ESTIMATING THE BENEFITS OF GROUNDWATER CONTAMINATION CONTROL

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Abstract

In this paper, a conceptual model for estimating option price for groundwater quality protection is developed, and the effects of subjective demand and supply uncertainty and other variables on option price are examined. A contingent valuation study to measure option price for groundwater quality protection was conducted in southwestern Georgia. Valuation results suggest that the monetary benefits to citizens of protecting groundwater supplies from agricultural chemical contamination are quite large.

Key words: option price, contingent valuation, uncertainty, groundwater contamination

Groundwater contamination is widely regarded as a major environmental problem now and in the future. A potential source of groundwater contamination is the agricultural application of pesticides and fertilizers. Scientists, engineers, and planners may propose various policies and programs for controlling groundwater contamination by agricultural chemicals. The direct costs of a groundwater contamination control program are relatively easy to measure. The benefits of contamination abatement are more difficult to measure because they are generally in the nature of uncertain future nonmarket commodity services.

The purpose of this paper is to report the results of a study which measured the potential benefits of groundwater contamination abatement. The specific objectives of the study were to: (1) develop a conceptual model for estimating the benefits of groundwater contamination abatement as measured by option price, (2) apply the contingent valuation method to estimate option price, and (3) examine the impact of subjective demand and supply uncertainty on the magnitude of option price.

CONCEPTUAL CONSIDERATIONS

Estimating the benefits of contamination abatement involves measuring the economic value of an environmental service. In the case of the protection of groundwater from agricultural chemical contamination, the environmental service provided by contamination abatement is high groundwater quality. Because of problems related to nonexclusiveness, groundwater quality is not traded in regular economic markets like other resource-based commodities such as gasoline. The economic value of groundwater quality resulting from contamination abatement must therefore be measured using something other than market prices.

One of the benefits of high groundwater quality is better human health. Because health care services are traded in economic markets, it may be possible to infer the value of human health resulting from high groundwater quality using health care expenditure data. However, such valuations would not completely capture the economic value of high groundwater quality. High groundwater quality is a component of overall environmental quality. Individuals ascribe nonmarketed benefits to environmental quality such as aesthetic enjoyment, peace of mind, and bequest values. In order to capture these benefits, as well as the human health benefits, a comprehensive value measure and valuation technique is needed.

An appropriate measure of economic value when uncertainty is present is option price (Brookshire et al.; Desvousges et al.). A general definition of option price is an individual's maximum willingness-to-pay (hereafter WTP) to secure the option to use a resource or commodity in the future (Freeman; Graham; Bishop). Option price measured in terms of WTP is a theoretically appropriate welfare change measure for public policy evaluation because it represents what an individual is willing to give up (e.g. income) for access to and use of a resource or commodity (Randall and Stoll).[1]

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[1] The technical relationship between option price and Hicksian welfare change measures for environmental commodities when uncertainty is present is discussed in detail elsewhere (Bishop; Randall; Smith, 1987.).

Bohm and Graham discuss the conceptual derivation of option price under demand uncertainty. Bishop, Freeman, Plummer, and Smith (1987) discuss the derivation under both demand and supply uncertainty. Edwards applied the previous results to analyze the option price of groundwater protection from nitrate pollution in Cape Cod, Massachusetts.

Option Price Utility Model

Suppose an individual derives personal utility from a Hicksian commodity[2] (X) and direct groundwater use (W). The utility function has the following form:

$$(1)\ U = U(X, W).$$

The budget constraint is $M = P_xX + P_wW$, where P_x is the price of other commodities and P_w is the price of groundwater. The maximization of utility (1) with respect to X and W and subject to the budget constraint, yields the indirect utility function:

$$(2)\ V = V(M, P_x, P_w).$$

An individual's WTP for protecting groundwater quality is defined generally as:

$$(3)\ V(M - WTP, P_x, P_L | S) = V(M, P_x, P_H | S),$$

where S represents individual characteristics (e.g. age), and P_L is the current, low price of groundwater and P_H is the higher price of groundwater if it is contaminated in the future.[3] WTP is the decrease in income which makes an individual indifferent between protecting and not protecting groundwater quality.

Now consider the effects of supply uncertainty. Without a groundwater protection program, let an individual's subjective estimation of contamination probability be denoted by δ. With a protection program, the probability of contamination is assumed to be zero. The addition of supply uncertainty therefore modifies (3) to:

$$(4)\ V(M\text{-}OP, P_x, P_L|S) = \delta V(M, P_x, P_H|S) + (1\text{-}\delta)V(M, P_x, P_L|S),$$

where OP is option price.

In (4), OP is conceptualized as a measure of the total economic value an individual places on protecting groundwater quality. Protecting groundwater quality provides a number of services to groundwater users. These services include health protection (e.g., reduction in the risk of cancer and other illnesses), avoidance of higher water costs (e.g., bottled water purchases, treatment costs), general aesthetic enjoyment derived from a clean environment, and any non-use values associated with protecting groundwater quality (e.g., bequest value, existence value). Thus, when an individual "purchases" groundwater quality as measured by OP, he or she is "purchasing" a set of environmental services. This implies that OP in (4) must be interpreted as a broad measure of an individual's total WTP to protect the complete set of services he or she ascribes to groundwater quality protection.[4]

Next, consider the effects of personal demand uncertainty. Even if an individual pays to ensure the supply of uncontaminated groundwater, he or she may not be around to use (or demand) the groundwater in the future. For example, the individual may move out the region for job reasons. Let an individual's subjective estimation of future demand be denoted by γ. The addition of demand uncertainty modifies (4) to:

$$(5)\ \gamma V(M\text{-}OP, P_x, P_L|S) + (1-\gamma)\, V(M\text{-}OP, P_x|S) = \delta V(M, P_x, P_H|S) + (1-\delta)\, V(M, P_x, P_L|S),$$

where the absence of P_L in $V(M\text{-}OP, P_x|S)$ indicates that groundwater is not consumed.

Measuring Option Price

The dichotomous choice approach (hereafter DCA) has been extensively used to empirically estimate welfare measures associated with changes in environmental commodities (Hanemenn; Sellar et al.; Edwards). In the DCA applied for this study, each

[2] Refers to all other commodities except water.

[3] For example, is groundwater supplies become contaminated in the future, water treatment costs may increase thereby increasing the price of groundwater. The price of water consumption may also increase if higher priced bottled water is substituted for local groundwater.

[4] Conceptual models can be developed which define WTP for specific services provided by a multi-attribute environmental commodity (Randall; Randall and Hoehn; Smith). For example, one may be interested in specifying a conceptual model which defines WTP for only the health protection services provided by groundwater quality protection. Empirically separating out and measuring the different components of total economic value, however, is a complicated and potentially controversial matter (e.g., Bergstrom and Stoll; Greenley et al.; Kahneman and Knetsch; Smith 1992).

respondent was asked whether or not he would be willing to pay an offer price of $A in order to have groundwater quality assured by a contamination protection program. Conceptually, the individual will accept the price if their utility does not decline under the program, i.e.,

$$(6)\ \gamma V(M\text{-}A, P_x, P_L|S) + (1-\gamma)V(M\text{-}A, P_x| S) + e_1 \geq \delta V(M, P_x, P_H | S) + (1-\delta)V(M,P_x,P_L | S) + e_0,$$

where e_0 and e_1 are random variables with zero means.

The probability of a "yes" response to the WTP question can be written as:

$$(7)\ Pr = Pr\ [\ \gamma V(M\text{-}A, P_x, P_L | S) + (1-\gamma) V(M\text{-}A, P_x | S) + e_1 \geq \delta V(M, P_x, P_H | S) + (1-\delta)V(M, P_x, P_L | S) + e_0\ ].$$

If η is defined as $\eta = e_0 - e_1$, then

$$(8)\ dV = [\gamma V(M\text{-}A, P_x, P_L | S) + (1-\gamma) V(M\text{-}A, P_x | S)] - [\delta V(M, P_x, P_H | S) + (1-\delta)V(M, P_x, P_L|S)\ ].$$

Next, if $F_\eta(.)$ is the cumulative distribution function for the random variable η, then $Pr = F_\eta(dV)$. So the DCA can be interpreted as the outcome of a utility-maximizing choice (Hanemann).

In the probit model, $F_\eta(.)$ is the standard normal cumulative density function and in the logit model $F_\eta(.)$ is the cumulative distribution function of a standard logistic variate, or:

$$(9)\ Pr = [1 + \exp(-dV)]^{-1}.$$

Following (8), let dV be approximated by:

$$(10)\ dV = K(\gamma, \delta, A, M, P_H, P_L, S).^5$$

Now, if (10) is substituted into (9), the result represents the probability that an individual will respond positively to paying a given offer price $A for protecting groundwater quality under demand and supply uncertainty:

$$(11)\ Pr = [1 + \exp(-K(\gamma, \delta, A, M, P_H, P_L, S)]^{-1}.$$

Using the coefficients estimated from (11) and assuming K(.) is linear in its arguments, option price (WTP) can be simply calculated by:

$$(12)\ OP = (-\sum_{j=1}^{n} \alpha_j Z_j) / \beta,$$

where β is the offer price coefficient, Z_j are the means of all other independent variables, and α_j are the estimated coefficients associated with Z_j (Cameron).

Confidence intervals for the estimated mean option price are calculated according to the method proposed by Krinsky and Robb. This consists of drawing 1000 randomly generated parameter vectors from the multivariate normal distribution representing the maximum likelihood parameter estimates of the logit model. For each draw, mean option price is estimated and the results saved. These 1000 option price values are then sorted from smallest to largest. A 95 percent confidence interval would then have as bounds the 26th and the 975th value from the ordered empirical distribution. Krinsky and Robb's procedure is analogous to a parametric bootstrap, relying on the asymptotic normality of maximum likelihood estimators. In the contingent valuation literature, it has been used to generate confidence intervals for welfare measures by Park, et al.

Study Area

Southwest Georgia, located in the southern Atlantic Coastal Plain, is a gentle terrain sloping from the Piedmont in the north, to the Gulf coast in the south. The area is underlain by a deep succession of sand, clay and carbonate rocks which forms one of the most productive multilayer aquifer systems in the United States (Rouhani and Hall). With its abundant groundwater, mild climate, and sandy soil, it is a major agricultural region.

Agriculture in the region is accompanied by heavy use of fertilizers and pesticides. Several researches have detected pesticides and nitrates in groundwater samples from this area (Hayes et al.; McConnell et al.). Although monitoring evidence to date suggests that groundwater quality, compared with EPA health advisory levels, is currently "safe" for drinking, southwest Georgia is among the major regions that have high pesticide contamination potential (Nielsen and Lee).

Dougherty county, including the City of Albany, is the largest population community in the

[5] When the utility difference in (8) is solved, P_x drops out of the equation.

region. By 1986, there were 109,969 people residing in the county, with approximately 86.6 percent living in urbanized areas and 13.4 percent in rural areas (Bachtel). About 87 percent of the Doughter County population is served by public water supplies (Hodler and Schretter). Groundwater, in turn, provides the sole source of public water supplies in the county (Pierce et al.). Groundwater is also the source of private well water supplies in the county. Because of the potential for groundwater contamination by agricultural chemicals, and the mix of urban and rural groundwater users, Dougherty County provides a good sampling frame for measuring groundwater quality benefits. The specific valuation problem is measuring the benefits of protecting currently "safe" groundwater from potential future contamination.

Questionnaire Design

The contingent valuation method (hereafter CVM) was used to elicit a household's WTP to eliminate the potential for groundwater contamination from agricultural chemicals. The objectives of the CVM survey were to estimate total WTP (option price) for a groundwater protection program and examine the potential factors affecting a household's WTP. The survey questionnaire contained a hypothetical referendum designed to measure a household's WTP for a new program which would definitely protect groundwater from contamination by agricultural chemicals.[6]

The questionnaire was divided into three sections. The first section asked questions about a respondent's residence and experiences with groundwater contamination by agricultural chemicals. Several attitude questions were then asked which were designed to help explain a household's contamination abatement demand.

The second section began by presenting information on the goal and the potential costs of a groundwater protection program. The valuation question for the program was then asked. The payment vehicle was a reduction in the amount of income a respondent had to spend on other goods and services (see Appendix). This payment vehicle was selected because it was easily understandable, neutral, and did not provide strong incentives for "free-riding" behavior.

The valuation question asked an individual whether he or she would "vote to support" the protection program or not, given a specific amount of income reduction (e.g., offer price) needed to support the program (Question 14 in the Appendix). A voting situation is consistent with the familiar market decision of whether or not to purchase some commodity at a given price. In order to gain additional information, participants were also asked to state maximum WTP for the program using an open-ended (i.e. "fill-in-blank") question (Question 15 in the Appendix). Respondents were then asked to give reasons for stating a zero bid to distinguish protest bids from legitimate zero bids. The last section of the questionnaire collected socioeconomic data.

Survey Procedures

The questionnaire was first applied in a small pre-test. The formal survey was conducted during October and November, 1989. Fourteen hundred forty households were randomly selected from a county registered voter list, which was thought to have reliable addresses. The sample was divided into twelve subgroups. Each of these subgroups received one of twelve offer amounts assigned for the DCA question. The offer amounts were $5, $20, $45, $70, $100, $150, $250, $350, $500, $1,000, $1,500, and $2,000 respectively. These offer prices were based on previous studies and the results of the pre-test survey.

The mail survey procedures followed the procedure suggested by Dillman. An initial questionnaire was sent to all households in the sample. One week later a follow-up postcard was sent to all households again. Two weeks later a second cover letter and replacement questionnaire were sent to all non-respondents.

ESTIMATION OF GROUNDWATER PROTECTION BENEFITS

Of 1,440 surveys sent out, 156 were returned as undeliverable, leaving an adjusted sample frame size of 1,284. Six hundred and sixty questionnaires were returned for an response rate of 51.4 percent. This response rate is quite comparable with those of other nonmarket valuation studies which have used a mail survey (e.g. Bowker and Stoll; Bergstrom et al.).

Cummings, et al. state that if a person bids zero as a "protest" to being asked to pay for an environmental good, the bid is not an indicator of his true valuation. Protest bids are inconsistent with an im-

[6] Scientific information was not available for estimating the actual effectiveness of groundwater contamination control program. An effectiveness level of 100 percent was therefore selected to simplify the valuation problem and questionnaire wording. It is important to note that estimated valuations were conditioned on this 100 percent effectiveness level. With less than 100 percent effectiveness, observed valuation would likely be lower.

plicit model of contingent valuation behavior and are therefore typically screened out of the sample (Desvousges et al.). Respondents who bid zero were asked to provide a reason. With respect to the DCA valuation questions, protest bidders only included respondents who indicated they had an inherent right to clean groundwater or they refused to place a monetary value on clean groundwater. The fact that 91.4 percent of respondents did not protest the DCA valuation question implies that most residents support the idea of paying for groundwater protection.

Upon eliminating the protest bidders, there were 603 valid observations (91.4 percent of responses) for the DCA. For these observations, the sample population had an average age of 45.2. Average years in residence was 23.1. Average education was 13.8 years. Average household size was 2.9 with 0.9 children. Average subjective pollution probability was 54 percent and average subjective move probability was 33 percent . The average annual household income was \$42,517 with a range between \$5,000 and \$500,000.

Empirical Logit Model

The empirical logit model was specified as:

(14) $P_1 = \{1 + EXP[-K(.)]\}^{-1}$,

where $K(.) = \alpha_0 + \alpha_1 \log(A) + \alpha_2 \log(M)$
$+ \alpha_3 \log(OWN) + {}_4\log(CONT)$
$+ \alpha_5 \log(DEMN) + \alpha_6 \log(AGE)$.

Because the true, utility-theoretic valuation model is unknown, (14) was selected as a pragmatic approximation. One of the objectives of this study was to examine the effect of certain independent variables (listed in Table 1) on WTP for groundwater quality protection. The multivariate specification of (14) allows for a rather simple and straightforward examination of these effects. The logarithmic specification of (14) was selected because of its consistency with neoclassical demand theory (Sellar et al.).

For a small region such as Dougherty county, P_L and P_H are assumed to be constant across individuals. Hence, the effects of P_L and P_H are captured by the constant term α_0 in (14).[7] As the offer price (A) increases, the probability of an individual answering "yes" to the dichotomous-choice valuation question is expected to decrease. Thus, α_1 in (14) was expected to have a negative sign. Demand for environmental quality is expected to increase with income (M). It was therefore expected that α_2 in (14) would have a positive sign. The more concerned a person is about his or her own health, the more likely is he or she to be willing-to-pay for groundwater quality protection. A positive sign on α_3 in (14) was therefore expected. An increase in the probability of future groundwater contamination is expected to increase the demand for groundwater quality protection. An increase in the probability of demanding high quality groundwater in the future is expected to increase the demand for groundwater quality protection. Thus, α_4 and α_5 in (14) were both expected to have positive signs. Conceptually, the effect of a person's age on preferences for environmental quality is rather ambiguous. The expectation of the sign on α_6 in (14) was therefore positive or negative.

The data used to estimate (14) are described in Table 2. Maximum likelihood estimates of the equation (14) coefficients are shown in Table 3. The

Table 1. Definition of Variables Used in Data Analysis

A = Posted-price or offer price in dollars.

M = Approximate annual household income in dollars.

OWN = Index for concern over pollution effects on own health. It is an element of S (vector of socio-dempgraphic variables).
1 = not concerned, 2 = somewhat concerned,
3 = concerned, 4 = very concerned.

CONT = Estimated subjective probability of groundwater contamination in 5 years without a protection program. It is a proxy for supply uncertainty δ.

DEMN = Estimated subjective probability of clean water demand within 5 years. It equals (1-MOVE), where MOVE is the probability of moving out of the county. DEMN is a proxy for demand uncertainty γ.

AGE = Respondent's present age. It is an element of S (vector of sociodemographic variables).

VOTE = Dummy variable indicating acceptance of offer price for the pollution control program.

[7] For a larger region, PL and PH may vary across individuals. In this case, it may be important to account for spatial price variations when estimating the empirical valuation model.

Table 2. Descriptive Statistics of Variables Used to Estimate Logit Model

Variable	Mean	Minimum	Maximum	Std. Deviation
A	476.6	5.00	2,000	616.7
M	42,517	5,000	500,000	35,490
OWN	3.43	1	4	0.790
CONT	0.541	0	1.00	0.281
DEMN	0.675	0	1.00	0.318
AGE	46.8	19	83	15.7

coefficients on income (M), own health concern level (OWN) and subjective contamination probability (CONT) had expected positive signs which were statistically significant. The offer price (A) coefficient had an expected negative sign which was also statistically significant. The coefficient on subjective demand probability (DEMN) had a positive sign as expected, but was not statistically significant. The age variable (AGE) had a statistically significant coefficient with a negative sign.

Using Cameron's approach, the mean option price of groundwater pollution abatement is calculated as \$641 annually per household.[8] This mean value was derived using the average values for the independent variables shown in Table 2. For example, the \$641 mean value was derived using the mean subjective contamination probability (without the control program) of 54 percent. The 95 percent confidence interval of the option price is between \$890 and \$493 (Table 4).

A sensitivity analysis was conducted by changing one independent variable by one standard deviation (or to the extreme value) and holding all other variables at their mean values. The results (Table 5) suggest that option price for a household with an annual income of \$78,000 is about \$1,450 annually, and option price for a household with an annual income of \$7,000 is about \$165 annually. If the head of household is age 31, option price is about \$870. If the head of household is age 62, option price is about \$469. Those who are very concerned about potential own health effects from contaminated groundwater have an option price of around \$905, but those who expressed no concern have an option price of only around \$71. Those who estimated 100 percent subjective probability of groundwater contamination have an option price of \$942. This compares with an option price of \$120 for those who estimated no contamination probability. Those who definitely will not move out of the county during the next five years have an option price of about \$682, compared with a \$451 option price for those who definitely will move out of the county during the next five years.

Table 3. Logit Analysis of Groundwater Protection

Variable	Coefficient	T-ratio	P-value
Constant	-1.08	-0.514	0.6073
log(A)	-0.813	-9.65**	0.0000
log(M)	0.737	5.51**	0.0000
log(OWN)	1.49	3.89**	0.0001
log(CONT)	0.363	3.18**	0.0015
log(DEMN)	0.0732	0.817	0.4140
log(AGE)	-0.718	-2.21*	0.0269
McFadden R^2	0.267		
Number of Obs.	591		

**Indicates significance at 1 percent level.
*Indicates significance at 5 percent level.

Table 4. Option Price Estimated from Logit Model (in Dollars per Year)

	Lower Tail			Upper Tail	
Mean Option Price	2.5 percent	5 percent	Median	5 percent	2.5 percent
641	493	516	636	842	890

IMPLICATIONS

The results of this study provide information to policymakers faced with decisions concerning efficient agricultural chemical usage and groundwater contamination abatement. The estimated benefits of groundwater protection can serve as a reference to compare the benefits and costs of potential groundwater protection programs. The option price model could also be used to simulate the marginal benefits of contamination abatement.

[8] It should be noted that the sample population appears relatively affluent (including the farm population). For a population with lower mean income, mean option price for high groundwater quality would likely be lower.

Table 5. Sensivity Analysis of the Independent Variables

Variable	Value	Option Price ($/yr)[a]
M	7,027 *	165
	78,007 #	1,452
OWN	1(min.)	71
	4(max.)	905
CONT	0(min.)	120
	1.00(max.)	942
DEMN	0(min.)	451
	1.00(max.)	682
AGE	31.3 *	870
	62.5 #	469

[a]The estimated option price using means of the variables has a mean of $641/yr. and a median of $636/yr.
* Indicates that the value is one standard deviation below the mean value.
# indicates that the value is one standard deviation above the mean value.

The empirical survey suggested that most groundwater users are willing to pay for a new groundwater contamination abatement program. The elicitation of option price suggested a very high value, from the consumer side, for groundwater contamination abatement from agricultural chemicals. This high value suggests that policymakers should seriously consider potential policies and programs for meeting this high demand for groundwater contamination abatement.

The exposition of the factors affecting household demand for contamination abatement can help policymakers analyze the sensitivity of option price to changes in various factors. For example, a new discovery of linkages between agricultural chemicals and cancer risks could elevate the own health concern level and raise valuations. New information which reduces (increases) expectations of contamination in the future without a protection program may reduce (increase) valuations.

The benefit analysis of groundwater protection from agricultural chemicals is inherently site-specific. Specific farm location and hydrogeological settings will likely affect subjective contamination probability. In addition, household income, move probability, own health concern, education and age vary across sites. Policymakers should recognize this potential variation in benefits across sites when analyzing the social desirability of proposed groundwater contamination control programs.

The methodology used in this study could be applied to other potential contamination areas in the future. Survey work should focus on the regions affected by current or potential contamination. Future research should attempt to improve, normalize, and validate valuation methodology in order to establish a more reliable data base for benefit-cost analysis of environmental protection.

APPENDIX

The Valuation Questions in the Questionnaire

** Suppose that <u>with</u> the program, pollution of groundwater by agricultural pesticides and fertilizers in Dougherty County will definitely be kept at safe levels for drinking and cooking (that is, <u>below</u> the EPA's health advisory levels).

Given this assumption, please evaluate and give <u>YOUR BEST ANSWERS</u> to question (14) and (15).

(14) Would you vote to support the program for preventing groundwater pollution from agricultural pesticides and fertilizers, if the program reduces the amount of money you have to spend on other goods and services by $__________ per year ?

1. YES.

2. NO.

(15) What is the **highest** amount the program could reduce the amount of money you have to spend on other goods and services <u>before</u> you would vote against it?

$ ______________ DOLLARS PER YEAR.

REFERENCES

Bachtel, Douglas C. *The Georgia County Guide*. 7th ed. Athens, Ga: The Cooperative Extension Service, The University of Georgia, 1988.

Bergstrom, J.C., and J.R. Stoll. "A Test of Contingent Market Bid Elicitation Procedures for Piecewise Valuation." *West. J. Agr. Econ.*, 12(1987): 104-108.

Bergstrom, J.C., J.R. Stoll, J.P. Titre, and V.L. Wright. "Economic Value of Wetlands-based Recreation." *Ecological Econ.*, 2(1990): 129-147.

Bishop, Richard C. "Option Value: An Exposition and Extension." *Land Economics*, 58(1982): 1-15.

Bohm, Peter. "Option Demand and Consumer's Surplus: Comment." *Am. Econ. Rev,. 65(1975): 733-736.*

Bowker, J.M., and J.R. Stoll. "Use of Dichotomous Choice Nonmarket Methods to Value the Whooping Crane Resource." *Am. J. Agr. Econ.*, 70(1988): 372-381.

Brookshire, D.S., L.S. Eubanks, and A. Randall. "Estimating Option Prices and ExistenceValues for Wildlife Resources." *Land Economics*, 59(1983): 1-15.

Brookshire, D.S., B. Ives, and W.D. Schulze. "The Valuation of Aesthetic Preferences." *J. Envir. Econ. Manag.*, 3(1976): 325-346.

Cameron, Trudy A. "A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression." *J. Envir. Econ. Manag.*, 15(1988): 355-379.

Cummings, R.G., D.S. Brookshire, and W.D. Schulze. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* Totowa, New Jersey: Rowan and Allanheld, 1986.

Desvousges, W.H., V.K. Smith, and A. Fisher. "Option Price Estimates for Water Quality Improvement: A Contingent Valuation Study for the Monongahela River." *J. Envir. Econ. Manag.*, 14(1987): 248-267.

Dillman, D.A. *Mail and Telephone Survey: The Total Design Method.* New York: John Wiley & Sons, 1978.

Edwards, Steven F. "Option Prices for Groundwater Protection." *J. Envir. Econ. Manag.*, 15(1988): 475-487.

Freeman III, A.M. "Supply Uncertainty, Option Price, and Option Value." *Land Econ.*, 61(1985): 177-181.

Graham, D.A. "Cost-Benefit Analysis under Uncertainty." *Am. Econ. Rev.*, 71(1981): 7157-25.

Greenley, D.A., R.G. Walsh, and R.A. Young." Option Value: Empirical Evidence from A Case Study of Recreation and Water Quality." *Quart. J. Econ.*, 96(1981):657-673.

Hanemann, Michael W. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *Am. J. Agr. Econ.*, 66(1984): 332-341.

Hayes, L.R., M.L. Maslia, and W.C. Meeks. *Hydrology and Model Evaluation of the Principal Artesian Aquifer, Dougherty Plain, Southwest Georgia.* Atlanta: Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geology Survey, Bulletin 97. 1983.

Kahneman, D. and J. Knetsch. "Valuing Public Goods: The Purchase of Moral Satisfaction." *J. Envir. Econ. Manag.*, 22(1992): 57-70.

Krinsky, Itzhak, and A. L. Robb. "On Approximating the Statistical Properties of Elasticities." *Rev. Econ. and Stat.*, 1986: 715-719.

McConnel, J.B. et al. *Investigation of Ethylene Dibromide (EDB) in Ground Water on Seminole County, Georgia.* Reston, Va: U.S. Dept. Inter., Geology Survey. Circular 933, 1984.

Nielsen, E.G., and L.K. Lee, *The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals.* Washington, DC: USDA ERS, Agr. Econ. Rpt. No 576, 1987.

Park, T., J.B. Loomis, and M. Creel. "Confidence Intervals for Evaluating Benefits Estimates from Dichotomous Choice Contingent Valuation Studies." *Land Economics*, 67(1991): 64-73.

Pierce, R.R., N.L.Barbar, and H.R. Stiles. *Water Use in Georgia by County for 1980.* Atlanta: Georgia Department of Natural Resource, Information Circular 59, p61. 1982

Plummer, M.L. "Supply Uncertainty, Option Price, and Option Value: An Extension." *Land Economics*, 62(1986): 313-318.

Randall, A. "Total and Nonuse Values." In *Measuring the Demand for Environmental Quality.*Braden, J.B. and C.D. Kolstad, eds. North-Holland: Elsevier Science Publishers, 1991.

Rouhani, S., and T.J. Hall. "Geostatistical Schemes for Groundwater Sampling." *J. Hydrology,* 103(1988): 85-102.

Sellar, Christine, J.P. Chavas, and J.R. Stoll. "Specification of the Logit Model: The Case of Valuation of Nonmarket Goods." *J. Envir. Econ. Manag.*, 13(1986): 82-90.

Smith, V.K. "Comment: Arbitrary Values, Good Causes, and Premature Verdicts. "*J. Envir. Econ. Manag.*, 22(1992): 71-89.

Smith, V.K. "Uncertainty, Benefit-Cost Analysis, and the Treatment of Option Value." *J. Envir. Econ. Manag.*, 14(1987): 283-292.