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A COST-BENEFIT ANALYSIS OF WATER QUALITY PROTECTION IN THE CATAWBA BASIN[1]

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ABSTRACT: The primary objective of this study was to perform a cost-benefit analysis of maintaining the current level of water quality in the Catawba River basin. Economic benefits were estimated using a stated preference survey method designed to value respondents' willingness to pay for a management plan to protect water quality in the Catawba basin over time. From the surveys conducted with 1,085 area residents, we calculated an annual mean willingness to pay of $139 for the management plan, or more than $75.4 million for all taxpayers in the area. Over the five-year time horizon in which respondents were asked to pay for the management plan, this resulted in a total economic benefit of $340.1 million. The Watershed Analysis Risk Management Framework model was used to estimate the amount of management activities needed to protect the current level of water quality in the basin over time. Based on the model results, the total cost of the management plan was calculated to be $244.8 million over a ten-year period. The resulting cost-benefit analysis indicated that the potential benefits of this management plan would outweigh the costs by more than $95 million.

(KEY TERMS: contingent valuation method; cost-benefit analysis; economics; net present value; water policy/regulation/decision making; water quality.)

INTRODUCTION

The Catawba River of North and South Carolina is a system of 11 reservoirs originally created by Duke Power Company for the purpose of hydroelectric power generation. The river flows for 224 miles from the mountains of western North Carolina to central South Carolina. Below Lake Wateree in central South Carolina, it becomes the Wateree River and eventually flows into the Atlantic Ocean near Charleston. The Catawba River supports various kinds of power generation as well as a variety of other commercial and industrial uses. Many of the surrounding municipalities, including Charlotte, Morganton, and Hickory, North Carolina, receive their drinking water from the river and return their wastewater to it. The reservoirs along the river are heavily used for recreation and are enjoyed for their aesthetic qualities.

Population growth and other factors are increasing the pressure on the Catawba River and the diversity of services it provides to local communities. Charlotte is the second fastest growing metropolitan region in the nation, and other parts of the Catawba River basin are growing quickly as well (Dodd and Mellnik, 2001). This growth may contribute to water quality problems. Monitoring studies show a steady decline in water quality in the lower reaches of the river (Duke Power Company, 1996).

The primary objective of this study was to perform a cost-benefit analysis to determine the economic efficiency of water quality management in the Catawba River basin. This information was intended to inform policy makers and stakeholders on the value of this resource and to help them weigh the costs and benefits associated with actions that could affect area water quality in the future.

METHODS

The contingent valuation method (CVM), a stated preference survey method, was used to estimate the economic value of protecting the current level of water quality in the Catawba River basin over time. Many researchers use stated preference methods since they

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can measure the use values of a good as well as its nonuse values, such as the value derived from the mere existence of the good. Despite an ongoing debate on the use of the CVM, the Federal government approved its use in the estimation of the damages caused by oil spills and other releases of hazardous substances (Carson *et al.,* 1994). In 1993, the National Oceanographic and Atmospheric Administration (NOAA) commissioned a panel of social scientists, chaired by two Nobel Laureates, to evaluate the validity of the CVM for measuring nonuse values. The NOAA Panel released a set of suggested guidelines for what it considered to be acceptable CVM studies (Arrow *et al.*, 1993).

Use of the CVM involves asking individuals, in a survey setting, to state their willingness to pay (WTP) for a specified level of change in an environmental resource. The monetary value of the good can then be estimated from these survey responses. In order to assess this monetary value as accurately as possible, CVM surveys typically include detailed information about the good (Mitchell and Carson, 1995).

Questionnaire Design

Half of this two-year study was devoted to survey design. The first major task involved collection of background information, including an extensive literature review and meetings with stakeholder groups. Next, we conducted four focus groups with residents in various geographic locations in the basin. These focus groups were used to gain information on the public's knowledge of water quality issues and to test specific survey materials as we developed them.

Upon completion of the focus groups, we drafted the survey materials and submitted them to peers and selected stakeholders for review. As recommended by the NOAA Panel (Arrow *et al.,* 1993), the materials included extensive information about the Catawba River basin and its water quality. This information was presented to respondents in a short color booklet. Besides general information on water pollution and management strategies, the booklet included photos and color maps.

The survey materials were then extensively pretested through a series of cognitive interviews conducted in person and more than 50 interviews conducted by combined phone/mail methods. As recommended by Presser and Blair (1994), we used a scoring method to uncover potentially problematic questions during the pretest.

The Watershed Analysis Risk Management Framework Model

Water quality modeling provided critical information for our survey design. We used output from the Watershed Analysis Risk Management Framework (WARMF) model to create color maps included in the survey information booklet. The WARMF model, developed by Systech Engineering, is an integrated watershed model that has been applied to the Catawba River basin (Chen *et al.,* 1998). This model was developed as a decision support system to estimate the Total Maximum Daily Loads (TMDLs) for various pollutants in a river system. It was designed for a diverse user group and integrates all models and databases in a Windows-based graphical user interface. The model can be used to specify certain management goals and objectives within a river basin and to run simulations that enable the user to see the outcomes of alternative management plans. Output from the model is shown in GIS-based maps, graphs, and tables.

The WARMF model operates by separating a watershed into various components, including land catchments, stream segments, and lake layers. In order to run water quality simulations, these components are connected into an integrated network allowing for the flow of pollutants between them. A hydrologic model within WARMF simulates canopy interception, snow pack accumulation and melt, soil infiltration, and other processes that track the flow paths of precipitation from land into various water bodies. A chemistry module performs various mass balance and chemical equilibrium calculations to account for changes in the composition of precipitation along its flow path. The data module of WARMF stores data on meteorology, air quality, point source pollution, reservoir release, and flow diversion. These data are used as input for the various water quality simulations run by the model (Weintraub *et al.,* 2000).

In this study, we used the WARMF model to prepare visual depictions of water quality in the Catawba basin and how it could change over time in the absence of active management. The two maps included in the survey information booklet showed the status quo of water quality in the Catawba basin and a future scenario of Catawba basin water quality in 10 years, given the projected levels of population growth and changes in land use. We obtained information for the status quo map through reviews of reports and consultations with staff at state regulatory agencies in North and South Carolina (South Carolina Bureau of Water Pollution Control, 1997; North Carolina Division of Water Quality, 1999). For the future scenario, the WARMF model was used to alter both point and nonpoint source pollution loadings in the Catawba basin based on projected changes in population and land use within the basin. The population projections, which we obtained from state agencies, were used to alter point source loadings in the basin. We used National Resources Inventory (NRI) data to project land use changes within the Catawba basin. Alterations in land use were entered into the WARMF model to predict changes in nonpoint source pollution. A water quality scenario was then run in WARMF to show water quality in the basin resulting from these changes over time. In the maps, water quality was rated on a scale of "good, fair, and poor," which was a simplified version of North Carolina's system of rating water bodies as fully, partially, or not supporting their designated uses (North Carolina Division of Water Quality, 1999).

The Contingent Valuation Scenario

The contingent valuation (CV) scenario was developed through reviews of other studies and refined during the focus groups and pretest. First, the survey information booklet described a management plan to respondents that was designed to maintain the current level of water quality in the basin over time (Box 1). Respondents were then asked if they would support this management plan. In accordance with the recommendations of the NOAA Panel (Arrow *et al.*, 1993), we framed the CV question as a referendum (Box 2). The management plan was offered to respondents at one of eight different price levels ranging from $5 to $250 per year for five years. Each respondent was randomly assigned one of these amounts. These assignments were done before we collected any information from respondents, and thus they were not correlated with any characteristics of the respondents such as household income.

Box 1. Summary of the Management Plan for Protecting Catawba River Basin Water Quality.

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.

Box 2. The Contingent Valuation Question Assessing Support for the Management Plan.

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?

Survey Implementation

The NOAA Panel recommends the use of in-person survey formats for the CVM, as opposed to self-administered formats such as mail surveys (Arrow *et al.,* 1993). Based on this recommendation, this survey employed a combined phone/mail format where respondents were mailed the information booklet and then interviewed by telephone. Survey implementation was contracted to Hagler Bailly Consulting, a leading survey research firm. With a team of roughly 20 professionally trained interviewers, Hagler Bailly conducted the telephone interviews and recorded the data using a CATI (Computer Assisted Telephone Interviewing) system.

Survey implementation began on September 9, 1998, and continued through December 31, 1998. Hagler Bailly completed surveys with 1,085 households in North and South Carolina in total. Survey respondents were randomly selected by random-digit-dialing and from address lists in the 16 counties having more than 10 square miles of land within the Catawba basin. We weighted the survey sampling by the population in each county. Accordingly, 80 percent of the sample was from North Carolina, and 20 percent was from South Carolina. The survey had a response rate of 47 percent.

RESULTS

The cost-benefit analysis involved estimation of the benefits and costs of the management plan for water quality protection. In this section, the benefit estimate as derived from the survey is discussed, followed by a review of the procedures for estimating the costs of the plan. This section concludes with a presentation of the cost-benefit analysis results. Additional information on the survey and the procedures used for the benefit estimation can be found in Kramer and Eisen-Hecht (forthcoming).

Survey Respondent Demographics

Survey respondents answered various questions about their socioeconomic profile. The sample was fairly evenly split in terms of gender and had an average age of 50. The average household size was three people, and 35 percent of the respondents reported that there was at least one person in their household less than 18 years of age. The median educational level of the sample was some college. The respondents had an average household income, before taxes, of $55,481. Other selected survey results are shown in Table 1.

Survey Respondents' Perceptions, Attitudes, Opinions, and Beliefs Regarding Water Quality

Respondents were asked questions relating to water quality in their area. Fifty-seven percent of the respondents said that they had previously heard of water quality concerns in the Catawba River basin, indicating that this issue has been getting attention in the media and among local residents. Thirty-nine percent of the sample stated that this issue was more important than other environmental issues in their state, and 59 percent said it was at least as important.

In order to assess respondents' perceptions about how water quality in their area was changing, we asked them if they thought area water quality had gotten worse, stayed the same, or gotten better over the previous five years. Roughly half (49 percent) of the respondents thought water quality had declined in their area over that time period, 27 percent thought water quality had stayed the same, and 8 percent thought it had gotten better.

Responses to the CV question indicated that, at the various price levels at which it was offered to them, 66 percent of the respondents said that they would vote for the management plan. Thirty-one percent of the respondents said they would not vote for the management plan, and the remaining 3 percent of the respondents said they did not know how they would vote.

The NOAA panel stressed the importance of respondents finding the proposed CV scenario plausible and argued that an implausible scenario could weaken the validity of the CV results (Arrow *et al.,* 1993). To measure the plausibility of the CV scenario, we asked respondents about their belief that the management plan would actually accomplish its goal of protecting water quality in the basin over time. Seventy-six percent of the respondents thought the management plan was somewhat likely or very likely to succeed, 9 percent thought its success was somewhat or very unlikely, and 12 percent had no opinion.

From the CV question results, we examined the proportion of respondents voting for the management plan at each of the different price levels. As indicated in Figure 1, the number of respondents voting for the plan declined steadily as the price of the plan increased from $5 to $250 per year.

TABLE 1. Results for Selected Survey Variables.

Variable	Result
Percent of respondents who thought reducing taxes was important to them	72% (n=1081)
Percent of respondents who had previously heard of efforts to control water pollution in the Catawba basin	71% (n=1082)
Percent of respondents voting for the management plan	66% (n=1079)
Percent of respondents who rated their own use of the Catawba River as an important reason the management plan would be of value to them	40% (n=1085)
Percent of respondents who rated the quality of their drinking water as an important reason the management plan would be of value to them	91% (n=1085)
Percent of respondents who rated the use of the Catawba River by their friends or family as an important reason the management plan would be of value to them	58% (n=1085)
Percent of respondents who thought the knowledge that basin water quality was being protected, regardless of their use of it, was an important reason the management plan would be of value to them	75% (n=1085)
Percent of respondents who thought the management plan was somewhat or very likely to succeed	76% (n=1085)
Percent of respondents who owned at least one item used for outdoor recreation	70% (n=1085
Percent of respondents who belonged to an environmental or conservation organization	12% (n=1081)
Percent of respondents who thought water quality in their area has gotten worse over time	49% (n=1085
Percent of respondents who thought their tap water was above average or excellent quality	45% (n=1085)
Average age of respondents	50 (n=1070)
Percent of respondents who had lived in the basin five years or less	12% (n=1085)
Percent of respondents who somewhat or completely trusted universities	69% (n=1085)
Percent of respondents who had completed some college	40% (n=1082)
Percent male	54% (n=1085)
Average household income of respondents	$55,481 (n=989)
Percent from North Carolina	80% (n=1085)
Average number of days between when the respondent was mailed the information booklet and when s/he were interviewed	25 (n=1085)

Probit Analysis of Support for the Management Plan

Using a Probit model, we regressed respondents' votes on the management plan against the series of explanatory variables shown in Table 1 to uncover factors having a significant influence on these votes. Table 2 presents the results of the Probit model. We assessed the model's "goodness of fit" through calculation of the pseudo R^2 of 0.573 (Zavonia and McElvey, 1975). Additionally, the model predicted 714, or 78 percent, of the 915 observations correctly (Greene, 1993).

The Probit model suggested that the respondents' answers conformed to the expectations of economic theory. For instance, respondents' votes on the CV question were negatively influenced by the price of the management plan and positively influenced by the income of the respondent. Economic theory also suggests that WTP should increase with increasing use of the good (Whittington *et al.*, 1994). This trend was seen in the results for the USE and OTHERUSE variables, which measured the importance respondents placed on the recreational use of the basin by themselves and their friends and families. It is interesting to note that the importance of the respondents' own use of the Catawba River (measured by the USE variable) was not statistically significant, but the importance of the use of the Catawba River by friends and family had a significant positive effect on respondents' votes for the management plan.

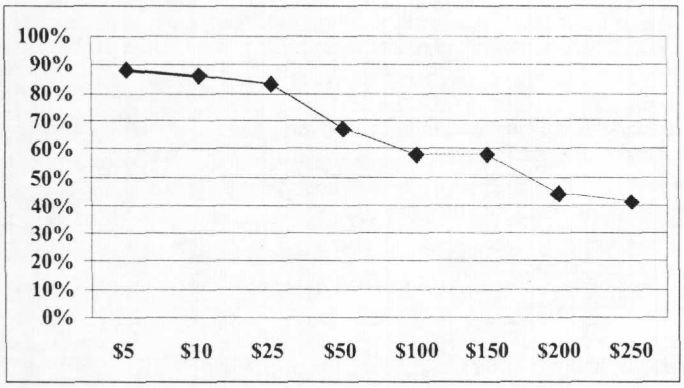

Figure 1. Percent of Respondents Voting for the Management Plan at Offered Price (n=1079).

Estimation of the Aggregate Economic Benefits of Water Quality Protection

Two approaches were used to estimate a mean WTP value for survey respondents. First, using the approach originally suggested by Hanemann (1984), we calculated a mean WTP value directly from the Probit model. This resulted in a mean WTP of $194 for the management plan. A second, nonparametric approach originally developed by Turnbull (1976) was used to calculate the mean WTP from the change in the percentage of votes for the management plan at each price level. This approach, which estimates a lower-bound value for WTP, is becoming more common in CVM research (Garrod and Willis, 1999; Lichtenberg and Zimmerman, 1999). An application of this approach resulted in a lower-bound mean WTP of $139. As suggested by the NOAA panel (Arrow *et al.*, 1993), we elected to use the most conservative measure of WTP, or the value of $139 per year for Catawba basin taxpayers that we estimated from the nonparametric Turnbull procedure.

Next, the mean WTP result was weighted to account for differences between the survey sample and the general population, as reported in 1990 Census data. Statistically significant differences were found between the sample and the general population in terms of their household incomes and educational levels. Correcting for these differences resulted in a weighted WTP value of $133, a $6 decrease from the unweighted value.

We next aggregated the mean WTP value across the relevant population to obtain a measure of the total economic benefits arising from water quality protection. Since the survey response rate was 47 percent, an important issue in the aggregation procedure was how to account for the remaining 53 percent of the sample population that did not answer the survey. Following the approach of Whittington *et al.* (1994), this percentage of the population was assumed to value the management plan at 50 percent of the amount estimated for survey respondents, or $67. Projections of the number of taxpayers in the 16 Catawba basin counties were then used to obtain the annual aggregate benefits of the management plan. This estimate of $75.4 million represents the benefits accruing to taxpayers in the Catawba basin from the protection of water quality over time.

This aggregate benefit estimate could be considered a conservative measure for a number of reasons. First, conservative methods were used in the benefits estimation, such as using the assumption that survey nonrespondents would value the management plan less than respondents would, and the use of the more conservative Turnbull estimate of mean WTP. Second, this estimate only measures the economic benefits accruing to individuals from the protection of water quality and did not attempt to estimate the value of water quality protection for commercial and industrial uses. Third, we made the conservative assumption that only residents of counties within the Catawba basin placed a value on water quality in the basin. It is likely that residents in other counties use the Catawba River for recreation and thus would probably value the protection of this resource. It is also likely that downstream residents would value the protection of Catawba basin water quality, since they are directly affected by the quality of the water that flows into their region.

Estimating the Costs of the Management Plan to Protect Water Quality

After estimating the economic benefits of the management plan over time, we estimated the costs of this plan. The management plan consisted of four distinct activities (Box 1). To derive a potential cost for the management plan, costs were estimated for each of these activities. Unlike the benefits, which we projected to accrue for five years, these costs were projected to accrue for ten years, corresponding with the time horizon of the water quality maps that respondents saw in the survey information booklet.

The first step in obtaining the cost of the management plan was to estimate the amount of management activities needed to maintain the current level

TABLE 2. Probit Model of Respondents' Votes on the Proposed Management Plan (n=915).*

Variable	Coefficient	t Ratio
TAX (1 if respondent rated reducing state and federal taxes as important to them, 0 otherwise)	-0.374	-3.216**
WPCONTROL (1 if respondent had previously heard of efforts to control water pollution in the Catawba basin, 0 otherwise)	-0.087	-0.775
WTPAMT (dollar amount of management plan, from $5 to $250)	-0.007	-10.966**
USE (1 if respondent rated their own use of the Catawba River as an important reason the management plan would be of value to them, 0 otherwise)	-0.098	-0.802
DRQUAL (1 if respondent rated the quality of the drinking water in their area as an important reason the management plan would be of value to them, 0 otherwise)	0.361	1.854
OTHERUSE (1 if respondent rated use of the Catawba River by their friends and family as an important reason the management plan would be of value to them, 0 otherwise)	0.374	3.017**
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 the management plan would be of value to them, 0 otherwise)	0.463	3.736**
LIKELY (1 if respondent thought the management plan was somewhat or very likely to succeed, 0 otherwise)	0.642	5.499**
ITEM (1 if respondent owned at least one item used for outdoor water-based recreation, 0 otherwise)	0.138	1.185
ENVORG (1 if respondent belonged to an environmental or conservation organization, 0 otherwise)	0.556	3.067**
QUALWORS (1 if respondent thought water quality in their area has gotten worse over the last five years, 0 otherwise)	0.165	1.600
TAPGOOD (1 if respondent thought their tap water was above average or excellent quality, 0 otherwise)	-0.213	-2.069***
AGE (age of respondent)	-0.001	-0.392
NEWAREA (1 if respondent had lived in the basin five years or less, 0 otherwise)	0.324	1.934
UNIV (1 if respondent somewhat or completely trusted universities, 0 otherwise)	0.418	3.826**
EDU (1 if respondent had completed some college or higher, 0 otherwise)	0.272	2.498**
SEX (1 if respondent was male, 0 if female)	0.101	0.955
INCOME (household income of respondent)	0.000	3.125**
STATE (1 if North Carolina, 0 if South Carolina)	-0.411	-3.057**
DATELAG (Number of days between when the information booklet was mailed to respondent and when the interview was conducted)	0.001	0.577

*Observations with missing data were dropped from the Probit model.
**Statistically significant at the 1 percent level.
***Statistically significant at the 5 percent level.

of water quality in the basin over time. The WARMF model enabled us to make these predictions through applying water quality management activities within the model. These activities were applied to the future water quality scenario in order to maintain the water quality in this scenario at a level that approximated the status quo, as opposed to the degraded condition that was shown by the model before the application of the management activities.

The management plan included a component to address point sources by upgrading and improving wastewater treatment plants in the basin. The effects of this activity were measured in the WARMF model with the assumption that this management activity would maintain point sources at their current level over time. To account for this assumption within WARMF, point sources were set back to their status quo level.

The primary management activity aimed at nonpoint sources was the use of Best Management Practices (BMPs) in farms, construction sites, and residential areas in the Catawba basin. We measured the effect of this management activity within WARMF by using the model's buffer zone component, which enables the user to establish buffers of variable width along water bodies. We applied 100-foot-wide buffers within WARMF to the areas where water quality had declined between the status quo and the future scenario. We then analyzed the results to determine the amount of buffer needed to maintain water at its current level, given the projected land use changes in the future scenario. Since at the time of the study the WARMF model did not contain any method for modeling the effect of stormwater management or other BMPs for use on impervious land, buffers were only applied to pervious surfaces, such as agricultural land and low-density urban areas.

For the remaining management activities – developing a basinwide land use plan and the purchasing and setting aside of critical tracts of land – no assumptions were made about how these activities would affect water quality. The water quality effects of the basinwide land use plan could not be easily modeled in WARMF, since this activity would only affect planning decisions. For the purchasing and setting aside of critical tracts of land, the precise effects of this activity would have been difficult to model due to uncertainty about which specific tracts of land would actually be purchased and protected.

Results of this analysis within WARMF indicated that these different management activities were sufficient to return water quality in the basin to a level roughly equivalent to its status quo level. The necessary management activities included applying 100-foot-wide buffers to 50 percent of the pervious land in areas where water quality had declined between the status quo and future model scenarios.

The next step was to determine the costs of these management activities. We consulted with staff members at local regulatory agencies to assess the costs of improving and upgrading wastewater treatment plants within the basin. Cost estimates were obtained for several plants in North Carolina that had upgrades planned or in progress (A. Wahab, personal communication, 1999, Division of Water Quality, North Carolina Department of Environment and Natural Resources, Raleigh, North Carolina). From this, we estimated a total cost of $160 million for improving and upgrading other plants in the basin ("WWTPs" in Table 3).

To obtain cost estimates for establishing and using BMPs on agricultural and urban land, we reviewed several reports and consulted with regulatory agencies. Separate costs figures were obtained for using riparian buffer strips on agricultural and on pervious low-density urban land. For agricultural land, the establishment of riparian buffer strips involves both installment costs, which would occur during the first year, and annual maintenance costs. Installment costs were estimated at $400 per acre with an annual maintenance cost of $20 per acre (5 percent of the installment cost). This installment cost represented an average of the costs associated with a number of different kinds of buffer strips (grass, shrubs, and trees) requiring different kinds of preparation (U.S. Department of Agriculture, Soil Conservation Service, 1991; T. Jones, personal communication, 1999, Farm Service Agency, Raleigh, North Carolina).

For the establishment of buffer strips on agricultural lands, we estimated an annual opportunity cost of $105 per acre for removing land from agriculture or other productive activities. This opportunity cost represented the payment that would be necessary for landowners to adopt the management activities, since they would not be willing to do so if it would represent a decrease in their income. This figure was derived from the current rental payment landowners receive for enrolling land in the recently established Conservation Reserve Enhancement Program and represented an average value for land of various types. This cost was projected to remain constant over the ten-year period, since fluctuations in this cost over time would likely be small (T. Jones, personal communication, 1999, Farm Service Agency, Raleigh, North Carolina).

Analysis performed in the WARMF model predicted the total number of acres of agricultural land to which buffer strips would be applied to maintain area water quality at the status quo level. The actual number of buffer strips applied to these acres of agricultural land would depend on the hydrology of the land and the number of streams and other water bodies on it. Since this actual number would vary greatly, the conservative assumption was made that 20 percent of the total amount of agricultural land in the affected areas would be put into riparian buffers. For the 42,900 acres of agricultural land in the affected areas, using 20 percent of this land for 100-foot buffer strips amounted to a total of 8,580 acres of land that would be removed from crop production. Based on the estimated establishment and maintenance costs, this amount of buffer strips would cost $3.4 million to establish in the first year, with an additional annual cost of $171,600 for annual maintenance ("Ag. BMPs" in Table 3). Additionally, there would be an annual opportunity cost of $900,900 for removing this land from productive activities ("Opp. Costs" in Table 3).

In addition to buffer strips on agricultural land, we also estimated the cost of using buffers on low-density developed land. After consulting with staff at regulatory agencies and reviewing several studies (Chazal *et al.*, 1993; Tippett and Dodd, 1995; A. Runge, personal communication, 1999, South Carolina Bureau of Water Pollution Control, Department of Health and Environmental Control, Columbia, South Carolina), we used $1,500 per acre as the establishment cost for BMPs in pervious low-density developed areas. This figure was based primarily on numbers derived for the use of BMPs on construction sites (Schueler, 1997). Additionally, an annual operation and maintenance cost of $75 per acre (5 percent of the establishment cost) was added to this estimate. In the WARMF model, low-density developed land is defined as 50 percent pervious. Accordingly, this $1,500 cost was applied to half of the 20,048 total acres of low-density developed land in the affected areas of the basin. The application of BMPs to half of this total acreage resulted in an establishment cost of $15 million during the first year and an annual maintenance cost of $751,800 ("Urban BMPs" in Table 3).

Cost estimates were then derived for the remaining management activities proposed in the management plan. The cost of developing a basinwide land use plan was estimated as the cost of adding one new staff member at regulatory agencies in each state in the basin, or two new staff members in total. Chazal *et al.* (1993) estimated this cost to be $50,000 per state or $100,000 in total. Using a 6 percent interest rate, we compounded this estimate from 1993 dollars to 1999 dollars for a total cost of $141,852, which was projected to accrue each year ("Land Use Plan" in Table 3).

To derive cost estimates for the purchasing of critical tracts of land, an estimate of the average cost per acre of land in the basin was derived from recent land acquisition efforts in Gaston, Lincoln, and Mecklenburg Counties (G. Smith, personal communication, 1999, The Trust for Public Lands, Charlotte, North Carolina). This average cost, calculated to be $5,243 per acre, was most likely an overestimate of land costs in the basin, since land in these highly urbanized areas may cost more than land in the more rural counties. For the purpose of allocating funds to this activity, we assumed that a total of 10,000 acres would be purchased and set aside throughout the basin. This resulted in a total cost of $52.4 million for this activity ("Purchase Land" in Table 3).

Comparing the Costs and Benefits of Protecting Water Quality

We then performed a cost-benefit analysis (Table 3) to compare the economic benefits of protecting water quality in the basin to the potential costs of achieving them. Cost-benefit analysis is a tool used by economists to examine the net economic benefits of a project or policy decision (Boardman *et al.*, 1996). It has been widely used to examine the economic feasibility of public investments in a variety of sectors including water resource, transportation, agricultural, and energy projects. Performed by comparing, in present dollar terms, the value of the total costs of a project or policy to the value of its total benefits, cost-benefit analysis indicates if a project or policy yields economic returns to the affected stakeholders over the costs they would incur.

For the purposes of the cost-benefit analysis, the economic benefits of the management plan were projected to accrue for five years, which was the length of time respondents were asked to pay for the management plan. Over this five-year time span, the benefits of the management plan were projected to grow with the population of the basin, since as more people move into the basin, more people will derive economic benefits from the waters in the Catawba basin. We applied a 7 percent discount rate to this stream of benefits to derive its Present Value (PV). The annual economic benefit of $75.4 million translated to a PV of $340.1 million for the five years over which respondents were asked to pay for the management plan. We assumed a zero rate of inflation for this calculation, since the survey respondents were not asked to consider inflation when making their decision to support the management plan.

The different categories of costs were then combined to derive a total cost for establishment of the management plan. Using a 7 percent discount rate resulted in a PV of $244.8 million for the implementation of the management plan over the ten-year period during which the costs were projected to accrue. An inflation rate of zero was assumed for the PV cost calculation to coincide with the assumptions of the PV benefit estimate.

We then compared the costs and benefits by subtracting the PV of the costs from the PV of the benefits. This resulted in a Net Present Value (NPV) of $95.4 million for the management plan, indicating that the benefits of the management plan outweighed its costs.

TABLE 3. Cost/Benefit Analysis of Management Plan to Protect Catawba River Basin Water Quality.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cash In										
Annual Benefits	75,365,152	76,561,920	77,687,707	78,812,992	79,957,479					
Total Cash In	**75,365,152**	**76,561,920**	**77,687,707**	**78,812,992**	**79,957,479**					
Discounted Cash In	**75,365,152**	**71,553,196**	**67,855,452**	**64,334,878**	**60,999,178**					
PV of Cash In	**340,107,856**									
Cash Out										
Ag. BMPs	3,432,000	171,600	171,600	171,600	171,600	171,600	171,600	171,600	171,600	171,600
Opp. Costs	900,900	900,000	900,900	900,900	900,900	900,900	900,900	900,900	900,900	900,900
Urban BMPs	15,036,000	751,800	751,800	751,800	751,800	751,800	751,800	751,800	751,800	751,800
Land Use Plan	141,852	141,852	141,852	141,852	141,852	141,852	141,852	141,852	141,852	141,852
Purchase Land*	52,430,000									
WWTPs*	160,000,000									
Total Cash Out	**231,940,752**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**	**1,966,152**
Discounted Cash Out	**231,940,752**	**1,837,525**	**1,717,313**	**1,604,966**	**1,499,968**	**1,401,839**	**1,310,130**	**1,224,421**	**1,144,318**	**1,069,456**
PV of Cash Out	**244,750,689**									
NPV (PV cash in minus PV cash out)	**95,357,167**									

*All capital costs are assumed to accrue in the first year.

Sensitivity Analysis

We performed various kinds of sensitivity analysis to examine robustness of the cost-benefit analysis results. First, we conducted a partial sensitivity analysis by varying each category within the cost-benefit analysis by 10 percent while holding the other categories constant. The three largest monetary categories were the benefit estimate ($340.1 million), the cost of upgrading wastewater treatment plants ($160 million) and the cost of purchasing critical tracts of land ($52.4 million). This 10 percent change in the value of these categories resulted in 35.7, 16.8, and 5.5 percent changes in the NPV of the management plan, respectively. In each case, the NPV of the management plan was still positive. Holding other categories constant, the benefit estimate would need to decrease by more than 28 percent to result in a negative NPV.

We also examined the effects of varying the discount rate. The cost-benefit analysis used a 7 percent discount rate to bring the value of future streams of costs and benefits to present dollar terms. We additionally ran the cost-benefit analysis using 5 and 10 percent discount rates to examine the effects on the NPV. With 5 and 10 percent discount rates, the NPVs were $106.7 and $79.7 million, respectively. While the choice of discount rate affected the magnitude of the NPV, it clearly did not change our basic finding of benefits exceeding costs.

Lastly, we performed a full sensitivity analysis by running a "worst-case scenario," in which all categories of costs and benefits varied simultaneously (Boardman *et al.*, 1996). When the value of the benefit estimate was decreased by 10 percent and all categories of costs were simultaneously increased by 10 percent, the resulting NPV decreased to $36.9 million. If the costs and benefits were varied in this manner by 20 percent of their initial values, the costs would then outweigh the benefits by $21.6 million. This analysis indicated that any simultaneous variations of all costs and benefits of more than 16 percent could result in a negative NPV for the management plan. We view this as an unlikely scenario.

DISCUSSION

The use of a water quality model is relatively rare among water quality studies using the CVM as a basis for cost-benefit analysis. This approach offered both advantages and disadvantages as compared to more traditional approaches.

Advantages of Using a Water Quality Model for Cost-Benefit Analysis

There were several desirable aspects of using a water quality model to undertake a cost-benefit analysis. The most significant advantage of this approach was that use of the model gives the researcher flexibility to compare costs and benefits for different magnitudes of water quality management schemes. Previous studies of this type have relied on "cost transfers" from existing projects as a basis for comparison to the estimated benefits of the project (Sanders *et al.*, 1990; Carson and Mitchell, 1993). Such an approach can be limiting, since the costs the researcher can estimate are tied to the range of existing or previously proposed projects.

Using a water quality model allows the researcher to compare costs and benefits of a limitless range of management schemes for water quality. Approximations of the costs of these management activities on a per-unit basis can then be used to cost out potential management strategies and compare these costs to potential benefits. The researcher can use the water quality model to examine the effects on water quality of any amount and combination of water quality management strategies. Modeling results are used to indicate the amount of water quality improvement that could result from a given set of management activities.

The ability to test the effectiveness of a proposed management plan is another significant advantage of using a water quality model. Without a model to use for this purpose, the researcher cannot measure the likelihood that the proposed management activities will actually achieve the desired result. For example, in a study of the costs and benefits of nutrient reduction in the Chesapeake Bay, Lindsey (1992) was unable to predict if the proposed management activities would be effective in achieving their goals as the modeling work had not been done.

Disadvantages of Using a Water Quality Model for Cost-Benefit Analysis

Use of a water quality model for cost-benefit analysis also has some disadvantages. One of them was related to the use of water quality information obtained from different sources. For instance, the status quo of water quality in the Catawba basin was obtained from state regulatory agencies. There were some differences in the status quo of water quality in the Catawba basin as presented by the WARMF model and the state agency reports. In order to reconcile these differences, advice was sought from various stakeholders and regulatory agency staff. This discrepancy in the water quality information was one source of uncertainty that arose from our approach.

Another source of uncertainty related to the problem of trying to depict complex water quality information to survey respondents who may be totally unaware of these issues. The WARMF model measures water quality by different intended uses of the water body, which are linked to certain water quality criteria. Realizing that displaying several sets of maps depicting different intended water uses would be too complex for many survey respondents, we devised a simplified rating scale of "good, fair, and poor" to depict water quality in the survey information booklet. This simplified rating scale was based on how often a water body met standards for certain designated uses within the WARMF model. While this rating scale was effective, uncertainty arose in the translation of the model output to this simplified rating scale, since this rating scale could not be applied directly into the model. We used the model output on designated uses of various water bodies to manually construct maps of the basin that rated water quality according to the simplified rating scale. The ability to directly display results from the model in terms of this simplified rating scale would have improved the level of detail of the modeling effort.

One final disadvantage of using the WARMF model for the cost-benefit analysis related to aspects of the model itself. While the WARMF model is extremely effective at linking catchments, river segment, and lakes to form a continuous water quality model, some shortcomings of the model added to the uncertainty of the study results. For example, at the time of this study, the WARMF model had no method for applying water quality management activities to impervious surfaces. We thus limited the water quality management activities to activities for pervious surfaces such as buffer strips along waterways. It is likely, however, that a water quality management plan for the Catawba basin would also attempt to address impervious surfaces, such as through stormwater management activities.

CONCLUSION

As the Catawba River basin continues to experience population growth, the region will be faced with important choices regarding resources such as the Catawba River. Due to their public nature, these resources do not have a price associated with them that adequately reflects their worth. Efforts such as this one are needed to bridge this gap in knowledge and provide stakeholders with information that can aid in making decisions that will affect the quality of the resource in question.

Results of the CVM study indicated that protecting water quality in the Catawba basin is an important issue to area residents. This importance was demonstrated by the mean WTP of $139 for taxpayers in the Catawba basin and the total annual economic benefit of $75.4 million for all taxpayers in counties within the Catawba basin. Additionally, results showed that the implementation of a proposed management plan to protect water quality passed a cost-benefit test with potential benefits exceeding potential costs by $95.4 million.

This study adds to a sizeable body of CVM studies that have estimated the economic benefits of water quality projects. The CVM is easily adaptable to other settings where similar analysis would be useful. The biggest impediment toward adapting this approach of benefit measurement is the high cost, in money and time, involved in conducting high-quality CVM studies. One potential resolution to this dilemma is benefit transfer, in which data from one study site are applied to a new site for which primary data do not exist. Through a variety of tests, research has shown benefit transfer to be reliable in many different cases (Rosenberger and Loomis, 2000).

Through the use of a water quality model, we were able to tailor the cost-benefit analysis to the benefit and cost estimations specific to the management plan devised for this study. This approach is easily adaptable to other locations where a water quality model such as WARMF was available. Our approach of estimating the costs of water quality management activities on a per-unit basis could facilitate the application of this method in other locations. Since many of the costs of the various water quality management activities used in our study were estimated specifically for the Catawba basin region, applications of this method in other locations would need to revise these estimates based on local information.

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