Economic Benefits of Reducing Mercury Deposition in Minnesota

This study was conducted on behalf of the

Minnesota Pollution Control Agency
and
The Legislative Commission on Minnesota Resources

by

Daniel A. Hagen, Ph.D.
Department of Economics
Western Washington University
Bellingham, Washington

James W. Vincent, Ph.D.
Department of Economics
University of St. Thomas
St. Paul, Minnesota

Patrick G. Welle, Ph.D.
Department of Economics
Bemidji State University
Bemidji, Minnesota

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Executive Summary

The State of Minnesota is considering the development of policies which would place limits on the emissions of mercury into the environment. Reduced deposition of mercury is projected to have beneficial human-health and environmental effects. These effects produce economic benefits, the estimation of which is the objective of this study.

Many of the economic benefits of improved environmental quality are not reflected in market-based transactions, thus there is no market mechanism in which people can reveal their willingness to pay for environmental quality. Therefore, in order to estimate the total economic value of improvements in environmental goods and services, a method is required which allows the estimation of economic benefits from non-price (non-market) data. A stated-preference estimation technique known as contingent valuation is employed.

Contingent valuation employs a survey in which the prospective policy and its effects are described. The survey also indicates to the respondent how much it would cost their household (through higher prices for goods and services) if the policy were adopted. Respondents are then allowed to state how they would vote in a referendum on this policy, given its effects and financial consequences. On the basis of peoples' stated choices it is possible to estimate the economic value people attach to the policy and its effects.

For this study a mail survey was sent to 2,500 Minnesota households and personal interviews were conducted with 250 others. The responses to the survey allows the monetization of the benefits that respondents see the described policy as producing. A statistical valuation function was estimated, and from this information the average annual willingness of Minnesota households to pay for the policy was computed.

This study evaluated the benefits that respondents derived from four different policy scenarios affecting anthropogenic mercury emissions: (1) a 50% reduction in Minnesota emissions, (2) a 50% reduction in regional Midwest emissions, (3) a 50% reduction in U.S. emissions, and (4) a 50% reduction in world-wide emissions. This study devoted most of its attention to a "baseline" scenario, the 50% reduction in regional Midwest emissions. This policy was projected to reduce mercury deposition in Minnesota by approximately 12%.

For the baseline policy scenario, the mail survey resulted in a "best estimate" of annual household willingness to pay of $118.91. The best estimate for the personal interview sample show a higher willingness to pay of $198.03, possibly indicating "yea-saying" behavior resulting from the personal nature of the interview procedure.

Using the more conservative mail-survey estimate, a state-wide willingness to pay can be computed by multiplying the per-household figure ($118.91) by the number of households (1.786 million in 1996) to yield an annual state willingness to pay of $212 million. With a state population of 4.683 million (1996 estimate) this translates into a figure of approximately $0.12 per person per day.

Section I.
Introduction

Mercury emissions into the environment raise concern because of the known toxicity of mercury in its various chemical forms. Mercury, particularly in its methylated form, bioaccumulates in the flesh of fish and is consumed by fish-eating species. The State of Minnesota tests lakes for the mercury content of fish. The Minnesota Department of Health has established guidelines for recommending restrictions on fish consumption if the mercury content is sufficiently high. Other agencies, such as the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources, have conducted or reviewed research which raises other environmental concerns, such as adverse effects to fish-eating wildlife. In light of this information, additional research has been conducted on the science of mercury emissions, transport, exposure and toxicity. This study described in this report focused on an economic aspect of environmental mercury. This research involved estimating the willingness of Minnesota households to pay for reductions in mercury emissions, given the current state of scientific understanding about the sources and effects of environmental mercury.

Ordinary goods and services which are traded in markets have prices which are indicators of their economic value. Market price data are relatively easy to obtain, thus facilitating efforts to estimate the economic benefits associated with marketable goods. In contrast, the benefits produced by reduced mercury pollution are not fully revealed in market transactions. In order to estimate the economic value of improved environmental quality, methods which infer economic value from non-price data must be used. This study employed a method with which willingness to pay can be estimated from peoples' stated preferences. This is known as the contingent-valuation method. The contingent-valuation method is a survey technique which is designed to elicit the willingness of a household to pay for a policy which will produce benefits for that household. This is a non-market analogue to the observation of a market transaction in which a consumer reveals his or her willingness to pay the market price for a good.

This report provides results from a state-wide contingent-valuation study which was designed to elicit the willingness of Minnesota households to pay for reductions in adverse health and environmental effects which result from mercury deposition. This study employed a dual mode of survey administration: mail and personal-interview. The mail survey was sent to a sample of 2,500 Minnesota households, and personal interviews were conducted with 250 households. On the basis of responses to this survey, a valuation function was statistically estimated. The results of these estimates provide information on the economic benefits Minnesota households receive as a result of projected reductions in adverse effects associated with mercury deposition.

Outline of the Report

Section II of this report summarizes some of the scientific information on mercury and its environmental effects. Section III lays out the conceptual principles which underlie the economic benefits of improved environmental quality. Section IV provides a brief overview of techniques which are employed in the estimation of the economic value of improved environmental quality.

Sections V through VIII describe the contingent-valuation method in general, and how the survey instruments for this study were designed and administered. Section IX contains results from the statistical analysis of the survey data. Estimates of willingness to pay are provided and the models from which they were derived are described. A set of appendices provides details and exhibits which supplement the discussion contained in the report.

Section II.

The Context for Possible Mercury-Emissions Policy

Atmospheric deposition of mercury raises concerns about a variety of possible environmental and health consequences. Mercury, particularly in its methylated form, bioaccumulates in the aquatic environment and principally affects piscivorous species, including humans. The primary pathway of exposure to environmental mercury is through fish consumption.

The State of Minnesota samples fish from lakes in order to test for toxic substances. The Minnesota Department of Health has developed criteria for setting "fish-consumption advisories". These advisories recommend limits on fish consumption depending on the concentrations of mercury and PCBs which are found in the fish. The stringency of the advisories vary by fish species, size class and by the sensitivity of the consuming population (e.g., children under six and women of child-bearing age).[1]

In addition to possible human-health effects, the possible impact of mercury accumulation on ecosystem integrity is of concern. Animals that rely upon fish for their diet may be receiving mercury exposure sufficient to cause adverse health or behavioral effects. Birds such as eagles and ospreys, and mammals such as river otters consume fish as a large proportion of their diet.

In order to provide a factual basis for the estimation of the benefits of mercury reduction, and ultimately for the development of sound emissions policy, a comprehensive study of mercury sources, human-health effects and environmental effects was undertaken. This study, "Impacts of Mercury Reduction in Minnesota", was conducted by Douglas Rae, a consultant for Hagler Bailly Services, Inc. of Boulder, Colorado. The following is a brief summary of some of the findings.[2]

The study found that the human-health effects of exposure to environmental mercury are possible developmental problems in fetuses and small children, and possible neurological problems in adults. Exposure to levels of mercury that would demonstrably result in these adverse effects would appear to be limited to populations that do not heed or are unaware of the fish-consumption advisories. However, there is substantial uncertainty regarding the behavior of such populations, and regarding the extent to which some peoples' exposure to mercury is increased by the presence of mercury-containing dental amalgams.

Evaluation of the state of science on other environmental impacts revealed several species of piscivorous animals that may be receiving doses of mercury sufficient to cause

[1] Although the fish-consumption advisories are based on both mercury and PCB content, the analysis conducted for this study focused solely on the mercury component.

[2] For a complete discussion see Rae (1997)--the full study has been included as Appendix A to this report.

adverse effects. Four bird species (bald eagles, common loons, belted kingfishers and ospreys) and two mammal species (river otters and mink) were identified. Disorders such as reduced reproductive success and reduced predatory success have potential implications for individual animal viability and for population stability.

The study also examined sources of mercury emissions and, using this information, predicted the likely effect on Minnesota deposition of a range of control strategies. Approximately 70% of mercury emissions worldwide are anthropogenic, with the remainder being natural background emissions. Of the mercury deposited in Minnesota, approximately 70% comes from all global anthropogenic sources. Of this 70%, it was estimated that 10% comes from Minnesota sources, 25% comes from regional Midwest sources (including Minnesota), and 42% comes from all U.S. sources (including the Midwest). The remaining 28% of anthropogenic mercury comes from non-U.S. countries.[3]

In addition to consolidating and interpreting research results on the effects of mercury in the environment, the Rae study estimated the impact in Minnesota of four different mercury-reduction scenarios. A reduction in anthropogenic mercury emissions was considered at each of the following policy scopes: (1) a 50% reduction in Minnesota emissions, (2) a 50% reduction in emissions from the upper-Midwest region, (3) a 50% reduction in U.S. emissions and (4) a 50% reduction in global emissions. Given the contribution of each of these more-inclusive sources to Minnesota deposition, these policy scenarios would reduce deposition in Minnesota by 5%, 12.5%, 21% and 35%.

This range of options was considered to be a useful starting point for policy analysis. Gaining an understanding of the value people attach to the environmental and human-health effects projected for each scenario was regarded as important information in assisting the State of Minnesota in developing sound mercury-emissions policy.

The economic-valuation study devoted most of its attention to a policy scenario deemed to be of greatest interest to policy-makers. This case is the 50% upper-Midwest reduction scenario, resulting in a 12.5% reduction in Minnesota deposition. (This will hereafter be referred to as the 12% scenario, as the 12.5% was changed to 12% for clarity in the economic-valuation survey.) The other policy options were evaluated for comparative purposes and to be able to test the validity of the economic-valuation instrument.

The information presented in the economic-valuation survey provides a comprehensive summary of the informational context in which mercury-emissions policy is being deliberated. The following is a verbatim excerpt from the mail-survey instrument for valuation of the 12% deposition-reduction scenario:

[3] See Rae (1997), Chapter 2.

THE EFFECTS OF MERCURY IN THE ENVIRONMENT

Almost all of the mercury deposited in our environment comes from the air.

- *About 30% comes from natural sources.*
- *About 70% comes from air pollution.*

Mercury pollution is regulated separately from the more common air pollutants like sulfur dioxide and carbon monoxide, for which there are both state and federal regulations.

Effects on Humans

Fish as a source of mercury

A major way in which humans are exposed is through eating fish. Mercury builds up in the tissues of fish, especially freshwater fish.

Limits on fish consumption help protect human health

Some fish contain enough mercury that the Minnesota Department of Health issues advisories recommending limits on the amount of fish eaten from some lakes and rivers. It is safe to consume fish from these lakes and rivers in quantities below the recommended limits. It may not be safe to consume fish in quantities above these advisories.

Most advisories apply to walleyes, northerns, trout, bass and other predator fish

The advisories apply primarily to predator fish (such as walleye, northern pike, lake trout, and bass) which build up mercury by eating smaller fish. There are relatively few advisories on pan fish (such as crappies, bluegills, and sunfish).

The advisories may cause some anglers to change or restrict their fishing

Fish advisories may cause some anglers to avoid fishing on lakes where they would otherwise fish or to switch to species of fish that they find less desirable. ***Advisories are more strict for young children and women of child bearing age***

- Because young children and fetuses are the most vulnerable to health damage from mercury, these advisories are more strict for children under six and women of child bearing age.

- Some health experts are concerned that children may be delayed in walking and talking or

suffer reductions in learning abilities similar to those caused by exposure to low levels of lead.

Some Minnesotans may be experiencing health effects, but these possible effects have not yet been documented

- At present, it is difficult for medical studies to determine whether or not any Minnesotans are experiencing health effects from exposure to mercury.

- While there are no documented cases of adverse health effects, up to five percent of Minnesotans (primarily anglers and their families) are eating enough mercury-tainted fish that it is possible that some undocumented health effects could be occurring. These people are being exposed to mercury above the level which medical scientists consider safe, but below the level where medical symptoms are easily observed and quantified.

- Exposure to much higher levels of mercury found in other parts of the world show that mercury can cause kidney problems, nervousness, insomnia, tremors, blurred vision, slurred speech, and fatigue.

Effects on Wildlife that Eat Fish

Some birds and mammals that eat fish are at risk

The primary risk to wildlife is to some birds that eat fish, including eagles, osprey, loons, and kingfishers. Mammals that eat fish, such as otters and mink, seem to face less risk than these birds.

Possible effects to animals include reproductive, muscle, and nerve damage

- The possible effects on birds and mammals that eat fish are to the muscles and nervous system, as well as possible decreases in their ability to bear and raise offspring.

- State, federal and university scientists have concluded that some fish-eating birds may die due to muscle and nerve damage caused by mercury. This damage may reduce their ability to catch food or avoid predators.

Local populations of some birds may be at risk

- Individual birds and local populations of these birds may be at risk on some lakes when fish contain mercury above the level which scientists consider safe, but below the level where wildlife damages are easily observed and quantified.

- While studies have shown that eagle populations are increasing due to decreases in chemicals such as DDT, little research has been done on whether mercury pollution may be affecting local populations of eagles or other species.

Plants, plant-eating animals, and the fish themselves are NOT at risk

Plants and plant-eating animals are not damaged by mercury at the levels found in the Minnesota environment. While mercury builds up in fish, and may damage the health of animals that eat fish, the amount of mercury found in Minnesota lakes and rivers probably doesn't damage the health of the fish themselves.

INFORMATION ABOUT THE PROPOSED LAW

Minnesota and other Upper Midwest states would limit emissions

The State of Minnesota is considering a regional mercury reduction program, which would limit future mercury emissions to half (50%) of the level of recent years, which is about 10,000 pounds per year in Minnesota. Other states in the region (the Upper Midwest) would join in placing this cap on mercury emissions.

Sources of Mercury Air Pollution

The three main sources of mercury emissions that would be reduced by the program are:

- coal-burning electric power plants
- incineration of garbage that contains mercury
- some manufacturing processes

In considering this program, it is important to keep in mind the following facts:

12% reduction in mercury deposition (full effect after 20 years)

- Of the mercury that is deposited in the Minnesota environment, about 25% comes from pollution emitted in Minnesota and the other Upper Midwest states. (The rest comes from other states, other countries, or natural sources.)

- The 50% reduction in emissions would thus result in about a 12% reduction in the amount of mercury deposited in Minnesota and these other states. The reduction in emissions would cause mercury deposition to begin to decline almost immediately, but the full 12% reduction in the mercury content in fish would take about 20 years to occur.

Reduction of most restrictive advisories for about 10% of fishable lakes

- Minnesota has nearly 6,000 lakes that are fishable. Based on the lakes that have been tested, about 70% have advisories that women of child-bearing age and children under six eat no more than one meal per month over the course of a year, or eat no fish at all.

- Due to the proposed mercury reduction, these most restrictive advisories would decrease from roughly 70% of the lakes down to about 60%. The mercury content in some rivers would also be reduced, but nearly all the reduction in advisories would be for lakes.

The number of lakes with fish which pose risks to wildlife would decrease

The percentage of lakes which pose risks to wildlife would change as follows:

Percentage of Lakes Where Species May be at Risk

Species	Now	Under Program
Kingfishers	50%	35%
Ospreys	35%	20%
Loons	6%	4%
Eagles	6%	4%
Otters	2%	0%
Mink	2%	2%

Section III.
Emissions Reduction and Economic Benefits

Economic Goods Defined

The usefulness of economic analysis in the evaluation of policy options derives from the fact that policy changes produce costs and benefits. While the economic costs of more-stringent emissions policies are understood by most people at a general level (e.g., costs of production may rise, resulting in price increases), the economic benefits are often less apparent. This is due, in part, to the fact that improvements in the quantity or quality of environmental goods and services are typically not the kinds of economic goods for which people "vote with their dollars" in the marketplace. Nonetheless, such improvements in environmental services are economic goods in a very real sense.

An economic good is something that produces improvement in human well-being. (In economic-theoretic terms, this means that there will be positive demand at a zero price.) Economic goods provide value irrespective of whether the good is traded in a market. Therefore, policy changes which result in improved or additional environmental services (e.g., greater opportunities for fish consumption, reduced risk to wildlife) can be viewed as "producing" economic goods, as long as some people receive value from such goods.

Categories of Economic Value

Economic goods reveal their value in two principal ways: through "use value" and through "passive-use value". Use value is said to be obtained when someone gets satisfaction from some form of direct interaction with the resource. For example, people may engage in activities such as fishing or wildlife watching in Minnesota's aquatic environment. Improvements in the quantity or quality of the resources that enable these activities will thus result in an increased quantity of goods that people value.

Value can also accrue to those who do not use the resource in a conventional sense. Some people may derive increased satisfaction (well-being) simply from knowing that measures are being taken to ensure ecosystem health, even if they do not pursue activities (such as fishing) as a resource user. These people derive economic value in a passive manner. A type of passive-use value that has received substantial attention in the literature is that of existence value.[4] There are several possible motives underlying existence value. These may include altruism, the desire to leave a bequest to future generations, or perhaps the capacity of people to derive satisfaction directly from the knowledge that ecosystems are being protected. Existence value has been identified in a variety of contexts, including for natural resources, places of historic significance, and great works of art.

[4] This concept was first articulated by Krutilla (1967). See Mitchell and Carson (1989) for an overview.

Market vs. Non-market Provision of Goods

At this point a central question about policy-making arises. If environmental improvements are economic goods, does their provision need to be assisted by a public-policy process rather than being left up to market forces? If the answer to this question is “yes”, then development of sound policies would require information on the magnitude of value people attach to the additional production of environmental goods and services. If the answer is “no’, then perhaps the marketplace would do an adequate job of providing the proper level of environmental services. As is discussed below, the economic characteristics of many environmental goods and services lead to the answer of “yes”.

Some goods, typically known as “private” goods, have a characteristic referred to as rival consumption. Such goods tend to be compatible with provision by the private marketplace. The value of a unit of such a good is realized only by the person consuming it. For example, consumption of a slice of pizza by one person precludes the consumption of that slice by anyone else. In the case of a private good, such as a slice of pizza, it makes economic sense to produce it if there is a person who places sufficient value on it to pay for the cost of production. Since each unit of a private good produces value only to the person consuming it, the value of the good is the value attached to it by that one consumer. In addition, the prices that people pay in the marketplace reveal information about the strength of economic value they attach to such goods.

Other goods have a characteristic known as non-rival consumption--these goods are collectively consumed, and are conventionally known as "public" goods. One person’s accrual of benefits from lower mercury content in fish, for example, does not "use up" or preclude anyone else from receiving benefits from the same environmental improvement. While there is some rivalry in the actual harvesting of fish, much of the economic benefit of a cleaner aquatic environment collectively benefits all users. In the case of passive-use value, consumption is non-rival in its purest form.

The public-goods character of many environmental resources results in distorted incentives in private markets, typically causing their underprovision. The absence of private markets for such goods means that people do not have the opportunity to "vote with their dollars". This implies that public intervention may be necessary to ensure provision of adequate levels of these goods. In addition, the lack of markets results in an absence of the price information which reveals economic value. An additional implication is that the value of each unit of the public good is the *sum* of values placed on it by each potential consumer. This is because the non-rivalry of the consumption allows each unit of the good to be enjoyed by all consumers.

Section IV.
Methods for Inferring Economic Value

Methods for estimating the willingness to pay (WTP) for environmental improvements fall into two classes: revealed-preference techniques and stated-preference techniques. Revealed-preference approaches involve examining peoples' behavior, and using this information to draw conclusions about WTP. Stated-preference approaches involve the use of surveys to elicit information which can be used to estimate WTP.

Referring to revealed-preference methods, Kopp, Krupnick and Toman claim, "The most developed probably are the hedonic-labor-market approach, the property-value approach, and the travel-cost approach to valuing recreation" (1997, p. 16). The hedonic-labor-market method is used for valuation studies on human health. It employs information on wage structures to see what "payments" (in the form of lower wages) workers are willing to make to have reduced job-related health risk. The property-value approach evaluates the contribution environmental quality makes to property values in the private-housing market. The travel-cost method uses information on the cost of travel to a recreation site as a proxy for the price people are willing to pay to use the site. This can reveal information on the strength of demand for the use-value of recreation services provided by increases in environmental goods. These are partial-valuation techniques in that they measure only some of the components of value that would accrue from improvements in environmental quality. In particular, they cannot measure some components of passive-use value, as such value is not associated with market behavior.

The principal stated-preference technique for environmental-policy analysis is the contingent valuation method (CVM). CVM employs a survey method which characterizes the object of choice (e.g., the bundle of effects associated with a policy change). It is for the object of choice that CVM is designed to produce a monetized value. The object of choice must be framed within a credible choice context, and with clear financial consequences attached to the choice. A survey format in common use is to place the object of choice in a referendum-voting context. The respondent is asked whether they would vote yes or no on the policy, where adoption of the policy will have specific financial consequences to the respondent. These mechanisms must be credible (higher taxes, higher product prices, etc. as appropriate) in order for the stated choices to be meaningful. Under circumstances where the object is properly framed and the credibility conditions are satisfied, the stated choices provided by respondents provide the basis for estimating WTP for the effects produced by the prospective policy change.

Section V.

An Overview of the Contingent-Valuation Method

The contingent-valuation method (CVM) is widely applied to the problem of estimating the economic value of goods and services which are not traded in markets and for which no economic behavior is observable. These non-market characteristics are present when the "good" in question is in the form of an environmental amenity. As a result, contingent valuation is receiving increasing use for estimating the economic value of environmental goods. These applications include the estimation of economic damages from oil spills, the value associated with ecosystem preservation, and the benefits of reduced pollution.

The contingent valuation method utilizes survey methodology to reveal the monetary values respondents place on goods. The CV researcher must provide respondents with a realistic portrayal of the policy change, and describe the cost burden to their household. The cost burden is defined both in terms of its magnitude and the vehicle through which these costs will be paid (e.g., higher prices for products, higher taxes, etc.). A valuation question then typically follows, in which respondents reveal either directly or indirectly their willingness-to-pay (WTP) for the stated good. For example, a dichotomous-choice (or referendum) valuation question allows the respondents to reveal how they would vote in a referendum on the policy, given the policy's cost to their household. From such responses, a household-average WTP can be estimated. Alternatively, the valuation question can have an open-ended or payment-card format. (See Mitchell and Carson, 1989, for an extensive discussion of these approaches.)

The credibility accorded to the results of contingent-valuation studies is evidenced, in part, by the increasing support for its use as a method for estimating the economic benefits associated with policy proposals. For example, it is included in the federal government's prescribed procedures for analysis (Water Resources Council, 1979, 1989 and Department of the Interior, 1986.) In addition, results from contingent-valuation studies were granted the status of rebuttable presumption in environmental-damage litigation cases by a U.S. Circuit Court of Appeals (*State of Ohio vs. the United States Department of Interior*, 880 F.2d 432, D.C. Circuit, 1989). These policy developments provide for the use CVM as an estimation technique to establish compensable environmental damages under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The same now holds true for the Oil Pollution Act of 1990. Along with this increasing use has come increasing scrutiny.

In recent years economists, psychologists and survey researchers have vigorously debated the validity of using the contingent valuation method to estimate the economic value of goods which are not traded in markets. An evaluation of CVM was conducted by a high-profile panel appointed by the National Oceanic and Atmospheric Administration (NOAA). This panel assessed the usefulness of the method and recommended research protocols to improve the tool's performance. The conclusions reached by the panel were used by NOAA in its rulemaking under the Oil Pollution Act of 1990. The panel consisted of five distinguished researchers, and was co-chaired by two Nobel laureates in Economics, Kenneth Arrow and Robert Solow. One of its members describes the task given to the panel as addressing the following question: "Is the

contingent valuation method capable of providing estimates of lost nonuse or existence values that are reliable enough to be used in natural resource damage assessments?" (Portney, 1994, p. 8).

Summaries of many of the issues can be found in surveys of the literature produced by Cummings, Brookshire, and Schulze (1986) and by Mitchell and Carson (1989). Carson, et al. (1994) have assembled a bibliography on CVM which contains 1,672 references. The studies referenced include applications of CVM as well as diagnostic research designed to assess its validity and reliability.

Much of the research on CVM has focused on the extent to which it is subject to random error (imprecision) or systematic error (biased results). The most serious concerns have related to the possibility of bias (systematic over- or underestimation). The categories of bias, and how surveys are designed to mitigate bias, are fully discussed below in Section VI.

Among the most interesting methodological studies are those designed to compare CV results to the values generated in simulated markets in which actual (as opposed to hypothetical) monetary transactions are made. Some of the most revealing work in this area is that by Bishop and Heberlein on the exchange of hunting permits (Bishop and Heberlein, 1979, 1990 and Bishop, et al., 1983). Contingent values on willingness to pay were statistically quite close to those revealed in actual cash transactions. Contingent values generated from a sealed-bid auction were 33% higher than cash-transactions values. When the CV questions were in the dichotomous choice format (in which the respondent must agree or refuse to pay a specified price for the good), the CV results for willingness to pay exceeded the values from the simulated market by 13%. In neither case were the differences statistically significant.

Concern about how a good's characteristics affect the reliability of CV estimates is addressed in research by Kealy, Montgomery, and Dovidio (1990). Their research examined contingent values of two goods "...at polar extremes of the private/public good continuum: a brand-name candy bar and a contribution to a program to alleviate acid rain damage in a major recreational area (Kealy, et al., 1990, p. 259)." They hypothesized "...that contingent values for our public good would be less reliable and less accurate predictors of actual willingness to pay than those for our private good because the private good was more well defined and concrete, and because of respondents' greater familiarity with the private good (p. 259)." Their results, however, contradict this hypothesis. They found comparable reliability and predictive validity for both types of goods.

Much concern has been expressed regarding "embedding" bias in CVM results, a phenomenon which results in respondents exhibiting "insensitivity to scope". Insensitivity to scope would have been exhibited if, for example, respondent revealed the same willingness to pay for a policy which would reduce emissions of a pollutant by 10% as for a policy which would reduce emissions by 90%. The NOAA panel recommended that CV studies should be conducted in a manner in which respondents sensitivity (or insensitivity) to scope could be tested. This would be used as one criterion by which the validity of the CV results could be judged.

Additional evidence regarding sensitivity to scope is discussed in Hanemann (1994). Some of the evidence reviewed by Hanemann is evidence contained in the meta-analysis by Walsh, Johnson and McKean (1992) on over 100 CVM recreation studies and in a study by

Smith and Osborne (1994) on 10 applications of CVM to air quality. Hanemann discusses at some length the evidence provided in a review by Carson (1994) of 27 papers testing for sensitivity to scope, and notes that only two failed to generate statistical evidence of sensitivity to scope, the one by Kahneman and Knetsch (1992) and the other by Boyle, et al. (1994). That is, only 2 of 27 papers found evidence of this type of embedding behavior. Hanemann notes that critiques of these two studies have pointed to methodological shortcomings which could explain their findings. In summarizing the evidence Hanemann claims, "At any rate, even if one regards these two studies as highly credible evidence that respondents were insensitive to scope, they certainly do not represent the majority finding in the contingent valuation literature regarding the variation of willingness-to-pay with scope" (Hanemann, 1994, p. 35).

Regarding estimation of passive-use values *per se*, the NOAA Panel's conclusions are the most comprehensive and authoritative statement to date. Given that the NOAA panel was considering the use of CVM for environmental damage litigation (in which a single party could be held liable for environmental damages) they were compelled to adopt very strict standards by which to judge the method. After obtaining input critical of CVM, the panel noted, ".... some antagonists of the CV approach go so far as to suggest that there can be no useful information content to CV results. The Panel is unpersuaded by these extreme arguments" (Arrow, et al., 1993, 4610). After thorough review of the validity CVM for measuring passive-use values, the preponderance of evidence supports the usefulness of results from carefully performed CV studies. The NOAA panel concludes, ".... the Panel concludes that CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values" (Arrow, et al., 1993, 4610).

Section VI.
Survey Design

The Role of Focus Groups and Pretesting

Assessing General Context Through Focus Groups

A major purpose of focus groups in CV research is in survey design. Focus groups not only provide evidence of how the survey population views the policy trade-off to be studied, but also provides an intensive setting in which to understand how people will process the information and structure of the survey instrument. The two focus groups conducted for this study began by assessing group participants background knowledge of air pollution and environmental policy in general, and mercury pollution in particular. Participants' discussion of their familiarity with mercury pollution revealed some level of knowledge about the problem, as well as some confusion with other pollution problems such as acid rain, lead and PCBs. After the initial discussion, participants were read drafts of the information on mercury pollution in Minnesota.

How Information is Understood and Interpreted

Further discussion was stimulated by asking participants to rate the importance of the various effects of mercury that had been described. This approach afforded the opportunity to observe how the participants' interpretations of the information affected their desire to see a reduction in effect of environmental mercury. The importance attached to the effects was influenced by the credibility people attached to the described environmental effects.

Participants were prone to touch on the economic consequences of the pollution or its control in explaining their importance ratings even prior to the portion of the focus group designed specifically to provoke discussion on the economic effects. In general, the discussion indicated a strong tendency of people to see the economic dimensions of the problem and its connection to their household budgets. Participants engaged in thoughtful discussion of the baseline case (the 12% reduction in deposition in Minnesota resulting from a 50% reduction in emissions in the upper-Midwest). People typically saw statewide control as most politically achievable but small in effect, but accepted as credible the notion of a regional, multi-state control plan in the area, on which the 12% scenario is based. Describing effects of nationwide or global reductions policies met with less acceptance due to doubts about gaining cooperation from other countries. Respondents identified the ways which conveyed the information most clearly and explained how it influenced their thinking.

Assessing Effectiveness of CV Questions

The focus group setting is extremely useful for understanding how respondents regard the CV questions in the specific policy context. Discussions tend to be very informative about the payment vehicle, in this case higher prices for goods and services affected by mercury-emissions limits. It is possible to anticipate payment vehicles which will elicit emotional reactions which confound the assessment of willingness to pay. Both focus groups indicated the need to emphasize the program would not be financed through higher taxes, but rather that emitters

would incur control costs and pass the burden (or at least part of it) on to consumers in the form of higher prices for energy and other products, as well as through higher fees for garbage disposal. Attention was also devoted to assessing the most effective ways to communicate that the household costs would occur each year for the foreseeable future.

Simulating CV Responses

Having focus-group participants engage in the referendum-style CV process and discuss their reaction to it is not only useful in generating preliminary indications of values attached to the policy, but also in "getting into people's heads" on how the CV mechanism is understood. It also affords the opportunity to debrief respondents on the motives which underlie their values and their reasons for favoring or opposing the proposed policy.

Implementation of Pretesting

As noted above, two focus groups were conducted as part of the survey design. They were held in July 1997: one in Minneapolis for Twin-Cities metro-area participants, and the other in Brainerd with people from the Crow Wing and Morrison County areas.

In addition to the focus groups, the three types of pretests recommended by Dillman were also performed.[5] Recommended pretests involve the following three groups: (1) professionals experienced in survey design, (2) users of the information, and (3) members of the survey population. The professionals who critiqued the numerous versions of the survey instruments included economists familiar with mercury policy, practitioners of CV and survey research, academics in related fields, and a reading specialist who evaluated the instrument for level of difficulty in vocabulary and reading.

The second pretest group provided substantial feedback on numerous versions of the instruments. Many improvements were suggested by the staff of the Minnesota Pollution Control Agency and the Minnesota Department of Health. Improvements were made in the technical accuracy of the descriptions and in the clarity of information delivery.

Pretests were also conducted with members of the survey population. Early drafts of the instruments were assessed using interviews with people intercepted at public places such as malls or coffee shops. As drafts became better-developed, people were recruited to self-administer the survey, followed by a debriefing session assessing the clarity of the instrument and the credibility of the described effects and payment mechanism.

The final pretest with the survey population was through a pilot mailing to 250 randomly selected Minnesota adults. This pilot allowed monitoring of the effectiveness of all elements of mail-survey administration, including postal processing, etc. No follow-ups were sent to the pilot sample. Responses to the pilot also produced information upon which the distribution of household costs for the full survey would be based.

[5] See Dillman (1979) for an authoritative guide to survey design and administration.

Defining the Good to be Valued

The Contingent Valuation Method is termed as such because values are elicited based on described policy changes which would produce public goods. Benefits would accrue if the effects of the policy are regarded as economic goods. The survey design process becomes all the more crucial because it defines the elements of the policy on which the benefits estimates depend.

The policy consequences which people may value in this case are reductions in mercury emissions, the consequent reductions in deposition levels in Minnesota, and ultimately the reductions in risks to human health and wildlife from exposure to mercury. All of these elements are described in the description of the policy, but the goods being produced are the reductions in risks to humans and wildlife. These were identified in the focus group discussions and pretesting as the primary sources of benefits.

This section will highlight key phrases employed in defining the good.[6] Identical information is provided in the mail survey and personal interview survey instruments, although wording and visual material were altered slightly to fit the delivery mechanism. In addition to placing the policy in the context of other public programs with questions Q-5 through Q-12 in the mail survey, a clear distinction is made between this mercury-reduction proposal and existing state and federal policies on other air pollutants, such as sulfur dioxide and carbon monoxide.

The Effects of Mercury in the Environment

Following are key phrases describing the effects of mercury. Focus group discussions addressed the most effective ways to convey these messages. Under EFFECTS ON HUMANS the phrases in boldfaced type in the mail survey are as follows: Fish as a source of mercury; Limits on fish consumption help protect human health; Most advisories apply to walleyes, northerns, trout, bass and other predator fish; The advisories may cause some anglers to change or restrict their fishing; Advisories are more strict for young children and women of child bearing age; Some Minnesotans may be experiencing health effects, but these possible effects have not been documented.

Under EFFECTS ON WILDLIFE THAT EAT FISH the phrases in boldfaced type in the mail survey are as follows: Some birds and mammals that eat fish are at risk; Possible effects to animals include reproductive, muscle, and nerve damage; Local populations of some birds may be at risk; Plants, plant-eating animals, and the fish themselves are NOT at risk.

Information About the Proposed Law

Following are key phrases providing additional information about the proposed law. Phrases stated in boldfaced type in the 12% reduction scenario in the mail survey are as follows: Minnesota and other Upper Midwest states would limit emissions, Sources of Mercury Air Pollution; 12% (or 5, 21, or 35%) reduction in mercury deposition (full effect after 20 years); Reduction of most restrictive advisories for about 10% of fishable lakes; The number of lakes with fish which pose risks to wildlife would decrease. Visual aids were provided in the personal

[6] For further reference see Section II of this report and the survey instruments. The complete survey instruments are contained in Appendix B.

interviews to highlight this section and to provide visual stimuli. The table on changes in percentages of lakes where species may be at risk was included in the mail survey under the four scenarios. Actual percentages for the four scenarios are provided with the complete instruments in Appendix B.

Potential Biases and Survey-Design Features to Mitigate Bias

As noted above in the section on CVM, much concern has been expressed in the literature about potential biases in benefits estimates based on CV responses. Recently the major concern has been with embedding bias, which would be seen empirically as insensitivity to scope. The benefits estimate might not vary with the scope of the good being provided if (1) people are predominantly supporting the policy to enjoy a "warm glow" or (2) if respondents misappropriate larger benefits from more comprehensive policies than the one being evaluated. That is, benefits which are overestimated due to part-whole bias will be insensitive to changes in scope, as long as those changes in scope are still within the improperly large scope within which respondents are embedding the actual policy.

Other biases of major concern in the literature are: (a) strategic bias, systematic error due to incentives to strategically understate or overstate value; (b) hypothetical bias resulting from the hypothetical nature of the market; error resulting from conveying incorrect information or information bias; (d) yea-saying bias, due to social pressure to support these kinds of policy proposals; and (e) starting point bias, which results from the household's value being influenced by the initial cost stated in the survey. The latter is primarily a concern in the open-ended CV format, so is not an issue in the referendum format utilized here. While the studies which investigate these potential biases are too numerous to review here, Mitchell and Carson (1989), Cummings, et al., (1986) and the NOAA Panel (1993) survey this literature.

This literature contains guidelines for designing CV instruments to mitigate these potential biases. The NOAA Panel protocol is among the more comprehensive and highly regarded within the field, though it has not garnered consensus in all of its recommendations. A common thread in the discussion of design features to mitigate biases is to achieve incentive compatibility, so that respondents are motivated and enabled to provide unbiased responses. The referendum format on willingness to pay is fundamental to an incentive compatible study design.

Another cornerstone of incentive compatibility is consequence realism, so that respondents believe the study results with actually affect policy as stated, as well as their household budget. The former is often referred to as policy consequence realism. The cover letter and booklet cover play on a strength of this study in that it truly is a part of a policy design process. The questions pertaining to geographical location and eligibility to vote are potentially useful covariates for statistical analysis. They also help serve the purpose of fortifying the image of the official nature of the study so that respondents take their task seriously..

The other element of incentive compatibility pertains to the household's consequences if this policy is actually enacted. Incentive compatibility also depends on respondents accepting that a burden will come from their household budget. The literature promotes a context which emphasizes the household's income constraint and the cost of the policy. Here again this study addressed these elements through the preliminary questions on commitment of money to various programs. These questions remind respondents of the public budget constraints and the

availability of substitute programs, in case respondents would not be mindful of these realities. They are also reminded to respond based on their current level of household income.

Focus group discussions indicated that people sensed a high degree of realism in both policy consequences and household budget consequences. Section IX, "Empirical Results" provides further evidence generated from follow-up (debriefing) questions regarding the credibility of the payment mechanism and the magnitude of the payment.

Cost of This Program to Households Like Yours

In accordance with the NOAA protocol and the recommendations of Mitchell and Carson, the study established a payment vehicle which is neutral and realistic. The costs to households were explained carefully according to suggestions offered in focus groups and pretesting. Following are key phrases in the section on THE COSTS OF THIS PROGRAM TO HOUSEHOLDS LIKE YOURS. Phrases stated in boldfaced type in this section of the mail survey are as follows: Prices of goods and services would rise due to higher production costs; Administrative costs will also cause price increases; No change in taxes; No single Minnesota company would suffer a large percentage increase in costs; Some households will adjust their purchases; While your household may not be typical, please vote based on the stated cost; The cost stated below is a fixed annual payment.

Other Aspects of Survey Design

Other aspects of the survey design were included not only to convey the proper valuation context, but also to mitigate potential bias. Questions were designed according to the NOAA recommendations on assessing respondent's acceptance of the information. Follow-up questions pertain to the respondents' views on the seriousness of the effects, the effectiveness of programs in general and this policy in particular, and acceptance that their household would have to pay higher prices. Households were also asked about their difficulty in paying the costs of the policy. The final questions establish a profile of recreational activities and demographics.

The Use of Two Different Survey-Delivery Mechanisms

This study is strengthened by the utilization of two methods for delivering the CV survey: personal interview and mail questionnaires. The NOAA Panel favors the interview delivery mechanism based on the recommendations of a majority of practitioners, though some continue to conduct mail surveys. This determination of the NOAA Panel was based more on the advice of experts than on hard empirical evidence on the relative advantages of any survey delivery mechanism.

Interviews allow researchers to monitor the attentiveness of respondents and to interact with them, especially in answering questions if the information is unclear. But interviews are much more expensive so the costs can be prohibitive for obtaining a sufficiently large sample. The presence of an interviewer may also encourage yea-saying bias to a greater degree than anonymous mail responses where material can be read and reflected upon at the respondent's own pace, much as in preparing to vote in a referendum.

Based on the research team's prior experience with mail surveys and the need for

adequate sample size, mail surveys were also utilized to corroborate the personal interview results and to investigate sensitivity to scope in a more cost-effective manner. The dual implementation methods allowed investigation of the methodological issue of whether interviews are necessary to generate useful results, or whether mail responses corroborate interview results so are preferable due to low expense, or whether mail is preferable as generating more conservative estimates by avoiding yea-saying bias.

The Purpose of Using Four Different Scopes of the Mail-Survey Instrument

The conceptual rationale for including at least two levels of the policy, or two levels of the good, is that demand estimation is founded on identifying at least two points on the demand curve for the good. In this study, four different levels of the policy were tested over four different sub-samples within the survey population. This type of split sample is referred to as intersample variation in the scope of the policy.

This leads to the methodological rationale for including four levels of the policy. It allows for a more thorough test for sensitivity to scope than found in most studies. But perhaps the most important reason for the four mercury reduction scenarios is the most basic, that this reflects the reality of the policy situation. The geographical scale of any reductions in mercury emissions which may eventually occur (only statewide, regional, national, or global) will greatly influence the magnitude of reductions in deposition levels and effects in Minnesota.

NOAA Guidelines and Summary of Design Features

The NOAA Panel recommended a protocol for CV design by providing survey guidelines in the following categories: "General Guidelines", "Guidelines for Value Elicitation Surveys", and "Goals for Value Elicitation Surveys. Specific NOAA recommendations are itemized below in parentheses with brief reference to design features in this study. This study was conducted to generate evidence to inform mercury policy not as a court proceeding for damage assessment. The NOAA Panel notes that whether a particular study incorporates certain features can be exactly determined (e.g. The valuation question has a referendum format) other features are a matter of degree. The panel states "A CV survey does not have to meet each of these guidelines fully in order to qualify as a source of reliable information to a damage assessment process." (NOAA . p. 4608)

General Guidelines

* (Sample Type and Size): Probability sampling was utilized as recommended.

* (Minimize Nonresponses): No exact response rate is established as being satisfied to guarantee reliable results. The mail and interview response rates are lower than anticipated but within the ranges found in the literature for other studies.

* (Personal Interview): Personal interviews were conducted and were augmented by a larger sample of mail surveys to enable comparative analysis.

* (Pretesting for Interviewer Effects): This study explores the possible "social desirability" bias effects of interviewers compared to the privacy of actual referenda. Comparative analysis with confidential and anonymous mail responses goes beyond the type of assessment which the panel deemed necessary.

* (Reporting): Information on sample size, questionnaire wording, cover letters, etc. is provided in this report. Carson *et al*. (1992) is cited as an example of good practice and the availability of this prototype informed this study to a large degree not only on reporting practices but on all aspects of study design.

* (Careful Pretesting of a CV Questionnaire): The careful, thorough pretesting performed in this study is described above in this section, including practice interviews, self-administered questionnaires, pretesting through intercepts at public places, focus groups and a pilot study.

Guidelines for Value Elicitation Surveys

* (Conservative Design): Where judgments were required, alternatives were chosen to understate the benefits of mercury reductions. The description of effects and the policy were designed to error on the side of caution.

* (Elicitation Format): The willingness-to-pay format was employed.

* (Referendum Format): The CV question was posed as a referendum.

* (Accurate Description of the Program of Policy): The study and policy description were carefully integrated with the MPCA Report (Rae, 1997).

* (Pretesting of Photographs): Visual aids were included in pretesting.

* (Reminder of Undamaged Substitute Commodities): Percentages of lakes affected and those not affected was made explicit.

* (Adequate Time Lapse from the Accident and Temporal Averaging): These features are more applicable to oil spills and damage assessment.

* ("No-answer" Option): A "not sure" option was provided.

* (Yes/no Follow-ups): These were provided.

* (Cross-tabulations): Results section reports extensive multivariate analysis.

* (Checks on Understanding and Acceptance): This was carefully pretested and assessed as

part of survey process, including interviewer debriefing similar to Carson *et al*. (1992).

Goals for Value Elicitation Surveys

In the NOAA Report, the panel states "The following items are not adequately addressed by even the best CV surveys." (p. 4609) The panel raises issues for further improvement of the CV method. This study incorporates improvements since the NOAA Report was released.

* (Alternative Expenditure Possibilities): Other expenditures for private and public goods are mentioned and the trade-offs for the household's budget are addressed specifically.

* (Deflection of Transaction Value): The realism of the policy consequences in this study and the referendum format are regarded as reducing the "warm glow" effect.

* (Steady State or Interim Losses and Present Value Calculations of Interim Losses): These features are also more applicable to damage assessment but are addressed in this study with the description of a time stream of effects and the establishment of an annual payment "for the foreseeable future."

* (Advance Approval): While this was not a part of a judicial damage assessment the survey was pretested with anticipated users of the results.

* (Burden of Proof and Reliable Reference Surveys): Results from elaborate pretesting are reported above in this section. While reliable reference surveys do not exist for this particular environmental impact, the design features (as noted above) are patterned closely after previous studies cited as good practice.

Section VII.
Survey Execution: Mail

Sample Selection and Source

The sample selection procedure employed here was also attentive to the NOAA guidelines in that probability sampling was performed on the population which matches the market of the policy. The random samples for the mail survey and the interviews were drawn by the Minnesota Department of Public Safety. Selecting from the list of Minnesota driver licenses and state identification cards yields the best available list of Minnesota adults (it was restricted to those 18 or over). This list also provides names in the official form which is the full name used for state identification purposes, as opposed to the initials for first and middle names found on many marketing research lists.

The Minnesota Department of Public Safety provided 2,500 randomly selected names and addresses. This number provided a large potential sample in anticipation of response which will support multivariate statistical analyses across different groups of respondents. Those results are reported in Section IX.

Mailing Technique: The Use of Multiple Follow-Ups and Their Timing

Five contacts were made with potential mail respondents, where possible: four mailings and a brief telephone contact. The first, third, and fourth mailings included a survey booklet, while the second mailing was just a reminder letter. The four mailings were sent on October 22, November 4, and November 13, 1997 and January 13, 1998. For those non-respondents where telephone numbers could be secured, up to five attempts were made at a phone contact during March to determine if the mailings had been received and to encourage response. Appendix C contains the cover letters from the mailings and the telephone script.

Section VIII.

Survey Execution: Personal Interview

Sample Selection and Source

As with the mail survey, sample selection was attentive to the NOAA guidelines. Probability sampling was performed from a spatially limited, but geographically representative, sample of the Minnesota population. The state was divided into three regions for the purpose of defining geographical representativeness. Sampling from these three regions avoided the expensive and logistically difficult procedure of sampling households from the state as a whole, where households could be selected which are great distances from any other given the sparse populations of many rural Minnesota counties. The most populous region, the seven-county Twin-Cities metro area of Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties was sampled randomly. The northern and southern regions of the state were sampled by selecting representative counties from which to draw the sample. The northern counties chosen were Saint Louis, Beltrami, and Clearwater. The southern counties chosen were Olmstead, Dodge, and Steele.

Again the list of driver licenses and state identification cards from the Minnesota Department of Public Safety was used to randomly draw names and addresses for interviews. As is often the case with spatial sampling procedures, the sampling unit was defined as a dwelling unit. Rather than taking a census of all structures in which people dwell in these counties, the addresses drawn from the Minnesota list defined the dwelling units from which the interview sample would be composed. While the person drawn from the list may have moved, maybe even out of state, the dwelling unit was still occupied in almost all cases.

Interviewer Training

All interviewers were trained carefully for delivering the instrument for this study. While some interviews were completed by professional interviewers, the special requirements and content for this project still required extensive interviewer training sessions. For those interviewers without experience, more elaborate training sessions were conducted on the conceptual background and guidelines of effective interviewing. Numerous practice interviews were conducted with project staff as part of the training, as well as supervised and unsupervised pilot interviews with members of the study population.

Advance Letters and Interviewer Contact Procedure

As is typically the case, potential interview participants were sent advance letters describing the study (in the most general of terms) so they could anticipate the visit by the interviewer during a specified time frame, without providing the person the chance (or specific reasons) to refuse participation immediately. Sometimes interviews were completed on the initial visit or the resident specified a more convenient time for completing the interview. Oftentimes no one was home when the interviewer visited, so a letter was left to that effect. Appendix C contains the advance letters and other letters sent to potential participants in the personal interviews.

Interview Delivery Procedure

The interview instrument is provided in Appendix B. The initial screening portion identifies the procedure for securing interview participation. Interviewers were trained to follow the interview protocol. The interview script and visual aids provided in Appendix B are self-explanatory of the interview procedure, including the post-interview assessment performed by the interviewer on distractions, attentiveness, etc.

Section IX.
Empirical Results

Mail Survey Results

Response Rate

A total of 862 completed booklets were received from Minnesota residents (where "completed" is defined as containing responses to a majority of the questions). An additional 30 booklets were received that were either not completed (containing no or very few responses) or were from nonresidents. The 862 completed, resident booklets represent 34.5 percent of the original sample of 2500. Of these 2500 mailings, however, 461 were not deliverable due to an incorrect address, 3 were not deliverable as a result of the recipient being deceased, and 16 were mailed to recipients who had moved out of state. Correcting for these 480 booklets that were not deliverable to Minnesota respondents, there were 2020 potential respondents. The 862 completed booklets thus represents a response rate of 42.7 percent of potential respondents. This is somewhat lower than what we have experienced from earlier CV studies that we have conducted within Minnesota. This may in part be due to a declining willingness to participate in surveys as a result of the recent increase in telemarketing and market survey research, which in turn reflects "improvements" in computerized telephone solicitation technologies.

Demographic Profile of the Respondents

The respondents represent all income and educational levels, and reside in all parts of the state. The following table shows mean income and educational levels for the respondents and for the state population as a whole:

Table IX-1

Income and Education Levels:

Mail Respondents vs. State Population

	Respondents	State Population
mean household income	$ 47,600	$ 46,086
mean educational level (of respondent)	14.3 years	12.8 years
Education by level:		
no high school diploma	3.3 %	17.6 %
high school graduate or some college (including. Assoc. deg.)	60.4 %	60.6 %
bachelor's degree	27.2 %	15.6 %
graduate degree	9.2 %	6.3 %

Note: Mean household income for the state is calculated using 1996 data on per-capita earnings and average household size, as reported by the State Demographer's Office.

As shown in the above table, average income is somewhat higher for the survey respondents than for the population as a whole. Regarding educational levels, there is a substantial difference in the two distributions at high and low levels of educational attainment. Specifically, those without a high school diploma are significantly under-represented in the sample, whereas those with a bachelor's or graduate degree are significantly over-represented. This may be due in part to the fact that the educational level given by the respondent is not the average for all adults in the household, but rather is for the respondent him-or herself. To the extent that a majority of the surveys are filled out by heads-of-households with higher than average educational levels within the household, the sample number would be biased upward. It is unlikely, however, that all (or even most) of the discrepancy between the sample and the population is attributable to this phenomenon, and thus it is necessary to consider the impacts of educational level on estimated willingness-to-pay to allow for the possibility of correcting for differences between the sample and the population.

Table IX-2 below compares the geographic distribution of the respondents to that of the population as a whole.

Table IX-2

Geographic Distribution:

Mail Respondents vs. State Population

	Respondents	State Population
Twin Cities-Metro Counties	46.7 %	56 %
Non-Twin Cities, South/Central	28.9 %	23 %
Northern	24.5 %	21 %

Notes: The metro county category refers to the seven-county Minneapolis-St. Paul metropolitan area, which includes Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties. The northern Minnesota category includes the following counties: Aitkin, Becker, Beltrami, Benton, Carlton, Cass, Chisago, Clay, Clearwater, Cook, Crow Wing, Douglas, Hubbard, Isanti, Itasca, Kanabec, Kittson, Koochiching, Lake, Lake of the Woods, Mahnomen, Marshall, Mille Lacs, Morrison, Norman, Otter Tail, Pennington, Pine, Polk, Red Lake, Roseau, St. Louis, Todd, Wadena, and Wilkin. All other counties are in the non-TC south central category.

The geographic distribution of the respondents corresponds roughly to that for the state population. The Minneapolis-St.Paul metropolitan area is slightly under-represented within the sample, but there is a good balance between northern Minnesota and the south/central parts of the state.

Regression Analysis

Choice of a Dependent Variable

As explained in Section VI, "Survey Design", the survey instrument contains two referendum questions: (1) a standard dichotomous choice question roughly midway through the booklet; and (2) a second, multi-category referendum question near the end of the instrument which allows the respondent to change their vote. For the regression results presented below, the second question is used to define the dependent variable, with a “definite” or “probable” affirmative vote being treated as a vote in favor of the referendum. (Results from the first, dichotomous choice question are also provided, but in much less detail.) As was explained above, we believe that this second question is more likely to provide reliable estimates. Moreover, the empirical results derived using this format have proven more robust in our analysis, and provide greater consistency with the predictions of economic theory.

Regression Results: Simple Specification

As noted above in Section VI, the mail instrument has four versions, corresponding to different percentage reductions in mercury deposition (and corresponding differences in the bundles of effects). The following results were obtained by estimating WTP using censored

logistic regression on each separate sub-sample. In each case, the dependent variable (vote) is regressed on the household cost variable using logistic regression, and the parameters are then transformed into a censored logistic regression model for which the dependent variable is expected WTP. (See Appendix D for details on the estimation procedure.)

Table IX-3

Split-Sample Estimates of Willingness-to-Pay

Subsample (listed by % reduction in deposition)	**Estimated WTP**	**Standard Error**	**n**
5 percent case	120.96	52.19	159
12 percent case (base)	118.91	24.84	348
21 percent case	160.22	81.05	164
35 percent case	225.57	173.72	174

These results show generally strong support for policies to reduce mercury deposition, as exhibited by the substantial WTP[7]. Moreover, the point estimates show a general pattern of rising WTP as a function of the magnitude of the effects (with the exception of the 5%-to-12% increment). Tests of statistical significance regarding sensitivity to scope are made problematic, however, by the small sample sizes on the alternative cases, which give rise to large standard errors for these cases. In short, the results are consistent with sensitivity to scope (that is, sensitivity to scope cannot be ruled out), but the results are also consistent with the absence of sensitivity to scope. The large standard errors on the alternative cases make it impossible to rule out either possibility.

Regression Results: Alternative Specifications

An alternative to the above approach of stratifying the sample into sub-samples is to use a single sample, but to include the effects case as an independent variable. This is done below. While ideally a separate variable would be included for each of the alternative cases, the shortage of observations (relative to the data demands of logistic regression) make it difficult to accurately identify the magnitude of the associated effects. In order to improve the efficiency of the estimation process, restrictions can be placed on the estimation (so long as those restrictions are consistent with underlying economic principles). In this case, we impose the restriction that increases in pollution reduction are monotonically related to willingness to pay (while allowing for the possibility that the "slope" may be zero). This is done by using the percentage reduction

[7] While there is no theoretical justification for assuming that non-respondents (57% of the sample) have zero WTP, a curious reader may be interested in determining what the WTP would be under such a conservative assumption. Such estimates could be produced by multiplying the WTP figures in Table IX-3 by 0.43, the response rate.

in mercury deposition as an effects variable. This variable serves as a proxy for a more complex set of effects resulting from reduced deposition. (As is discussed below, other effects variables were also tried, with no significant impact on the results.)

Another distinction between the estimation results highlighted in this section and those presented above involves the treatment of households who reveal through their responses that they would be unwilling to support the policy at any price (even if there were no cost to their household). Such households do not perceive reductions in mercury deposition as providing any benefit to the household. In other words, for such households reduced deposition is not a "good" and hence the probability of support for the policy zero regardless of the cost to the household.

The overall sample thus consists of two groups: one group for which reduced deposition is a "good" (and for which the probability of support varies with the cost to the household), and one group (the "NG" group) for which reduced deposition is *not* a good. Equation IX-1 is estimated only for the first group, since for the "NG" group there is no functional relationship between cost and support. Approximately 17 percent of the respondent households fall into the "NG" category. These households are added back in (at a WTP of zero per household) following the estimation of the equation. The logistic regression equation for the sample that combines the different effects levels (but excludes the "NG"s) is as follows:

Equation IX-1

Logistic Regression

Estimation using Combined Sample,

"NG" Households Initially Excluded

(standard errors in parentheses)

$$\ln[Pi/(1-Pi)] = .539 - .00511\ Ci + .00991\ EFFECTS + .518\ COLLEGE + .0363\ INC$$

$$(.291)\quad (.00161)\quad (.00847)\qquad (.193)\qquad (.0177)$$

As noted above, EFFECTS is the percentage reduction in mercury deposition. COLLEGE is a dummy variable equal to 1 if the respondent holds at least a bachelor's degree, and INC is household income (measured in 5,000-dollar increments). In the above logistic regression, the "effects" variable is significant at a 76 percent confidence level. All of the other variables are significant at much higher confidence levels (as is apparent by taking the ratios of the coefficients to their standard errors). Using the transformations discussed in Appendix D, the above equation yields the following censored logistic regression equation:

Equation IX-2

Censored Logistic Regression

(derived from IX-1)

Estimation using Combined Sample,

"NG" Households Initially Excluded

(standard errors in parentheses)

$$E(WTPi) = \underset{(45.96)}{105.40} + \underset{(1.77)}{1.94}\,EFFECTS + \underset{(48.80)}{101.28}\,COLLEGE + \underset{(4.04)}{7.11}\,INC$$

It is interesting to note that the above equation implies that respondents holding a bachelor's degree (or above) have a mean WTP that is $101.28 higher than for those with lower educational attainment. Given the over-representation of such households in the sample, this suggests that the results need to be corrected to reflect for this disparity (as is done below).

The population mean for the COLLEGE variable is .219 (given the 21.9 percent of the population with a bachelor's degree or above—see Table IX-1). Given the scaling of the INC variable (in $5000 increments), the population mean for the INC variable is 9.717 (reflecting a mean household income of $46,086). The effect of using the population means (as opposed to the sample means) for the income and education variables is to reduce estimated WTP by about $16.84 (approximately $14.69 of which is due to the adjustment to education and $ 2.15 of which is due to the adjustment for income).

Evaluating equation IX-2 at the population means for education and income, and adding back in the 17 percent of the sample with zero WTP, yields the following results:

Table IX-4

Implied Willingness-to-Pay from Equation IX-2:

Estimation using Combined Sample,

"NG" Households Initially Excluded

Effects Case	**Estimated WTP**
5 percent case	171.29
12 percent case (base)	182.56
21 percent case	197.05
35 percent case	219.59

These results are somewhat higher than for the split-sample approach, and the differences between the two low-effects cases and the higher-effects cases are somewhat more compressed. Several alternative (and more complex) effects variables were also tried. The effects presented in the survey instrument fall into three broad categories: reductions in the percentage of lakes subject to advisories (regarding human consumption of fish), reductions in the percentage of lakes for which fish-eating birds are "at risk", and reductions in the percentage of lakes for which fish-eating mammals (otters and mink) are at risk.

There are no significant differences between the different versions with regard to the effects on fish-eating mammals. Rather, the difference are primarily in terms of the impacts on consumption advisories and on fish-eating birds. Separate variables for each of these were attempted, but these effects are highly correlated. The resulting multicollinearity creates identification problems. As an alternative, a composite variable was constructed by averaging across species the bird-related effects (defined as the percentage reduction in lakes where each species is at risk), and then it turn by averaging the bird-related effects with the percentage reduction in consumption advisories. This yields the following average percentage reduction values for the four cases: 4.625, 9.25, 16, and 26. Using this variable results in *slightly* compressed WTP estimates, however for each case the estimated WTP is within two dollars of the estimates derived from the reduction-in-deposition approach presented above in Table IX-4

Finally, for purposes of comparison, we present estimated WTP from the multivariate approach when the logistic regression equation is estimated using *all* households (including the "NG"s). The implied WTP from this approach (evaluated using the population means for income and education) are presented below in Table IX-5. Note that this approach results in somewhat lower estimates that are more consistent with the estimates provided by the split-sample approach presented above in Table IX-3.

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Table IX-5

Implied Willingness-to-Pay:

Estimation using Combined Sample,

"NG" Households Initially Included

Effects Case	**Estimated WTP**
5 percent case	126.81
12 percent case (base)	138.78
21 percent case	154.17
35 percent case	178.11

Credibility of the Payment Vehicle

In order for the contingent valuation method to provide valid results, the respondents must believe that there is some payment consequence attached to the policy being considered. It is sometimes argued that respondents do not actually believe that will have to pay should the policy be adopted. However if respondents were to believe that they do not have to pay, there would be no reason for them to condition their responses on the stated cost to their household, or on their income. And yet the results presented above show that both of these variables are significant, suggesting that the respondents are in fact conditioning their responses on these variables.

A more direct way to test for a tendency on the part of households to ignore the potential costs to their household is to ask the respondents if they believe that will have to pay the amount stated in the survey instrument. This was done in the mail instrument via question Q-24, which asks "Do you believe your household would pay roughly the dollar amount shown in Q-14 in higher prices for products every year for the foreseeable future if this proposal passes?" The results to this question are shown in Table IX-6.

Table IX-6

Credibility of Payment Vehicle: Responses to Q24

Question: "Do you believe your household would pay roughly the dollar amount shown in Q-14 in higher prices for products every year for the foreseeable future if this proposal passes?"

Yes	37.1 %
No, actual cost would be higher	48.4 %
No, actual cost would be lower	14.5 %

As the responses to this question show, only a very small percentage of the sample (14.5 percent) expressed a belief that they would pay less than the stated amount. A substantial majority expressed the belief that they will pay as much or more than the stated cost (with nearly half suggesting that it will cost more than is stated).

Personal Interview Results

The results from the personal interviews are presented below in Table IX-7 for the first referendum question and for the follow-up referendum question (which allowed respondents to change their vote). For the interviews, all respondents were confronted with a 12 percent reduction in deposition. The corresponding cases are presented for the mail survey. Identical specifications are used in each case. (For a discussion of the specification, see the discussion in the section above entitled *"Regression Results: Simple Specification."*) Two sets of estimates are provided: estimates obtained by trimming the tails of the distribution (of the cost variable) and estimates for the full sample. When the number of observations is low, estimates of the logistic function can be very sensitive to the tails of distribution of the cost variable. For example, if there are a small number of observations in the upper tail (as we have here with only 14 observations with a cost to the household at or above $215), small shifts in the percentage of "yes" votes within the tail can significantly alter the estimates, and can result in an increase in the standard errors. The estimates are less sensitive to observations that are between the tails of the distribution, and thus a trimmed-tail subsample may provide more robust estimates when there is a small number of observations in the tails. We thus provide estimates for a subsample with trimmed tails and for the full sample.

Table IX-7

Estimates from Personal Interviews

(comparison with corresponding mail survey estimates)

Sample	Estimated WTP	Standard Error	n
mail (12%, V1)	131.32	22.39	351
mail (12%, V2)	118.91	24.84	348
interv., trimmed, V1	214.68	60.57	200
interv., trimmed, V2	198.03	45.32	200
interv., full, V1	454.85	423.71	250
interv., full, V2	1327.90	5516.75	250

Notes: V1 refers to estimates for which the dependent variable is based on the first referendum question; V2 refers to estimates for which the dependent variable is based on the second version of the referendum question at the end of the survey. The "trimmed" version of the interview estimates excludes observations in the tails of the distribution; only those observations for which

the cost to the household exceeds $45 and is less than $215 are included. This excludes 14 observations in the upper tail and 36 observations in the lower tail.

As with the mail survey results, the substantial WTP estimates from the personal interviews are consistent with a strong level of support for the mercury reduction policy. The average household clearly perceives there to be a substantial benefit associated with such reductions. This is most apparent with the trimmed subsample, since the full sample, while yielding higher point estimates, also yields very large standard errors due to the problem of an insufficient number of observations in the tails of the distribution.

The estimates also show a tendency for the interview approach to yield higher values than the mail survey. The lower estimates from the mail survey may reflect the "impersonal" nature of the mail survey. Moreover, the presence of an interviewer may lead some respondents to react more favorably to the survey questions than if the survey were conducted in greater anonymity. In any case, there is no evidence from these results that the estimated WTP from the mail survey is biased upward vis-a-vis a personal interview approach (contrary to concerns expressed during the NOAA Panel proceedings).

Finally, both the mail survey results and the statistically-significant personal interview results (the trimmed estimates) show a slight tendency for the estimated WTP to fall when respondents are given a chance to change their vote at the end of the survey. This may provide an additional reason for favoring the use of the second referendum question over the first.

Credibility of the Payment Vehicle for the Interview Sample

As noted above in the discussion of the mail survey, in order for the contingent valuation method to provide valid results, the respondents must believe that there is some payment consequence attached to the policy being considered. One way to test for this is to ask the respondents if they believe they will have to pay, and if they believe they will have to pay the amount stated in the survey instrument. This was done in the interview instrument via question 2-7, which asks "Do you believe your household would pay higher prices for products if this proposal passes"; and via question 2-8, which asks "Do you believe your household would pay roughly the dollar amount I told you in higher prices for products every year for the foreseeable future if this proposal passes?" The results for these questions are shown in Table IX-8.

Table IX-8

Credibility of Payment Vehicle in the Personal Interviews

Question 2-7: "Do you believe your household would pay higher prices for products if this proposal passes?"

Yes	89.2 %
No	7.2 %
Not sure	3.6 %

Question 2-8: "Do you believe your household would pay roughly the dollar amount I told you in higher prices for products every year for the foreseeable future if this proposal passes?"

Yes	66.8 %
No	22.4 %
Not sure	10.8 %

As Table IX-8 shows, only 7.2 percent expressed a disbelief in the notion that they would have to pay higher product prices. Approximately 22 percent expressed a belief that they would pay either more or less than the stated amount (with 11 percent not sure of the amount they would have to pay). Unlike the mail respondents, the interview respondents were not asked whether they thought that the stated cost is an overestimate or an underestimate. The results from the mail survey show a very strong preponderance for those respondents who question the credibility of the cost estimates to think that the cost estimates are too low. It is quite possible, therefore, that the majority of the 22 percent who expressed disbelief at the cost estimates did so primarily because they thought that the estimates are too low. This would be consistent with attitudes expressed by respondents during pre-testing and by participants in the focus groups, many of whom expressed a belief that "these things always cost more than is expected". In any event, the evidence from all of these sources--the interviews, the mail survey, the focus groups, and the pre-testing--suggests that an overwhelming majority of respondents believe that they will in fact have to pay.

Section X.

Summary and Conclusions

Reductions in mercury emissions will have beneficial human and environmental effects. A contingent-valuation study was employed in order to provide a monetized measure of these benefits to Minnesota households. This study involved a mail survey of 2,500 Minnesota households and personal interviews with 250 Minnesota households.

Analysis of survey responses produced a statistical estimate of a valuation function. The valuation function is used to compute the average annual willingness of Minnesota households to pay for the projected effects of reduced mercury emissions. For the baseline policy scenario (the 12% deposition reduction), the mail survey resulted in an estimated annual household willingness to pay of $118.91.[8] The personal interview results (for the trimmed subsample) show a higher WTP of $198.03, possibly indicating "yea-saying" bias from the personal nature of the interview procedure.

Using the more conservative mail-survey estimate, a state-wide willingness to pay can be computed by multiplying the per-household figure ($118.91) by the number of households (1.786 million in 1996) to yield an annual state WTP of $212 million.[9] With a state population of 4.683 million (1996 estimate) this translates into a figure of approximately $0.12 per person per day.

[8] See Table IX-3 in Section IX.

[9] Population figures are estimates produced by the Minnesota Office of State Demographer.

Section XI.

References

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner and H. Schuman, "Report of the NOAA Panel on Contingent Valuation", *Federal Register*, 58(10), January 15, 1993.

Bishop, Richard C. and Thomas Heberlein, "Measuring Values of Extra-Market Goods," *American Journal of Agricultural Economics*, 61, 1979, 925-930.

Bishop, Richard C. and Thomas A. Heberlein, "The Contingent Valuation Method," in R.L. Johnson and G.V. Johnson, eds., *Economic Valuation of Natural Resources: Issues, Theory, and Application*, Westview Press, Boulder, CO, 1990.

Bishop, Richard C., Thomas A. Heberlein, and Mary Jo Kealy, "Contingent Valuation of Environmental Assets: Comparisons With a Simulated Market", *Natural Resources Journal*, 1983.

Bishop, R.C., and M.P. Welsh, "Existence Value and Resource Evaluation." In Western Regional Committee W-133, *Benefits and Costs in Natural Resource Planning*, Third Interim Report, ed. J.P. Hoehn. East Lansing: Michigan State University, 1990.

Bjornstad, D. and J. Kahn, *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*, Edward Elgar, 1996.

Boyle, K.J., W.H. Desvousges, F.R. Johnson, R.W. Dunford, and S.P. Hudson, "An Investigation of Part-Whole Biases in Contingent-Valuation Studies, *Journal of Environmental Economics and Management*, 27, 1994, 64-83.

Brookshire, D.S., L.S. Eubanks, and A. Randall, "Estimating Option Prices and Existence Values for Wildlife Resources," *Land Economics* 59:1, 1983.

Brookshire, D.S., M.A. Thayer, W.D. Schulze, and R.C. d'Arge, "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches", *American Economic Review*, 72, 1982, 165-177.

Brookshire, D.S., M.A. Thayer, W.D. Schulze, and R.C. d'Arge, "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches," *American Economic Review*, 72, 1982, 165-177.

Brown, T., P. Champ, R. Bishop, and D. McCollum, "Which Response Format Reveals the Truth about Donations to a Public Good?", *Land Economics*, May 1996.

Cameron, Trudy Ann, "A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression," *Journal of Environmental Economics and Management*, 15, 1988.

Carson, R., et al., " Referendum Design and Contingent Valuation: The NOAA Panel's No-Vote Recommendation", *Review of Economics and Statistics*, May 1998.

Carson, R., et al., “Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods”, *Land Economics*, February 1996.

Carson, R. et al., “Prospective Interim Lost Use Value dut to DDT and PCV Contamination in the Southern California Bight”, National Oceanic and Admospheric Administration, September 1994

Carson, R. et al., “Was the NOAA Panel Right about Contingent Valuation?”, Discussion Paper 96-20, Resources for the Future, Washington, D.C., May 1996.

Carson, R.T., "Contingent Valuation Surveys and Tests of Insensitivity to Scope," Paper presented at the International Conference on Determining the Value of Non-Marketed Goods: Economic, Psychological, and Policy Relevant Aspects of Contingent Valuation Methods, Bad Hamburg, Germany, July 1994.

Carson, R.T., Mitchell, R.C., "The Issue of Scope in Contingent Valuation Studies," *American Journal of Agricultural Economics*, 1993, Vol 75, Iss 5, pp 1263-1267.

Carson, R., J. Wright, A. Alberni, N. Carson and N. Flores, *A Bibliography of Contingent Valuation Studies and Papers*, Natural Resource Damage Assessment, Inc. La Jolla, CA, March 1994.

Cummings, R.G., D.S. Brookshire, and W.D. Schulze, *Valuing Environment Goods: An Assessment of the Contingent Valuation Method*, Rowman and Allanheld, Totowa, NJ, 1986.

Desvousges, W.H., V.K, Smith and M.P. McGivney, "A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements," Office of Policy Analysis, U.S. Environmental Protection Agency, Washington D.C., 1983.

Dillman, Don A., *Mail and Telephone Surveys*, Wiley, New York, 1978.

Duffield, John W. and David A. Patterson, "Inference and Optimal Design for a Welfare Measure in Dichotomous Choice Contingent Valuation," *Land Economics*, May 1991.

Freeman, A.M., III, "Nonuse Values in Natural Resource Damage Assessment," in R. Kopp and V. K. Smith, eds., *Valuing Natural Assets: The Economics of Natural Resource Damage Assessment*, Resources for the Future, 1993.

Hagen, D. A., J. W. Vincent, and P. G. Welle, "The Benefits of Preserving Old-growth Forests and the Northern Spotted Owl," *Contemporary Policy Issues*, April 1992.

Harris, C.C., B.L. Driver, and W.J. McLaughlin, "Improving the Contingent Valuation Method: A Psychological Perspective," *Journal of Environmental and Economics Management*, 17, 1989, 213-229.

Harrison, G.W., "Valuing Public Goods With the Contingent Valuation Method: A Critique of Kahneman and Knetsch," *Journal of Environmental Economics and Management*, 23, 1992, 248-257.

Hausman, Jerry A., ed., *Contingent Valuation: A Critical Assessment*, Contributions to Economic Analysis, Vol. 220. North-Holland; Elsevier, Science, New York, 1993.

Hoehn, John P., "Contingent Valuation in Fisheries Management: The Design of Satisfactory Contingent Valuation Formats," *Transactions of the American Fisheries Society*, 116, 1987, 412-419.

Hoehn, John P. and Alan Randall, "A Satisfactory Benefit Cost Indicator from Contingent Valuation," *Journal of Environmental Economics and Management*, 14, 1987, 226-247.

Kahneman, Daniel and Jack Knetsch, "Valuing Public Goods: The Purchase of Moral Satisfaction," *Journal of Environmental Economics and Management*, January 1992.

Kealy, M.J., M. Montgomery, and J.F. Dovidio, "Reliability and Predictive Validity of Contingent Values: Does the Nature of the Good Matter?", *Journal of Environmental Economics and Management*, 19, 1990, 244-263.

Kopp, R., A. Krupnick, and M. Toman, "Cost-Benefit Analysis and Regulatory Reform: An Assessment of the Science and Art", Discussion Paper 97-19, Resources for the Future, Washington, D.C., January 1997.

Kopp, R.J., "Why Existence Value Should Be Used in Cost-Benefit-Analysis," *Journal of Policy Analysis and Management*, 1992, Vol 11, Iss 1, pp 123-130.

Loomis, J.B., "Comparative Reliability of the Dichotomous Choice and Open-Ended Contingent Valuation Techniques," *Journal of Environmental Economics and Management*, 18, 1990, 78-85.

Loomis, J.B., M. Lockwood, and T. DeLacy, "Some Empirical Evidence on Embedding Effects in Contingent Valuation of Forest Protection," *Journal of Environmental Economics and Management*, 25, 1993, 45-55.

Loomis, J., A. Gonzales-Coban, and R. Gregory, "Do Reminders of Substitutes and Budget Constraints Influence Contingent Valuation Estimates?", *Land Economics*, November 1994.

Milon, J.W., "Contingent Valuation Experiments for Strategic Behavior," *Journal of Environmental Economics and Management*, 17, 1989, 293-308.

Mitchell, Robert C. and Richard T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington D.C., 1989.

Neill, H.R., R.G. Cummings, P.T. Ganderton, G.W. Harrison, and T. McGuckin, "Hypothetical Surveys and Economic Commitments," *Land Economics*, 70, 1994, 145-154.

Nickerson, C.A., "Valuing Public Goods: A Comment on Harrison's Critique of Kahneman and Knetsch," *Journal of Environmental Economics and Management*, 25, 1993, 93-102.

Patterson, David A. and John W. Duffield, "Comment on Cameron's Censored Logistic Regression Model for Referendum Data," *Journal of Environmental Economics and Management*, May, 1991.

Portney, P.R., "The Contingent Valuation Debate: Why Economists Should Care", *Journal of Economic Perspectives*, 1994.

Rae, Douglas, “Impact of Mercury Reductions in Minnesota”, report prepared for the Minnesota Pollution Control Agency and Hagler Bailly Services, Inc., September 30, 1997.

Sellar, C., J.R. Stoll, and J.P. Chavas, "Validation of Empirical Measures of Welfare Change: A Comparison of Nonmarket Techniques," *Land Economics*, 61, 1985, 156-175.

Smith, V. Kerry, "Arbitrary Values, Good Causes, and Premature Verdicts," *Journal of Environmental Economics and Management*, January 1992.

Smith, V.K. and L. Osborne, "Do Contingent Valuation Estimates Pass a 'Scope' Test?: A Meta Analysis," Discussion Paper 95-25, Resources for the Future, Washington, D.C., June 1995.

U.S. Bureau of the Census, *Statistical Abstract of the United States*, 1997.

U.S. Court of Appeals, Washington, D.C., *State of Ohio v. U.S. Department of Interior*, 880 F. 2d 432, 1989.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Natural Resource Damage Assessments Under the Oil Pollution Act of 1990," *Federal Register*, 58, 1993, 4601-4614.

U.S. Department of the Interior, "Final Rule for Natural Resource Damage Assessments under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980" (CERCLA), *Federal Register*, 51, 1986, 27674-27753.

U.S. Department of the Interior, "Final Rule for Natural Resource Damage Assessments under the Comprehensive Environmental Response, Compensation and Liability Act of 1980" (CERCLA), *Federal Register*, 51, 1986, 27674-27753.

Viscusi, W. Kip, "The Value of Risks to Life and Health", *Journal of Economic Literature*, December 1993.

Water Resources Council, "Procedures for Evaluation of National Economic Development (NED): Benefits and Costs in Water Resources Planning (Level C), Final Rule," Federal Register, 44, 1979, 72892-72977.

Water Resources Council, Principles and Guidelines for Water Related Land Resources Implementation Studies, Washington, D.C., 1983.

Appendix A

"Impacts of Mercury Reduction in Minnesota", by Douglas Rae.

Appendix B

Mail-survey instruments

Appendix C

Personal-interview-survey instrument, visual aids

Appendix D

Cover letters, follow-up letters and phone script for mail survey

Appendix E

Contact letters and phone-verification script for personal-interview survey

Appendix F

Estimation Techniques: Logistic and Censored Logistic Regression

The conventional technique for estimating mean willingness-to-pay (WTP) from referendum data involves the estimation of a logistic regression equation of the following form:

$$ln[P_i/(1-P_i)] = \alpha C_i + \gamma' X_i,$$

where,

P_i = probability of an affirmative vote,

$ln[P_i/(1-P_i)]$ = "log odds" of an affirmative vote,

C_i = cost to household i if the policy is adopted,

X_i = other explanatory variables (income, education, etc.) for household i,

α, γ = model parameters (to be estimated).

Solving for P_i yields:

$$P_i = [1 + exp-(\alpha C_i + \gamma' X_i)]^{-1},$$

which is the cumulative density function (c.d.f.) of the logistic p.d.f. From this expression the log-likelihood function can be derived and maximized with respect to α and γ. The estimated mean WTP is obtained by integrating the fitted logistic c.d.f. with respect to C_i.

Censored logistic regression represents an extension of the above approach. Censored logistic regression has the advantage of providing an explicit expression for estimated mean WTP in the following form:

$$E(WTP_i) = \beta' X_i .$$

The β parameters can be obtained from the parameters of the conventional logistic regression model through the following transformation (Cameron, 1988):

$$\beta = -\gamma/\alpha .$$

Moreover, the asymptotic standard errors of the estimated β can be obtained from the variance-covariance matrix of the standard logistic regression model using the following transformation (Patterson and Duffield, 1991):

$$Var(\beta_j) = (g_j^2/\alpha^4)Var(\alpha) - 2(g_j/\alpha^3)Cov(\alpha,g_j) + (1/\alpha^2)Var(g_j) \quad \text{(F5)}$$

This yields estimates that are equivalent to those obtained by maximizing the censored logistic log-likelihood function. (Patterson and Duffield, 1991, demonstrate the mathematical equivalence of these two approaches, and provide an example. Hagen, Vincent and Welle, 1992, utilize both approaches and find that the results are identical.) All of the censored logistic regression estimates presented in this report were obtained by transforming the logistic regression parameters in the manner described above.

Appendix G

Biographical Information

Daniel A. Hagen is Associate Professor of Economics at Western Washington University. He received his B.A., M.A. and Ph.D. degrees in Economics from the University of California, Berkeley. His teaching and research focuses on environmental and resource economics, and on international trade. He has published articles and technical reports on a variety of topics, including environmental valuation, energy pricing, natural resource management, forecasting, and international trade. Dr. Hagen has served as a consultant to a variety of public agencies and private firms.

James W. Vincent is Associate Professor of Economics at the University of St. Thomas in St. Paul, Minnesota. He received a B.A. in Economics from the University of Montana and the M.S. and Ph.D. degrees in Economics from the University of Wisconsin-Madison. He has served as a consultant and expert witness for organizations such as the Colorado Office of Consumer Counsel, the Colorado Public Utilities Commission, the Colorado Division of Wildlife, the Montana Public Service Commission and U S West Communications. He conducts academic research in the areas of energy and environmental economics and has produced published papers and technical reports on energy pricing, environmental valuation and electric utility systems.

Patrick G. Welle is Professor of Economics at Bemidji State University. He holds an M.A. and Ph.D. in Economics from the University of Wisconsin, Madison. Dr. Welle's consultant work includes research for state, regional, and local units of government and public and private economic development agencies, as well as advising private businesses, particularly on matters of tourism and economic development. Much of this work has involved the utilization of economic surveys. Dr. Welle has published numerous articles and reports on topics such as benefit-cost analysis, environmental policy, natural resource management, tourism, and economic development. Dr. Welle directed a project for the Minnesota Pollution Control Agency as part of the rule-making process on acid rain and served as an expert witness. He authored the report "Potential Economic Impacts of Acid Rain in Minnesota: The Minnesota Acid Rain Survey."