Lake Champlain
Basin Program

Technical Report No. 4D

Lake Champlain Economic Database Project

Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain

Prepared by
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for
Lake Champlain Management Conference

March 1993

PUBLICATION SERIES

THIS PROGRAM IS SPONSORED BY U.S.E.P.A. AND THE STATES OF NEW YORK AND VERMONT.

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March 25, 1993

This technical report is the fourth in a series of reports prepared under the Lake Champlain Basin Program. Those in print are listed below.

Lake Champlain Basin Program Technical Reports

1. *A Research and Monitoring Agenda for Lake Champlain.* Proceedings of a Workshop, December 17-19, 1991, Burlington, VT. Lake Champlain Research Consortium. May, 1992.

2. *Design and Initial Implementation of a Comprehensive Agricultural Monitoring and Evaluation Network for the Lake Champlain Basin.* NY-VT Strategic Core Group. February, 1993.

3. (A) *GIS Management Plan for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc., and Associates in Rural Development. March, 1993.

   (B) *Handbook of GIS Standards and Procedures for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

   (C) *GIS Data Inventory for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

4. (A) *Lake Champlain Economic Database Project. Executive Summary.* Holmes & Associates. March 1993.

   (B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin.* Holmes & Associates. March 1993

   (C) *Potential Applications of Economic Instruments for Environmental Protection in the Lake Champlain Basin.* Anthony Artuso. March 1993.

   (D) *Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain.* Anthony Artuso. March 1993.

This report was funded and prepared under the authority of the Lake Champlain Special Designation Act of 1990, P.L. 101-596, through the U.S. Environmental Protection Agency (EPA grant #EPA X 001840-01). Publication of this report does not signify that the contents necessarily reflect the views of the States of New York and Vermont, the Lake Champlain Basin Program, or the U.S. Environmental Protection Agency.

The Economic Database Study is a survey of existing data and national literature intended to provide an overview of economic and demographic characteristics, and market-based approaches to facilitate water pollution control and prevention. Specific calculation of economic impacts of proposed actions will usually require additional information and data to apply principles from this compilation of existing data and literature to the Champlain Basin. In particular, current Lake Champlain Basin Program research in the areas of agriculture, recreation and fisheries will provide underlying data needed for refined estimates of costs and economic impacts of potential management actions.

March 1993

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Project Description and Introduction

This report is the fourth of four volumes developed under the Lake Champlain Management Conference (LCMC) project: Economic Database for the Lake Champlain Basin. The project was intended to provide the Lake Champlain Basin Program (LCBP) with the following information: an accurate, accessible economic database for the entire basin; a description of economic sectors closely related to the lake; a literature review and analysis of the use of economic instruments for environmental protection; and a framework for evaluating pollution control strategies and water quality standards. The four volumes of the report are listed below.

Volume I: Summary Report

Volume II: Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin

Volume III: Potential Applications of Economic Instruments for Environmental Protection in the Lake Champlain Basin

Volume IV: Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain

This report outlines the analytical techniques, data requirements, and decision criteria involved in developing and evaluating alternative water pollution control programs and water quality standards. The report is intended to provide a comprehensive analytical framework that can be utilized to guide the LCMC's research activities and policy formulation process.

1.0 A Framework for Environmental Policy Analysis

To obtain the information necessary for sound policy analysis, the research program of the Lake Champlain Management Conference (LCMC) should be guided by a comprehensive analytical framework for developing a water pollution control strategy and water quality standards. This report proposes the use of an analytical framework based largely on benefit-cost (B/C) analysis, but with added emphasis on evaluating risk and uncertainty, the distribution of benefits and costs, and the institutional and administrative issues involved in successful implementation of pollution control programs. The proposed framework includes five phases of research and policy analysis as outlined below.

1. Quantifying the effects of changes in pollution discharges on water quality parameters.
2. Identifying sources of pollution, determining their magnitude, and estimating the costs of increasingly stringent pollution controls.
3. Quantifying the relationship between improvements in water quality parameters and public health, recreational, aesthetic, and ecological benefits.
4. Evaluating the technical, political, and administrative feasibility; cost-effectiveness; and fairness of alternative pollution control strategies.
5. Utilizing results of phases 1 - 4 to compare the benefits and costs of achieving alternative water quality standards.

The analytical process summarized above is not strictly sequential. Although the results of phases 1, 2, and 3 provide the essential data for evaluating alternative pollution control strategies and establishing appropriate water quality standards, the first three phases can be conducted in almost any order. In addition, there should be some iteration between the design of the pollution control program (phase 4), and the evaluation of alternative water quality standards (phase 5). Once the general outlines of the pollution control strategy have been determined, the expected costs of various levels of pollution control can be compared with expected benefits. Given the preferred pollution control strategy, water quality standards should be chosen in order to maximize the net benefits that are expected to result from achieving those standards.

1.1 Estimating Benefits and Costs

The LCMC has already initiated or scheduled several projects to determine how pollution discharges affect water quality and ecological processes. These include the Hydrodynamic Modeling Project, the Phosphorus Diagnostic Study, and the Food Web Interactions Study. To be most useful for subsequent policy development, it is important that these scientific studies develop stochastic models that incorporate the effects of natural variability and statistical uncertainty. In addition, the effect of pollution discharges on water quality parameters or fish populations provides only a portion of the information needed to evaluate the benefits of pollution control. In terms of policy analysis, quantifying the public health, recreational, and aesthetic benefits of changes in water quality is just as important as modeling the underlying physical and biological processes. The Economic Database Project (of which this report is a part), and the recent effort to evaluate the impacts of the lake on the economies of two communities in the basin, will be helpful in evaluating the benefits of water quality improvements. However, these projects represent only the first steps in determining how water quality improvements affect public health, recreational opportunities, property values, and the general economy of the Lake Champlain Basin.

Several ongoing projects such as the Phosphorus Diagnostic Study, the Nonpoint Pollution Assessment, and the Comprehensive Agricultural Monitoring and Evaluation Project, focus on quantifying the magnitude of pollution discharges from various sources and the costs of controlling them. It is important to ensure that these and other analyses of the costs of pollution control are comprehensive enough to permit well informed policy decisions. This requires that the costs and reliability of increasingly stringent pollution control measures are estimated for all major sources of pollution.

1.2 Comparing Alternative Pollution Control Strategies

In addition to estimating the potential benefits and technically feasible costs of pollution control, it is important that the LCMC begin to evaluate alternative regulatory strategies. The costs and other important characteristics of the preferred pollution control strategy should be taken into account when establishing water quality standards. A pollution control strategy that achieves any given level of pollution control at relatively low per unit costs (i.e. is highly cost-effective) will enable residents and businesses in the Lake Champlain Basin to afford a higher level of water quality.

An effective pollution control program is likely to involve a combination of legal mandates, economic incentives, public information, and direct public expenditures for pollution control or remediation. Criteria for comparing alternative pollution control strategies should include:

- Cost-effectiveness
- Financing mechanisms
- Distribution of cost and benefits
- Relationship to existing institutional and legal framework
- Administrative, monitoring, and enforcement requirements
- Incentives for innovation, and flexibility in response to change
- Clarity and intelligibility to the public.

It is difficult and perhaps inappropriate to rank the above criteria in order of priority. Obviously, technical, legal, and political feasibility are prerequisites for any successful pollution control program. But even technical feasibility is rarely a certainty. Instead, there are varying degrees of risk associated with different control technologies. Moreover, uncertainty over legal authorization can often be eliminated through new legislation. This highlights the need for a political analysis of the proposed pollution control strategy which, in turn, should lead to a review of the merits of the program, and the degree to which they can be communicated to the public. A comparison of the cost-effectiveness, distributional consequences, and administrative requirements of traditional regulatory approaches, and economic incentives for pollution control is contained in Volume 3 of this project. Section 4 of this volume discusses additional research and a participatory planning process that can assist in the development of a cost-effective and equitable pollution control strategy.

1.3 Establishing Environmental Quality Standards

Establishing environmental standards, like most other public policy decisions, involves judgments about the most effective means of improving the quality of life, given limited resources. Development of environmental quality standards should therefore include a comparison of costs and benefits for a range of alternative standards, consider the distributional consequences of these alternatives, and explicitly consider the implications of risk and uncertainty.

Benefit-cost (B/C) analysis is a well established methodology for systematically comparing the consequences of alternative policy options. As described in Section 2 below, a well-designed B/C analysis can take account of risk and uncertainty, provide information on the distribution of benefits and costs across segments of society, and provide the basis for consistent comparison of policy options where the timing of benefits and costs differ. As will be argued below, B/C analysis can be a useful tool in the policy development process, but it is should not be employed as a substitute for personal judgments, public debate, and democratic decisionmaking.

2.0 Uses and Abuses of Benefit-Cost Analysis

Ideally, benefit-cost analysis involves the estimation of all benefits and costs of a project, policy, or program, in terms of a standardized unit of measurement. Since the monetary value that consumers and producers place on marketable products can be relatively easily determined, most B/C analyses also attempt to estimate the value of non-market goods and services in monetary terms. If the monetary value of any benefits or costs cannot be adequately estimated, they should still be described and quantified as much as possible.

On the assumption that resources can always be productively invested elsewhere, future benefits and costs are discounted to permit comparison in current dollars. Distributional considerations can be explicitly taken into account in the analysis by providing different weights to the benefits and costs accruing to different groups. However, it can be difficult to reach agreement on whether costs or benefits accruing to certain groups should be given the same, slightly more, or significantly more weight than benefits accruing to other segments of society. It may therefore be appropriate to simply present the disaggregated detail of costs and benefits along with an unweighted summary. Decision makers and the public can then apply their own implicit or explicit weightings.

Any framework for policy analysis has its own set of limitations and difficulties. B/C analysis is no exception.[1] Like all other frameworks for environmental policy development, B/C analysis must grapple with uncertainty in the relationships between pollution discharges, environmental quality indicators, human health, recreational enjoyment, and other public policy concerns. Knowledge of these relationships can be increased through additional research, but some residual uncertainty will always remain. B/C analysis has the added difficulty of estimating the benefits of pollution reductions in monetary terms, which can be particularly problematic for goods or services, such as clean air or water, that are not actively traded in competitive markets. Other methodologies for decisionmaking do not really avoid the problem of developing monetary estimates of all benefits and costs. Rather, the comparison of monetary and non-monetary costs and benefits is simply left open to subjective judgments. The strength of B/C analysis is that it forces us to think explicitly and systematically about the underlying assumptions and values involved in public policy decisions.

A brief introduction to several techniques utilized to value non-market goods and services is included in Section 3 of this report. At this point it is sufficient to note that although environmental economics has made significant strides over the past several decades, estimates of the monetary value of reduced public health risks, enhanced recreational opportunities, or aesthetic enjoyment, should be viewed only as a rough approximation of the value of certain aspects of environmental quality.

One of the most controversial aspects of B/C analysis is the use of a discount rate to translate future benefits and costs into present values. A widespread concern is that the interests of future generations are what is being discounted as a result of this procedure. But the existence of positive real interest rates, even on virtually risk free assets such as treasury bills, indicates that most people will not invest a dollar today without an expectation of receiving more than a dollar next year. Discounting is merely a reflection of this virtually universal manifestation of human impatience. Some may argue that impatience should not be publicly reinforced through the use of

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[1] See Schwartzman (1982, 53-85) for a discussion of the methodological, political, and ethical issues involved in utilizing B/C analysis to evaluate environmental policies.

discount rates in evaluating public projects and policies. But to proceed with a public project that does not yield a rate of return at least as great as the return that can be achieved through other similarly risky investments would be detrimental to the interests of future generations. It would leave them with fewer resources and benefits than they would otherwise have. Given the existence of positive rates of interest on other investments, the use of appropriate discount rates in analyzing public projects and policies can help ensure that the resources available to society are used most productively.

This seems reasonable enough for prosaic investment decisions, such as whether to construct a new public building or purchase new equipment. But environmental policy decisions often involve such precious resources as clean water, unique habitats or human health. To many people, it seems almost sacrilegious to discount these benefits simply because they occur in the future. This sentiment has at least two sources.

One source of concern about using discounting in environmental B/C analysis is the recognition that environmental resources are becoming increasingly scarce. It is difficult to understand why the future benefits of increasingly scarce resources should be discounted. In order to understand this apparent paradox, it is necessary to distinguish between two separate economic concepts. If any resources involved in a B/C analysis are expected to become increasingly scarce, then the analysis should incorporate increases, in excess of the general rate of inflation, in the future value of the benefits or costs related to these resources. Nevertheless, the projected future values of all benefits and costs (whether increasing or decreasing in real terms) must still be discounted at the same rate to determine their present values. It is only when stated in terms of their present values, that costs and benefits occurring at different periods in time can be meaningfully compared.

A second source of uneasiness with the use of discount rates in environmental policy analysis is a widespread perception that it is somehow unethical to discount future benefits associated with human health or longevity. Why should improvements in the health of human beings be worth less next year than this year? Some insight into this difficult issue can be provided by restating the above question. Should improvements in human health that occur today be valued more highly than those that occur in the future? Consider two projects, both of which will reduce the incidence of a certain disease by the same percentage and for the same length of time in the same target population. Both projects have identical costs and expenditure schedules. However, one project will reduce disease rates after one year, while the other will do so only after five years. If resources are available for only one of these projects, most people would choose the one that provides the more immediate benefits. This is a form of discounting.

Even if the discounting of future benefits and costs is accepted as an appropriate analytical tool, the question still remains what discount rate to use. There is no simple or universally accepted answer to this question. The main theoretical insight is that the most appropriate discount rate is the rate of return available on other similarly risky investments.[2] The difficulty lies in quantifying the risks involved in the public investment project or policy decision, and then identifying other investment opportunities with similar risk profiles. Further discussion of the appropriate discount rate is included in Section 4 of this report.

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[2] See Hartman (1990), Lind (1990), Lyon (1990), Moore and Viscusi (1990), and Portney (1990) for a more complete discussion of the issues involved in determining the appropriate discount rate.

Another ethical concern about the use of B/C analysis is that it strengthens self-interest as the guiding principle in public decisionmaking (Schwartzman 1982, 70). The relevance of this critique depends on the manner in which the B/C analysis is performed and utilized. As will be discussed in Section 3, techniques have been developed to estimate the value that individuals place on environmental resources that is not associated with their use of those resources. For instance, many people may take pleasure in knowing that a unique environment will be preserved, even if they never intend to visit it. For unique environmental resources, these non-use or existence values are likely to be substantial, and should be incorporated into the B/C analysis whenever possible.

B/C analysis should not be utilized as a kind of black box that combines scientific data, economic statistics, and public preferences to generate an objective and universally correct answer. The assumptions, forecasts, and preferences reflected in the B/C analysis should provide a starting point for public discussion rather than a final decision. Unfortunately, B/C analysis can often become an obscure, technical exercise intelligible only to bureaucrats and economists. To avoid this, the assumptions, data collection methods, analytic techniques, and results of the analysis must be presented for public review and debate. If those responsible for performing the B/C analysis cannot explain their procedures to non-specialists, the results should rightly be regarded with some suspicion. However, a thorough, well documented B/C analysis that quantifies the effects of a reasonable range of assumptions and risk factors on the outcomes of alternative policies can provide public officials and interested parties with important information for formulating and critically examining their own judgments.

2.1 Accounting for Risk and Uncertainty

An important aspect of any decision process is the evaluation of risk and uncertainty. The basic analytical technique utilized to evaluate the implications of risk and uncertainty is known as decision analysis.[3] This technique expands upon deterministic approaches to B/C analysis by evaluating the net benefits of a set of possible future conditions. A probability of occurrence is assigned to each chance event together with an associated set of benefits and costs. Summation of the products of each probability and its associated net benefits (or costs) yields the expected net benefit of a given decision.

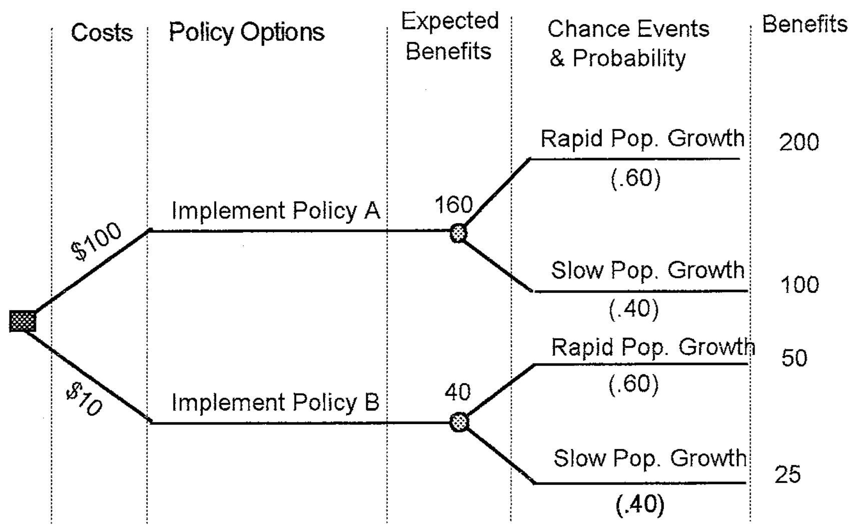
A simple example of decision analysis is presented in Figure 1. The cost of pursuing policy A is $100, but benefits depend on whether there is rapid or slow economic growth in the future. The expected benefits of pursuing policy A can be computed by multiplying the outcome of each state of affairs with its probability of occurrence and then adding the resulting products. For Policy A in Figure 1, the expected benefit is (.60 x $200) + (.40 x $100) = $160. Similarly for Policy B, which costs $10 to implement, the expected benefit is (.60 x $50) + (.40 x $25) = $40. The expected net benefits of Policy A are therefore $160 - $100 = $60, and the expected net benefits of Policy B are $40 - $10 = $30.[4]

Figure 1 is referred to as a decision tree. It permits evaluation of the outcomes of alternative decisions in the presence of risk or uncertainty. By constructing more complex

[3] For an accessible introduction to decision analysis see Stokey and Zeckhauser (1978). For a more complete but still very readable introduction to this subject see Raiffa (1968).

[4] For simplicity, the timing of costs and benefits are ignored in this example.

Figure 1 A Simple Decision Tree



decision trees, decision analysis can be expanded to incorporate any number of choices and potential outcomes. This makes it a very powerful analytical tool for systematically comparing the expected benefits and costs of alternative public policies.

An important refinement to the basic methodology of decision analysis involves events with substantial costs. Suppose you were offered the opportunity to play a game of chance where you had a .99 probability of winning $5,000 and a .01 probability of losing $450,000. The expected value of the gamble would be (.99 x $5,000) - (.01 x 450,000) = $450. Even though the chances of losing are small and the expected monetary payoff is positive, many people would refuse to play. For all except the very rich, losing $450,000 would be disastrous, and most people would not want to risk it. Those who would refuse to play this game are referred to as risk averse.

The modification of expected monetary benefits and costs to account for risk aversion, draws upon a body of economic research known as utility theory. Although the essential conclusions of utility theory are easily understood, the mathematics, and experimental methods required to estimate an individual's utility function are relatively complex.[5] In the context of environmental policy options for Lake Champlain, the costs of negative outcomes are shared, however unevenly, by residents of the entire basin. Therefore it is difficult to determine at what point the risk of a highly negative outcome becomes unacceptable. Nevertheless, given the importance of the lake to the region's economy and cultural identity, it is reasonable to assume that estimates of the monetary costs associated with severe, long-term degradation of major parts of the lake would not fully reflect the negative utility of this potential outcome.[6] As a result, the expected net benefits of any policy option that included a significant probability of severe water quality degradation would need to be adjusted downward. .

5 For a rigorous presentation of utility theory see Luce and Raiffa (1957) chapter 2.

6 Noel et al. (1992) discuss the potential for bottom sediments to become a substantial, continuous source of phosphorus once a lake's dissolved oxygen drops below a critical level. This phenomenon may already be contributing to the water quality problems of St. Albans Bay.

3.0 Techniques and Data Requirements for Estimating the Costs and Benefits of Water Quality Improvements

3.1 Sources of Pollution and Costs of Pollution Control

The LCMC has initiated several projects to identify the major sources of water pollution in the basin. These projects include, the Nonpoint Source Evaluation, the Phosphorus Diagnostic Study, the Toxics Characterization Project, and the Atmospheric Deposition Monitoring Program. In addition, the Comprehensive Agricultural Monitoring and Evaluation Project, the Nonpoint Source Evaluation, the Vermont Phosphorus Reduction Plan, and other studies conducted by federal and state agencies will provide the LCMC with important data on the costs of water pollution control. However, in order to be able to evaluate alternative policies and programs, the LCMC should ensure that these and subsequent studies will provide the following information.

1. Total mass, chemical characteristics, and annual pattern of discharges of priority pollutants (e.g. phosphorus, pathogens, heavy metals, pesticides) from all point and nonpoint sources.
2. Minimum costs of controlling these priority pollutants from all major sources at increasingly stringent levels of pollution control. For example, the costs of reducing phosphorus export from cropland should be determined at reduction levels of say 25%, 50%, 75%, and 90%. The costs of a similar range of pollution reduction levels should be determined for dairy and other livestock operations, urban/suburban runoff, construction sites, municipal treatment plants, and industrial facilities.
3. Degree of variability in the cost and effectiveness of increasingly stringent pollution control measures for each major source of pollution.

Information outlined in items one through three above can be utilized to calculate the costs of each incremental increase in the level of pollution control (i.e. the marginal cost curve). Surrounding these estimates of marginal costs will be a range of potential variation. If sufficient data is available on a particular pollution control technology, the marginal costs can be estimated with a quantifiable degree of confidence to lie within a certain range. This range, and the degree of confidence associated with it, is known as a confidence interval. .

One of the strengths of economic instruments such as discharge fees and transferable discharge permits discussed in Volume 3 of this project, is that they can reduce the amount of information necessary to cost-effectively achieve any given level of pollution control. Nevertheless, to estimate the level of pollution control that will maximize the expected net benefits to society, it is necessary to obtain information on the average marginal costs of controlling all major sources of pollution. Understanding the potential variability of these costs is beneficial in evaluating the risks involved in a alternative pollution control strategies.

3.2 Estimating the Benefits of Pollution Control

The first step in benefit estimation is to understand how reductions in discharges of a given pollutant, such as phosphorus, will affect water quality parameters (e.g. chlorophyll counts, frequency of algal blooms, dissolved oxygen). As evidenced by the continuing study of phosphorus attenuation, deposition, and resuspension in the St. Albans watershed, the relationship between phosphorus inputs and water quality indicators can often be quite complex. But even if the relationship between pollutant discharges and water quality can be reasonably well defined, it is still necessary to determine how changes in water quality parameters affect human health, ecological processes, recreational enjoyment, and aesthetic appreciation. Finally, it is important to translate these public health, recreational, aesthetic, and ecological effects into estimates of monetary value.

The LCMC has already initiated several studies that will contribute to understanding the linkages between pollution discharges and water quality parameters. These projects include the Phosphorus Diagnostic Study and the Hydrodynamic Modeling Project. A few recently initiated or planned studies, such as the Food Web and Bioenergetic Modeling projects, have begun to address the relationship between water quality parameters, ecological health, and recreational opportunities. In addition, the Economic Database Project (of which this volume is a part), the Lake Champlain Recreation Plan, and the economic impact analysis for two lake basin communities will provide critical data for estimating the monetary value of water quality improvements.

The LCMC has made an impressive start toward developing the information it requires for policy analysis. Nevertheless, it is important to ensure that critical linkages and data requirements are not being overlooked. Given the diverse resources, recreational opportunities, economic activities, and aesthetic pleasures associated with Lake Champlain, it would be beneficial to employ several techniques to develop a composite estimate of the value of improving or maintaining water quality in the lake. The following sections outline several analytical techniques and associated data requirements for estimating the monetary benefits of water quality improvements.

3.2.1 Estimating Public Health Benefits

Potential public health risks associated with Lake Champlain water quality include consumption of lake fish with elevated levels of heavy metals, swimming in waters with high bacteria counts, and the presence of residual pollutants in public water supplies drawn from the lake. To the degree that people are fully aware of the risks of eating certain types of lake fish or swimming in certain areas at particular times, it is reasonable to assume that they have modified their recreational choices to reflect an evaluation of the benefits and potential costs of these activities. Given the availability of recreational opportunities that do not pose health risks, a large portion of the benefits of water quality improvements that would reduce public health risks from swimming and fish consumption can be estimated using the techniques for quantifying recreational benefits outlined in Sections 3.3.2 and 3.3.3 below. However, for those who do not have or do not choose to utilize other recreational options, then the dose-response methodology outlined below could also be applied to swimming in polluted areas or the consumption of lake fish with elevated levels of metals or other pollutants.

Use of the lake as a source of drinking water poses a set of analytical issues similar to those outlined above for public health risks associated with recreational activities. For many pollutants, the monetary value of public health benefits associated with reduced pollution levels are simply the lesser of any resulting reductions in the costs of purifying public water supplies or the avoided costs of obtaining drinking water from another source. However, if purification techniques for certain pollutants are unavailable or are not completely effective, and if alternative water supplies are unavailable or prohibitively expensive, then a portion of the benefits of improving Lake Champlain's water quality can be measured by quantifying any associated reductions in medical costs and increases in labor productivity.

The basic technique for evaluating the public health benefits of reduced pollution requires an understanding of the dose-response relationship between pollution levels and the incidence of associated illnesses. Critical data requirements for a dose-response analysis of public health benefits are outlined below.

1. Size and characteristics of population using the lake as a source of drinking water.
2. Current treatment processes and residual levels of pollutants for water supplies drawn from the lake.
3. Estimated health effects of various consumption levels of pollutants remaining after water supply treatment (i.e. a dose-response relationship).
4. Average cost of medical treatment for pollution-induced health effects.
5. Average value of reduced productivity or income attributable to pollution-induced health effects.

Information on the size and characteristics of the population using the lake as a source of drinking water, as well as the value of lost productivity or income per sick day can be readily obtained from published data. Average medical costs for treating various illnesses related to water pollutants should be available from state regulators, medical insurance providers, and regional health care associations. Although some data may be available from an analysis of pollutant levels and disease rates for different water supply districts in the region, quantifying the degree to which certain pollutants of concern in the Lake Champlain basin may contribute to human health problems should also involve the review of national and international studies.

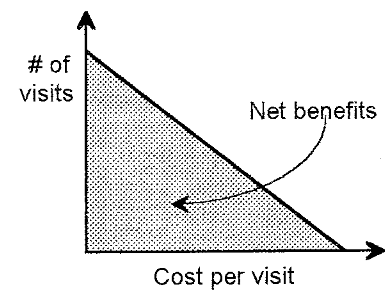
3.2.2 Valuing Recreational Benefits and Aesthetic Appreciation

The recreational resources and natural beauty of Lake Champlain attract hundreds of thousands of visitors a year and are an important factor in locational decisions of residents and businesses in the region. There are several techniques that can be utilized to provide partial estimates of the monetary value of maintaining or enhancing the recreational opportunities and aesthetic benefits provided by the lake including travel-cost studies, hedonic price analysis, and contingent value surveys. Each of these techniques has its own set of strengths and limitations as outlined below.

3.2.2.1 Travel Cost Studies

The travel-cost methodology focuses on the costs that various users incur in traveling to and utilizing Lake Champlain recreational sites. From an analysis of the differences in these costs, monetary estimates can be derived of the net benefits these users enjoy. For example, a survey of recreational users can yield data on travel costs (including the value of time spent in transit), frequency of visits, income, and access to other recreational opportunities. Through statistical analysis of this information a demand curve for recreational visits can be derived such as that shown in Figure 2.

Figure 2 Imputed Recreational Demand Curve



The area under the demand curve in Figure 2 is an estimate of the net benefits of recreation at a particular site for users in a particular income group. Summing the areas under the demand curves for all major income groups and recreational sites yields a monetary estimate of the total net benefits of recreational use of the lake.

Some additional survey and statistical work must be completed in order to use the travel-cost methodology to estimate the benefits of improvements in water quality. A comparison of the demand curves for several recreational locations on the lake having similar facilities but variations in water quality can indicate the willingness of users to pay for improved water quality. Given sufficient information on water quality and recreational facilities at major recreational sites, a series of comparative travel-cost analyses could be utilized to estimate the value of improved water quality to recreational users of the lake. Data requirements for this analysis include:

1. Distance, income levels, frequency of visits, and mode of travel used by a representative sample of visitors to recreational sites.
2. Costs of licenses, user fees, equipment, and lodging associated with recreational visits.
3. Comprehensive data on recreational sites on the lake including annual use rates, recreational facilities, and water quality at each site.

Although much of the necessary data on Lake Champlain recreational facilities and visitation rates may already have been collected in developing the Lake Champlain Recreation

Plan, development of a travel-cost model need not be estimated solely from Lake Champlain data. Other recent studies that estimate the value of water quality improvements to recreational users could be combined with site specific recreational use, facility, and water quality data for the Lake Champlain Basin. However, if estimates from other studies are employed, it is important to be certain whether they are measuring the benefits of changes in the water quality parameters that are of concern in the Lake Champlain basin.[7]

3.2.2.2 Hedonic Price Analysis

Any property owner knows that location is an important determinant of property value and that environmental quality is an important component of location. All other things being equal, a home located adjacent to a polluted stream will be worth less than one with frontage on a relatively pure stream. The key phrase in the last sentence is "all other things being equal". In addition to differences in local environmental quality, residential properties might differ in age, size, or any number of other characteristics (e.g. proximity to schools and employment opportunities, the value of other homes in the neighborhood). Hedonic price analysis utilizes a statistical technique known as multiple regression to estimate the property price effects attributable solely to variations in local environmental quality.[8] One or both of the following sets of data would be required to utilize hedonic price analysis to estimate the monetary value of benefits associated with changes in Lake Champlain water quality.

1. Annual estimates of property values for a relatively small number of similar lakefront or lake-access homes where water quality has changed significantly over time (time series data).
2. Property values and data on the important variables influencing housing prices (age, size and type of house, quality of neighborhood and schools, employment opportunities, etc.) for a large number of dissimilar lakefront or lake-access properties at the same point in time (cross-sectional data).

It may be necessary to separately estimate the effect of water quality on prices for vacation properties and primary residences, on properties in different price classes and on properties located within different regions of the lake.

If statistically significant estimates of the property price effects of changes in water quality can be obtained, it is important to recognize that these are capitalized values of present and future benefits. In addition, the capitalized value is reduced due to the effect of property taxes. Using the appropriate discount rate and adjusting for the effects of property taxes, it is possible to express the capitalized value of water quality improvements in terms of a stream of monetary benefits over time. However, if the benefits of water quality improvements are being compared with the present value of the costs of achieving them, then the capitalized value, adjusted for property tax effects, is the appropriate measure.

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[7] Smith and Desvouges (1986) developed a national travel cost model as part of a comprehensive study of the benefits of water quality improvements.

[8] For a more complete discussion of the theoretical issues and statistical techniques involved in hedonic price analysis, see Freeman (1979).

Obviously, hedonic price analysis cannot be utilized to provide meaningful estimates of the value of water quality improvements to those living some distance from the lake. However, for lakefront or lake-access property owners, the hedonic price analysis would incorporate both recreational and aesthetic benefits. Hedonic price analysis should therefore yield higher estimates of the value of water quality improvements than those derived using the travel cost method for similar households living near the lake. Comparison of the estimates derived from these two techniques for similarly situated households, can provide a check on their validity, and, if the above relationship holds, the difference between the two estimates can be used as a measure of aesthetic benefits to households living near the lake.

3.2.2.3 Contingent Value Analysis

Contingent value (CV) studies are based on a very simple concept: ask people what they are willing to pay for improvements in environmental quality. For the results to be meaningful, the survey or questionnaire must be designed to elicit responses that reflect what individuals would pay for environmental quality improvements if they could actually be purchased in some organized market.[9] To create an artificial or contingent market for environmental quality, it is essential that survey respondents have some familiarity with the effects of changes in the environmental quality variables that are the subject of the study. For example, if respondents are asked what they would be willing to pay for reductions in the frequency and duration of algal blooms or other aesthetic and recreational characteristics associated with reduced phosphorus concentrations, they must have some experience of these different water quality conditions, or have some means of envisioning them, such as photographs or verbal descriptions.

In most CV studies, respondents are not directly asked to state an amount they would be willing to pay for a given improvement in environmental quality. Rather, the questioner suggests a relatively low initial "price" which is gradually increased until the respondent indicates that he or she would no longer be willing to pay it. The questioner or survey instrument must also provide information on what institutions would be responsible for achieving the environmental improvements, how the improvements would be paid for (e.g. user fees, increased taxes), and over what period of time.

Since a CV survey does not actually involve the exchange of money, there is the potential for bias between survey responses and what would actually occur in a real market. One potential source of bias is strategic responses designed to achieve a certain objective. For instance, if respondents believe they will not be required to pay their fair share of the costs of pollution control, they may indicate a much higher willingness to pay in the hopes of influencing policy decisions. Conversely, if respondents believe that their actual payments will be related to their responses, they may understate their willingness to pay, in an attempt to reduce their share of the costs. Other potential sources of bias involve the information available about the water quality improvements offered for "sale", the starting price suggested for the improvements, and whether willingness to pay (WTP) or willingness to accept (WTA) compensation is the proper way to

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9 See Smith and Desvouges (1986, 13-116) for an introduction to CV analysis and an application to water quality improvements. For a comprehensive treatment of the theoretical and practical issues involved in contingent value analysis see Cummings, Brookshire and Schulze (1986) or Mitchell and Carson (1989).

structure the price question (Pearce and Markandya, 1989, 35). The choice between WTP and WTA is related to the question of who owns the rights to environmental resources.

If the status quo is the basis on which property rights are defined, then WTP would be the correct measure of the value of environmental quality improvements (Smith and Desvouges 1986, 35). In this context, a CV survey would attempt to estimate the benefits of pollution control by asking what people would be willing to pay (WTP) to obtain improvements in environmental quality relative to existing conditions. However, if it is acknowledged that the general public has a right to some relatively pristine state of the environment, then the logical line of questioning for a CV survey would be how much compensation would be required in order to induce individuals to accept various levels of pollution. Although economic theory and public attitudes about the right to a clean environment might argue for the use of willingness to accept (WTA) compensation as the correct measure of the benefits of pollution control, experience with CV surveys indicates that questions posed in terms of WTP are more easily understood by survey respondents, and consequently lead to less bias in survey results (Mitchell and Carson 1989, 30; Cummings, Brookshire and Schulze 1986, 35).

The design of the CV survey, the selection of the sample population to interview, and the statistical tests utilized to evaluate the responses can help to minimize or adjust for biased responses. Another means of evaluating the accuracy of CV responses is to compare them with valuation estimates obtained from dose-response, travel-cost, and hedonic price analyses. To promote this kind of comparison it may be beneficial to structure the CV survey to permit separate valuation of health, recreational, and aesthetic benefits.

3.3 Existence Value

So far the discussion of the benefits of water quality improvements has focused on direct use and experiences of the lake, either as a source of drinking water, a site for recreation, or simply as an object of aesthetic appreciation. But direct experiences are not the only benefits provided by a unique natural resource such as Lake Champlain. In addition to the direct benefits received from visits to the lake, many people living in the Lake Champlain basin and throughout New York, Vermont and Quebec are likely to derive satisfaction from simply knowing that the water quality and ecology of the lake are being protected and restored. This may be true even for those who have no plans to ever visit Lake Champlain. Some will find satisfaction knowing that others, including future generations, will have the opportunity to enjoy this resource in a relatively unspoiled state. Others may simply feel an obligation to preserve such a unique and beautiful ecosystem.

One of the strengths of CV surveys is that they can be designed to estimate direct use benefits as well as existence values. By obtaining information on a respondent's occupation, place of residence, frequency of visits to the lake, and whether they use the lake as a drinking water source, some allocation of a respondent's willingness to pay for water quality improvements can be made between direct use benefits and existence value. In addition, CV surveys can be designed to elicit separate responses for willingness to pay for recreational, aesthetic, and other direct use benefits, as well as for non-use benefits. Of course, for those who live in the basin or frequently vacation there, it may be difficult to distinguish between direct use and existence values. Existence values may be more accurately measured by selecting a sample population for a CV survey that has some knowledge of the lake, but rarely visits it.

3.4 Regional Economic Effects

The Lake Champlain pollution control and restoration program is an investment in the region's economy and quality of life. This investment will result in various direct benefits and costs as described above. The program will also cause numerous secondary or multiplier effects throughout the regional economy. On the benefit side, improved water quality can be expected to attract new vacationers to the Lake Champlain Basin. Every dollar of increased recreational expenditures will result in added income and employment not only at hotels, restaurants, and campsites, but also in other economic sectors that provide goods or services to the recreation industry. Similar multiplier effects can be expected if new businesses are attracted to the region. In addition, new pollution control requirements will also increase output and employment as a result of increased capital, operating and maintenance expenditures.[10]

Balanced against these beneficial effects are the detrimental impacts of higher pollution control costs on industries, farmers, municipalities, and developers. Higher sewer rates and pollution control requirements could be expected to increase prices and reduce income and employment in some economic sectors. Although these detrimental impacts will be at least partially offset by the economic stimulus of increased pollution control expenditures, the net effects may be unevenly distributed across sectors of the regional economy. Depending on the magnitude and distribution of the costs of the pollution control program, some farming and business operations, particularly those that export goods outside the region, might no longer be able to produce their products at competitive prices, and could therefore be forced to close. Business closures would obviously have more significant impacts on regional income and employment than incremental shifts in expenditure patterns.

The difficult task for the LCMC and associated federal, state, and provincial regulatory agencies is to devise a water pollution control program that will enhance the attractiveness of the region as a location for vacationers and new business ventures, while ensuring that the costs of the program are equitably distributed and do not jeopardize the competitiveness of key economic sectors. A highly cost-effective pollution control program will make it easier to improve water quality without excessively burdening the regional economy. In addition, a careful analysis of the various sources of water pollution in the basin could be used by public officials to develop an equitable distribution of pollution control costs. As discussed in detail in Volume 3 of this project, incorporating transferable discharge permits and other economic incentives into the pollution control plan can both increase the cost-effectiveness of the program and provide the flexibility to achieve an equitable distribution of costs.

The travel-cost analysis outlined in Section 3.2.2.1 of this report can be structured to provide information on the increase in recreational visitors from outside the region that can be expected as a result of improvements in water quality. Additional analyses of the expenditure

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[10] Pollution control expenditures funded entirely from local revenues will primarily shift local resource from one use to another with little change in regional income or employment. However, if a portion of the pollution control program is funded from federal, state and provincial revenues, an increase in regional income and employment in the Lake Champlain Basin could be expected.

patterns of vacationers would be required in order to develop estimates of increased recreational expenditures. The resulting data could then be utilized in conjunction with an input-output model for the Lake Champlain region in order to determine the total effects of increased recreational expenditures on output, income, and employment in the regional economy.[11] Similar analyses can be made of the total effects on regional income and employment of increased pollution control expenditures and of reductions in output of various economic sectors due to higher pollution control costs.

It is important to note that estimates of changes in gross income and employment that could result from the Lake Champlain pollution control program cannot simply be added to the direct benefits and costs discussed in Sections 3.1, 3.2, and 3.3 of this report. The full cost of producing additional output must be subtracted from the market price of that output in order to derive an estimate of the benefits (cost) of additional (reduced) production. Similarly, increases in employment require workers to reduce other valuable uses of their time. There is some wage at which most workers will find the costs of working to be greater than the benefits received. Consequently, only a portion of the value of wages earned (lost) can be counted as a benefit (cost). It is technically possible to estimate the net benefits or costs of changes in output and employment. However, by first estimating the gross income and employment effects of alternative pollution control programs, it may become apparent which if any economic sectors merit more detailed analysis of the net benefits and costs of changes in output and employment.

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11 The Bureau of Economic Analysis of the U.S. Commerce Department has developed an updated regional input-output model (RIMS II) that can be used to estimate multiplier effects for any state, or any region composed of one or more counties. For an introduction to potential uses of RIMS II, see U.S. Department of Commerce (1992).

4.0 Evaluation of Alternative Pollution Control Strategies

It is comforting, but misleading, to believe that the most cost-effective, technically feasible pollution control strategy will be the universally preferred option for achieving any given level of environmental quality. If the least-cost strategy were adopted, an acceptable distribution of costs could theoretically be achieved through government subsidies. If necessary, new legislation could be passed to provide legal authorization for the program, and the resources of public agencies could be increased or redirected to ensure proper monitoring and enforcement. Unfortunately, using subsidy programs to redistribute costs can be politically difficult to accomplish. In addition, since government agencies usually have limited funding and multiple objectives, technical feasibility does not guarantee successful implementation. Given these realities, the preferred pollution control strategy for the Lake Champlain Basin will need to strike a balance between several potentially conflicting objectives. Essential criteria for evaluating alternative pollution control strategies were presented in Section 1 and are summarized again below.

- Cost-effectiveness.
- Distribution of cost and benefits.
- Financing mechanisms.
- Relationship to existing institutional and legal framework.
- Administrative, monitoring, and enforcement requirements.
- Incentives for innovation and flexibility in response to change.
- Clarity and intelligibility to the public.

Volume 3 of this project includes a detailed discussion of the strengths and weaknesses of various regulatory approaches, including transferable discharge permits and discharge fees. One important aspect of that discussion, is that all regulatory programs involve some tradeoffs between ease of administration, cost-effectiveness and equity in the distribution of costs. Simple regulatory approaches, such as technology standards or uniform reductions in pollution discharges, are easy to understand and administer, but they often are much more costly than other pollution control strategies. It is possible to achieve a highly cost effective pollution control program by requiring sources of pollution with the lowest marginal costs of pollution control to reduce their pollution by the greatest amount. Unfortunately, this may result in a highly uneven cost distribution. As outlined in Volume 3, an appropriate allocation of transferable discharge permits can result in both a highly cost-effective pollution control program and an equitable distribution of pollution control costs. The use of transferable discharge permits and other economic instruments for environmental protection also provides greater incentives for innovation, and the ability to utilize market forces to promote cost-effective solutions even in the face of technological, economic, or demographic changes. However, an efficient system of transferable discharge permits for a large, ecologically complex watershed such as the Lake Champlain Basin could be more difficult to administer than pollution control programs based upon more traditional regulatory requirements.

Whatever balance between cost-effectiveness, fair distribution of costs, simplicity, and flexibility is ultimately selected, it is important that these essential characteristics of the preferred pollution control strategy are reasonably well defined prior to comparing the costs and benefits of alternative levels of pollution control and promulgating water quality standards for the lake. A more cost-effective pollution control strategy would enable public officials to consider adopting a set of water quality standards that required a relatively high level of pollution control. On the other hand, a pollution control strategy that resulted in a highly uneven distribution of costs might prevent the adoption of stringent water quality standards.

Quantifying the magnitude of pollution discharges from all major sources, the costs of various levels of pollution control, and the distribution of pollution control costs and benefits should be part of the required scope of work in the studies discussed and recommended in Sections 3.1 and 3.2 of this report. This information is essential to evaluating both the cost-effectiveness and cost distribution of any pollution control strategy. The information itself, however, is not sufficient for determining what is an equitable distribution of costs. This requires a certain understanding of property rights combined with personal judgments about social justice.

The principle that the polluter should pay, is based on an understanding that rights to clean water are vested with the general public. Application of this principle would lead to a distribution of costs based on relative pollution discharges. In contrast, if rights to water resources are defined in terms of current conditions and practices, then the distribution of the costs of water pollution control should reflect the distribution of benefits. Obviously there is substantial room for compromise between these two extremes. It is essential to involve all affected parties as early as possible in order to develop pollution control strategies that are generally perceived as fair, or at least acceptable.

It is useful to note that significant benefits from Lake Champlain water quality improvements will be enjoyed by those living outside the basin. Depending on the principles adopted to distribute the costs of water pollution control, the magnitude of these benefits (which can be estimated utilizing the travel-cost and contingent value methods outlined above in Sections 3.2), may be relevant in designing financing mechanisms for the pollution control program.

Any effective pollution control program for Lake Champlain must incorporate financial, political, and organizational incentives that will ensure coordination between the regulatory agencies of two states and one province. The involvement of public officials and administrators from New York, Vermont, and Quebec will be critical in evaluating the feasibility of alternative regulatory strategies. However, it can be difficult for public administrators to gain enough distance from their daily responsibilities to envision alternative operating procedures and institutional structures. To obtain information on innovative regulatory approaches, the LCMC should initiate a study of the legal, institutional, and administrative arrangements of other regional pollution control programs, particularly those involving interstate lakes, estuaries, or rivers.

5.0 Establishing Water Quality Standards

The benefits of improving the water quality of Lake Champlain include increased economic vitality for the region, reduced public health risks, enhanced recreational and aesthetic opportunities, and the satisfaction that comes from protecting a unique ecosystem. However, these benefits come at a price. Water quality improvements can only be achieved by increasing the costs of water pollution control for businesses, farmers, local governments and property owners. The studies and data collection efforts outlined in Section 3 of this report, and the development of an appropriate pollution control program as outlined in Section 4, should provide the information necessary to estimate the expected benefits and costs of achieving various water quality standards. Based upon these estimates, a set of water quality standards should be established for Lake Champlain that maximizes expected net benefits, given the constraints imposed by the preferred pollution control strategy. As illustrated in Figure 3, net benefits are maximized when the expected cost of incrementally increasing water quality standards (i.e. increasing pollution control) begins to exceed the expected benefits of the resulting water quality improvements. Figure 3 also illustrates that a more cost effective pollution control strategy will increase the net benefits of water quality improvements, and result in a higher optimal level of pollution control (i.e. more stringent water quality standards), all other things being equal.

In order to calculate the net benefits of achieving a given set of water quality standards, expected future benefits and costs should be stated in terms of their present values, as discussed in Section 2. A general guideline was presented that defined the appropriate discount rate as the rate of return that can be achieved on similarly risky investments.[12] Given the difficulty of fully quantifying the risks of public projects and policy decisions, and then identifying similarly risky investment alternatives, net benefits should be calculated using a reasonable range of discount rates. If the selection of water quality standards that maximize net benefits is quite sensitive to changes in the discount rate, it may be possible to narrow the range of potential discount rates by expending additional effort in quantifying the potential variation in estimated costs and benefits, and identifying similarly variable investment alternatives.

The introduction to B/C analysis presented in Section 2 also underscored the important distinction between general inflationary increases in the value of goods and services and nominal real increases in benefits or costs (i.e. net of inflation). Given continued population and economic growth in the Lake Champlain basin, the benefits associated with improving or maintaining water quality in the lake could reasonably be expected to increase more rapidly than the costs of water pollution control. If this expectation is correct, it should be reflected in policy analyses regarding the optimal water quality standards for the lake. The LCMC should develop a consistent set of demographic and economic forecasts and require all researchers engaged in estimating benefits or costs of pollution control to utilize this information to determine whether particular benefits or costs can be expected to increase more or less rapidly than the general rate of inflation.

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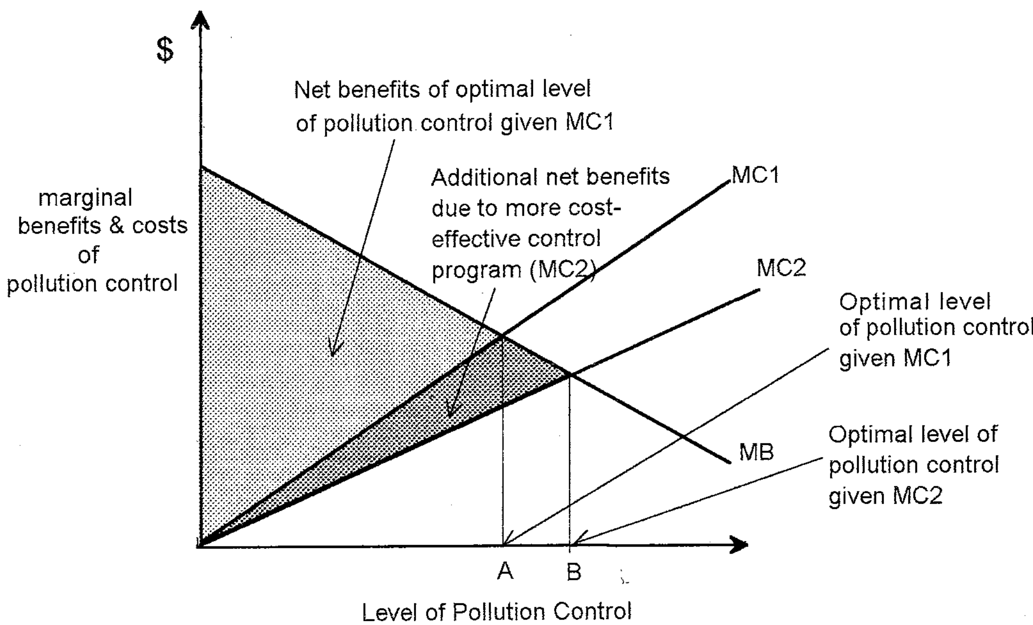
12 If both benefits and costs have been estimated in terms of constant dollars, i.e. without any increases due to general inflation, then the discount rate should reflect the expected rate of return on similar investments, net of inflation. For example, if returns on Treasury bonds are 7.5% and the inflation rate is currently 4.5%, then the expected real rate of return, net of inflation, is approximately 3.0%.

Figure 3 The Optimal Level of Pollution Control



Given marginal pollution control cost designated by MC1, the optimal level of pollution control occurs where marginal costs (MC1) are equal to marginal benefits (MB). The shaded area above the MC1 curve and below the MB curve represents the net benefits of pollution reduction up to the optimal level of control.

With a more cost-effective pollution control strategy (MC2), any given level of pollution control at lower cost than strategy 1 (MC1). As a result, the optimal level of pollution control is higher, as are the net benefits resulting from the pollution control program.

Another aspect of the B/C analysis that merits additional emphasis is the effect of risk and uncertainty. If estimated probabilities can be attached to the potential range of future benefits and costs associated with a given policy decision, then decision analysis can be utilized to compute the expected net benefits of various water quality standards. The use of decision analysis is most valuable if the potential variations in benefits and costs are quite large or are not evenly distributed around some mean outcome.

After estimating future benefits and costs, computing their present values, evaluating alternative pollution control strategies, and selecting a set of water quality standards that maximizes expected net benefits, the entire analysis must be subjected to public review, comment, and debate. For a researcher, analyst, or public administrator that has invested a substantial amount of time and intellectual capital in the policy development process, this can be a frightening prospect. The likelihood of public support for to the proposed water quality standards or pollution control strategy can be significantly increased however, if representatives from those groups most affected by the recommendations have been closely involved in the policy development process.

6.0 Summary of Analytical Framework and Recommendations for Further Research

This report has presented a conceptual framework for evaluating water quality standards and pollution control programs for the Lake Champlain basin. This framework is not a deterministic methodology, guaranteed to yield the correct answer. Rather, it is a means of gathering essential data, understanding interactions, revealing values and preferences, and systematically evaluating alternative policy options. The major phases of the policy analysis framework recommended in this report are summarized below.

1. Determination of the effect of changes in pollution discharges on key water quality parameters.
2. Estimation of technically feasible costs for increasingly stringent levels of pollution control.
3. Estimation of direct use benefits and existence values for water quality improvements utilizing dose-response, travel-cost, hedonic price, and contingent value methods.
4. Evaluation of changes in regional income and employment under alternative pollution control strategies and water quality standards.
5. Identification of sources of risk and uncertainty and, whenever possible, quantification of potential variability in cost and benefit estimates.
6. Development of a preferred pollution control strategy based upon criteria of cost-effectiveness; distribution of costs and benefits; relationship to existing institutional and legal framework; administrative, monitoring and enforcement requirements; incentives for innovation; flexibility in response to change; and clarity and intelligibility to the public.
7. Comparison of the expected present values of the benefits and costs of achieving alternative water quality standards, given the preferred pollution control strategy.
8. Presentation of proposed water quality standards and pollution control strategy to the public and adjustment of the standards or control strategy based on public comment and debate.

There is a loose sequential ordering to the policy analysis process outlined above. Although phases one through three can be conducted in any order, they should be completed prior to evaluating alternative pollution control strategies (phase five) and water quality standards (phase six). There is also likely to be the need for one or more iterations between phases five, six, and seven. Preliminary selection and subsequent adjustments of water quality standards may require a reevaluation of the pollution control strategy and vice-versa. In addition, comparison of the expected costs and benefits of various water quality standards may indicate the importance of further research on critical physical or biological processes or benefit and cost estimates.

Who should be involved at each stage of the policy development process is at least as important a consideration as the analytical techniques employed in that process. If respected representatives of major business, agricultural, environmental, and recreation interests are involved, along with public officials, regulators, and academics, the credibility of the decision process will be greatly enhanced. The participation of all major interest groups is particularly important when complex studies of physical, biological, and economic factors are being reviewed, and at stages in the decision process (such as phases five and six above), where quantitative information must be interpreted in the context of subjective judgments and values.

The LCMC has made significant progress in gathering data on the effects of pollution on the ecology of the lake as well as the sources of pollution and costs of pollution control. In addition, the socio-economic database developed as part of this project and the analysis of the effects of the lake on two communities in the lake basin will provide important information from which to develop estimates of the benefits and cost of water quality improvements. The recommendations for additional research summarized below are intended to ensure that the LCMC will have sufficient information to evaluate the merits of a range of pollution control strategies and water quality standards.

1. Ongoing and subsequent studies of sources of pollution and control costs should provide information on the mass, chemical characteristics, and annual pattern of discharges of priority pollutants (e.g. phosphorus, pathogens, heavy metals, pesticides) from all point and nonpoint sources. It is essential that these studies attempt to quantify the minimum costs of controlling priority pollutants from all major sources at increasingly stringent levels of pollution control and the degree of variability in the effectiveness of least cost pollution control measures.
2. Public health benefits associated with water quality improvements in the Lake Champlain basin should be evaluated by the appropriate regulatory agencies from New York, Vermont and Quebec. Any potential benefits should be categorized as to whether they can be achieved through improved treatment of public water supplies, and the costs of the necessary improvements in water treatment should be quantified. Benefits of reducing pollutants that cannot be eliminated through water supply treatment should be evaluated using the dose-response methodology outlined in Section 3.2.1.
3. The LCMC should issue a request for proposals (RFP) for an analysis of the monetary value of recreation benefits associated with improvements in key water quality parameters. Respondents to the RFP should be required to propose a basic model, suggest data sources, and indicate the time and cost necessary to conduct the analysis.
4. The LCMC should issue an RFP for an analysis of the effect of a range of variations in water quality on lakefront and lake-access property values. The property value analysis should be closely coordinated with the recreational benefit study to ensure that similar locations, income groups, and water quality parameters are included in both studies.
5. The LCMC should issue an RFP for a contingent value survey of a representative sample of lake basin residents to estimate their willingness to pay for a range of improvements in recreational opportunities, and aesthetic qualities associated with improvements in water quality. The CV study design should be closely coordinated with the public health, recreational benefits and property value analyses to permit comparison of results and avoid double counting of benefits. The CV study should also focus on quantifying the existence value of improving Lake Champlain's water quality, to residents of New York, Vermont, and Quebec, particularly those residing outside of the basin.
6. To obtain information on innovative regulatory approaches, the LCMC should initiate a study of the legal, institutional, and administrative arrangements of other regional

pollution control programs, particularly those involving interstate lakes, estuaries, or rivers.

7. Once sufficient information is available on pollution sources and technically feasible costs of pollution control, the LCMC should issue an RFP to estimate the changes in regional income and employment associated with various combinations of water quality standards and pollution control strategies.

The incorporation of financial incentives and market mechanisms into the water pollution control strategy for Lake Champlain has the potential to reduce costs, increase the optimum level of pollution control, and result in a more equitable distribution of costs. Volume 3 of this project includes additional recommendations for research and policy analyses necessary to develop appropriate uses of economic instruments for environmental protection in the Lake Champlain Basin.

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