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TOWARD MEASUREMENT OF THE OFF-SITE BENEFITS OF SOIL CONSERVATION

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IN COOPERATION WITH:

ECONOMIC RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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This study is concerned with the off-site water quality benefits of agricultural soil conservation practices. Study objectives include both a review of benefit measurement methodology and application of these methodological alternatives to selected cases of water quality problems linked to agricultural run-off. Water quality improvement benefits given particular attention are related to recreation, municipal water treatment and harbor dredging.

Recreational effects from water quality changes were studied at three lakes in southwestern Michigan using a cross-sectional experimental design. Data were collected through on-site interviews with recreationists. The survey instrument was designed to allow the use of both the Clawson-Knetsch travel cost method and a bidding game approach in analyzing recreational benefits. For water treatment effects, potential cost savings were examined using data from three small municipal treatment plants in southeastern Michigan. Potential cost savings for harbor dredging were investigated using data provided by the U.S. Army Corps of Engineers and an environmental engineering firm.

A further study objective was to compare the travel cost and bidding game techniques for measuring recreation benefits. They were compared in the context of a single recreational sample.

The comparison and evaluation of the travel cost and bidding game methods dealt with several important technical and public choice issues. Reliability of travel cost as a proxy for benefit was brought into question, as was any benefit associated with reduction in lake turbidity. Another technical issue concerns the fact that the travel cost and bidding game techniques measure recreational demand for an environmental change with different levels of consumer information.

Further methodological conclusions are presented as are policy implications and suggestions for further research.

PREFACE

This report is drawn from a larger study conducted by Dr. Birch, as part of a Cooperative Research Agreement between the Economic Research Service, U.S. Department of Agriculture, and Department of Agricultural Economics, Michigan State University. Additional support by the Michigan Agricultural Experiment Station is also gratefully acknowledged.

The manuscript was reviewed by Dr. A.A. Schmid, MSU, Dr. William Crosswhite, ERS, and Dr. Anthony Grano, ERS. Their comments were helpful in producing what is hopefully a useful and readable research report. The reviewers should not, however, be held accountable for the final product.

TOWARD MEASUREMENT OF THE OFF-SITE BENEFITS OF SOIL CONSERVATION*

by

Alfred Birch
Carmen Sandretto
Lawrence Libby

Introduction

There is broad public concern regarding protection of the quality and adequacy of the U.S. natural resource base. One key aspect of that concern is the incidence, distribution, dimension, etc., of both benefits and costs. That is, what do we know about who gains from and who pays for environmental quality and conservation programs? Quality and adequacy of resources are frequently closely related. Soil erosion, for example, is a "problem" that affects both the on-site adequacy of productive land as a natural resource, and the downstream or off-site damages caused by run-off. Actions to reduce erosion may involve both on and off-site benefits (and/or costs) from conservation expenditures.

This paper focuses on the off-site economic benefits of soil conservation efforts. The working hypothesis is that reduced sediment delivery from farmers' fields to streams and lakes will generate certain environmental services for which people are willing to pay. These services may be either inputs to production processes (like fish production) or such consumer goods as the general attractiveness of a lake or stream. The purpose of this study has been to generate information about off-site effects of erosion to improve chances that conservation policy decisions of the future will be based on perceived

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*Michigan Agricultural Experiment Station Article No. 10862. Authors are Resource Economist, Alberta Agriculture; Agricultural Economist, Economic Research Service, USDA; and Professor of Agricultural Economics, Michigan State University.

benefits. The study examines three types of off-site costs of erosion, with related benefits of abatement:

1. sediment impact on quality of a recreation experience, using both the travel-cost and bidding game methods of benefit estimation for selected Michigan lakes

2. cost of municipal water treatment as affected by run-off

3. dredging costs in lake and navigational channels

A. Off-Site Impacts of Soil Conservation--The Physical Dimensions

Understanding the basic physical processes of soil erosion and sedimentation is essential to the economic valuation of such changes. The complexity of the physical, chemical and biological linkages create some important limitations for any economic analysis. First, there is little reliable information on the relationship between adoption of soil conserving practices and changes in sediment level at downstream locations. Second, because of interdependence among several parameters of the physical systems under study, it has been impossible to identify ways in which people react to changes in sediment level alone. While it would be ideal to vary the level of soil erosion while holding "all other relevant variables" constant, and to measure changes in economic response, this is clearly impossible.

Definition of Terms

The term "sediment" commonly refers to particulate material which has been deposited following suspension and possibly transport by water. "Sedimentation," then, is the deposition of suspended material. Suspended material is usually measured in milligrams per liter of water or similar weight/volume ratio. Sediment may also be transported as "bed load," material moved but not suspended by the flowing water. In this report, the term "sediment" will be used as a general reference to particulate material and will be qualified as suspended or deposited.

Sediment may be of either organic or inorganic composition. While inorganic sediment originates almost exclusively with the erosion process, organic sediment may come either from erosion or from aquatic or riparian plant growth. The process of lake eutrophication is largely one of organic sedimentation resulting from the growth and decay of aquatic plants, a process enhanced by delivery of nutrients to the water body. The focus of the present study is on sediment generated by upland erosion, but because of the difficulty in establishing sediment source and because of a lack of information on any difference in impact by sediment from different sources, the source of sediment is assumed here to have no effect on the production of environmental services.

Unless the level or change in level of sediment resulting from soil erosion has some impact on the uses which people make of water at the downstream location, no economic consequences will occur. Furthermore, the nature of the impact of sediment on environmental services will critically determine the nature of the economic consequences.

Nemerow and Faro list "recreational withdrawal, wastewater disposal, bordering land uses, and such instream uses as commercial fishing, navigation and hydroelectric power generation as beneficial water uses." The following impacts of sediment pollution would appear to have particular importance:

1. Recreational/aesthetic--both the direct visual appearance of suspended soil material and the biological impact on such things as game fish and aquatic plants.

2. Siltation--affecting such things as reservoirs and navigational channels.

3. Withdrawal--for municipal and industrial water supply.

There are also many connections between the level of sediment and various biological processes that involve productive inputs or direct consumer services (Farnworth, et al., Ch. 9). For example, sediment deposition in game fish spawning areas will reduce spawning success by smothering eggs, resulting in reduced game fish availability for some species. Turbidity will also affect water temperature and light penetration, thus influencing the growth of algae or larger aquatic plants.

There are several important issues in the definition of the physical damage function. First is the problem of dealing with a single pollutant, such as sediment, which is often associated with or travels with other pollutants. Small sediment particles may adsorb nutrients or pesticides, thus causing the two to travel in association. The impact of this is particularly evident in the case of dredged material. Because open water disposal of dredged material will reintroduce chemicals which are trapped in deposited sediment, current environmental regulations require disposal of such material in diked disposal areas in order to prevent this reintroduction of chemical pollutants. To correctly assess the impact of sediment on environmental services, therefore, the effect of associated pollutants must also be taken into account.

Another potentially important issue in determining the relationship between sediment and environmental services is that of threshold effects. While some physical damage functions such as the relation between siltation and reservoir life are linear, others may show a sharp change in response over a small range of sediment delivery levels. For example, the dosage of chemical coagulants in municipal water treatment may be directly related to turbidity levels up to some point. Above this level of turbidity no further increase in chemical dosage may be required. Threshold levels may also be important with respect to aesthetic perceptions. Recreationists may not notice a change in the level of sediment until it exceeds some amount (Markin, p. 201).

A final important issue in the definition of physical damage functions is the possibility of trade-offs, or substitution effects. Upland and channel erosion may be "substitutes" in the physical "production" of downstream sediment delivery. Another example of this effect is the trade-off between suspended soil material and algae in causing turbidity in a water body. If the input of soil particles is reduced, light penetration and algae growth may both increase, resulting in only a very small, or even no change in turbidity. Such substitution effects may at times counteract other main effects, making the net results difficult to predict.

The approach which this study takes in dealing with the physical process causing the off-site impacts of soil erosion is to employ empirical rather than mechanistic models. In other words, general causes and consequences are examined, rather than specific explanations of the complex interconnections which are involved. The significance of the sediment transport and impact considerations presented here is, however, that to employ empirical models successfully, some understanding of causal relationships must be available.

B. Case Studies of Off-Site Erosion Impact on Michigan Lakes

While rivers may display significant variation in average sediment level, most sediment comes in periods of high concentration and stream flow which are closely correlated with upstream storm events. Since fewer people participate in outdoor recreation during periods of poor weather, there would be less opportunity for recreational perception and response to high turbidity levels in rivers. Lakes, on the other hand, retain water longer and thus give more opportunity for recreational response. Since sediment deposition is usually higher in lakes, they may also give more opportunity for response to that factor. These factors made the use of lakes as recreational analysis locations desirable.

Chapter I

Selection of Lakes for Recreational Sampling

Lake selection initially focused on southwestern Michigan because of the number of lakes and amount of agriculture in that area. U.S. Department of Agriculture Soil Conservation Service district conservationists and Michigan Department of Natural Resources fisheries biologists were consulted in an attempt to identify lakes which had high sediment delivery rates and reasonably high recreational use. From an extensive list of lakes initially considered, only Thornapple Lake in Barry County met both of these requirements. Personal visits and comments from local residents confirmed these characteristics.

In order to employ a cross sectional experimental design for identifying the recreational response to turbidity it was necessary to select a number of other lakes for purposes of comparison with Thornapple Lake. To isolate response to turbidity alone, it was necessary to select lakes which were cleaner than Thornapple Lake but with the same basic recreational demand factors. In order to control for other factors which might affect recreational demand, it might also be possible to use a multiple regression framework in which these other factors would be statistically controlled. The major reasons for using the experimental control approach were, however, that data were not available on lake characteristics and it was not known which of these characteristics should be considered or how they should be included in a regression model. Also, if many potentially important characteristics were to be controlled and their effects kept distinct from that of turbidity, a large number of lakes would be required.

The lake selection procedure finally used was to record lakes identified by recreationists themselves as substitutes during the pretesting of the survey questionnaire and the first two days of data collection. Recreationists were asked which other lakes they visited and which of these were "about as good" for the type of recreation involved as the lake at which the interview took place. The assumptions involved are that they would identify substitute lakes in accordance with their particular perceptions and preferences and that these factors are more relevant for determining demand than are objective measures of lake characteristics. The weakness of this approach is that the effect of varying turbidity levels is necessarily controlled along with the net effect of all other features. It is not clear whether this eliminated or reduced the effect of water quality on recreational demand.

A. Characteristics of Selected Recreational Locations[1]

This section describes the location and relevant physical characteristics of the sites selected for recreational analysis in order to provide a basis for evaluating this lake selection procedure and to compare this location to others not investigated. Four interview locations at three lakes were selected. These were the Michigan Department of Natural Resources public access sites at Thornapple and Middle Lakes, and at the beach areas and boat launches at Charlton Park on Thornapple Lake and Yankee Springs Recreation Area on Gun Lake. Charlton Park is operated by Barry County and Yankee Springs is a state park under the administration of the Michigan DNR Parks Division. Figure 1 indicates the locations of these sites. Table 1 gives some relvant lake and interview site characteristics.

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[1]Further information on Thornapple Lake can be gained from the U.S.E.P.A., National Eutrophication Survey report on Thornapple Lake.

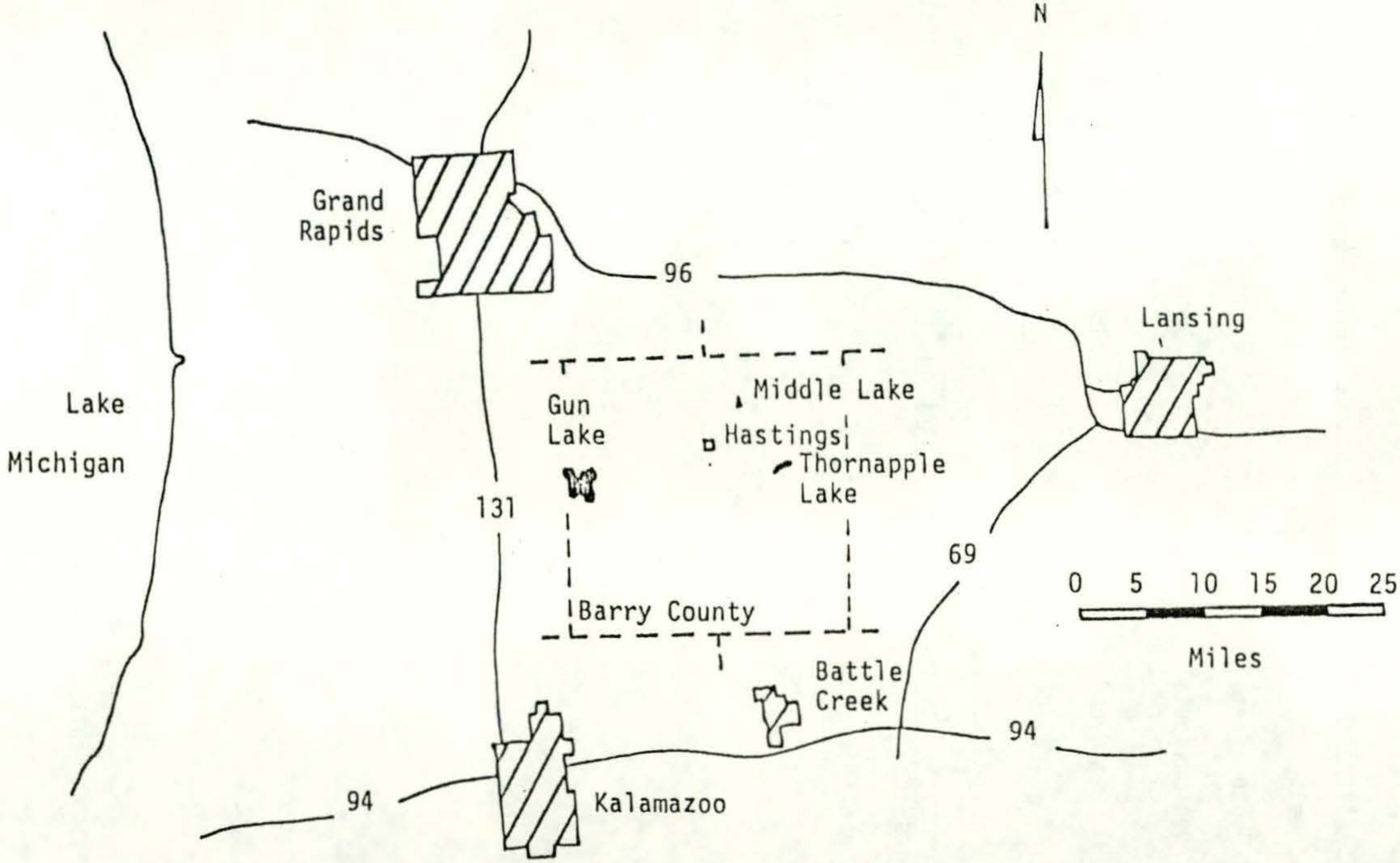

Figure 1. Location of Recreational Survey Lakes

Source: Michigan State Highway Map

Table 1. Recreational Lake and Site Characteristics.

Lake Characteristics	Thornapple Lake	Middle Lake	Gun Lake
Area (acres)[a]	409	131	2680
Average Depth (feet)[a]	14	20	10
Maximum Depth (feet)[a]	33	40	68
Percent of Area Less Than 10 Feet Deep[a]	32	27	80
Percent of Shoreline Developed[b]	60	60	85

Site Characteristics and Facilities[c]	Thornapple Lake Charlton Park	Thornapple Lake DNR Access Site	Middle Lake DNR Access Site	Gun Lake Yankee Springs State Park
Boat Launch Type	hard. surf.	gravel	gravel	hard. surf.
Toilets	yes	yes	yes	yes
Picnic Area	yes	no	yes	yes
Camping	no	no	no	yes
Beach	yes	no	yes	yes
Lifeguard	no	no	no	yes
Admission fee:				
daily-car	$2.00	nil	nil	$2.00
daily-boat	$1.00	nil	nil	nil
seasonal-car	$7.00	nil	nil	$7.00
seasonal-boat	$2.00	nil	nil	nil

SOURCES:

[a]Institute for Fisheries Research, Lake Inventory Maps, distributed by Michigan United Conservation Clubs (see Figures 4 to 6).

[b]Estimated by Michigan DNR, Inland Lakes Unit.

[c]Personal observation.

B. Recreator Sample Selection

Most of the data for the present study's recreational analysis were collected by administering a four page questionnaire in direct personal interview, commonly taking 5 to 10 minutes each.[1] Survey period was May 24 to July 6, 1980. During this period interview days were chosen more or less at random with somewhat greater emphasis being given to weekends when more recreationists were present.

Interviews were usually conducted with an adult member of the recreational party who was willing to answer questions. In many cases other members of the party also responded.

This procedure was believed to have produced a sample which was randomly drawn from the population of all recreationists visiting these locations during the overall period. In order to draw inferences from this study's analysis it is necessary to estimate how representative this sample was of recreational patterns at other periods. While the major sampling period for this study was early in the summer, an additional 20 interviews were conducted at Thornapple Lake (at both the DNR public access site and Charlton Park) on August 23, 1980. It was believed that this end-of-summer check on the characteristics of recreationists would allow greater confidence to be placed in the sample.

As noted, there are difficulties in experimentally distinguishing the effects of various turbidity sources on recreational demand. It is therefore assumed that recreationists are not able to distinguish, or at least do not respond to a distinction between turbidity from eroded soil and that from sources such as algae or resuspension of bottom sediments as a result

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[1] Full questionnaire is contained in the parent study by Birch.

of power boat activity. It is also assumed that the identification of a relationship between water clarity and recreational demand would imply a response to changes in soil erosion if those changes could account for the observed changes in water clarity.

On each day that interviews were conducted at a lake, turbidity measurements were taken by means of a Secchi disk.

C. Estimation of Total Annual Recreational Use of Thornapple Lake

In order to determine aggregate demand for Thornapple Lake and the value of water quality improvements there it is necessary to estimate total annual recreational use of the lake. Recreationists can be classified as residents (those who own lakeshore property) or non-residents. Non-residents may gain access to Thornapple Lake through the Michigan Department of Natural Resources public access site, through Charlton Park, or by boat along the Thornapple River (usually from downstream). Because of the difficulty of counting or estimating the number of resident recreationists and those entering the lake from the river, these users had to be ignored for the purposes of this study.

Chapter II

Methodology of Benefit Estimation

A. Travel Cost Analysis: Dependent and Independent Variables

1. Visitation Rate.

The visitation rate was used as the dependent variable in the regression models. It was defined as the annual number of visits to the study lake by the recreational group. There are two potential ambiguities in this definition. The first is that such groups are clearly not consistent over all recreational trips; many different combinations of people may be involved in recreational travel. It is not known to what extent or in what way this variation in group composition will affect the results of a travel cost analysis based on these disaggregated data. Fifty-four percent of the interviewed groups identified themselves as single households and many others were households plus one or two friends. The effect of variation in group composition likely depends on the way in which recreational decisions are made within each group. This question was not addressed here. In the relatively few cases where the respondent expressed uncertainty as to how to express a visitation frequency because of variation in group composition he was instructed to give a visitation rate for himself.

A second potential ambiguity with this definition of visitation frequency concerns the cases where the frequency is sharply different from one year to the next. Recreationists may have just found out about the location or they may be expecting to make a major household move, they may have recently made a large purchase such as a boat which will enable them to make greater use of a lake, or they may have had a change in their employment situation which will alter their visitation frequency. In this research, recreationists were asked to give a frequency for last year (1979) and an expected frequency for 1980.

In cases where these figures differed appreciably, the reason for the difference was determined and either an average of the two figures, or a visitation rate which the respondent considered indicative of his preference for the lake was recorded. It is acknowledged that this procedure allows a degree of error in the model, yet unless the model treated numerous personal circumstances this error would remain. Bouwes and Schneider also employed questions about visitation frequency in the past and present year.

2. Cost of Travel

The primary intent of the travel cost approach is to identify the marginal relationship between the cost of traveling to a recreational location and the frequency of making that trip. While the major cost of the recreational trip is usually transportation, other costs should also be included. Those which are correlated with distance will influence the nature of the relationship between cost and visitation frequency. Those which are not correlated with distance will not affect this marginal relationship, though they will affect the intercept of the demand function (i.e., the constant term in the regression model) and must also be taken into account because of their influence on the estimate of total benefits.[1]

In the present study two alternative definitions of travel cost were used:

$$\text{Transportation cost} = \frac{\text{one way mileage x 2}}{\text{miles per gallon}} \text{ x gas price x } \frac{\text{lake as \% of}}{\text{reason for trip}}$$

Total trip cost = transportation + entrance fee + boat operation cost + other on-site costs

[1]Freeman (1979, p. 207) makes this point with respect to the treatment of on-site time, a point which will be discussed below.

Respondents reported the one way mileage from their homes to the interview site, the type of fuel used by their vehicle, the fuel efficiency (miles per gallon) of their vehicle, and how much of their reason for leaving home involved the lake visit. Respondents also reported the non-transportation components of the total trip cost. It was assumed that gasoline costs are the only off-site costs of the recreational trip and these were assigned to the various trip purposes in accordance with the respondents' estimate of the relative importance of the various purposes. Statewide average gas prices were obtained from the American Automobile Association by week and type of fuel (e.g., regular, no-lead, diesel).

3. Travel Time

The use of the recreational group as an observational unit allowed the separate inclusion of travel money and time cost in the regression model. Travel time was reported by respondents. The correlation of travel time and transportation cost was 0.58, showing considerable independent variation, as expected. There are several reasons for this lack of close correlation between time and money costs. These include variations in vehicle fuel efficiency, variation in average driving speed and any stops enroute.

For the recreationists which were sampled in this study, average one-way trip distance was 28.4 miles and the standard deviation was 31.3 miles (Table 3). There was therefore insufficient variation in trip length to lead to a significant on-site time variation.

4. Preference Variables

In specifying a demand model it is necessary to control for personal preferences and tastes which may affect the level of demand. Such variables as age, sex, and income may be used as proxies for preferences not directly price related. Mueller and Gurin found a significant relationship between socioeconomic characteristics and the demand for outdoor recreation. They also found substantial correlation among characteristics such as age, sex, income, educational attainment and occupation. The implication of this is that the inclusion of measures of a small number of these characteristics may be sufficient for controlling the effect of preferences on recreational demand.

Gum and Martin included a measure of the total annual days of outdoor recreation in their demand model as a "surrogate for positive tastes and preferences for rural outdoor recreation" (p. 561). A similar variable has been used in this study.

5. Substitute Locations

Availability of substitute recreational locations may create bias in the analysis. Recreationists were asked what other lakes they visited for the type of recreation they were undertaking at the time of the interview, up to a maximum of five other locations. They were then asked which of these were "about as good as" the present location.

Both these substitute locations and the respondents' home locations were then coded by means of a Michigan Department of State Highways and Transportation code which covers in and out of state locations with 547 origin-destination zones. (Michigan Department of State Highways and Transportation) The Department of Transportation calculated average driving times for all identified origin-destination pairs using minimum distance routes between zones (using the state highway trunkline system and some county roads) and adding average intrazone driving times. Assuming that driving times to substitute locations are a proxy for the "cost" of these substitutes, the identified travel times to substitutes were averaged for each individual and included in the regression model as an independent variable.

6. Water Quality

This study ignored water quality at substitute sites because of the lack of information on turbidity at Michigan lakes. The Inland Lakes Unit of the Michigan Department of Natural Resources collects such information, but their coverage of lakes is not complete enough to make feasible the inclusion of water quality at substitute sites.

This study included water quality measures in two alternate ways: by Secchi disk readings (Table 2) and by means of a dummy variable (Thornapple Lake = 0 = dirty, Middle and Gun Lakes = 1 = clean). The second method assumed that recreationists only distinguish between clean and dirty and not between points on a continuous clarity scale. This assumption is discussed again with respect to the bidding game.

7. Recreation Type

It was hypothesized that the type of recreation that respondents were involved in would have an effect on their demand for the site in question and their response to water quality. During the interview process several respondents said that water quality was important to them for swimming but not for fishing. Recreational type was included in the regression model by means of a series of dummy variables. In cases where more than one type of recreation was reported, one was selected at random to classify the respondent.

B. Bidding Game Implementation and Analysis

The results of the bidding game approach to environmental benefit estimation are at least as dependent on the details of question design and implementation as are those of the travel cost approach. It is, therefore, necessary

Table 2

Secchi Disk Readings at Thornapple, Gun and Middle Lakes, in Inches*

	-------Thornapple Lake------					
Date (Month/Day)	Site A	Site B	Site C	Average of all Sites	Middle Lake	Gun Lake
1980						
5/24	49	53	57	53	200	
5/26	60	66	69	65	190	
6/5	45	27	22	31	144	
6/13	55	62	66	61		156
6/14	74	80	80	78	180	
6/16	98	98	90	95	162	150
6/20	68	72	72	71		150
6/21	74	68	62	68	116	
6/26					122	150
6/27	68	58	70	65		
6/28	66	58	68	64	114	128
7/2	44	36	42	41	102	
7/4	44	42	42	43	108	
7/6	34	34	30	33	114	
Average				59	141	147

*The higher numbers in this table indicate greater clarity or lower turbidity.

to make these design and implementation details clear in order to analyze and evaluate the results of this procedure. Further details on this procedure are contained in the parent study by Birch.

1. Question Design

While the bidding game was essentially hypothetical in nature, it was based on the actual water quality situation at Thornapple Lake, a situation which respondents could see during the interview and with which previous questions in the interview had dealt.

The first part of the bidding game question described the actual physical setting believed to be responsible for reduced clarity in Thornapple Lake. The connection was made between soil erosion and water clarity. The physical connection between soil erosion and turbidity is one which respondents could fairly easily understand. These factors enhanced the realism of the question.

The second part of the bidding game question described the hypothetical institutional setting, including a public soil conservation and water quality program and a proposed fee schedule. Here again the objective was to present a realistic and easily understood institutional setting for the bidding game so as to increase the accuracy of the responses. Since entrance fees are already charged at Charlton Park this was a fairly realistic option. Further, using the entrance fee increased the comparability of the results of the bidding game with those of the travel cost analysis.

The institutional setting proposed in the bidding game was an integral part of the question. Some respondents expressed strong feelings about the proposal of a state program to encourage soil conservation and improve water quality. Their attitude toward state government appeared to substantially affect their willingness to pay (Birch and Schmid, p. 305). If a federal rather than a state program had been proposed, or if some other payment vehicle had been suggested bids would likely have been different. The institutional setting is part of the "product" for which the respondent expresses a willingness to pay. This does not support the suggestion by Randall, Ives and Eastman that several payment vehicles be tested in a bidding game so as to increase the response rate (p. 39). Different payment vehicles should be tested, as those authors did, but the results must be interpreted as bids for different products.

In the present case respondents were told that the hypothetical entrance fee was to be collected as a daily fee per vehicle and that the revenue generated would not be applied to any changes in related recreational facilities such as boat launch ramps or other park features.

The hypothetical nature of the bidding game was stressed to respondents before their bid was requested. This may have had the effect of reducing both the incentive for strategic response and the incentive for accurate responses. The interview and questionnaire were clearly identified with Michigan State University rather than with some branch of government.

A final and highly important aspect of bidding game question design has to do with the specification of a common water quality improvement for which the bid was to be offered. While an objective measure of water quality change such as a given change in Secchi disk reading would have been satisfactory for public decision makers it would not have had sufficient meaning for recreationists. Several approaches to describing a quality change to support a bid have been tried. One is to use photographs for comparison purposes (Randall, Ives and Eastman; Brookshire, Ives and Schulze; Walsh, et al.). The use of photographs assumes that respondents can interpret the information on the photo in terms of a complex environmental good which may affect them in a variety of ways. Lake turbidity and other sediment effects cannot easily be portrayed in photographs, however. Another approach to this problem has been to determine a recreationist's subjective rating of environmental quality in a scaled question. A hypothetical change in environmental quality is then proposed in terms of this scale (Bouwes and Schneider). This approach has the weakness of assuming the respondent can master the conceptual refinement necessary to answer the question. It also assumes interpersonal comparability of a given subjective rating change and that the hypothetical change will have meaning for public decision makers.

The approach used in the present study was simply to say that Thornapple Lake would be "cleaned up", that water clarity would be improved. While there was considerable imprecision in this specification, the underlying assumption was that respondents were only able to distinguish between clean and dirty water and not between finer increments of water clarity. This assumption is supported by the fact that the correlation coefficient between objective and subjective water quality measures was only 0.1279, indicating a very weak relationship between the two. On a scale of 1 to 10 (1 = dirty, 10 = clean), the average subjective ratings for the three lakes were:

Thornapple	5.96
Middle	6.29
Gun	6.43

This corresponds to the order of the average Secchi disk reading (Table 2) but does not show the amount of divergence between Thornapple Lake and the other two which might be expected.

Probably the most significant weakness of the definition of water quality improvement used in this bidding game approach was that it assumed that respondents had a fairly common exposure to the range of lake water quality levels and that "clean" meant approximately the same thing to all respondents. In order to compare the results of the bidding game and travel cost approaches the assumption must therefore be made that respondents at Thornapple Lake would consider Middle and Gun Lakes clean and that their bid measures willingness to pay for the difference in water quality between Thornapple and the other two.

Finally, an error in the design of the bidding game question must be made clear. Respondents were asked, "How much would you be willing to pay before you refused to use this lake?" This could have been interpreted as a willingness to pay for the proposed improvements in water quality. It could also have been interpreted, though, as willingness to pay for access to the lake in an improved condition. It is not known how much respondents would have been willing to pay for access to the lake in its present condition. This serious ambiguity was not recognized until after the completion of all interviews. As a result, the bids which were received must be interpreted as an upper limit to the amount which respondents would have been willing to pay for the improvement in water quality which the question proposed.

2. Question Implementation

Not only are bidding game results likely to be sensitive to the design of the question which is used, but also to certain details of its implementation or administration. An important factor is the starting point and increments used in deriving the bid. Randall, Ives and Eastman used \$0.25 increments above a starting point of \$1.00 and recorded the highest bid that the respondent said he would be willing to pay.

In this study respondents were not prompted where to start the bid and thus no suggestion was given to indicate what the interviewer might consider a reasonable amount. However, in order to ensure that the stated amount was a maximum bid and not a randomly acceptable bid, the respondent was asked whether he would refuse to pay slightly higher amounts. If he indicated he would be willing to pay the higher amount, the process was repeated until a negative response was obtained.

A second important issue in the implementation of the bidding game concerns the treatment of zero bids. Both Randall, et al., and Brookshire, et al., suggest that a distinction should be made between those who give a zero bid because they consider the environmental improvement to have no value for them and are thus unwilling to pay anything for it, and those who give a zero bid because they object to the proposed institutional setting of the question. In all bidding games in which willingness to pay is investigated, the presupposed distribution of rights is such that the respondent cannot claim the good or service at zero cost. This is the same as the normal market situation faced by potential buyers. Therefore, willingness to pay in the face of predetermined rights should be determined and not an expression of preferences concerning those rights.

In this case, therefore, respondents who gave a zero bid were questioned as to the reason. Those that expressed disagreement with the institutional setting of the question were again asked what their response would be if faced with the choice of paying a positive amount or not using the lake in an improved condition. Zero bids were, of course, recorded if the respondent stated he would be unwilling to pay anything because of the institutional setting. Once again, the institutional context is an integral part of the "product" for which the bid is being given.

3. Bias and Accuracy

In this study the incentive to bias was reduced by emphasizing the hypothetical nature of the game.

Another test for the existence of bias was developed and applied here. Assuming that the true preference which respondents have for the environmental improvement or other good in question could be observed, the correlation between that preference and the bid which the respondent gives would convey important information about the way in which the bidding game question was answered. A zero correlation between the bid and the respondent's preference level (assuming that the latter is distributed somehow along a continous scale) would mean that there was an equal chance of a high bid coming from someone with a high preference or from someone with a low preference for the environmental improvement.

To derive aggregate values for the proposed reduction in turbidity at Thornapple Lake, the average bid was multiplied by the estimated total number of recreational groups using the lake each year. It was not possible to determine the marginal relationship between water quality and willingness to pay. We have assumed, supported by other studies which have examined the relationship between subjective and objective water quality ratings, that recreationists are not able to distinguish small variations in water quality, particularly for a single parameter such as turbidity.

C. Non-Recreational Sediment Impacts

These impacts proved to be particularly difficult to analyze and held less potential for methodological development than did the analysis of recreational sediment impacts. Thus they are less central to the overall scope of this study. Attempts were made to analyze the benefits from sediment reduction in the areas of municipal water treatment and dredging. It is hoped that this account will prove useful for future research by pointing to some areas in need of further investigation.

1. Water Treatment

Most of the economic literature on water treatment deals with the topic from a broad, cost analysis perspective, using data from a large number of plants and deriving general accounting relationships for major cost categories such as acquisition, treatment, distribution and administration (see, for example, Stevie, et al.). The few studies which have dealt with the impact of environmental quality on water treatment costs made simplifying assumptions about the physical production relationships which reduced their empirical usefulness (Brandt, et al.).

This study has attempted to identify the impact of sediment or turbidity on municipal water supply. Basic information on water treatment technology was gathered from managers of the treatment plants selected for study at Blissfield, Deerfield, and Dundee, Michigan;[1] and from engineers with the Water Supply Division of the Michigan Department of Public Health. The three areas of potential impact which were identified were chemical costs, filtration costs, and sludge disposal costs.

An increase in turbidity is expected to raise the flocculent chemical doseage requirements, up to some turbidity level. The chemicals whose doseages were identified as being related to the level of turbidity were alum, soda ash, activated carbon and chlorine. The doseage rate is also dependent upon the temperature at which the treatment takes place and the acceptable level of turbidity of the finished water.

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[1]These plants were selected because of the high turbidity level in their water source, the Raisin River, and because they do not soften their water during the treatment process.

A regression analysis was undertaken. The dependent variable in this analysis was an aggregate chemical cost, calculated by converting doseage rates for each chemical into a total weight measure, multiplying by chemical prices and summing. The dependent variables were raw water turbidity, finished water turbidity, and temperature.

The attempt to analyze filtration costs did not progress as far. Two of the three plants selected for the study backwash their filters at fixed intervals and not in response to loss of filter efficiency. Analysis of sludge disposal costs was similarly hampered. Information was unavailable on the relationship between turbidity levels and the amount of sludge generated.

Water acquisition costs were also examined. Water treatment plants may withdraw their supplies from either surface or groundwater sources. Where investment decisions concerning acquisition are influenced by water quality in alternate sources, a long run change in sediment level in a potential surface source may affect investment decisions, creating costs or benefits for municipalities. For example, a long run reduction in sediment level in a river may mean that possibly higher costs of groundwater acquisition can be avoided when the plant invests in facilities for acquiring water from one source or the other. However, no plants in Michigan were identified as having made water supply source choices by taking turbidity level into consideration.

2. Dredging

Dredging and disposal costs are influenced by many factors such as the type of equipment used, the type of material dredged, environmentally related disposal regulations, and numerous local conditions. Since it was impossible to gather information on all these factors, average costs per cubic yard of dredged material over many locations were calculated. This approach was based on the assumptions that other factors would be averaged out and that there would be a linear relationship between dredging costs and the sediment deposition rate.

The costs of dredging were based on equipment rental charges paid to a revolving fund as well as on contract costs. The accounting procedures used by the Corps of Engineers mean that the reported costs may include cost adjustments for certain pieces of equipment from previous years' work. It was assumed, however, that by averaging costs over all locations reporting dredging work in 1979, the influence of this practice on the calculated cost per cubic yard of material would be minimized.

The U.S. Environmental Protection Agency and the Michigan Department of Natural Resources require that dredged material which contains pollutants exceeding allowable standards must be deposited in confined disposal areas rather than dumped in open water disposal. The cost of acquiring land for such areas and of construction and maintenance of facilities for retention of the dredged material substantially raises the cost of disposal.

Chapter III

Results

The empirical results include recreation benefits from environmental improvement, and non-recreational impacts. Also included is discussion of the survey data.

A. Recreational Survey: Descriptive Statistics

Table 3 summarizes the recreational survey results. These statistics characterize the recreational population sampled in this study and facilitate a more complete appraisal of the travel cost and bidding game analyses. Details on the collection and definition of these data were presented in earlier sections. Table 4 shows a cross-tabulation of interview frequency by recreational type and interview location.

B. Travel Cost Results

The basic form of the regression model which was used in the travel cost analysis was:

$$Q_{ij} = \alpha + \sum_{k=1}^{n} \beta_{ik} X_{ijk} + e_{ij}$$

in which Q is the annual number of visits by the recreational party (i) to the lake (j) at which the interview was conducted, X_k is the value of independent variable (K), e_{ij} is the error term, and α and β are estimated coefficients. Regressions were performed with the following variations in model specification and form:

1. various combinations of independent variables;
2. time and money cost variables and the squared values of each, following Bouwes and Schneider and Gum and Martin;
3. log-log transformations; and
4. regressions run independently for different recreational types and for each lake.

Table 3

Selected Characteristics of Recreationists and Recreational Travel, Thornapple, Middle and Gun Lakes

1980

Variable	Mean	Standard Deviation	Minimum/ Maximum
One way distance (miles)	28.4	31.3	0.5/300.0
One way driving time (minutes)	67.1	62.1	3.0/720.0
Annual visitation frequency	12.8	20.8	1/170
Total annual water recreation days	27.2	27.4	2/200
Transportation cost ($)	4.13	5.15	0/67.00
Total trip cost ($)	8.16	8.42	0/69.00
Age	37.0	12.8	15/79
Group size	3.6	2.4	1/18
Household income ($)	19,030	10,615	2,500/45,000
Personal income* ($)	16,597	9,819	2,500/45,000
Subjective water quality rating			
Thornapple Lake	5.96	1.82	1/10
Middle Lake	6.29	2.11	3/9
Gun Lake	6.43	2.46	2/9

*Annual income of person being interviewed in contrast to the annual income for the entire household. The household may have more than one income earner.

Table 4

Cross-Tabulation of Recreational Type and Interview Location

Recreation Type	Thornapple Lake D.N.R. Access Site	Thornapple Lake Charlton Park	Middle Lake	Gun Lake	Total	Percent
	--------------------Numer of Responses--------------------					
Fishing	88	17	22	17	144	48.0
Swimming	3	40	15	49	107	35.7
Water Skiing	3	14	2	2	21	7.0
Sailing	3	1	1	11	16	5.3
Other Boating	6	3	1	2	12	4.0
	103	75	41	81	300	
Percent of Total	34.3	25.0	13.7	27.0		100

From among the many alternative models available, a number of specifications and forms of the demand model were investigated. It is clearly recognized that this is not the usual approach to the selection of a single model since peculiarities in the data set may lead to false conclusions about recreational demand. In light of the investigative and exploratory nature of this work, however, the present approach was felt to be justified.

The presentation of results in Table 5 reflects this exploratory approach. The alternative regression model specifications and forms are shown as rows and are labeled "equations" in Table 5. The exact specification and form of each regression run can be determined from the entries in each row.

1. Cost of Travel

The standard theoretical model asserts that there will be a negative relationship between the cost of recreational travel and quantity (visitation frequency). In other words, recreationists from farther away will visit a site less frequently. Response to both an entrance fee (variations in which are not observed) and travel time requirements are expected to be negative and larger (more elastic) than the response to travel money costs.

The estimated coefficients for both the transportation cost and total trip cost variables show that a $1.00 increase in these costs would result in a reduction of less than one-half visit per year with an average recreational party. The estimated coefficients from the cost variables are statistically insignificant at the 95 percent confidence level. Furthermore, with 300 observations, this lack of statistical significance cannot be attributed to a small sample.

The results show very little recreational demand response to changes in money cost over the observed range. The only cases in which cost appears to be statistically significant at the 95 percent level or higher are equations where travel time is omitted. The effect of time appears to be confounded

Table 5

Travel Cost Analysis Regression Results

Equations \ Variables	Transportation cost	$(\text{Transportation cost})^2$	Total trip cost	$(\text{Total trip cost})^2$	Travel time	$(\text{Travel time})^2$	Total trip cost + household income	Average travel time to substitutes	Water Quality: Secchi disk reading	Water Quality: Water quality dummy	Water Quality: Subjective water rating	Age	Sex	Household income	Total water recreation days	Recreation Type Dummy: Fishing	Recreation Type Dummy: Swimming	Recreation Type Dummy: Water skiing	Recreation Type Dummy: Sailing	Log Values (Common Logs): Total trip cost	Log Values (Common Logs): Travel time	Log Values (Common Logs): Average travel time to substitutes	Log Values (Common Logs): Secchi disk reading	Log Values (Common Logs): Age	Log Values (Common Logs): Sex	Log Values (Common Logs): Household income	Log Values (Common Logs): Total water recreation days	Constant	$\bar{R}^2$	F
1			-.12		-.07			....	-.02			.08	-2.11	-1.04		-18.3	-19.1	-20.6	-18.1									40.0	.07	**
2			-.05		-.06			....		-2.0		.08	-2.22	-1.08		-18.7	-19.0	-19.9	-18.2									39.9	.07	**
3			-.26	-.002	-.13	.0002		....	-.01			.06	-2.85	-1.05		-18.0	-19.9	-19.1	-18.6									45.5	.09	**
4			-.85	.001	-.15	.0002		....		-1.7		.06	-2.67	-1.04		-18.1	-19.3	-18.7	-18.0									45.3	.09	**
5			.001		-.05			....	-.02			.15	.63	-.68	.41	-20.7	-16.2	-17.4	-17.6									20.4	.37	**
6			.02		-.05			....		-1.44		.15	.55	-.68	.41	-20.9	-16.3	-17.1	-17.9									19.6	.37	**
7			-.57	.004				....	-.02			.07	-2.54	-1.12		-20.1	-19.7	-18.1	-19.4									43.2	.05	**
8			-.26					....	-.02			.09	-2.28	-1.14		-19.7	-19.4	-18.2	-18.9									39.7	.04	*
9					-.06		-.65	....	-.02			.09	-2.06	-1.68		-18.1	-19.2	-18.0	-18.0									44.0	.07	**
10			-.09	....	-.15	.0002			-.009							-16.7	-20.0	-18.4	-18.1									40.1	.09	**
11	-.01				-.06				-.01		-.21	.08	-2.39	-1.08		-18.4	-19.3	-20.3	-18.2									38.9	.06	**
12	-.45	.003			-.13	.0002			-.009		.08	.06	-3.09	-1.1		-18.0	-20.0	-18.9	-18.2									44.7	.09	**
13	.06				-.05				-.02		.36	.14	.59	-.68	.41	-21.0	-16.6	-17.2	-18.4									18.5	.37	**
14																				-.02	-.47	.009	.09	-.25	.15	-.06		1.9	.13	**
15																				.03	-.42	-.01	.03	-.12	.24	-.05	.66	.69	.39	**
Fishing 16			-.27		-.05			....	-.01					-.92														22.4	.06	*
Fishing 17					-.03		-1.9	....	-.01					-2.5														30.8	.10	
Swimming 18			.36		-.09			....	-.01					-.79														16.9	.05	
Swimming 19					-.07		.34	....	-.02					-.37														16.8	.03	
W. Skiing 20			.006		-.07			....	-.02					-.87														19.2	.07	
W. Skiing 21					-.08		.26	....	-.03					-.13														15.6	.12	
Sailing 22			-.41		-.02			....	.009					-1.98														23.0	....	
Sailing 23					-.02		1.57	....	-.04					-.99														19.5	....	
Thornapple 24			-.61	.01	-.17	....			.16							-18.1	-20.0	-14.9	-25.5									37.5	.09	*
Thornapple 25																				.08	-.72	.006	.41	-.21	-.43	.04		1.6	.20	**
Middle and Gun 26			.16	-.001	-.16	....			-.03							-17.6	-18.2	-20.6	-16.1									38.7	.09	*
Middle and Gun 27																				.01	-.28	.007	-.23	-.21	-.02	-.26		2.3	.04	

Table 5 (cont.)

Notes on Variables

Number of observations: Equations 1-15 = 300
Equations 16-27: see subcategory totals in Table 4

Dependent variable: Equations 1-13, 16-24, 26: number of visits to interview lake by recreational party per year
Equations 14-15, 25, 27: common log transformation of above

Independent variables:

$$\text{Transportation cost} = \frac{\text{(one way mileage x 2)}}{\text{miles per gallon}} \times \text{(gas price in dollars)} \times \text{(lake as \% of reason for trip)}$$

Total trip cost = transportation cost + entrance fee + boat operation cost + other on-site costs

Travel time = (one way travel time in minutes x 2) x (lake as % of reason for trip)

Total trip cost/household income

Average travel time to substitutes

Water quality indicated by:

a. Secchi disk reading (see Table 2)

b. Water quality dummy variable (Thornapple Lake = 0 = dirty, Middle and Gun Lakes = 1 = clean)

c. Subjective water appearance rating scale (Dirty = 1, Clean = 0)

Age

Sex

Table 5 (cont.)

Household income	(1 = 0-$5,000	5 = $20,001-$25,000
	2 = $5,001-$10,000	6 = $25,001-$30,000
	3 = $10,001-$15,000	7 = $30,001-$40,000
	4 = $15,001-$20,000	8 = greater than $40,000)

Total water recreation days = total days of any type of water-based recreation per year

Recreation type dummy variable = 1 if stated recreation type, 0 otherwise

$\bar{R}^2$ = coefficient of determination, adjusted for the number of independent variables

F = ratio of regression to residual variance

** or ═ = statistically significant at 99% confidence level

* or — = statistically significant at 95% confidence level

.... = absolute value less than 0.0005

with that of cost and the cost coefficients are biased estimates of the relationship between the cost of travel and visitation frequency. These results support the hypothesis that there is little or no recreational response to variation in travel cost within the observed range.

Coefficients for the travel time variable show the expected negative sign. Although these coefficients also appear to be very small (in absolute terms) it must be remembered that the unit of time being used is minutes ($1.00 is equal to 24 percent of the mean transportation cost; 24 percent of the mean travel time is 16 minutes). The estimated travel time coefficients are significant at the 99 percent confidence level.

These results support the hypothesis that there is a greater recreational demand response to time than money costs for the type of recreational travel observed in this study.

This conclusion can be further substantiated in two ways. First, it corresponds to the conclusion drawn in a similar study by Bouwes and Schneider. Their study also used observations on individual recreational groups, examined a small number of individual locations, and investigated the recreational consequences of changes in water quality. Bouwes and Schneider estimated a demand model which incorporated both travel cost and time, and their results were consistent with those obtained in the present study.

The conclusion that travel time is a more significant determinant of recreational demand than is money cost is also supported by its logical basis. The earlier discussion of travel time presented several reasons why the correlation coefficient between travel time and total trip cost is no higher than 0.58. Factors such as variation in vehicle fuel efficiency, variation average driving speeds and variation in gasoline price paid by different recreationists account for this low correlation. They may also account for differences in perception and reaction by recreationists to time and money costs since they make variation in money costs less apparent. Money costs of travel may be dispersed, deferrable or seen as fixed with respect to distance, particularly on short trips. Filling the car's gas tank, for example, may be a weekly event whether or not one goes fishing, but spending an extra hour driving to a more distant lake is a more apparent cost because it reduces the amount of time available for fishing.

Additional perspective on the relative importance of time and money costs can be gained by comparing an approximate shadow price of travel time with the reported money cost of recreational trips. It is attempted here through estimation of the relative significance of time and money costs for travel. If time costs converted to dollars are much greater than the actual dollar costs of recreational travel, that factor might explain part of the greater response to time than money cost.

Using the reported annual personal income (Table 3) of $16,597 and 2080 working hours per year (40 hours per weektimes 52 weeks per year), the average hourly wage rate for respondents in this study is $16,597/2080 = $7.98 per hour. The average value of recreational driving time can be calculated by using three alternate hypotheses about the relationship between wage rate and the shadow price of recreational travel time. These are that travel time should be valued, arbitrarily, at 33 percent, 66 percent or 100 percent of the wage rate, giving travel time shadow prices of $2.66, $5.31 and $7.98 per hour respectively. The average round trip driving time reported by recreationists in this study was 2.24 hours. This then yields average recreational travel time values of $5.96, $11.89 and $17.88, respectively, for the three hypotheses about travel time and wage rate. The average money cost of transportation (gasoline only) reported in this study was \$4.13 and the average total trip cost was \$8.16.

If Cesario's suggestions regarding the relationship of wage rate and travel time value are adopted, a shadow price for time of 33 percent of the wage rate would appear to be the best of the three alternatives above. This would mean that the average value of travel time in this study is \$5.96, very close to the reported average transportation and total trip costs. This evidence would not support the hypothesis that large time costs, relative to money costs, make time a more significant determinant of recreational demand.

2. Water Quality

Water quality (turbidity) is taken into consideration in the travel cost regression models in this study through the use of Secchi disk readings, by a water quality dummy variable and by means of subjective water quality ratings. It is hypothesized that water quality improvements will shift the demand curve to the right; at each price (distance) recreationists will visit the lake more frequently after an improvement in water quality. This implies that the estimated coefficient of the water quality variable will be positive.

The estimated coefficients show, in most cases, an unexpected negative sign indicating a reduction in the rate of visitation associated with an improvement in water quality. This may well be explained, however, by the lack of statistical significance at the 95 percent level. (The average statistical significance level for the Secchi disk variable coefficients is 46 percent and for the water quality dummy variable coefficients is 54 percent.) The signs of the estimated coefficients are not meaningful at this low level of statistical significance. These results indicate no perceptible influence on visitation frequency by water quality between Thornapple Lake and Middle and Gun Lakes.

It could be argued that recreationists' perceptions of water quality have a more significant effect on visitation frequency than does a single objective water quality measure. However, when recreationists' subjective ratings were incorporated the estimated coefficients were again statistically insignificant at the 95 percent level of confidence. (The average significance level was 77 percent.)

The conclusion that water quality (turbidity) does not have a perceptible effect on recreational demand can be set in perspective by looking at results from other studies. Bouwes and Schneider examined the recreational impact of changes in overall water quality. They found a significant relationship between subjective ratings of lake water quality and a composite objective measure which took into account such parameters as dissolved oxygen, Secchi disk transparency, winter fish kill, and plant growth. They then included the subjective rating measure (transformed to log values) in their travel cost regression model and detected a significant effect on recreational demand. Neither of these relationships was detected in the present study. While the reason for the difference in results is not clear, it may be that composite measures of water quality reflect overall lake characteristics which are more important to recreationists than are single pollutants.

The insignificance of the estimated water quality coefficients does not correspond to the importance which people <u>say</u> water quality has in their recreation or choice of recreational location. Respondents were asked how important the appearance of the water was in their choice of a lake for recreation. The results are shown in Table 6.

The majority of respondents feel that water appearance is somewhat or very important to them in their choice of a lake. It is essential, however, to interpret these results in light of the intentionally suggestive way in which the

Table 6

Importance of Water Appearance In
Recreational Lake Selection

Stated Importance of Water Appearance	Thornapple Lake	Middle And Gun Lakes
	---------Percent---------	
Not Important	13	11
Somewhat Important	42	34
Very Important	45	55
TOTAL	100%	100%

question was asked. The subject of water appearance is explicitly mentioned and respondents may have felt that to say that the appearance of water is not important to them would have been to display a lack of environmental sensitivity. To an earlier open-ended question with precoded response categories in which respondents were asked about the actual factors affecting their choice of a lake on the interview day, the responses were as shown in Table 7. Here only a small number of respondents mentioned water appearance as a reason for going to Gun or Middle Lakes. None at Thornapple mentioned this.

The major conclusion to be drawn from these results is that, although respondents may indicate, when prompted, that the appearance or clarity of water is important to them, far fewer will do so when no prompting is done or when a specific locational choice is referred to. This conclusion is in accordance with the statement above that the travel cost method does not reveal a recreational demand response to water quality variation. While recreationists may have a positive attitude toward the concept of clear or clean water, it does not appear to be a factor which is central in their recreational choice.

Table 7

Factors Affecting Recreational Lake Selection

Reason	Thornapple Lake	Middle And Gun Lakes
	---------Percent---------	
Desire for Variety	13	7
Distance	29	19
Expected Fishing Success	24	10
Water Appearance	0	7
Related Facilities	8	19
Other Reason for Being In This Area	10	8
Other	16	30
TOTAL	100	100

3. Other Regression Results

It can be seen in Table 5 that the $\bar{R}^2$ for each of the equations is low. Table 5 also shows insignificant coefficients for the age, sex and income variables. With regard to age and sex this result is not unexpected. Only 18 percent of the respondents in the survey were traveling alone. While it is not clear how recreational decisions are made by multi-person groups, it is likely that there are many factors affecting such decisions and the age and sex of one member of the group are not likely to be good proxies for all or most of these factors. The significance of the income factor is similarly limited. For groups made up of people from different households, information on how costs were shared would be required, as would information on each household income.

C. Bidding Game Results

Table 8 gives the results of the bidding game, including the total bid amount and the total reported visits. Since bids were collected on a per visit basis, the total bid amount is calculated within each bid category and then summed across these categories (column D). The average bid per recreational party visit is \$.92 (\$2,233.32 total bid/2,430 group visits = \$0.92). Given an estimated 17,000 recreational party visits per year to Thornapple Lake, the estimated total value of the improvement in water quality is approximately \$15,600. This result must be qualified in several respects, however.

First, it can be seen from Table 8 that a large number of respondents gave a bid in round numbers such as 0, \$0.50, \$1.00 and \$2.00. These figures clearly act as "focal points". Given the expectation of a continuous distribution of preferences for environmental improvement, the existence of these focal points may distort the true distribution of bids.

The second qualification has to do with the estimation of the total recreational use of Thornapple Lake. It was mentioned previously that the estimate of 17,000 party visits per year did not include recreationists who gained access to the lake other than through the DNR public access site or Charlton Park. The total use estimate is, therefore, an underestimate of actual recreational use of the lake. It is not known what value these excluded recreationists would place on an improvement in water quality.

Third, the ambiguity in the wording of the bidding game question, unrecognized during the administration of the survey, made it unclear as to whether respondents were expressing a willingness to pay for the improvement in water quality or for the use of the lake after such an improvement. Since recreationists would likely be willing to pay some amount for use of the lake in its

Table 8

Bidding Game Results

A. Bid Amount Per Visit	B. Number of Respondents	C. Total Number of Reported Visits	D. Total Bid Amount (AxC)
$0	38	648	$ 0
.13	1	40	5.20
.25	6	117	29.25
.50	15	571	285.50
.60	1	120	72.00
.66	1	2	1.32
.75	2	5	3.75
1.00	38	281	281.00
1.50	9	38	57.00
2.00	31	234	468.00
2.25	1	5	11.25
2.50	7	134	335.00
3.00	4	79	237.00
4.00	5	26	104.00
4.50	3	8	36.00
5.00	9	87	435.00
5.50	1	35	192.50
TOTAL	172	2,430	$2,233.32
No Response	6		

present condition, the average bid of \$0.92 per group visit must be considered an upper limit on the willingness of respondents to pay for water quality improvement. The net effect of underestimating the total recreational use of Thornapple Lake and possibly overestimating the average willingness to pay is not known, but is likely less than either of these effects alone.

Finally, there is a critical qualification of the estimated total value of water quality improvement which has to do with the way in which this bid might be collected. The implicit assumption was made in designing the bidding game question that the visitation rate per recreational party is fixed. Although the travel cost analysis in this study did not detect a recreational demand response to travel cost, there are strong theoretical reasons for expecting that individual demand curves will not be perfectly inelastic, particularly with respect to an entrance fee. Since no other information is available on what the individual demand response to an entrance fee is, however, it is impossible to define an aggregate demand curve from the bidding game results.

If there is a negative response of individual visitation rates to entrance fees, then the total bid amount (\$15,623) could not be collected by means of such entrance fees. That estimated total value of turbidity reduction at Thornapple Lake would be a valid indication of total value if the money were not going to be collected or if it were collected by some lump sum payment not related to the visitation rate. The qualification of the estimated value has apparently not been recognized in previous bidding game studies (Randall, Ives and Eastman; Brookshire, Ives and Schulze; Walsh, et al., 1978b).

A test for the existence of the strategic bias mentioned above, consisted of the estimation and interpretation of two correlations. The first is between the importance which the respondent placed on the appearance of water in selecting a lake for recreation and his bid level. In order to more accurately detect bias, only bids of 0 or \$3.00 or more were considered. The simple correlation coefficient between these extreme bids and the stated importance of the appearance of water was 0.227. Although this was slightly stronger than the correlation of all bids with the importance of water appearance, it still appears to be a weak relationship and thus supports the hypothesis that strategic bias is not significant in these bidding game results.

The second part of the test for strategic bias involves an examination of the correlation between bid level and the responses to a question concerning the reasons for water pollution at Thornapple Lake. In this case, a cross-tabulation of extreme bids and responses to the water pollution question was used, rather than a calculation of a correlation coefficient. It would be expected that those with high preferences for environmental improvement, and thus an incentive to bias their bid upward, would have a lower than average response of "don't know" concerning the source of pollution. Instead, 54 percent of those bidding \$3.00 or more said they did not know the reason for water pollution at Thornapple Lake, while only 29 percent of those giving 0 said they did not know the reason for water pollution.

While the results of either of these correlations are very weak indications concerning the existence of strategic bias, their results do correspond and make plausible the proposition that little strategic bias exists in the bidding game responses.

D. Non-Recreational Impact Results

1. Water Treatment

The description of a cost saving approach to benefit estimation identified three stages in the water treatment process that are believed to be related to the level of raw water turbidity. These are chemical treatment, filtration and sludge disposal. With respect to the analysis of chemical treatment costs, the regression model which was suggested by treatment plant managers and engineers with the Michigan Department of Public Health was:

$$CC = \alpha + \beta_1 RWT + \beta_2 TEMP + \beta_3 FWT + e$$

where CC is aggregate chemical costs per day for alum, chlorine, carbon and soda ash, RWT is raw water turbidity, TEMP is water temperature, FWT is finished water turbidity, and e is the error term. The model was estimated separately for Blissfield, Deerfield and Dundee as well as with pooled data from all locations.

The results of these analyses showed general statistical significance of the hypothesized relationships, but the average R^2 value for these regressions was only 0.10. The very low R^2 value obtained here raises questions about specification of the model. No attempt was made to pursue this inquiry further by seeking to improve the model specification.

Despite these poor statistical results, it is instructive to note the following means and standard deviations:

	Blissfield	Deerfield	Dundee
Mean daily chemical costs (alum, chlorine, carbon and soda ash)	\$30.50	\$36.65	\$36.48
Standard deviation of daily chemical costs	\$14.07	\$10.09	\$30.08

These figures are calculated for the period of January 1978 to June 1980, using June 1980 chemical prices. They give an indication of the order of magnitude of chemical treatment costs in these plants and thus of the upper bound of savings that could be realized from reduced raw water turbidity.

There would be no impact of reducing turbidity on filtration costs at Deerfield and Dundee since these plants backwash their filters at regular intervals. It is not believed that variation in raw water turbidity will have much effect on filtration costs at Blissfield either, since there appears to be only a very weak correlation between turbidity levels in raw and pre-filter water.

Plant managers suggested that sludge disposal costs may be the area where the greatest potential savings from reduced raw water turbidity lie. Because of a lack of any information on the relationship between raw water turbidity, measured in nephalometric turbidity units (Duchrow and Everhart), and the volume of sludge generated, it was impossible to investigate this area of potential benefits in any detail. Both Blissfield and Dundee water treatment plants pump their sludge directly into the municipal sewage system. The Deerfield water treatment plant discharges its sludge directly into the Raisin River, thus incurring negligible sludge handling costs. A rough indication of maximum potential benefits from the reduction in sewage treatment costs was determined to be less than $1400 per plant.

The upper limit on annual benefits from turbidity reduction for these three plants would be ($1400 per plant x 2 plants for sludge disposal) + ($34 per plant per day x 365 days per year x 3 plants for chemical costs) = $40,000 assuming (unrealistically) a total elimination of raw water turbidity, all chemical treatment, and all sludge generation. It is likely that the actual benefits from a realistic reduction in turbidity would be far below this upper limit.

2. Dredging

Two types of dredging are considered in this study. The first is the dredging of inland lakes. Efforts to determine actual dredging costs are hampered by data shortcomings and a lack of general information on the many factors involved in calculating average dredging costs per cubic yard of material removed under different circumstances.

a. Navigational Channels. The Corps of Engineers carries on dredging operations at 67 locations in Michigan. Many of these require only periodic attention in order to maintain satisfactory channel depth. For those locations at which dredging was reported during 1979, the total volume of material removed was 2,107,317 cubic yards at a cost of $5,033,688. Thus, the average cost of dredging during that year was $2.39 per cubic yard.

Many of the locations at which dredging is conducted are harbors at the mouths of rivers flowing into the Great Lakes. At some of these locations dredging must be performed to remove both sediment transported by the rivers from upstream erosion sources, and that deposited by wave action moving material along the lake shoreline (littoral drift). While data on the amount of sediment which can be attributed to each of these sources is unavailable, a rough estimate of the proportions can be gained from the estimate by the Corps that 80 to 90 percent of its dredged material must be deposited in confined disposal areas. This is polluted material and comes almost exclusively from rivers, though not necessarily from agricultural sources. Consequently, it might be safely assumed that 85 percent of the 1979 dredging cost, or $4.3 million, is attributable to river transported sediment.

The complexities of local conditions and the accounting procedures used by the Corps prevent the calculation of an average cost of disposal in confined disposal areas. In personal communication, however, members of the Corps staff stated that the cost of such disposal ranged from \$3 to \$20 per cubic yard. In a study of erosion and sedimentation in the Cuyahoga River in Ohio, the Corps of Engineers estimated the average cost of confined disposal to be \$5.29 per cubic yard. While the cost of confined disposal is highly variable and an average figure would have little relevance for any single location, applying an average confined disposal cost of \$5.00 per cubic yard to 85 percent of the 1979 volume of dredged material yields a disposal cost of \$8.9 million for confined disposal, or a total cost of \$13.2 million for dredging and disposal of river transported sediment. Wade and Heady (p. 140) report that the proportion of sediment from cropland sources is approximately 34 percent in Michigan. Thus, a total elimination of agricultural soil erosion might result in a dredging cost saving of \$4.5 million.[1] Lower levels of sediment reduction would mean proportionately less saving. Finally, no estimate is available of the potential benefits which may result when dredged material is disposed of in such a way as to restore or protect a shoreline wetland area.

b. Inland Lakes. Two inland lake dredging projects were investigated in this study. The dredging of Lake Lansing in Ingham County, Michigan, involves the removal of approximately 2,022,000 cubic yards of dredged material. Approximately 39 percent of the dredged material will be deposited in upland spoil areas at a cost of \$1.10 per cubic yard for dredging and disposal. The remaining 61 percent will go to wetland spoil areas at a cost of \$1.05 per cubic yard. These costs were quoted at 1980 price levels.

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[1] This may be an underestimate since soil conservation may also reduce the level of chemical contaminants and thus the need for confined disposal.

The dredging of the Messenger-Hodunck chain of lakes in Branch County was completed in 1976. It involved the removal of approximately 1,444,000 cubic yards of material at an average cost of $.48 per cubic yard. This cost is quoted at 1977 price levels and does not include the cost of disposal.

In assessing the importance of these results in terms of the potential benefits from soil conservation, two important qualifications must be made. First, since disposal costs are highly dependent upon local conditions and the availability and accessibility of disposal sites, these cost figures may have little relevance for predicting costs which might be incurred at another location. However, they give a rough idea of the magnitude of the cost of dredging, which may be more constant between locations, and an indication of possible disposal costs.

The second qualification which must be made is that inland lake sediment is likely to be largely organic in nature, resulting from the decay of algae and other aquatic plants rather than from soil erosion. The Snell Environmental Group indicated that the cost of dredging inorganic material is somewhat higher than the cost for organic material because of the higher specific gravity of the former. Both of the projects considered here involved organic sediment almost exclusively.

Chapter IV

Conclusions and Recommendations

A. Recreational Methodology: Comparisons of the Travel Cost and Bidding Game Techniques

Empirical investigation of the recreational impacts of sediment reduction showed a difference in the estimate of benefits derived from the travel cost and bidding game techniques. The travel cost method revealed no recreational demand response to variations in the observed range of turbidity and thus no implied willingness to pay for a corresponding reduction in turbidity. The bidding game, however, revealed an average willingness to pay of $.92 per recreational party per visit. A number of important issues are raised by this empirical result.

1. Consumer Information

A vital determinant of preferences, and therefore of demand, is the information which the consumer has regarding the characteristics of the product, its price, and the price and characteristics of substitute products (Markin). Goods such as environmental improvements are distinctive in the complexity of their characteristics, making it difficult for consumers to be fully aware of the complexities of the physical relationships involved in erosion, sediment transportation and the impact of sediment on environmental services, and thus the preferences which they reveal for environmental improvement are based on incomplete information. These preferences may also change as information is added.

In light of these considerations it is significant that the travel cost and bidding game techniques do not measure demand for an environmental improvement or other good with the same implicit level of consumer information. The travel cost method examines recreational patterns and the inferred demand for environmental improvement without additional information being imparted during the measurement process. The bidding game, on the other hand, describes and draws attention to the product in question. In this study the existence of turbidity in Thornapple Lake and its relationship to soil erosion were described for respondents before their bid was sought.

A second distinction between the two techniques is the extent to which they require explicit consideration of consumption trade-offs. The travel cost technique is based on past behavior and choice in which habit may have been important. The bidding game, however, requires respondents to consider a new product and their willingness to pay varying prices for it. The explicit choice which the bidding game requires is likely more reflective of the conscious choice which they would have to make if faced with a newly imposed or increased entrance fee. In this respect, it may be a more realistic indicator of short run consumer response to a fee.

The bidding game is also distinctive in that it draws attention to one product at a time and does not ask or require respondents to consider consequent adjustments in other purchases.

A final distinction between the travel cost and bidding game treatment of consumer information is that the former examines consumer response to existing static differences in environmental quality among sites while the latter asks respondents about their reaction to change in quality at a given site. Questions regarding a change may provide more information on short run than long run demand response.

It is clear that the travel cost and bidding game techniques are potentially quite different from one another in terms of the amount of consumer information which is implicit in the measured level of demand. In actual practice this difference will depend on the good in question, the amount of prior information which respondents possess, and the amount of learning which takes place during the measurement process.

Given these differences, it is impossible to make a strictly technical choice between the travel cost and bidding game approach on the basis of their treatment of consumer information or to say whether the value of reduced turbidity at Thornapple Lake is 0, \$.92 per recreational party per day, or some other value that might have been determined had a different amount or type of information been provided to respondents. The difference between the benefit estimates derived by the two techniques is, at least in part, attributable to the difference in their provision of information.

2. Other Methodological Comparisons

Although the differences in the provision of consumer information by the bidding game and travel cost techniques may be an important factor in explaining the empirical results of this study, other characteristics of the two methods could also account for such results.

a. Income Restraint. An important characteristic of the bidding game is that it does not force the normal income restraint or consideration of trade-offs in consumer choice. It does not necessarily give the same income weights to consumer preferences as does market-expressed, effective demand such as is measured by the travel cost method, but bids are not necessarily unrelated to income. Respondents with low incomes, for example, may relate their bid to their normal expenditure level, particularly if they do not consider the game purely hypothetical. It is, therefore, possible that the bidding game yielded a higher benefit estimate than did the travel cost technique because respondents were unconstrainted by their normal budget restrictions present in actual market choices.

b. Sensitivity to Wording. The bidding game approach is potentially very sensitive to question wording, and the possibility of strategic response bias and inaccuracy in assessing preferences were discussed earlier. The precise definition of the "product" and the information which is conveyed regarding its characteristics will likely have a decisive effect on the average bid. The travel cost technique is likely to be less sensitive to question wording, but is sensitive to such things as the accuracy with which respondents recall the requested information and their subjective assignment of costs among multiple purpose trips. Travel cost results are also sensitive to the chosen analytical procedures and the assumptions employed.

c. Benefit Definition. The approach chosen in defining benefits will clearly affect the magnitude of the estimated benefits. In the present study the travel cost analysis did not detect a recreational response to variation in turbidity over the observed range. Since there was no need to select a particular definition of benefits, this issue did not affect the observed difference in results from the travel cost and bidding game methods.

d. Option Demand. A well-known feature of the bidding game is its potential capability of measuring option demand or other demand from nonusers. This clearly distinguishes it from the travel cost method.

e. Product Specification and Experimental Design. A critical aspect of a bidding game is its specification of a standard "product." In cases where potential water quality improvement is being investigated, the best definition of a standard amount of improvement will depend on the particular situation. Photographs, a reference lake or river may be used, but using a reference location in a bidding game will raise the problems of experimental design which are present in the travel cost method.

The experimental design problem in the travel cost method is one of controlling the influence of factors other than the one in question.

f. Detection of Strategic Response Bias. Considerable attention has been given in past theoretical and empirical studies of the bidding game to the reduction of strategic response bias. This study presented and applied a weak test for the existence of strategic response bias, using measures of correlation between extreme bids and indicators of respondents' preference for environmental improvement. It is one which seems to have potential for improvement.

g. Observational Unit. The observational unit used in this study's travel cost analysis was the recreational party. This procedure is practicable only in situations where multiple annual visits are common. Its use allowed the inclusion of travel time in the model without raising the complex problem of the determination of a shadow price for time. It also allowed the assumption of homogeneous origin zone characteristics to be relaxed.

h. Spatial Validity of the Travel Cost Method. One criticism of the travel cost method has been the lack of correspondence between recreationists' responses to travel costs and entrance fees. The response to travel costs may well differ from the response to an entrance fee if recreational trips are short and travel costs are low. For example, within a certain range, a recreationist may not associate the cost of gas directly with the particular trip and therefore may not respond to variations in gas cost.

This implies that there may be spatial limits to the travel cost method defined by recreationists' response to costs of various sizes. Clawson and Knetsch (p. 77) mention the inappropriateness of the travel cost method for analyzing recreational demand at what they refer to as "user-oriented areas." They point out that one shortcoming of the travel cost method in this case is the difficulty of accurately defining travel costs. The weakness of the technique for analyzing short distance recreational travel is also due to the fact that many recreational locations such as county parks, state boating access sites or small state parks may fall into the category in which there is limited perception of money costs.

The empirical results of the present study did not reveal the expected relationship between money costs of travel and the level of recreational demand. It may be that the average one-way travel distance of 28.4 miles (standard deviation 31.3 miles) is below the lower limit for the valid application of the travel cost method. This minimum distance limit is imposed by characteristics of recreational decision making and not by the use of simplifying assumptions.

Smith and Kopp argue that there is a maximum spatial limit for the travel cost method imposed by the assumptions of single purpose recreational trips and homogeneous travel mode and on-site time. They believe that as average recreational travel distance increases each of these assumptions is likely to be less tenable, thus imposing an outer limit to the average trip distance to which the travel cost technique can be applied.

B. Benefit Size and Incidence

1. Recreational Benefits

It is impossible to generalize the results of this study's recreational analysis to a statewide benefit estimate. It is impossible to determine how much recreationists would be willing to pay for turbidity reduction at other locations. The lake survey of several recreational lakes in southwestern Michigan revealed only Thornapple Lake as having high sediment delivery rate, high recreational use, and characteristics where turbidity might be significantly affected by soil conservation. Thus, it appears that potential recreational benefit estimates from sediment delivery reduction at Thornapple Lake cannot be extended to other lakes in that part of the state.

2. Water Treatment Benefits

Criteria for selecting the three treatment plants were that turbidity in their raw water was periodically very high and that they did not soften their treated water. The upper limit on total benefits from a reduction in raw water turbidity at these three plants was estimated at $40,000 per year. It is likely that actual benefits from some feasible reduction in turbidity would be far below this estimate. Furthermore, since turbidity at other Michigan municipal water treatment plants is lower than at the three which were selected and since the total number of such plants is small, it is likely that total benefits from soil conservation for turbidity reduction would be small.

3. Dredging Benefits

Dredging costs incurred by the Corps of Engineers in Michigan during 1979 were approximately $5 million. Of this, approximately $4.3 million could likely be attributed to river transported sediment. The estimation of disposal costs is much less accurate, but using a conservative figure of $5 per cubic yard, it appears that disposal costs attributable to river transported sediment were approximately $8.9 million in 1979 in Michigan, making a total of approximately $13.2 million for dredging and disposal for the maintenance of navigational channels. Assuming that approximately 34 percent of total sediment in Michigan is derived from cropland sources (Wade and Heady, p. 140), the maximum dredging and disposal cost saving per year at 1979 price levels would be approximately $4.5 million. Since these benefits accrue as cost savings and it can be assumed that the rate of sediment deposition does not affect the nature of the "product" (dredged channels), the result of reduced sedimentation would be smaller budget requirements for dredging by the Corps of Engineers. Finally, no estimate is available of the potential benefits from disposal of dredged material in such a way as to restore or protect a shoreline wetland as is being done in some locations in Michigan.

Inland lakes dredging projects appear to be infrequent and the proportion of dredged material resulting from soil erosion appears to be relatively small. Potential benefits in this area from soil conservation are likely to be limited to particular sites with special characteristics.

An accurate assessment of the actual benefits from a statewide soil conservation program would involve converting a geographical pattern of conservation practice adoption into a geographical pattern of sediment reduction. The complexity of the physical and biological relationships involved in determination of appropriate sediment delivery rates into objective turbidity units make this a very difficult undertaking.

C. Policy Relevance

One of the significant results of the present study is that it provides guidance for future use of the travel cost and bidding game techniques. The technical and public choice issues which this study has raised should be considered before these procedures are employed for similar studies in the future.

Technical issues relevant to the travel cost method include such things as the spatial limits within which the technique can be validly applied, the choice of a unit of measurement for the dependent variable, and the isolation of single environmental factors through experimental design and statistical control. The technical issues involved with the use of the bidding game method include the matter of "product" specification (communication to respondents of the nature of the good for which they are to offer a bid) and the likely trade-off between strategic bias and response accuracy in terms of the hypothetical nature of the bidding game.

The technical issues that are involved with the travel cost and bidding game methods may directly limit the applicability of the procedure or they may introduce error into the results where assumptions are used which are not well founded. In some cases the collecting of additional information may allow these assumptions to be relaxed, but information acquisition may be costly.

In addition to these technical matters, a number of public choice issues must be kept in mind in using either technique. One of these has to do with consumer information and the sensitivity of the bidding game to question wording. Another public choice issue is the definition of benefits or the procedure by which benefit estimates are to be derived from a demand curve. An approach to deal with these public choice issues should consider three factors. First, it is essential that the analyst recognize the issue as being a matter of public choice and not a technical question. Second, the public decision maker should be informed of the issue in some way. It may be possible to display alternate results corresponding to alternate answers to the issues involved. For example, if a single-price measure of benefits is to be employed, varying benefit estimates corresponding to varying price levels can be shown. Third, it might be possible in some cases to involve the public decision maker in the design of the procedures to be used. This would be appropriate, for example, with respect to the issue of the level of consumer information where the decision must be made prior to data collection.

A number of the technical issues which this study has raised with respect to the travel cost and bidding game methods have been previously dealt with in the literature. For example, is there a dependable relationship between bid level and the amount of information provided to the respondent? What are the minimum and maximum spatial limits of the travel cost technique? Additional investigation is required to extend, substantiate or amend the conclusions which this study has drawn and the policy implications which have been stated.

Although the major focus of this study has been on the methodology of environmental benefit evaluation, distributional conclusions are also important. Information on the size and pattern of benefits resulting from program alternatives can help the decision maker arrive at an informed choice between program alternatives. In the case of water quality improvement, the choice might be between a soil conservation program which would deal with a cause of non-point source pollution and a downstream pollution management program (Sharp and Bromley). Information on the full effects of both alternatives would be very useful in making a choice between them.

A second function of distributional information is to facilitate decisions on cost sharing. The incidence of benefits from a public program provides one pattern for sharing program costs. Perhaps large off-site benefits (reduction in sediment induced damages) from soil conservation should be accompanied by public subsidies to encourage implementation of conservation practices. These subsidies could take the form of generous cost sharing arrangements with farmers and land owners, financed perhaps through some type of fee schedule levied on beneficiaries. A much different pattern for sharing the costs of soil conservation would result from the imposition of land use regulation to control soil erosion, or penalties (taxes) for excessive soil loss (sediment production) as an alternative mechanism to encourage compliance and adoption of soil conservation measures. The funds obtained from penalties levied for noncompliance could be earmarked for the mitigation of off-site costs or damages resulting from waterborne sediment. These hypothetical examples demonstrate that whatever the public choice, information on benefit size and incidence is a vital input in selecting from among the various policy alternatives available.

A final policy implication of this study derives from the complexity of physical relationships such as the processes of erosion and sediment transport and the number of potential sediment and turbidity sources. It is not possible, given the current state-of-the-art, to attribute off-site benefits to specific soil conservation activities in anything more than a very general manner beyond the level of an individual field or small run-off area. Even if this research had been able to identify large off-site benefits, the implications for agricultural soil conservation programs and related cost sharing would not have been clear. Further investigation and understanding of the physical processes is needed before downstream benefits from water quality improvement can be confidently linked to soil conservation activity in the upstream watershed.

D. Suggestions for Further Research

At many points throughout this study unanswered questions have been raised and limitations acknowledged. These present opportunity for further research into the methodological issues of benefit evaluation and the distributional consequences of soil conservation.

1. Physical Questions

There is considerable imprecision in the current understanding of the relationship between soil conservation and downstream water quality. The use of empirical models such as the Universal Soil Loss Equation (Wischmeier and Smith) and sediment delivery ratios is possible, but these need much more refinement. This may be achieved through the incorporation of information on the mechanical processes of erosion and sediment transport, topics which are currently under investigation.

Additional information is also required on the impacts of sediment on environmental services. It is impossible to investigate the economic consequences of a change in sediment concentration, for example, if it is not known how this will affect the turbidity of water, the survival of fish species or other casually perceptible features. Investigation of this topic would enable a comparison to be made between various units such as cubic yards of deposited sediment and Secchi disk turbidity measurement.

Third, the physical relationships and "production functions" having to do with municipal water treatment are not well understood. Incomplete information on the relationship between turbidity and both chemical treatment costs and sludge disposal requirements was an impediment in the present study. Similar questions may exist in other water using processes.

Finally, additional data are required on the physical characteristics of recreational locations. For example, there is little information on turbidity levels in Michigan lakes.

2. Economic Questions

One set of "economic" questions raised by this study has to do with the psychological basis of consumer demand. These questions are fundamental to the construction of demand models such as those used here. First, are people able to distinguish fine variations in water quality without additional information? If they are not, then the basis for measuring marginal valuation of of environmental quality changes is placed in question. Second, do consumers perceive various costs differently and do they hold different attitudes toward them? Also, how is the magnitude of the costs related to perceptions and attitudes? In the case of recreational demand, the magnitude of travel costs is related to distance traveled and thus the type of recreation area being studied.

In addition to these fundamental psychological issues, there are a number of researchable questions relating specifically to the travel cost and bidding game techniques. There are also a number of suggestions for designing future research projects which may use the travel cost method or a bidding game in evaluating the recreational or aesthetic impacts of environmental change.

a. Travel Cost. One of the very important issues in the use of the travel cost technique is the specification and form of the demand model. The specification and form which are chosen will usually have a decisive effect on the estimated coefficients which are used. Studies which use the travel cost technique should state as clearly as possible what the theoretical expectations were which formed the basis of the chosen form and specification and then state the findings with respect to these expectations.

Another important issue raised by this study is the possibility of a minimum average travel distance to which the travel cost technique can be validly applied. It may be that recreational travel which consists predominantly of day trips is not suitable for analysis by this technique. The results of the study by Bouwes and Schneider give some support to this suggestion , but further investigation is clearly needed.

Closely related to the selection of model specification and form is the choice of observational unit. This study has used the individual recreational party as the observational unit, though potential problems with respect to variable group composition and definition of visitation frequency were noted. Future studies would do well to experiment with alternate observational units, possibly comparing more than one in a single study (Boyet and Tolley, Wetzstein and McNeely).

Another aspect of the model specification issue is the treatment of travel time discussed at length above. A key factor in determining the approach which will be used in treating travel time is the correlation between time and money costs of recreation given different observational units. This correlation will not be known, however, until the data are collected and analyzed. It would seem to be appropriate, therefore, to collect data on a disaggregated observational unit so as to leave open several optional levels of aggregation for analysis.

Experimental design is another very important issue in the use of the travel cost technique. There appears to be no substitute for a thorough familiarity with the field setting for the research project. The objective is to be able to distinguish the effect of the environmental change in question from all other factors influencing recreational demand. Some combination of experimental and statistical control will likely prove to be most satisfactory. The potential problems of unavailable data, such as on recreational location characteristics, and the complexity of recreational demand patterns must be appreciated before embarking on a research project in this area. In the present case, close to one-half the total time for the research was spent on this topic.

b. Bidding Game. Several interesting and potentially important issues with respect to the use of bidding games have been raised in this study. Further investigation of each of these is needed. First, what is the responsiveness of bids to variations in the amount and type of information conveyed in the bidding game? This question does not appear to have been recognized or investigated in previous uses of the bidding game. A related issue has to do with the responsiveness of bids to various incentives to strategic behavior. Most of the evidence from previous studies suggests that strategic bias is not, in practice, a serious problem. Further investigation of the relative importance of strategic bias and of the divergence between equivalent and compensating variation measures of consumer surplus would also be useful (Bishop and Heberlein).

Attention must also be given in future use of bidding games to the trade-off between strategic bias and response accuracy. The perspective of costs and returns to accuracy, suggested by Freeman (1979), seems useful in designing questions which will encourage increased accuracy without encouraging bias. Techniques such as the development of rapport between interviewer and respondent may increase the incentive for accuracy without raising the incentive for strategic response. Similarly, questions should require a minimum of effort by respondents, thus lowering the cost of accuracy which the respondent faces. This may be accomplished by reducing the hypothetical nature of the bidding game, though there is a trade-off here with strategic incentives and the capability to deal with such matters as option demand.

Finally, a very important issue in the design of the bidding game question is the manner in which the "product" will be specified. As discussed, it is possible to use such techniques as photographs, proposed adjustments in subjective scales, or simply a broad and possibly imprecise description such as that used in the present study. The choice of a method for conveying such information will obviously depend on the nature of the product in question. Some products can be easily defined and communicated while others, which involve multiple perceptual dimensions (e.g., sight, odor, taste) will be difficult to convey. Not only is there a question of accuracy and experimental control here, but the issue of the level of consumer information is clearly present.

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