Estimating the economic value of water quality protection in the Catawba River basin

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Received 29 June 2001; revised 3 December 2001; accepted 3 December 2001; published 28 September 2002.

[1] This study used stated preference methods to estimate the economic value of protecting water quality in the Catawba River basin of North and South Carolina at its current level. Telephone interviews were completed with 1085 randomly selected households, who were also mailed a short information booklet about these issues. Respondents expressed a mean willingness to pay $139 for a management plan designed to protect water quality at its current level over time. Aggregation of this mean willingness to pay value amounted to an annual economic benefit of over $75 million for all taxpayers in Catawba basin counties. By using a split-sample survey design, this study also compared the effectiveness of different combined mail and telephone survey formats. Results indicated that while a phone-mail-phone approach is preferred for some reasons over a mail-phone approach, the survey format did not significantly affect the economic valuation results. *INDEX TERMS:* 6309 Policy Sciences: Decision making under uncertainty; 6319 Policy Sciences: Institutions; 6304 Policy Sciences: Benefit-cost analysis; 1857 Hydrology: Reservoirs (surface); 1871 Hydrology: Surface water quality; *KEYWORDS:* stated preference methods, contingent valuation survey, willingness-to-pay, management plan

Citation: Kramer, R. A., and J. I. Eisen-Hecht, Estimating the economic value of water quality protection in the Catawba River basin, *Water Resour. Res.*, *38*(9), 1182, doi:10.1029/2001WR000755, 2002.

1. Introduction

[2] The Catawba River of North and South Carolina provides a wide variety of services to residents in the roughly 5000 square mile (8045 km^2) Catawba River basin. These services include various forms of recreation, drinking water, and wastewater assimilation. The main stem of the river consists of 11 reservoirs constructed by Duke Power Company for hydroelectric power generation. Along its 224 miles (~360 km) the river supports nuclear and fossil fuel plants as well as a variety of other commercial activities.

[3] The health and vitality of this river system is being threatened by rapid population growth and land use changes. Charlotte, North Carolina, is currently the second fastest growing metropolitan region in the country [*Dodd and Mellnik*, 2001]. These factors contribute to point and primarily nonpoint source pollution which, as indicated by water quality monitoring along the river, results in declining water quality as the river flows downstream [*Duke Power Company*, 1996].

[4] In an attempt to help policy makers and stakeholders assess the value of the Catawba River, this study's primary objective was to determine the economic value of protecting water quality in the Catawba River basin. A secondary objective was to examine the relative strengths and weaknesses of different survey formats that combine a telephone and mail approach. Since the *U.S. Water Resources Council* [1983] first recommended the use of the contingent valuation method, and following the groundbreaking work of *Smith and Desvousges* [1986] and *Mitchell and Carson* [1989], this survey-based methodology has been increasingly used in the economic valuation of water resources [*Mitchell and Carson*, 1993; *Whittington et al.*, 1994; *Garrod and Willis*, 1999]. Although many researchers favor in-person interviews, mail and telephone surveys have become increasingly common in contingent valuation (CV) research [*Mitchell and Carson*, 1995]. A hybrid approach of combining mail and telephone surveys allows researchers to utilize the advantages of both survey formats. Respondents can be personally interviewed over the telephone, giving the researcher control over survey administration, and the respondents can be mailed any written and visual information needed for the survey effort. Of the two possible approaches for this type of survey, phone-mail-phone and mail-phone, the former has been seen as the preferred method among CV researchers [*Loomis and King*, 1994; *Smith and Mansfield*, 1998]. By using a split-sample design, this study compares results from each type of combined phone-mail survey format.

2. Methods

[5] This study used the contingent valuation method (CVM) to estimate the economic value of protecting water quality in the Catawba River basin. The CVM is one of a handful of stated preference techniques used by economists to place a monetary value on nonmarket goods such as water quality. An advantage of stated preference techniques, such as the CVM or conjoint analysis, is that they can measure both the use values and nonuse values of a good. Although some economists question the validity of the CVM, the method has been accepted by the judicial system for estimation of the damages caused by oil spills or other

0043-1397/02/2001WR000755$09.00

environmental injuries [*Carson et al.*, 1994]. In 1993 a panel consisting of several Nobel Laureate economists commissioned by the National Oceanographic and Atmospheric Administration (NOAA) published guidelines for acceptable practices for use of the CVM [*Arrow et al.*, 1993].

[6] CVM studies rely on responses to public opinion surveys to estimate a monetary value for a nonmarket good. The surveys ask individuals to state their willingness to pay (WTP) for a specified level of change in the provision of a good. These questions are typically preceded with a detailed description of the good and the proposed changes to it, as well as socioeconomic questions and questions about respondents' use of the good and their perceptions of it [*Mitchell and Carson*, 1995].

[7] An individual's WTP is equivalent to the well being they receive from knowing that this specific change will be provided to them. Two key assumptions of welfare economics are inherent in measures of WTP. The first assumption is that individuals seek to maximize their utility and that they have clearly defined preferences that can be revealed through the choices they make. The second key assumption, known as consumer sovereignty, is that individuals are the best judges of their own utility [*Lindsey*, 1992].

[8] An individual's WTP for the change in an environmental resource can be defined in terms of their utility. Assuming that q represents the amount or quality of an environmental resource and that the proposed change q_1 is preferred over the status quo of q_0, WTP for this change can then be described by

$$\mathrm{WTP} = e(p, q_1, u_0) - e(p, q_0, u_0),$$

where p is a vector of prices, u_0 is the is the individual's given utility level, and $e(\,)$ is the function that represents the minimum expenditures necessary to obtain utility level u_0.

[9] Relating the above equation to the initial levels of price and the individual's income m_0, this equation can be rewritten as

$$\mathrm{WTP} = m_0 - e[p, q_1, v(p, q_0, m_0)],$$

with $v(p, q_0, m_0)$ representing the indirect utility function derived from the status quo conditions of p, q_0, and m_0 [*Smith*, 1997].

2.1. Survey Design

[10] Survey design consisted of collection of background information, focus groups, questionnaire development, and pretesting, that were conducted over the first half of this 2-year study. The first phase of survey design involved meetings with stakeholder groups and an extensive literature review. Four focus groups were then held in different locations within the Catawba basin to assess the public's level of knowledge of water quality and management of water pollution. The focus groups were also used to test specific survey materials, such as passages of text, photographs, and maps.

[11] The survey design process continued with the drafting of the survey materials. Besides a questionnaire, an information booklet, "Water Quality in the Catawba River Basin," was designed for survey respondents to read before being interviewed. This booklet introduced respondents to water quality issues and ways that these problems can be managed. It also included color photos and maps of the river basin. These maps showed the current level of water quality in the basin and a potential future scenario of what water quality in the basin could look like if water quality problems were not actively managed. Information for these maps came from the Watershed Analysis Risk Management Framework model, an integrated watershed model developed by Systech Engineering [*Chen et al.*, 1998]. Use of the model enabled us to show what water quality in the Catawba basin might look like in 10 years, given projected levels of population growth and land use changes. Peers and selected stakeholders reviewed drafts of the survey materials and provided important feedback.

[12] The final phase of survey design involved extensive pretesting of the survey instrument. First, several cognitive interviews were conducted with respondents in a face-to-face setting. Besides administration of the survey, these interviews included extensive debriefing sessions to uncover any potential problems. Second, 54 interviews were completed using combined mail and telephone methods. In all pretesting interviews a behavioral coding technique was used to identify any problematic survey questions [*Presser and Blair*, 1994].

2.2. Survey Implementation

[13] The data collection period ran from 9 September through 31 December 1998. The telephone interviewing was contracted to Hagler Bailly, a leading market research firm specializing in complex survey efforts. Roughly 20 of Hagler Bailly's professionally trained interviewers worked on the project. In order to test the effectiveness of different survey formats, a split-sample design was used for the study. Half of the sample was surveyed using a phone-mail-phone (PMP) approach, and the other half was surveyed by a mail-phone (MP) approach. Despite these differences in survey format, respondents in both formats were asked an identical set of questions. For both survey formats, respondents were required to be over 18 years of age and to be a decision-maker regarding the household budget.

[14] Respondents for the PMP survey format were selected through a random-digit-dialing (RDD) procedure. At eligible households the interviewers asked respondents to participate in a short survey on an undisclosed topic. At the end of this interview the interviewers recruited respondents for a second telephone interview, again on an undisclosed topic, that would require them to receive some information by mail. Respondents agreeing to participate were sent a cover letter and the booklet and were then called to complete the second interview. Respondents in the MP survey were randomly selected from name and address lists purchased from a survey-sampling firm. These respondents were sent the information booklet and a cover letter explaining the survey and telling respondents they would receive a call from an interviewer within 1 week of receiving the package. The cover letter in both survey formats explained to respondents the importance of their participation, even if they were not personally concerned with these issues. In both survey formats the interviewers asked respondents if they had read the booklet before starting the interview.

Respondents who had not yet read the booklet were called back at a later date.

[15] Respondents were sampled from the 16 counties that have more than 10 square miles (~16 km^2) of land within the boundaries of the Catawba River basin. A total of 1085 interviews were completed with households in these counties. To account for different population densities, the sampling was weighted by the percentage that the population in each county contributes to the total population of the 16 counties. Owing to this weighting, 80% of the sample was from North Carolina and 20% was from South Carolina.

[16] For the PMP survey format, 1328 respondents completed the initial interview and 966 of them agreed to participate in the second interview, for a recruitment rate of 73%. For the second interview, 560 of the 966 who agreed to participate actually completed the interview, for a response rate of 58%. For the MP survey format, 1455 households were mailed booklets and were reached by phone. The interview was completed with 525 of those households, for a response rate of 36%. The overall survey response rate, based on a proportional combination of the individual rates, was 47%, which is within the range reported by recent CV studies conducted by similar methods [*Smith et al.*, 1997; *Smith and Mansfield*, 1998].

2.3. Survey Description

[17] The telephone interviews lasted an average of 24 minutes. The survey began with a set of questions about various current issues, population growth in the area, and respondents' recreational activities. Respondents were then asked a series of questions relating to water quality in their region. The interviewers asked the contingent valuation (CV) question after reiterating the management plan to respondents and reading additional text that set up the CV scenario. Following the CV question, respondents were asked questions aimed at assessing their level of understanding of the CV scenario and their reasons for their vote for or against the CV referendum. Owing to their sensitive nature, demographic questions were asked at the end of the interview for the MP respondents and the end of the recruiting interview for the PMP respondents.

3. Results

[18] This section presents results of a selected set of survey questions and of the economic valuation effort. Respondents were informed that they were free to skip any questions if they desired, so the number of responses to each question changes slightly on the basis of the number of respondents choosing to skip a question.

3.1. Respondent Demographics

[19] Selected socioeconomic characteristics of the survey respondents are presented in Table 1 alongside results for the same area as obtained from the 1990 U.S. Census. As discussed in section 3.6, differences between the survey sample and the general population are corrected through the use of weighting techniques. In addition to general socioeconomic information the survey also asked how long respondents had lived in the basin. Results to this question showed that despite the rapid influx of new residents, the majority of the survey respondents (60%) had lived in the basin longer than 20 years.

Table 1. Socioeconomic Characteristics of Survey Respondents

Socioeconomic Characteristic	Percentage or Mean/Median Value	
	Survey Data	Census Data
Percent female	46% (n = 1085)	52%
Mean age	50 (n = 1070)	49
Percent high school graduates	92% (n = 1082)	69%
Percentage college graduates	39% (n = 1082)	17%
Percent Caucasian	89% (n = 1072)	80%
Percent African American	7% (n = 1072)	19%
Mean annual household income	$55,481 ($n$ = 989)	$45,477

3.2. Respondents' Perceptions, Attitudes, Opinions, and Beliefs Regarding Water Quality

[20] Questions about water quality indicated that this was an important issue to survey respondents. Fifty-seven percent of the respondents had previously heard of water quality concerns in the Catawba basin prior to taking the survey. Additionally, 37% of the respondents thought that this issue was more important than other environmental issues in their state, and 59% thought that it was just as important. Forty-nine percent of the respondents thought that water quality had declined in their area over the last 5 years.

3.3. Contingent Valuation Scenario

[21] Following the approach of *Whittington et al.* [1994], the CV scenario involved a management plan for water quality in the basin. Described to respondents in the information booklet, this management plan was designed to protect the current level of water quality in the Catawba basin over time (Figure 1). This management plan was developed through a review of planning documents from state regulatory agencies that addressed water quality issues in the Catawba basin and through consultation with staff at these regulatory agencies.

[22] To elicit a WTP from respondents, this management plan was offered at one of eight different price levels. These payments, ranging from $5 to $250, would be collected each year for 5 years. Assignment of a dollar value to respondents was done randomly by computer before any information was collected from respondents on their income or any other information that might indicate their water quality preferences. The actual text of the CV question is shown in Figure 2. In accordance with suggestions of the NOAA panel, a referendum format was used for this question.

[23] As indicated by the CV question results, respondents expressed a strong willingness to support the management plan for protecting area water quality. Sixty-six percent of the respondents said that they would vote in favor of the management plan at the various prices at which it was offered to them. Of the remaining 34%, 31% said they would not support the plan, and 3% said they did not know how they would vote (n = 1079). For the purpose of the economic valuation, "don't know" responses were set equal to votes against the management plan.

[24] Another question in this part of the survey assessed how much respondents believed that the management plan would actually accomplish its goal of protecting water

A POTENTIAL MANAGEMENT PLAN FOR THE CATAWBA RIVER BASIN

This management plan addresses the main water pollution problems in the basin: sediment and nutrients. It also continues to manage related problems such as pollution by toxic substances and bacteria and viruses. While this specific management plan has not been proposed by state governmental agencies, it is drawn from their best available information. This includes information on the condition of the basin and how to best manage the problems.

This potential management plan includes the following components:

1. Construction and use of best management practices (BMPs) within the basin. These include buffer strips and holding ponds for farms, construction sites and residential areas.

2. Development of a basinwide land use plan. This would encourage land uses in the basin that are consistent with the goals for water quality in the basin. Government agencies could use this land use plan to make decisions that would affect water quality.

3. Improving and increasing the capacity of sewage treatment plants in cities within the basin.

4. Purchasing and setting aside of tracts of land that have been determined as critical to the protection of water quality.

This plan would be in effect for five years. At the end of that period, the plan would be re-evaluated. Modifications would be made to the plan at that point if the plan was not meeting the goal of preventing declines in water quality in the basin.

Figure 1. Management plan for protecting water quality.

Now, assume a vote is being held today to approve or reject this management plan. Your payment for this plan would be collected through an increase in your usual state income taxes. All residents in counties within the Catawba River basin would make identical payments. This money would **only** be used for implementing this management plan for the Catawba River basin. If a majority of Catawba basin county residents vote in favor of this management plan, it will go into effect. Before you answer the following question, please consider your current income, as well as your expenses.

15. Suppose that this management plan would cost you $____ (5, 10, 25, 50, 100, 150, 200, 250) **each** year for the next **five** years in increased state income taxes. Would you vote in favor of the management plan?

Figure 2. The contingent valuation question.

quality in the basin over time. Results from this question showed that 76% of the sample thought the management plan was somewhat likely or very likely to succeed.

3.4. Econometric Evaluation of the Contingent Valuation Responses

[25] Additional testing of the validity of the WTP responses was accomplished through an econometric evaluation. A Logit model is a nonlinear, maximum likelihood estimation procedure that can be used to analyze the relationship between a dichotomous variable and independent variables [*Kennedy*, 1998]. In the Logit model the probabilities of a yes or no response to the management plan by respondents were expressed as

$$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_k x_k + \varepsilon_i,$$

where Z = log (probability of yes)/(probability of no), $\beta_0 \ldots \beta_k$ are the estimated parameters of the coefficients, x_1 is the price at which the management plan was offered to the respondent, $x_2 \ldots x_k$ are various independent variables, and ε_i represents the unobservable, stochastic component of the respondent's utility function.

[26] The predicted probabilities of the Logit model were then calculated using

$$P = \frac{1}{1 + e^{-z}}.$$

Results of the Logit model are presented in Table 2.

[27] The results of the Logit model showed that respondents' WTP for the management plan was negatively correlated with the price of the plan and positively correlated with their income. Since these and other variables have their expected signs, the model indicates that respondents gave thoughtful answers to the CV scenario and were considering the price of the management plan as well as their own income constraints [*Carson et al.*, 1994]. There was also indication from the Logit model that WTP increased with increasing use of the good, as indicated by the positive correlation with the OTHERUSE variable, which rates the importance that respondents placed on the use of the river by their friends and family.

[28] Besides the ratings on the importance of the recreational use of the Catawba River, the Logit model also tested the effects of other reasons for valuing the management plan. Placing an importance on the existence value of the Catawba River (EXIST) had a positive influence on respondents' votes for the plan, as did placing an importance on the quality of area drinking water (DRQUAL).

[29] A number of other variables included in the Logit model had a positive influence on respondents' votes on the management plan. As indicated by the LIKELY variable, respondents who thought the management plan was likely to succeed in protecting water quality were more willing to support the plan. Also, membership in environmental or conservation organizations (ENVORG) had a positive influence on respondents' votes on the management plan. Respondents who said that they somewhat or completely

Table 2. Logit Model of Respondents' Votes on the Proposed Management Plan[a]

Variable	Coefficient	*t* Ratio
Constant	−0.841	−1.273
Continuous Variables		
WTPAMT (dollar amount of management plan, from $5 to $250)	−0.011	−10.628
AGE (age of respondent)	−0.001	−0.107
INCOME (household income of respondent)	0.000	3.204
DATELAG (number of days between when the information booklet was mailed to respondent and when the interview was conducted)	0.002	0.536
Dummy Variables		
FORMAT (1 if PMP survey format, 0 if MP survey format)	0.202	1.060
TAX (1 if respondent rated reducing state and federal taxes as important to them, 0 otherwise)	−0.669	−3.261
WPCONTROL (1 if respondent had previously heard of efforts to control water pollution, 0 otherwise)	−0.123	−0.715
USE (1 if respondent rated their own use of the Catawba River as an important reason why the management plan would be of value to them, 0 otherwise)	−0.140	−0.661
DRQUAL (1 if respondent rated the quality of the drinking water in their area as an important reason why the management plan would be of value to them, 0 otherwise)	0.612	1.823
OTHERUSE (1 if respondent rated use of the Catawba River by their friends and family as an important reason why the management plan would be of value to them, 0 otherwise)	0.635	2.981
EXIST (1 if respondent rated the knowledge that water quality in the basin was being protected regardless of their use of it as an important reason why the management plan would be of value to them, 0 otherwise)	0.833	3.907
LIKELY (1 if respondent thought the management plan was somewhat or very likely to succeed, 0 otherwise)	1.060	5.245
ITEM (1 if respondent owns at least one item used for outdoor water-based recreation, 0 otherwise)	0.256	1.278
ENVORG (1 if respondent belonged to an environmental or conservation organization, 0 otherwise)	0.979	3.033
QUALWORS (1 if respondent thought water quality in their area has gotten worse over the last 5 years, 0 otherwise)	0.242	1.349
TAPGOOD (1 if respondent thought their tap water was above average or excellent quality, 0 otherwise)	−0.369	−2.075
NEWAREA (1 if respondent had lived in the basin 5 years or less, 0 otherwise)	0.566	1.922
UNIV (1 if respondent somewhat or completely trusted universities, 0 otherwise)	0.685	3.661
EDU (1 if respondent had completed some college or higher, 0 otherwise)	0.468	2.493
SEX (1 if respondent was male, 0 otherwise)	0.198	1.046
STATE (1 if North Carolina, 0 if South Carolina)	−0.679	−2.914

[a] Income responses were converted from a categorical to a continuous variable for use in the Logit model; 170 of the 1085 observations have been dropped from this model because of missing responses (n = 915). Chi-square is 314.7803.

trusted universities (UNIV) were more likely to vote for the plan. Additionally, having at least some college education (EDU) had a positive effect on respondents' support of the management plan.

[30] Respondents who had lived in the area 5 years or less (NEWAREA) were more likely to support the plan. One possible explanation is that the most rapidly growing areas of the basin are the ones that are experiencing the most degradation in water quality. Respondents in these areas may have more to gain from the management plan than respondents living in areas not experiencing as much of a decline in water quality. Another explanation is that newer respondents may hold different attitudes toward water quality protection.

[31] A number of variables had a negative effect on respondents' support of the management plan. It is reasonable to expect that people who currently rated their tap water as high quality (TAPGOOD) would be less likely to support the plan, since they did not perceive that there was currently a problem. Since North Carolina is upstream from South Carolina and experiences less of the water quality problems in the basin, it is understandable that residents in North Carolina (STATE) would be less willing to pay for the management plan than residents in South Carolina.

[32] The Logit model also showed that a number of variables were not significant in their effect on respondents' support of the management plan. Although the survey format (FORMAT) did not have a statistically significant influence, the relatively high t statistic on this variable indicates that the survey format might be marginally influential in respondents' votes for or against the CV scenario. Demographic variables such as respondents' age (AGE) or gender (SEX) did not have a significant effect on their votes. Finally, the number of days between receiving the information booklet and being interviewed (DATELAG) did not have a significant effect on respondents' votes for the plan.

Table 3. Estimate of the Turnbull Lower-Bound Mean WTP[a]

Lower Bound of Interval, $	Upper Bound of Interval, $	Probability of Voting for the Management Plan at the Upper Bound	Change in Density	Lower Bound of Interval × Change in Density, $
0	5	0.875	0.125	0
5	10	0.865	0.01	0.05
10	25	0.832	0.033	0.33
25	50	0.672	0.16	4.00
50	100	0.577	0.095	4.75
100	150	0.581	−0.004	−0.40
150	200	0.444	0.137	20.55
200	250	0.414	0.03	6.00
250	∞	0	0.414	103.50

[a] Estimate of lower-bound mean WTP is $138.78, log likelihood is −620.14, and standard error is $1.55.

3.5. Estimating the Economic Value of Water Quality in the Catawba River Basin

[33] Mean WTP values were estimated from the survey data using two different techniques. First, using the approach originally developed by *Hanemann* [1984], a mean WTP value was calculated from a Logit model using

$$\text{mean WTP} = \frac{\beta_0 + \sum_{i=2}^{m} \beta_i \bar{x}_i}{|\beta_1|},$$

where β_0 is the Logit model constant, β_1 is the coefficient on the bid term (the price of the management plan), and β_i and x_i are the coefficients and means of the independent variables. From the Logit model the mean WTP for the management plan was estimated to be $194.

[34] The second method for calculating the mean WTP involved the use of the maximum likelihood, nonparametric approach originally developed by *Turnbull* [1976] and expanded by *Carson et al.* [1994]. This approach involves using the percentage of respondents that voted for the management plan at each price level to estimate a lower-bound or upper-bound mean value. Some CV researchers have begun to favor the use of nonparametric estimation procedures over the more traditional parametric approach of logistic regression since nonparametric estimators are less prone to bias arising from misspecification errors [*Haab and McConnell*, 1997; *Garrod and Willis*, 1999; *Lichtenberg and Zimmerman*, 1999].

[35] For the nonparametric WTP estimation, different "steps" were constructed as defined by the various price levels for the management plan. In Table 3 the lower and upper values of each interval are presented along with the percentage of the sample that were willing to pay for the referendum at the upper value in the interval. For instance, of the respondents who were offered the management plan at $5, 88% of them voted for the plan. This is represented by the 0.875 value in the "Probability of voting for the management plan at the upper bound" column. The first entry in the "Change in density" column is the percentage of the sample voting against the referendum in the first interval. Subsequent entries in the "Change in density" column are the difference between the values in the "Probability of voting for the management plan at the upper bound" column for the current interval and the previous one.

[36] The lower-bound mean WTP is then estimated from the change in density obtained for each of the price intervals. A WTP value is assigned to each price interval by making the conservative assumption that respondents in each interval have a WTP equal to the lower value of that interval. For instance, respondents in the 0–$5 interval are assumed to have a WTP of 0, and respondents in the $5–$10 interval are assumed to have a WTP of $5. The lower-bound mean estimate is then obtained by summing the product of the change in density and lower value of each interval. An application of this approach yielded a lower-bound mean WTP for the management plan of $139 per year for Catawba basin taxpayers [*Carson et al.*, 1994].

[37] Comparison of the mean WTP values obtained from the parametric and nonparametric approaches led us to favor the nonparametric mean WTP of $139. Besides the advantages of the nonparametric approach mentioned above, the mean WTP calculated from the nonparametric model was the more conservative measure, resulting in a mean WTP that was over $50 lower than that obtained from the Logit model. In accordance with the NOAA panel recommendation of using the most conservative estimation techniques and procedures available in CV studies [*Arrow et al.*, 1993], the Turnbull mean is used as the final estimate.

3.6. Weighting of the WTP Estimates

[38] To correct for differences that could arise from sample bias, the mean WTP estimates were weighted according to 1990 Census data. As shown in Table 1, the sample population and the general population of the Catawba basin differed in terms of educational level, income, and racial background. The statistical significance of these differences were examined by the following likelihood ratio (LLR) test using a chi-square test statistic

$$-2\left[\text{LLR}_p - (\text{LLR}_1 + \text{LLR}_2)\right],$$

where LLR_p is the log likelihood for the total sample and LLR_1 and LLR_2 correspond to the relevant subgroups of the sample [*Loomis*, 1996].

[39] Using the nonparametric approach, mean WTP values were estimated for subgroups of the sample according to racial background and educational level. Although the sample and the general population also differed in household income, following the approach of *Whittington et al.* [1994], educational level is used as a measure of overall

socioeconomic status owing to the correlation between education and income. While the likelihood ratio test results for different respondents with different racial backgrounds were not significant, statistically significant differences were found for the WTP of respondents with different levels of education. Respondents with a college education or higher had a lower-bound mean WTP of $154, while respondents with less than a college education had a mean WTP of $129.

[40] Because of the differences found in valuation behavior, the WTP estimates were weighted based on the educational level of the respondents. Weights were calculated as the ratio of the percentage of members in each subgroup of the general population (as determined by Census data) over the percentage of members in each subgroup of the sample population. These weights were multiplied by the estimated mean WTP values for each subgroup to obtain weighted mean values. Multiplying these weighted means by the proportion of the total sample population that each subgroup comprised and adding them together resulted in an overall weighted mean WTP value of $133.

3.7. Aggregation of WTP Responses

[41] In CVM studies the estimated mean WTP value is typically aggregated over the relevant population to obtain a measure of the total economic benefits arising from the proposed change. For the purpose of this study the relevant population was the 16 counties in the Catawba basin from which the sample was drawn. A large number of the votes against the management plan could be considered protest responses based on stated reasons for voting against the plan [*Carson et al.*, 1994]. In this study, the most conservative approach was followed of retaining all these responses in the data set. Since only 47% of the sample answered the survey, assuming that the other 53% of the sample would have the same WTP value may not be correct. In response to this concern, survey nonrespondents were estimated to have a mean value for the management plan that was 50% of the value given to it by survey respondents, or $67 [*Whittington et al.*, 1994]. While the most conservative approach would have been to assume that survey nonrespondents placed zero value on this good, the assumption that they valued the good at 50% seemed reasonable for several reasons. First, nonrespondents may have declined to participate for many reasons besides not caring about this resource. Second, results of several other survey efforts in the area indicate that water quality is an important issue to residents in the area [*University of North Carolina at Charlotte Urban Institute*, 1998; *Newman*, 1999].

[42] With WTP values determined for both respondents and nonrespondents, data on federal tax returns were then used to determine the appropriate population in Catawba basin counties for use in the aggregation of benefit measures. The use of tax return information coincided with the payment vehicle of the CV scenario, which was an increase in state income taxes. Federal tax return information was used owing to the fact that the researchers were unable to obtain this information for state tax returns. Numbers of tax returns filed in the relevant counties were obtained from the Internal Revenue Service for 1997, the most recent year available (S. Byberg, Internal Revenue Service, personal communication, 1999). Using population growth estimates from state agencies, a projection on the number of tax returns for 1999 was made for the relevant counties. Using this projected number of tax returns (768,875) for 1999 resulted in an annual economic benefit of $75.4 million arising from the protection of water quality in the basin at its current level over time.

4. Comparison of the Different Survey Formats

[43] A secondary objective of this study was to examine the relative strengths and weaknesses of two different approaches to combining mail and phone surveys. The phone-mail-phone (PMP) approach has the advantage of allowing the researcher to collect information on the survey nonrespondents and can reduce self-selection by soliciting participation in the second telephone interview before the respondents receive the mailed information and are thus made aware of the survey topic. This practice, however, has a substantially higher cost than a mail-phone (MP) approach. Although costs vary with the size of the sample owing to economies of scale, the cost of obtaining a completed survey with a PMP format is roughly 1.5 times the cost of obtaining a completed survey with a MP format. To examine the differences in results obtained by each survey format, means and proportions of several variables were compared between the PMP and MP samples.

4.1. Evidence of Self-Selection

[44] Several results from the comparisons of survey variables indicated that the MP sample had a higher degree of self-selection than the PMP sample. This is most likely due to the fact that the MP respondents were aware of the survey subject matter before they made the decision to participate in the survey. For instance, more of the MP sample engaged in outdoor recreation than the PMP sample, as shown by comparisons of the recreational behavior of each sample. The MP sample had a higher score on an index variable for recreation within the Catawba basin (respondents received a score of 1 for each recreational activity they engaged in during the last 12 months). The difference was significant at the 95% level ($t = 3.284$, $p = 0.001$). A similar result was observed for an index variable of the ownership of items used in outdoor water-based recreation, with the difference again being significant ($t = 2.116$, $p = 0.035$).

[45] Other evidence toward greater self-selection in the MP sample was observed in questions asking about area water quality. The percentage of respondents who had previously heard of water quality concerns in the basin was significantly higher for the MP sample (77%) than the PMP sample (65%, $z = 7.623$). Also, a significantly higher percentage of the MP respondents said that protecting water quality in the Catawba River basin was more important to them than other environmental issues in their state (43% for MP and 35% for PMP, $z = 2.777$).

4.2. Comprehension of Survey Materials

[46] To test whether comprehension of the information booklet was different among respondents in each survey format, respondents were asked if they remembered reading about the management plan, which was prominently featured in the information booklet. A higher percentage of the PMP respondents (88%) remembered reading about the management plan (68% for MP respondents). This differ-

ence was significant at the 95% level ($z = 7.946$), indicating that the PMP respondents paid closer attention to the information mailed to them than the MP respondents did.

4.3. Comparison of Socioeconomic Characteristics

[47] To examine how the socioeconomic characteristics differed between the two groups of respondents, several comparisons were made. The two samples differed in the length of time respondents had lived in the basin. The PMP sample had a significantly higher percentage of respondents that had lived in the basin <5 years (15% for PMP and 8% for MP, $z = 3.898$) and a significantly lower percentage of respondents that had lived in the basin longer than 20 years (57% for PMP and 63% for MP, $z = 2.281$). This difference is most likely related to the different sampling frames used in each survey format. The PMP sample, using RDD telephone numbers, may be better at reaching respondents who had recently moved, whereas the MP sample, relying on listed addresses, may be better at reaching respondents who had been at the same address for several years.

[48] In comparing the ages of the samples, the mean age of the PMP sample (47) was significantly lower ($t = 6.610$, $p = 0.000$) than that of the MP sample (53). Other significant differences arose in the comparison of education level of the samples. The MP sample generally had a higher level of education than the PMP sample, as indicated by the fact that a significantly higher percentage of the MP respondents (43%) reported graduating from college (35% for PMP, $z = 2.530$). These results also indicated that the PMP sample more closely matched the educational level of the general population than the MP sample (17% college graduates according to the 1990 Census). In comparing household income, the difference between the samples was not significant. A comparison of the racial or ethnic background of the samples also yielded no significant differences.

[49] A comparison of the gender of respondents revealed that the MP sample (68%) had a much higher percentage of males than the PMP sample (41%). This difference was significant ($z = 9.107$) and points to a possible strength of the split-sample design. Each survey format was heavily skewed toward one gender. With the split-sample approach, the gender composition of the sample (54% male) fairly closely matched the gender composition of the general population according to 1990 Census data (48% male).

[50] Other differences between the samples arose in comparisons of household size and composition. The MP households were significantly smaller than PMP households ($t = 2.237$, $p = 0.025$) and had a significantly smaller number of children under 18 than the PMP households ($t = 2.679$, $p = 0.008$). The difference in the percentage of respondents who reported owning their homes was not significant.

4.4. Comparison of WTP

[51] To determine how the survey format affected the economic valuation of the management plan, the Turnbull lower-bound mean WTP estimates derived from each sample were compared. The MP sample had a lower-bound mean WTP of $134 (standard error, $2.24), and the PMP sample had a lower-bound mean WTP of $143 (standard error, $2.15). Despite the greater evidence of self-selection in the MP sample and the fact that these respondents had a higher educational level than the PMP sample, there was no significant difference in WTP between the two survey formats.

5. Discussion and Conclusion

[52] Results of the survey of Catawba basin residents provided information about the social, environmental, and economic importance of this resource to area residents. First, results clearly indicated that protecting the health of the Catawba River basin is important to respondents. Second, results indicated that respondents took the survey effort seriously and gave thoughtful, consistent answers to the survey questions. Third, results of the contingent valuation question indicated that respondents place a considerable monetary value on the protection of water quality in the basin over time. This monetary value, which is equivalent to the economic benefit provided by this resource, was estimated at a value of over $75 million for taxpayers in the 16 Catawba basin counties included in the sample.

[53] Through the secondary objective of this paper some conclusions could be drawn on the effectiveness of different methods of combining mail and telephone survey formats. The phone-mail-phone approach offered advantages over the mail-phone approach through reducing the amount of self-selection and encouraging respondents to pay closer attention to the materials mailed to them.

[54] Despite these advantages of the PMP approach, some results of this comparison suggested that a combination of PMP and MP formats offers advantages over a strictly PMP format. Each survey format was better at reaching certain types of respondents, and using a split-sample tended to even out these effects. For instance, in terms of gender, using only the PMP format would have resulted in a sample that was biased toward female respondents. Since, on the other hand, the MP sample was biased toward males, the split-sample format resulted in a sample that was fairly evenly distributed across genders.

[55] Another advantage of the split-sample design was related to the costs associated with each survey format. Since the PMP format involves two separate interviews with the same respondent, this format has a much higher per unit cost than the MP format, which only involves one telephone interview. Besides the possibility of reaching different sets of respondents, a split-sample approach may represent a more cost-effective method of surveying than a strictly PMP format. Since the economic valuation results were not significantly different between the two samples, the additional costs associated with using only a PMP approach may not be justified.

[56] **Acknowledgments.** This research was supported in part by a grant from Duke Power Company. The authors thank Gene Vaughan and Larry Olmsted at Duke Power Company for their assistance and comments. Thanks are also due to colleagues at the Nicholas School and other organizations for their suggestions regarding the study. The authors would like to thank the staff of Hagler Bailly Consulting for administering the survey and Systech Engineering for their assistance in the use and application of the Watershed Analysis Risk Management Framework (WARMF) model. The authors would also like to thank John Whitehead, Carol Mansfield, and anonymous reviewers for comments on earlier drafts of this paper.

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