WTP is higher when nitrates were mentioned as the source of the groundwater contamination, if the dichotomous choice question format is used and if mail survey response rates are lower. See Boyle (1994) for a more detailed review of the studies in the meta-analysis. A brief summary of these studies, and others, follow.[3]

[3] Two papers with developing country applications are not reviewed here since we are focusing on studies relevant to the Safe Drinking Water Act (see Whittington, et al. 1992 and Kwak and Russell, 1994).

Edwards (1988) presents WTP estimates for a "regional aquifer management plan" in Cape Cod, Massachusetts. Data was collected with a mail survey (59% response rate). Annual WTP estimates were elicited with dichotomous choice questions. The payment vehicle was a bond referendum. The WTP estimates are sensitive in the expected directions to income, demand uncertainty (whether the respondent would be living on Cape Cod when the expected contamination would occur) and supply uncertainty (the subjective difference between the probabilities of future contamination with and without the plan). Option prices ranged from $581-$2324 as the change in supply uncertainty increased from 25% to 100%, assuming demand certainty. At the average supply uncertainty, 80%, the average annual option price is $1858 with demand certainty. These values are assumed to be related only to insuring a cost-effective water supply and bequests to future generations with no health benefits included in the scenario. Edwards' WTP estimates are higher than all others reviewed which may be due to income effects. The average income in the Cape Cod sample is $79,000 which is twice that of the U.S. median family income.

Schultz and Lindsay (1989) estimate the WTP, including both use and passive use values, for groundwater protection plans in Dover, New Hampshire. The description of plans emphasize the uncertainty of their success: "these plans are an *attempt* to protect community groundwater supplies from future protection." Mail surveys are sent to 600 property owners with a 59% response rate achieved. The payment vehicle was an increase in property taxes and the WTP question was dichotomous choice. In the empirical models WTP varied in the expected direction with land value (+), age (-), and household income (+). Schultz and Luloff (1990) present results of an in-person and telephone survey of the nonrespondents to the original Dover, NH survey.

The resurvey increased the response rate to 86.5%. Nonresponse bias was found. Including both respondents and nonrespondents raised the annual WTP value from $171 in the original study to $178, although the difference in WTP between respondents and non-respondents is not tested.

Sun, Bergstrom, and Dorfman (1992) present option price estimates from an application of CV to Doughtery County in southwest Georgia. A mail survey of over 1000 residents achieved a 51% response rate. Respondents are asked to respond yes or no on a vote to support a "program for preventing groundwater pollution from agriculture pesticides and fertilizers." The program was described as able to definitely keep groundwater below EPA's health advisory levels for drinking and cooking. The payment vehicle is a "decrease in income." A regression model reveals that WTP increases with income, concern about health risks, and the subjective probability of future contamination. WTP decreases as age increases. WTP is not sensitive to the probability of future demand of clean water in Doughtery County. Further, Bergstrom and Dorfman (1994) find that WTP is sensitive to objective information about characteristics and consumption services of the groundwater resources. The annual household option price estimate is $811 in a county with a $55,000 average household income.

McClelland, et al. (1992) conducts a methodological study of survey design procedures in order to estimate valid passive use values for groundwater cleanup. A mail survey (1,983 useable responses, 60% response rate) is employed to collect payment card WTP values for a program to completely clean a 40% contamination of national groundwater supplies from leaking landfills. The contamination level is described as requiring treatment of water for drinking and cooking. The payment vehicle is an increase in the water bill. Annual household WTP was $97 for the complete cleanup and less for other survey treatments. WTP varied with income (+), age (-), race

(+ for whites), education (+), and other scenario specific variables. Lazo, et al. (1992) reports that annual passive use values for the cleanup range are about $41.

Caudill (1992) and Caudill and Hoehn (1992) estimate groundwater protection benefits in Michigan. Use and passive use values are elicited through a mail survey (67% response rate) with dichotomous choice and open-ended WTP questions. The payment vehicle used is higher taxes. The average annual WTP is $65 which increases with income and education (rural respondents) and passive use value motivations.

Poe and Bishop (1992, 1993) report findings from a groundwater valuation study in Portage County, Wisconsin (Poe 1993). Information about groundwater contamination (i.e. nitrates and baby blue syndrome, nitrates and cancer) was presented to one sub-sample. Mail survey respondents (78% response rate) were asked to vote with a dichotomous choice question on a groundwater protection program that would definitely keep nitrate levels below government health standards where their risk perceptions about nitrate contamination was the reference level risk. The payment vehicle was a combination of increased taxes, lower profits, higher costs, and higher prices. The information about groundwater contamination increased WTP for the groundwater protection program by 42%. All respondents were then invited to have their groundwater tested. Along with presentation of the nitrate test results, another survey was administered (83% response rate) where respondents had good information about their health risks. Respondents stated an annual WTP value of $290 for the protection program.

Jordan and Elnagheeb (1993) estimate the WTP to protect safe drinking water for two types of water consumers: those using municipal sources and private wells. A mail survey obtained payment card WTP data for 180 Georgia residents. The proposed policy was installation and maintenance of equipment to clean water for private well users and cleaning by the local water supply company for uses of other sources. Average annual WTP was between $166 and $194 for those who received their water from private wells and those who used municipal sources, respectively. For those who received their water from municipal sources, WTP increased with income, high school degree, and if the respondents were female, black, or uncertain about their current water quality. For the other respondents, WTP increased with income, high school degree and if the respondent lived on a farm, was female, or black.

Powell, Allee, and McClintock (1994) and Powell (1991) report on a CV study in which several communities in three northeastern states are surveyed by mail. Payment card WTP data was obtained for 1021 respondents (50% response rate). Increases in water bills (if public water supply) and property taxes (if water was private supply) were the payment vehicles. The annual household WTP was $72 per year for establishment of water supply protection districts that would ensure that drinking water remained safe. In their regression models, WTP increased with income, perceptions about safety risk, experience with drinking water contamination, expenditures on bottled water, private wells as the water source, and number of perceived contamination sources.

Laughland, et al. (1992, 1996), in addition to their averting behavior survey, present open-ended WTP estimates from a telephone survey during the Milesburg, Pennsylvania giardia episode. Respondents were asked to rank their favorite alternative water source option and then provide maximum WTP values. An increase in utility bills was the payment vehicle. Annual household WTP averaged $276 for the first choice among the three alternative water sources. In a regression model they found that WTP increased if the respondent had attended a public meeting about the contamination episode. WTP was not statistically related to income, water risk perceptions and other demographic variables.

Clemons, Collins, and Green (1995) conduct a CV study with Martinsville, West Virginia Municipal Water Department customers. Data from 576 respondents to a mail survey (64% response rate) were used. Two contingent markets described a groundwater protection program that would eliminate the risk of exposure to nitrate and VOC contamination of the water supply. The ordering of presentation of these markets was randomly varied. The payment vehicle was an increase in the current water and sewer bill. Dichotomous choice WTP questions elicited quarterly, household WTP estimates of about $5.50 and $3.50 for the nitrate and VOC programs. The only independent variables which help to explain the yes/no responses to the WTP question are number of years as a Martinsburg resident for the nitrate program and income and perceived seriousness of contamination for the VOC program. Surprisingly, detailed information about nitrate contamination and the objective risk of contamination did not influence responses.

Krug (1995) estimated the WTP for drinking water quality in western Massachusetts. Three hundred and ninety-seven responses were obtained from a mail survey (40% response rate). Respondents were presented with one of two policies: a public aquifer protection plan or the installation of a private pollution control device in the tap. Payment card willingness to pay questions were used. The payment vehicle for the public good was increases in utility bills and taxes while for the private good it was a price for the pollution control device. Annual household WTP was $67 and $79 for the public and private goods, respectively.

<u>Conjoint Studies</u>. Two studies have used conjoint analysis to value groundwater resources. Opaluch, et al. (1993) include groundwater quality as a characteristic of a landfill

siting choice in Rhode Island. The conjoint questions are paired comparisons of different potential five-hundred acre landfill sites. The characteristics of the sites include household cost and five environmental characteristics: acres of marsh, acres of woods, acres of farmland, quality of wildlife habitat, and quality of groundwater. The location of the site, near homes, parks, and schools, was also varied across choices. The survey was carried out with in-person administration of a survey booklet in public locations including shopping malls, libraries, and government buildings. The sample size is over one thousand individuals who considered six landfill site comparisons. Using estimated coefficients from their empirical model (p. 53) we estimate that the annual household WTP of avoiding "high" groundwater relative to "low" groundwater for the landfill site is over $400. This WTP estimate should be considered a lower bound since high quality groundwater also increases the marginal WTP of avoiding ponds and marsh areas.

Barrett, Stevens, and Willis (1997) conduct a conjoint study of groundwater protection in western Massachusetts. The survey was conducted through mail with over one-thousand residents of 56 Western Massachusetts towns. Respondents were asked to rank five options on a scale of 1-10 with the endpoints being "definitely vote in favor of" and "definitely not vote in favor of." The characteristics of the options were the type of policy, the scope of beneficiaries, payment schedule and cost, and voluntariness of the policy. The policies were a groundwater protection district, installation of a private pollution protection device, construction of a water treatment plant, and private purchase of bottled water. The reference option was no new groundwater protection program at zero cost to the household. The traditional rating, ratings differences, and discrete choice conjoint models are estimated. In general, regression results for each of the models indicate that respondents preferred policies with lower costs and were willing to pay for drinking water quality. The WTP results are quite variable as in Roe, et al. (1996). Annual WTP estimates range from $58 to $323 for the ratings model, $3 to $243 for the ratings difference model, and $9 to $35 for the discrete choice model. The lowest estimates are for the bottled water plan and the highest estimates tend to be for the aquifer protection district.

IV. An Assessment of the Studies

This review has revealed a wide range of economic values for safe drinking water. Monthly WTP for groundwater quality protection ranges from a low of about $1 to a high of almost $500. The most recent averting behavior studies, with the exception of the Harrington, Krupnick, and Spofford study, the earliest conducted, generate defensive expenditures estimates that have a narrow range. This is not surprising since the averting behavior studies have all been conducted in the same region of the country. In contrast, the range of WTP estimates from the CV studies is larger, $1-$155, but this should be expected due to the wide range of policies described in the contingent markets and the diverse populations sampled. Also, the Boyle, Poe, and Bergstrom meta-analysis, which includes most of these studies, concludes that the variation in these values can be adequately explained by characteristics of the groundwater issue and study design. The conjoint analysis studies tend to produce WTP estimates that are greater than the CV WTP estimates, but, the number of conjoint studies related to drinking water to date is low and the development of conjoint analysis for environmental values is still in its early stages.

Two of the studies directly compare the estimates derived from different methods of valuation. Laughland, et al. (1996) compare the defensive expenditures from the averting behavior portion of their telephone survey to the CV responses in terms of the magnitudes of the estimates and the correlation of values across respondents. They conclude that both types of estimates have validity if the true opportunity cost of time for hauling water and other averting behaviors is less than the market wage rate. However, their regression and other results raise questions about the validity of the two measures. Barrett, Stevens, and Willis (undated) in a comparison of the conjoint results of Barrett, Stevens, and Willis (1997) and the CV results of Krug (1995) find that conjoint WTP estimates are significantly greater than CV estimates. The conjoint WTP values are bounded by averting cost estimates from surveys of water treatment suppliers and actual averting expenditure estimates suggesting that the conjoint estimates have validity. However, the Krug study used payment card values, which have been found to generate WTP estimates lower than dichotomous choice WTP estimates, which may be driving these results.

No clear patterns of benefit estimation emerge after this brief comparison of WTP estimates for safe drinking water across region and valuation method. Further, too few comparison studies have been conducted with which to assess the validity of WTP estimates from different valuation methods. This raises the question of how best to value standards under the SDWA for use in benefit-cost analysis. As stated earlier, a cost-effective approach to benefit estimation is the benefits transfer approach in which the analyst uses results from primary studies as secondary data and applies estimates to the study site. For instance, the meta-analytic regression model in Boyle, Poe, and Bergstrom could be used as a drinking water valuation model with parameters from the study site plugged in and the predicted WTP values used as benefit estimates. However, Boyle, Poe, and Bergstrom caution that their model relies on too few studies for reliable benefits transfer. This suggests that a more reliable benefits transfer model could be developed by including the drinking valuation studies from other methodologies, the additional contingent valuation studies of groundwater protection, and the CV drinking water studies reviewed here.

Alternatively, it might be possible to transfer a benefits function from one study site to another. Crutchfield, Feather, and Hellerstein (1995) illustrate how this type of benefits transfer could be accomplished in the groundwater protection context. They first examined the groundwater valuation literature to screen for studies that were a close match to the study sites, that were published after peer-review, and that developed valuation functions that were appropriate for benefits transfer. After choosing three studies that meet their screening criteria (Shultz and Lindsay; Jordan and Elnagheeb; and Sun, Bergstrom, and Dorfman), they derive estimates for the relevant independent variables from the study sites and plug these into the valuation functions from the transfer sites. Aggregate WTP values from the benefits function transfer gives similar results to a simple benefits transfer, in which WTP values from the transfer site is applied to the study site, for two out of three studies. The authors also illustrate how measures of risk can be developed for study sites to plug into transferred benefits functions. While the final WTP estimates can only be narrowed to a rather large range of values in this illustration, the benefits function transfer approach provides defensible order-of-magnitude bounds for WTP for safe drinking water, without the cost of conducting a study to collect primary data.

Another related and promising approach is developed by Mauskopf and French (1991) and French and Mauskopf (1992). This approach is similar to benefits transfer in that it allows use of primary data collected for other purposes. However, the method approximates WTP by estimating first the quality-adjusted life-years lost from an illness that results in death and then attaching a WTP value by using the value of a statistical life at age 40 ($5 million). Then, the approach finds the number of days lost from the illness and approximates the WTP to avoid the illness days. Mauskopf and French (1991) apply this method to foodborne disease. The economic damages of a case of botulism range from less than $200 for a mild case to over $1 million for a severe case.

In terms of the collection of primary data to conduct a benefit-cost analysis of a drinking water quality standard, the most promising approach appears to be a combination of methods. In particular, drawing on the successful completion of averting behavior and contingent valuation studies, a comparison study using these two methodologies and the contingent behavior approach could produce valid and reliable estimates of WTP. In cases where related markets and revealed behavior exist, CV estimates can be compared to contingent and averting behavior estimates (when a contamination episode has occurred) and the data analyzed jointly to improve the validity of the estimates. Jakus (1994) describes conditions under which this approach could be successful and Dickie and Gerking (1996) provide an empirical example. This type of study could be conducted in several study sites, both similar and different, so that the benefits transfer and benefits function transfers can be employed in order to examine this approach in a controlled setting. Finally, many of the techniques currently being used in the valuation of food safety policies are applicable in the drinking water context. Revealed and stated preference methodologies in the laboratory and the field are leading to many insights about the value of food safety and could be applied to evaluate SDWA policy (see Caswell, 1995).

V. Conclusions

In this paper we have reviewed the valuation methodologies appropriate for estimating the economic benefits of safe drinking water quality. While there are several valuation methodologies that are capable of providing these estimates, the most commonly used are the averting behavior and contingent valuation methods. Reviews of the applied valuation literature reveals a wide range of willingness to pay estimates for protection of drinking water quality. We provide an assessment of this literature, including the validity of the studies and the potential for transferring these estimates for use in policy analysis related to the SDWA. In general, benefits transfer is feasible at this point in the evolution of the literature but questions remain regarding the accuracy of these transfers. Comparative research with revealed, including the COI and averting behavior approaches, and stated, including CV, contingent behavior, and conjoint analysis in different study areas is needed.

Table 1 Assessment of Methods for Valuation of Safe Drinking Water: Can These Economic Values be Estimated?						
	Revealed Preference			Stated Preference		
Economic Value	Cost of Illness	Averting Behavior	Hedonic Pricing	Contingent Valuation	Contingent Behavior	Conjoint Analysis
Private Direct Cost	yes	yes	yes	yes	yes	yes
Lost Earnings	yes	yes	yes	yes	yes	yes
Lost Non-market Work	may	yes	yes	yes	yes	yes
Lost Leisure	may	yes	yes	yes	yes	yes
Third-Party Costs	yes	no	no	no	no	no
Averting Costs	no	yes	yes	yes	yes	yes
Pain and Suffering	no	yes	yes	yes	yes	yes
Altruistic Values	no	no	no	may	may	may

Table 2 Averting Expenditure Studies of Safe Drinking Water					
Study	Location	Nature and Duration of Episode	Averting Behaviors (a)	Sample Size	Costs (b)
Harrington, Krupnick, and Spofford (1989)	Luzerne County, Pennsylvania	*Giardiasis* outbreak (12/83 - 9/84)	1, 2, 3	50	$153 - 483
Abdalla (1990)	College Township, Pennsylvania	Detection of *percholoroethylene* in wells (6/87 - 12/87)	1, 2, 3, 4	1012	$26-32
Abdalla, Roach, and Epp (1992)	Perkasie, Pennsylvania	Detection of *trichloroethylene* in wells (6/88 - 12/89)	1, 2, 3, 4	761	$16 - 35
Collins and Steinback (1993)	Rural West Virginia	Bacterial, Mineral and Organics detected in drinking water supplies (1/87 - 12/89) (c)	1, 2, 3, 4, 5	291,151	$32-36 (d)
Laughland, et al. (1993)	Milesburg, Pennsylvania	Giardia detected in (surface) drinking water supplies (1/89 - 4/89)	1, 2, 3	226	$16-42

(a) 1=hauling safe water, 2=boiling water, 3=purchasing bottled water, 4=installation of home water treatment system, 5=clean or repair water system
(b) Monthly averting costs are adjusted to the monthly household level using 4.3 weeks per month and 30 days per month in 1996 dollars
(c) Dates of water tests for nonpublic water systems, duration of episodes varied by household.
(d) Bacterial - mineral contaminants.

Table 3
Contingent Valuation Studies of Safe Drinking Water

Study	Location	Commodity Valued	Sample Size	WTP (a)
Edwards (1988)	Cape Cod, Massachusetts	An aquifer management plan to reduce the probability of nitrate contamination	585	$155
Schultz and Lindsay (1990)	Dover, New Hampshire	Protections plans to protect community groundwater supplies	346	$15
Sun, Bergstrom, and Dorfman (1992)	Doughtery County, Georgia	Protecting "safe" groundwater from potential future contamination	603	$67
McClelland, et al. (1992)	National	Complete groundwater cleanup from a 40% contamination	1983	$12
Caudill and Hoehn (1992)	Michigan	Action to prevent contamination; maintenance of well water quality	1213	$65
Poe and Bishop (1992)	Portage County, Wisconsin	Groundwater protection program to prevent nitrate contamination	244	$24(b)
Jordan and Elnagheeb (1993)	Georgia	Preventing groundwater pollution that would make sure water is safe for drinking	180	$14, $16 (c)
Powell, Allee, and McClintock (1994)	Massachusetts, New York, and Pennsylvania	Establish water supply protection districts that would ensure safe drinking water	1021	$6
Laughland, et al. (1996)	Milesburg, Pennsylvania	Connection to an alternative source so that drinking water meets standards	226	$23
Clemons, Collins, and Green (1995)	Martinsburg, West Virginia	Wellhead protection program to eliminate risk of contamination	576	$1.8, $1.2 (d)
Krug (1995)	Western Massachusetts	Aquifer Protection District and purchase of a private water filter	397	$6,$7 (e)

(a) Monthly household WTP (1996 dollars) is adjusted using 4.3 weeks/month, 30 days/month.
(b) With information sample.
(c) WTP is for private wells, municipal sources.
(d) WTP for nitrate, VOC contamination.
(e) WTP for protection district, private water filter.

Appendix: Consumer Price Index-All Urban Consumers
Source: Bureau of Labor Statistics [http://stats.bls.gov/]

Year	CPI
1980	52.52
1981	57.93
1982	61.50
1983	63.48
1984	66.22
1985	68.58
1986	69.85
1987	72.40
1988	75.40
1989	79.03
1990	83.30
1991	86.81
1992	89.42
1993	92.10
1994	94.46
1995	97.13
1996	100

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