IDENTIFYING AND ASSESSING THE ECONOMIC BENEFITS OF **CONTAMINATED AQUATIC SEDIMENT CLEANUP**

Sediment Priority Action Committee

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Foreword

In recognition of the scope of the contaminated sediment problem and the limited progress in addressing it, the International Joint Commission (IJC) has identified contaminated sediment as a program priority. The IJC assigned this priority to the Great Lakes Water Quality Board (WQB) with support from the Science Advisory Board (SAB) and the Council of Great Lakes Research Managers (CGLRM). The Sediment Priority Action Committee (SedPAC) was formed from agency experts, as well as WQB, SAB, and CGLRM members, to carry out this work. During the 1995-1997 biennial cycle, SedPAC (1997) prepared a white paper which summarized the contaminated sediment problem, specified key obstacles to sediment remediation, identified options to address key obstacles, and presented recommendations regarding contributions the IJC could make to help address current obstacles to sediment remediation. During the 1997-1999 biennial cycle, SedPAC:

- compiled and disseminated information on the economic and environmental benefits of sediment remediation; and
- developed guidance for making decisions regarding management of contaminated sediment.

I. BACKGROUND

In its 1997 White Paper, the International Joint Commission's (IJC) Sediment Priority Action Committee (SedPAC) identified six main obstacles to sediment remediation in the Great Lakes: limited funding, regulatory complexity, lack of a decision-making framework, limited corporate involvement, insufficient research and technology development, and limited public and local support (SedPAC 1997). A workshop in June of 1997 (reported on in the White Paper) helped establish priorities for the IJC's work to help overcome these obstacles. Two main recommendations were offered:

- Compile and disseminate information on the economic and environmental benefits of sediment remediation; and
- Develop guidance for making decisions regarding the management of contaminated sediment.

The rationale for recommending further work on identifying the economic benefits stemmed largely from the relatively low profile of the contaminated sediment issue in the Great Lakes. Although $580 million has been spent on 38 sediment remediation projects in the last thirteen years in Great Lakes Areas of Concern (AOCs) (SedPAC 1999a), there is still a significant problem. In-place pollutants potentially pose a challenge to restoring 11 of the 14 beneficial use impairments identified in the Great Lakes Water Quality Agreement (GLWQA). Over 80% of all AOCs have restrictions on fish and wildlife consumption, degradation of benthos, and loss of fish and wildlife habitat due to potential links with contaminated sediment (Table 1). Further, in 31 AOCs, the sediment problem is still under assessment and management decisions regarding intervention are still required (IJC 1998). The inclusion of economic benefits information may help strengthen and expedite the decision as to whether some form of intervention (remediation) is warranted.

The interest in resource valuation has experienced somewhat of a renaissance of late. The U.S. EPA is developing a Framework for the Economic Assessment of Ecological Benefits (U.S. EPA In print) targeted at promoting increased communication between scientists conducting ecological assessments and economists conducting economic benefit analysis. Environment Canada has developed the Environmental Valuation Reference Inventory (EVRI), a state-of-the-art database of benefit values that might be used in other locations (benefits transfer). In the Great Lakes area, the Northeast-Midwest (NE-MW) Institute and National Oceanic and Atmospheric Administration (NOAA) are developing a Guidebook on Great Lakes Environmental Benefits Valuation (NE-MW Institute and NOAA In print). The primary motivation for all of these products is much the same - to demonstrate the utility and importance of economic valuation in improving resource-related decision-making and policy formulation. A secondary motivation is the frustration with the tendency of many existing policies and practices to discount or exclude the costs of environmental degradation, or the benefits that natural resource systems provide.

The rationale for this paper is the same. Identifying and assessing the likely benefits of remediating contaminated aquatic sediment can help raise the profile of the problem and facilitate and support the decision as to whether cleanup is warranted in a given site, and if so, to what extent. Raising the profile can also help identify possible funding opportunities, stimulate corporate involvement, and generate local support when the decision to intervene has been made.

Table 1 Number and percent of AOCs experiencing impairment of ecological beneficial uses arising from contaminated sediment (SedPAC 1999a)

USE IMPAIRMENT	**NUMBER OF AOCs IMPAIRED** (% OF 42 AOCs)
Restrictions on fish and wildlife consumption	36 (86%)
Degradation of fish and wildlife populations	30 (71%)
Fish tumors or other deformities	20 (48%)
Bird or animal deformities or reproduction problems	14 (33%)
Degradation of benthos	35 (83%)
Loss of fish and wildlife habitat	34 (81%)
Eutrophication or undesirable algae	21 (50%)
Degradation of phytoplankton or zooplankton populations	10 (24%)

Few economic valuation case studies on contaminated aquatic sediment exist. There are at least two reasons for this. First, concern about aquatic sediment contamination has been relatively recent. Historically, most of the economic analyses have been undertaken in conjunction with navigational dredging, mostly in U.S. ports and harbors. These analyses focused largely on the economics of dredging and disposal. However, by the late 1980s, in part a result of the 1987 revisions to the GLWQA, the focus in the Great Lakes was shifting to the consideration of broader ecological impacts of contaminated sediment. The second reason why economic benefits assessment has been sparse is that documentation of the sediment problem has not been quantitatively coupled to the ecological beneficial use impairments. Of the 38 sediment remediation projects undertaken in the last thirteen years in Great Lakes AOCs, only 2 have adequate information and data on the ecological effectiveness of that remediation (SedPAC 1999a). This lack of quantitative biophysical data makes it difficult to identify the principal benefit categories, much less to prepare quantitative estimates of economic benefits.

This short paper is directed at generating a greater awareness of the potential economic benefits associated with aquatic sediment cleanup. However, it is a work in progress, not the definitive piece on this subject. More case studies are required to develop a clearer picture of the types of economic benefits and suitable valuation methodologies for the sediment issue.

The specific objectives of this paper are to:

- identify the types of potential economic benefits that may result from aquatic sediment remediation, which may also be seen as the economic costs of inaction;
- assess the potential economic valuation tools to identify those that may be better suited to the sediment remediation issue;
- highlight methodological challenges; and
- identify areas for further action.

This paper does not identify potential funding sources, nor does it attempt to identify the ability or responsibility for sediment cleanup. Furthermore, as the case studies discussed in Section VI are completed, it may be appropriate to update this paper to incorporate the results of those studies.

II. BIOPHYSICAL BENEFITS OF SEDIMENT REMEDIATION

The presence of contaminants, particularly persistent toxic substances (PTS), in sediment is thought to cause a variety of biophysical harms. The remediation of that sediment should reduce or eliminate those harms upon completion. The reduction or elimination of harm can be seen as the benefits of remediation. Before we can perform an economic evaluation of the benefits of remediation, we need to have a description of the biophysical changes that lead to reduced harm. Economic analysis can then be used to determine the value of those biophysical changes.

For example, a study found that remediation of contaminated sediment from the Northern Wood Preservers site in Thunder Bay, Ontario would likely enhance fish, bird, and wildlife populations in the harbor; improve recreational opportunities along the waterfront; and facilitate economic development of the waterfront that might involve investment exceeding $50 million. (Sustainable Futures 1996). In Waukegan Harbor, Illinois, contaminated sediment gave rise to fish advisories in the Harbor and to prohibitions on navigational dredging, which led in turn to increased costs for moving partly loaded ships in and out of the Harbor. Removal of 136 tonnes of PCB contamination has led to removal of the Harbor fish advisories; and removal of the remaining contamination will allow dredging of the channel to its full depth, saving hundreds of thousands of dollars per year in shipping costs (SedPAC 1999a). A survey of the residents of Ashtabula County, Ohio developed estimates of willingness-to-pay for the removal of contaminated sediment from the Ashtabula River, which the respondents said was due to a desire to reduce contamination in the River, in the Ashtabula harbor, and in Lake Erie. (Lichtkoppler and Blaine 1999). A Sierra Club report on sediment contamination in the Great Lakes reviews health risks to humans from contaminated sediment along with economic harm to fishing, transportation, tourism, and development. Four case studies argue strongly that there would be considerable economic benefits in all four categories from proper remediation of the sediment (Sierra Club 1993). Although all of these studies present a clear biophysical description of the problem, there continues to be uncertainty as to the precise magnitude of the biophysical benefits that will result from remediation. Consequently, any efforts to quantify economic benefits are also subject to considerable uncertainty.

The biophysical description of harm can be in the form of a description of the harm that will be caused in a “do-nothing” scenario in which the contaminated sediment remains in its present condition. Remediation can lead to another scenario in which some different harm is caused, presumably less harm. The biophysical benefits of remediation are the difference between the “do-nothing” scenario and the remediation scenario.

The biophysical benefits may arise in the near future in the immediate vicinity of the contaminated sediment. For example, remediation within a harbor may lead to reductions in the concentration of PTS in local fish, and thus the lifting of a fish advisory in that harbor. The immediate benefits would be increased enjoyment of sport fishing in the harbor, and perhaps improved health for those who would eat some of the contaminated fish despite the advisory. If the fish advisory would otherwise have continued for the foreseeable future, then the benefits are experienced for a long period of time, so the benefits consist of a stream of annual benefits for a definite or indefinite period. Furthermore, in the absence of remediation, the sediment may be transported from the harbor to the main lake and even downstream to rivers, other lakes, the St. Lawrence River, and then the Atlantic ocean. If remediation reduces or eliminates this transport, then the benefits include the reduction in harm that the sediment might cause as it is transported to these downstream locations. In some cases the benefits in the immediate area of the contaminated sediment may be small, while the benefits from not damaging a much more valuable downstream area may be large, as in the case of the Grand Calumet River in Indiana. Again, a long time period may be relevant.

A variety of fish and wildlife injuries arise from the uptake of PTS from contaminated sediment. One of the problems in evaluating the magnitude of the benefits of remediation in such cases is the lack of data as to the proportion of harm to the aquatic ecosystem arising from the contaminated sediment in question, and the proportion of harm arising from other sources, such as other contaminated sediment in the vicinity and water-borne PTS from point sources, non-point sources, and air deposition. This paper is intended to address the benefits that arise from remediation of contaminated sediment, whether those changes have their effect directly or indirectly through improving water quality or reducing the intake of PTS into the food chain. This means that the benefits can be evaluated only to the extent that scientists can determine the effects on beneficial uses of sediment remediation, apart from reductions in other inputs of PTS to the watershed.

If contaminated sediment is concentrated pollution that may cause harm for a long time in the future wherever it is, and if that harm is significant, it is likely to be less costly to deal with it while it is still concentrated in the original location than after it has been dispersed through the lake system. An important biophysical question is whether contaminated sediment that is transported and dispersed will cause more or less harm than will be caused in its original position. While this paper does not attempt to determine the extent to which remediation is justified, it will consider both long term and fate and transport as elements to be included in analyses of the benefits of remediation. Another SedPAC paper (SedPAC 1999b) deals more fully with this decision-making framework.

Economic Benefits to Restoring Beneficial Uses

Studies of contaminated sediment in the Great Lakes basin and elsewhere have identified a variety of harmful effects that should be reduced by remediation. (Lichtkoppler and Blaine 1999; Sierra Club 1993; Rivers 1999; Sustainable Futures 1996). The description of these harms in the Great Lakes is generally organized around the impairment of the 14 beneficial uses listed in Annex 2 of the Great Lakes Water Quality Agreement of 1978. The organizing principle here will be the beneficial uses, rather than the specific local studies, but we will refer to those studies in discussing the benefits. The connections between these use impairments and contaminated sediment are discussed in SedPAC (1999a) and in the studies cited above. Below we provide examples of harms that may arise for each beneficial use, but this list is not exhaustive; the sources cited above provide more complete listings.

In some cases the beneficial use is an activity or thing that can be evaluated directly by economic analysis, such as improved aesthetics of the water. In other cases the beneficial use is associated with or leads to some other activity that may be subject to economic analysis, such as reductions in fish advisories, which leads to more enjoyment of recreational fishing. For each use impairment, we will identify one or more categories of economic benefit that could be measured and evaluated. The economic benefit categories are listed in the first column of Table 2. The second column lists some specific biophysical activities that are affected directly by the contaminated sediment and give rise to the harm or benefit in the first column.

Restrictions on fish and wildlife consumption

In many AOCs, the fish and/or wildlife have concentrations of PTS in their flesh that may cause harm to humans who consume them in substantial quantities. This leads to the issuance of advisories recommending the limitation of consumption of those species. If the remediation of contaminated sediment reduces the concentration of PTS in the fish, the human health risk is reduced, and advisories can be relaxed or eliminated. This should increase the enjoyment of those who wish to consume the fish and wildlife, which may be seen as an increase in fishing and hunting for sport, for commercial ends, or for sustenance, particularly in native communities. In the case of native communities, the harm caused to the social structure as a result of banning a traditional food source that is central to the traditional way of life may be quite great, and the benefits of restoring that food source should be correspondingly great. To the extent that the advisories are not adhered to by some individuals, there should also be an improvement in human health, or a reduction in risks to health.

Economic benefits: *A. Human health;*
B. Recreation (fishing & hunting);
C. Commercial fishing & hunting;
D. Social-Cultural (aboriginal).

Degradation of fish and wildlife populations

If the contaminated sediment has contributed to the degradation of fish and wildlife populations, remediation may help to restore those populations. This may improve the quality or quantity of fishing and hunting for sport, for commercial ends, or for sustenance, particularly in native communities. It may also contribute to the restoration of a more complex and robust aquatic and terrestrial ecosystem in the local vicinity. This, in turn, might or might not lead to increased human enjoyment of the area for recreational purposes including fishing, hunting, and viewing. In addition, there is the question of how to value such an ecosystem restoration beyond these active uses. If some individuals value the existence of a healthy ecosystem in itself, apart from their use of it, there may be added benefits from restoring ecosystem integrity.

Economic benefits: *B. Recreation (fishing, hunting, viewing);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Degradation of fish and wildlife habitat

If the contaminated sediment has contributed to the degradation of fish and wildlife habitat, this presumably leads to degradation of the populations themselves. Remediation can help to restore those populations and thus lead to benefits similar to those listed above for populations.

Economic benefits: *B. Recreation (fishing, hunting, viewing);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Fish tumors and other deformities

Contaminated sediment may contribute to fish tumors, deformities, and reproductive failure. Remediation that reduces these problems should make the fish more attractive for fishing, particularly fishing for consumption, and should increase the quantity of fish consumed. The benefits are therefore similar to those for improved fish populations, but also include improvements in the health of the birds and animals, as well as increases in their numbers.

Economic benefits: *B. Recreation (fishing & hunting);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Bird and animal deformities and reproductive problems

Contaminated sediment may contribute to deformities and reproductive failure in birds and animals. Remediation that reduces these problems should make the them more attractive for hunting, particularly hunting for consumption, and should increase the quantity of wildlife harvested. It could also better support viewing, including birdwatching. The benefits are therefore similar to those for improved wildlife populations, but also include the increase in quality.

Economic benefits: *B. Recreation (fishing, hunting, viewing);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Degradation of benthos

Remediation of contaminated sediment can begin a process of the recovery of the benthos. This could in turn lead to improvements in the aquatic ecosystem in general, and hence to improved fish and wildlife populations, for which the benefits could be measured.

Economic benefits: *B. Recreation (fishing, hunting, viewing);*
E. Ecosystem Integrity;
H. Economic Development.

Eutrophication or undesirable algae

The existence of eutrophication or algae can reduce the quality of water for fish and wildlife, and for human recreation. The benefits from remediation could be measured as benefits to fish and wildlife populations, as direct benefits to recreational activity, and as benefits to ecosystem integrity.

Economic benefits: *B. Recreation (fishing, hunting, swimming);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Degradation of phytoplankton or zooplankton

The degradation of phytoplankton or zooplankton can have an impact on the aquatic ecosystem, particularly on the quality and quantity of both fish and wildlife in the vicinity. The benefits of remediation that reduced this degradation could be measured by estimating the benefits of improving the fish and wildlife populations.

Economic benefits: *B. Recreation (fishing & hunting);*
C. Commercial fishing & hunting;
D. Social-cultural (aboriginal);
E. Ecosystem integrity.

Added cost to agriculture or industry

In some cases, it appears that the presence of contaminated sediment may pollute the water column and cause the water to be unsatisfactory for agricultural or industrial use. The most likely mechanism for such contamination is the resuspension of contaminated sediment during high water flow, or some other disturbance such as navigation or dredging. The presence of contaminated sediment may increase the cost of dredging in the vicinity of private ship berths and around private and municipal water intakes. If this pollution is episodic, the costs may be intermittent, but they need not be insignificant, so they should be considered. Since contaminated sediment may lead to special treatment of private or public drinking water supplies, remediation may reduce those treatment costs.

Economic Benefits: *F. Avoided costs to agriculture and/or industry.*

Restrictions on dredging

The presence of contaminated sediment may lead to restrictions or prohibitions on dredging to avoid redispersal of the contamination. The physical effect of the restrictions is that channels become silted up, interfering with navigation of commercial and recreational vessels thereby increasing shipping costs, sometimes substantially. The economic effect is the restriction on use of the channel, the increased cost of shipping with reduced loads, or the very high cost of employing environmentally protective dredging. The presence of PTS may increase overall dredging and disposal costs by three to five times, from $3-10 per cubic yard to $10-50 per cubic yard. These benefits of sediment remediation may be greatest when water levels are relatively low, as this is the time when navigation is most seriously impeded.

Economic benefits: *G. Avoided costs for navigation.*

Redispersal and transport

Contaminated sediment may be disturbed and transported by current flows, by navigation, and by storm flows. While this is not an Annex 2 use impairment, it is a mechanism that may lead to the impairment of such uses at later times, and at other locations than the current location of the contaminated sediment in question. The harm that may be caused by a particular deposit of sediment should include not only the harm caused in that location, but also the harm that may be caused to downstream locations if the sediment is transported. If the contaminant is a PTS, then we must assume that it will pose a risk for decades or centuries, whether in this location or downstream. The benefits of remediation should include not only the reduction in harm in this place, but also the reduction in the expected harm in the future at downstream locations. Those harms could fall in any of the categories listed above.

Economic benefits: *A through F.*

Human health

While effects on human health are not an Annex 2 use impairment, several of the use impairments above provide a link to human health. If contamination from sediment enters the food chain and becomes concentrated in fish or wildlife that are consumed by humans in sufficient quantities, it appears that injury to human health can result. We should not discount those effects simply because significant consumption may be required to cause observable health effects, so long as it appears that there are individuals or communities who engage in such consumption.

To the extent that contaminated sediment may be released into the water column, either slowly and continuously or occasionally during disturbance of the sediment, we should be concerned about the ingestion of the contaminants by humans, either through drinking the water or through eating contaminated fish or wildlife. If there is a threshold concentration below which no harm occurs, then some of these concerns may be put to rest. If, however, there is reason to believe that adverse health effects may occur at very low concentrations, then benefits of remediation may include small per capita health risk reductions for large numbers of persons who take their drinking water from the Great Lakes downstream from the contaminated sediment.

Economic benefits: *A. Human health.*

Aesthetics/Perceptions

While contaminated sediment rarely leads to visible pollution of the water that might, in itself, constitute aesthetic damage, the presence of PTS on the bottom may lead to a reluctance to engage in swimming and boating activities in the area. The knowledge that the sediment contains such pollution may also create a perceptual problem whereby the river, harbor, or lakefront is regarded as unclean and dangerous, preventing people from engaging in recreational or other activities that might not, in fact, be harmful to them, and discouraging economic development that might be tainted by the perception of the area as undesirable. The linkage between the benefits listed above and the economic development may be as much psychological as biophysical, but this does not mean that they should be ignored. If sediment remediation leads to a belief that the harbor is now "safe" while before it was not, and if this allows lakefront land to be moved to more valuable uses, then there is an economic benefit that flows from the biophysical improvement. In such a case, remediation may stimulate more activities than those that are formally prohibited because of the contamination.

Economic benefits: *B. Recreation (swimming and boating);*
H. Economic Development.

III. CLASSIFICATION OF ECONOMIC BENEFITS

Identifying the potential economic benefits of any project requires an understanding of how the project affects the quality of life or the satisfaction of people who are affected by it. Everything that in some way provides value to an individual is classified as an economic benefit, whether or not the benefit has a tangible material value to anyone else. While eliminating the need for costly treatment of a polluted water supply (economic benefit F. Avoided Costs to Agriculture or Industry, above) is an obvious economic benefit to the user, the enjoyment of a clean river, the preservation of the integrity of an ecosystem for future enjoyment or use, or the satisfaction derived from knowing that a species of animal has been saved from extinction can also provide value to an individual and thereby constitute an economic benefit (economic benefit E. Ecosystem Integrity, above). The latter benefits may be intangible and difficult to quantify, but they can make up a significant part of the benefits of any project, so they need to be examined. Even if these benefits matter to only one segment of the population or even to only one person, they should still count as a benefit, although when quantifying them, the fact that only a few people value them will make the value quite small.

Some will argue that environmental assets such as plants or animals have an inherent value that is independent of any human valuation. Indeed this argument has been the subject of a scholarly debate over the question whether trees or other aspects of the environment should have standing to sue for environmental protection in U.S. courts. To the extent that this argument asserts a value independent of the value placed on it by humans, no one has been able to demonstrate a means for humans to determine such a value. Moreover, there is a real question whether such values can be legitimately recognized in a democracy in which governments are bound to do the will of the people, subject to constitutional constraints. Such values are therefore not included in any economic benefit framework.

One classification of economic benefits is the distinction between "use" and "non-use" benefits. "Use" benefits are those derived from the direct physical use of a good such as drinking water from a lake, eating fish from the lake, or using the lake water to irrigate a farm. "Non-use" benefits are those where value is obtained without any direct physical use by the individual. Examples of non-use values are the value derived by an individual when the lake is used by friends and family, or the satisfaction obtained by the knowledge that a diverse and stable ecosystem has been preserved. Table 2 shows the classification of the economic benefit categories discussed above according to whether they represent use or non-use benefits.

The second classification of economic benefits is the distinction between "market" benefits and "non-market" benefits. Market benefits arise where the item providing the benefit is bought and sold; examples would be fish caught in a lake by commercial fishers or the drinking water pumped from it. Virtually all market benefits are also found in the use category. "Non-market" benefits have no market-determined value and are not generally bought or sold, but may possess significant value to individuals who would pay to receive these benefits if a market existed. Examples of non-market benefits are things such as the scenic view of a lake or the value of a thriving ecosystem, although if a private property charges admission to look at the view, they capture some of the value of the view in the admission revenues. Non-market benefits can be found in both the use and non-use categories. Table 2 shows the classification of the economic benefit categories according to whether they represent market or non-market benefits.

Three types of value fall in the non-use, non-market category in the present: option value, inherent value, and bequest value, although some may involve the physical use of the resource in the future. These values are difficult to measure, but they are important, since they may reflect an individual's fundamental values and beliefs.

Option value derives from the individual having the ability, in some future period, to make use of a resource, despite not currently using the resource. An example would be people who do not currently fish, seeking to protect the health of the fish population in the event that they feel like fishing in the future. Having the option to fish in the future gives the individual a valuable benefit today.

Inherent value is associated with the existence of aspects of nature, even if the individual never plans to make any use of them. An example would be the value people place on preserving the health of a species of fish even though they will never directly benefit from the animal's health; the value is derived from the feeling of meeting some ethical obligation to preserve the environment.

Bequest value is derived from the preservation of a natural phenomenon for possible use by future generations. It is associated with a sense of stewardship felt by many individuals who feel it is important to pass on the environment to their descendants in at least as good shape as they received it. An example would be an individual foregoing the pollution of a lake, where the pollution would mainly cause harm in the distant future. Bequest value is different from inherent value in that it attaches value to the future use of the resource by descendants, not to the existence of the resource itself.

Table 2 Classifications of economic benefits of sediment remediation

Economic Benefit Category	**Biophysical Activity**	**Use/ Non-use**	**Market/ Non-market**
A. Human Health	1. Food from fishing and hunting 2. Drinkable water	Use Use	Market Market
B. Recreation	1. Fishing and hunting; boating and swimming; nature observation 2. Perceptions	 Use	 Non-market
C. Commercial Activities	Fishing, hunting, and trapping	Use	Market
D. Socio-cultural	Fishing, hunting, and trapping	Use	Non-market
E. Ecosystem Integrity	Contamination of the local water column, food chain, and ecosystem.	Non-use	Non-market
F. Industry and Agriculture costs	1. Irrigation 2. Livestock watering 3. Industrial processes 4. Waste disposal	Use Use Use Use	Market Market Market Non-market
G. Navigation	Restrictions on dredging	Use	Market
H. Economic Development	1. Recreational resorts 2. Broader land use 3. Perceptions	Use Use	Market Market

IV. BENEFIT VALUATION METHODS

In Section II we noted that quantitative descriptions of the biophysical benefits of sediment remediation are required before economic analysis can begin. The data should describe two scenarios, the "do nothing" scenario and the "remediation" scenario. They should describe the biophysical condition of the sediment, water quality, concentrations of contaminants in fish and other elements of the ecosystem, limitations on beneficial uses, and likely health effects on humans over the relevant time period. Once these data are in hand, the next step is to determine the economic value of the improvements in these biophysical parameters.

While the economic benefits of sediment remediation are highly diverse, as shown in Table 2, the economic benefits of environmental improvement generally are at least as broad, and a number of estimation techniques have developed over the years to evaluate them. To date, no one method has emerged as a dominant means of benefit valuation. Instead, each technique has both advantages and problems. A substantial literature discusses the relative merits of these techniques for environmental benefits generally. Freeman (1993) presents an excellent and comprehensive theoretical analysis of the principal methods; Cropper and Oates (1992) present a concise but thorough survey; Hanley and Spash (1993) present a good overview with several case studies. With the variety of estimation methods that are available, matching a valuation method to a benefit category must be done on a case-by-case basis, as there is often a choice of several methods to value a given benefit. On the other hand, many benefits are complex and intangible, such as the value a person receives from saving an ecosystem from damage, rendering it costly to collect data that illuminate such values. Furthermore, while these techniques have been applied to environmental problems many times, there have been few applications to contaminated sediment, so the details and accuracy of such applications have not been proven in practice.

This paper will not provide a handbook for applying these methodologies, nor a theoretical derivation, nor even detailed description, the latter two of which are provided in the references listed above. Instead this paper will provide a brief description of each, with an indication of its relevance to sediment remediation issues. A more detailed description of each methodology with a more complete description of strengths and weaknesses are presented in the *Guidebook on Great Lakes Environmental Benefits Valuation* prepared by the NE-MW Institute and the U.S. NOAA. SedPAC has been in contact with the NE-MW Institute during the preparation of that Guidebook, and this paper has benefited from the resulting cooperation. That handbook and other sources deal with numerous assumptions that are made in performing benefit assessments, and the limitations that these assumptions impose on the interpretation of the results.

We note one major conceptual issue in estimating benefits of environmental improvement in general, determining the scope of the analysis. This problem arises with respect to a variety of benefits, but can be illustrated most forcefully with respect to economic development.

Suppose that studies show that sediment remediation will improve the quality of the harbor area such that a $10 million resort hotel will be built on the waterfront. While the economic benefit of this investment is much less than $10 million, an analysis of Happy Harbor alone will likely find some economic benefits from that development. However, a regional analysis might find that the developer intended to build the resort hotel somewhere in the region and that the sediment remediation in Happy Harbor was the factor that brought it here instead of Beauty Bay. In this case, there may be a benefit to the economy of Happy Harbor, but there is a loss to Beauty Bay. The net benefit for the region may still be positive, but smaller than if only the effect on Happy Harbor is considered. Indeed, it is possible that the loss to Beauty Bay exceeds the benefit to Happy Harbor so that there is no net benefit at all. In many cases, it is important to decide what perspective to use in calculating benefits - local, regional, or national - and to recognize that if a local perspective is used, a broader perspective might yield different results. Similarly, tax revenues and payments from governments are generally treated by economists as transfers, so they do not enter into a calculation of social costs or benefits. For a local area, however, such payments or receipts may seem quite important. Care must be taken in designing any study of economic benefits to ensure that the scope of the analysis is carefully chosen, that the methodologies are applied in a way that is consistent with this scope, and that the scope is carefully explained.

Two basic classes of techniques have been distinguished in the literature, direct and indirect. Direct valuation methods seek to place a value on the benefit itself without the use of intermediate steps or inference; examples include the damage function approach and contingent valuation. Indirect methods seek to infer the value of the benefit by connecting the benefit to something that has an easily obtained value, and using the known value to estimate the worth of the benefit; examples of indirect methods are averting behavior, travel cost, and hedonic methods. Benefits transfer may be used to apply the results of a previous study derived by any method to the present problem.

To facilitate the discussion of these valuation methods, we will suggest how they might be applied to different aspects of the following problem. Suppose that Happy Harbor has a substantial and well-known area of sediment contaminated by PTS laid down during the first half of this century. All of the sources of the contamination have been closed or controlled, but releases of PTS from the sediment cause a variety of harms today. Studies have been done to predict the consequences of a particular sediment remediation project. These studies indicate that sediment remediation, along with some other work on the harbor environment may: increase fish stocks and diversity; reduce the concentration of PTS in the fish, so that existing warnings regarding fish consumption can be lifted; eliminate some eating of contaminated fish in violation of current warnings; cause an increase in sport fishing days of 10,000 per year; increase the commercial fish catch by 10,000 tonnes per year; improve the local aquatic ecosystem, returning a number of birds and animals that have been scarce; increase the use of the harbor for recreational fishing, boating, and swimming; eliminate the stigma attached to the harbor, thus facilitating $10 million in economic investment; defuse public demands for costly improvements to the town water supply, which is taken from the harbor; and allow dredging of the ship channel, saving $1 million per year in shipping costs for lake freighters using the harbor.

Direct Methods

The Damage Function Approach: Producer and Consumer Surplus for Market Goods

In the damage function approach, the pollution affects the production or consumption of a good that is purchased in a market, such as fish. The relationship between the amounts of fish available for sale and the amount of pollution is then calculated; this is the biophysical damage function. In many cases, determining this biophysical damage function will be a challenge, given the current state of scientific knowledge. Estimates of the demand for fish and the cost of catching and marketing the fish are determined using market data. The benefit from the pollution reduction can be calculated from the increased quantity of fish consumed and the net benefits, that is, the net increase in value for producers and consumers from producing and eating those fish. The main advantage of the damage function method is that it uses real values from market goods, and values pollution through an estimate of how it damages those goods. The disadvantages with it include the need for an easily valued market good, and its failure to capture any non-use values.

Example: If marine biologists can predict the increased quantity of fish stocks as a result of the Happy Harbor remediation, the benefits of remediation with respect to the commercial fishery would be the increase in value to consumers who purchase the 10,000 tonnes of fish (less the cost of the fish purchases) plus the increase in revenue to the commercial fishing industry (less the increase in industry cost). If commercial sports fishing is also improved, the value of this improvement would be the increase in value to the fishers who hire commercial sports fishing boats and guides (less the cost of the hiring) plus the increase in revenue to the commercial sports fishing boats and guides (less the increase in their cost). However, any improvement in recreational fishing would be difficult to measure by the damage function approach because there is no market transaction for the individual who takes his or her own boat out on the lake or who fishes from the town dock. For recreational fishing, the travel cost method is more appropriate (see below). If the Happy Harbor remediation allows the town to avoid special treatment of the drinking water, this saving, which represents a direct expenditure, would be a benefit of remediation measured by the damage function approach.

Application - use values of market goods:

C. Commercial fishing and hunting;
F. Agricultural and Industry costs;
H. Economic development.

Contingent Valuation

Contingent valuation uses surveys of the public to determine the value that they place on environmental amenities. Contingent valuation has the great advantage that it can incorporate all categories of value in its benefit calculation; indeed, it is the only technique that is capable of capturing the non-use values which may play such a large role in valuing sediment remediation. The technique is also flexible because it can be focussed directly on the values the researcher is interested in.

Contingent valuation is simple in principle. The interviewer uses a survey that presents several hypothetical situations and asks respondents about their willingness to pay for programs that transform one situation to another by improving environmental quality. In many cases the interview must be in person so that the interviewer can provide the respondent with a wide variety of information on the topic to allow informed decisions to be made. The survey can be open ended (how much would you pay for a program to clean up a certain pollution site?) or referendum style (would you pay $10, $20, $30 etc.), although the latter is preferred.

Contingent valuation is perhaps the most controversial valuation technique. Its supporters tend to be ardent and its detractors dismissive. Why are such divergent opinions held in regards to this technique? Some people feel that the survey method is inherently unreliable, so that any value determined from it must be suspect. In addition, contingent valuation can be very expensive, particularly where the public is unfamiliar with the specifics of the situation, as might be the case with sediment remediation.

Several problems are commonly associated with the survey method. First, people may respond differently to hypothetical situations than they would to the real situation (e.g. they declare a value of $20 for cleaning up a certain site, but would hesitate to pay the $20 if asked). Secondly, people may respond strategically, believing their responses will influence policy in their favor, rather than giving a genuine response. Thirdly, people may have difficulty incorporating all of the relevant information or dealing with changes that involve small probabilities of serious outcomes (a reduction in cancer risk from 2 per million to 1.5 per million) that are often involved. Finally, there is the problem of framing bias; widely different responses are given if people are asked their willingness to pay (WTP) for an improvement or willingness to accept (WTA) a degradation of the same magnitude.

Example: The residents of the area around Happy Harbor could be surveyed to determine their willingness to pay for the remediation project. They would be given a full description of the biophysical effects of the remediation. However, because the damage function approach can likely provide reasonably accurate estimates of the value of improved shipping and commercial fishing, these might be omitted from the survey. The survey should in principle capture all values, including the desire by those who never visit the harbor, to know that the local ecosystem has been restored, the desire to leave the environment in good condition for future generations, and the desire to provide the option of using the harbor in the future. If there is little current public understanding of the problem, it may be difficult to conduct an accurate survey without providing extensive background information, raising the cost of the survey. If it was thought that persons outside the Happy Harbor area might also value the Happy Harbor improvement, this would be captured only if the survey included some persons living outside the area.

Applications - use and non-use, market and non-market:

All benefit categories.

Indirect Methods

Averting Behavior

The averting behavior method relies on the fact that many costs of pollution can be mitigated by the purchase of goods in the market. The benefits of reducing the pollution are then valued at the reduction in money spent by individuals and companies to mitigate the damage. The advantage is that it is simple and uses real expenditures; however, it has several disadvantages. First, it is only applicable if the mitigating purchases by individuals completely offset all of the harm. Second, this method is limited to cases where the pollution damage can be mitigated by private expenditures. Finally, it ignores non-use values of the polluted area.

Example: The averting behavior method may not be very helpful in Happy Harbor. If residents currently purchase bottled water because they mistrust the municipal water taken from the harbor, the cost of that bottled water would provide a minimum estimate of the value of that mistrust. If residents travel to other areas for recreation, one might use the cost of that travel in an estimate of the benefits of restoring the Harbor for similar recreation.

Applications - use, market and non-market:

A. Human Health;
B. Recreation (swimming and boating);
C. Commercial Fishing and Hunting;
F. Agricultural and Industry costs;
G. Navigation costs;
H. Economic Development.

Travel Cost

The travel cost method recognizes that a large part of the implicit cost of many recreation activities is the time and expense that people commit to travel from their home to the recreation site. This means that the full cost of a visit to a recreation site includes not only the entry fee but also the monetary cost of travel, the time cost of travelling to the site, and the cost of time spent at the site**.** There is some debate over how to value time, but the wage rate that the individuals can or do earn is a good first approximation. If one gathers data on the cost of travel to various recreational areas, one can derive a curve of the value to those people of the recreational experience, a "demand curve." If sediment remediation provides recreational opportunities where they do not now exist, then the demand curve derived from the travel cost method can be used to determine how many person-days of visits will occur, and what their value may be. If sediment remediation improves the quality of the recreational experience, then a more complex travel cost study can determine both the projected visits and the increased value to users of the higher quality experience. The main advantage of this method is that it relies in part on real expenditures by individuals. The main problems are that it is limited to recreation benefits, it ignores non-use values, and the relevant costs must be estimated rather than measured directly.

Example: If the residents of the Happy Harbor area currently travel to several aquatic recreational sites, a survey of the users of those sites can determine the value that they attach to those visits, and thereby the demand for those visits. If sediment remediation will allow similar recreational activities in Happy Harbor with a lower travel cost, one could estimate both the likely usage of Happy Harbor and the value or benefits to the recreational visitors. If there is currently some recreational use of Happy Harbor, and remediation will improve the quality of that experience and increase usage, then the travel cost study must be able to determine the demand for recreational sites of differing environmental quality.

Applications - use, non-market:

B. Recreation.

Hedonic Methods

The hedonic methodology asserts that every commodity or service can be described by a bundle of attributes, and that the price paid for the commodity or service is determined by the price and quantity of each attribute. The method (usually performed with house prices for environmental matters) uses statistical methods to relate the price of the commodity to its attributes, one of which could be environmental quality. The estimates obtained can then be used to calculate a value for each attribute, including environmental quality. The advantage of the hedonic method is, once again, that it uses market data: real rather than hypothetical expenditures. The problems include the fact that it only captures values that are known to buyers and sellers of the commodity, the environmental quality estimates derived are only those that are connected with the use of the particular good included in the study, and that the estimates are only applicable for small changes in the attributes, so a large scale environmental clean-up might not be able to use the derived values. With regard to the first of these, if buyers and sellers of residential properties are unaware of the contamination, then the prices will not reflect that contamination, and the hedonic method cannot be used to measure the benefits of remediation. Thus a challenge for the application of the hedonic method to contaminated sediment would be to find a study area where the residents and participants in the local property market were well informed about the existing contamination and about its physical and biological effects.

Example: Suppose that there are residential and commercial properties in Happy Harbor that are sufficiently close to the contamination that real estate experts believe that their value would be affected by it, and that there are other properties farther away, perhaps outside the Harbor, that are clearly not affected. One could gather data on sales prices of both types of properties and on the physical characteristics of those properties, including lot size, number of rooms or floor space, amenities (number of bathrooms, fireplace, garage space, etc.), and proximity to the contamination, which would be used to estimate the value of each characteristic. Such an estimation might produce the result that proximity to the contamination reduced the value of a property by 10 percent or by $10,000. This information could be used in a further estimation of the increase in property value if the contamination were eliminated.

Applications - use, market, and non-market:

B. Recreation;
H. Economic Development.

Benefits Transfer

Benefits transfer is not a valuation methodology in itself like those listed above. Benefit transfer refers to the use of results found in a previous study for analysing the current problem. This can be done at either of two levels. We can use the values estimated in the previous study directly in the current study or we can use equations and functions from the previous study and input data from the current study. Consider the following examples of the former approach. If scientists can predict that sediment remediation will reduce health effects among fish-eating populations by six cases per year in Happy Harbor, and if studies elsewhere have found that these particular health effects are valued at $10,000 per case, we might apply the $10,000 per case value to the forecast reduction in cases in Happy Harbor study rather than try to estimate a new value of these health effects there. If a study found that remediating contaminated sediment increased the prices of lakefront properties by $10,000 each in Euclid Beach on Lake Erie, we might assume that a similar remediation would raise beachfront property values by $10,000 in Hamilton Harbour on Lake Ontario. If previous studies have found that recreational activities similar to those that could take place in a remediated Happy Harbor were worth $6 per person-day in some other Great Lakes community, we might assume a similar value per person-day in Happy Harbor and simply estimate the likely number of person-days that would result from remediation. These estimates can be adjusted for known differences between the two projects such as different population densities or different intensity of use, to make them more applicable to the project at hand.

The great advantage of this method is that it saves time and money. The disadvantages are that the two situations are assumed to be roughly the same, so that unique elements of the current problem are ignored, and the quality of the first estimates is critical to the reliability of the current study. Perhaps the best use of benefits transfer arises with risks of human mortality; it would be hard to argue that saving a life in town A was worth more than saving a life in town B. A more problematic use of benefits transfer arises with recreation; can we assume that increasing daily visits to a Chicago beach is worth the same amount per visit as increasing daily visits to a beach in Southern California? In some cases, the situations will be sufficiently different that transferring the benefits will be hard to defend. In addition, some values may change over time as people's tastes change or they learn more about the implications of a particular environmental problem, causing estimates from studies undertaken several years in the past to be less applicable, and greatly reducing the number of data sources to draw on.

Finally, there is the problem of finding relevant studies. By now there is a considerable body of empirical data on the value of a variety of environmental qualities or assets, but very little of this data relates to contaminated sediment. If the remediation project yields more recreational person-days of a traditional type of recreation, benefits transfer may be quite useful. But if the problem is to determine the extent to which sediment remediation will have any impact on recreational demand, it is unlikely that past studies can be found that will illuminate the answer. We need data linking sediment remediation to the biophysical or economic activity before benefits transfer can take place.

Applications - use and non-use, market and non-market:

All benefit categories; all valuation methods.

Human Health

Human health has been separated into its own category because the methods used to value human health consequences of programs are often exclusive to health or somehow adapted methods of those used elsewhere. There are two types of health risks, each of which has its own valuation techniques; mortality risks are those which lead to death, while morbidity risks lead to non-fatal illnesses. The costs of health risks include both the risk itself and the cost of health care to reduce the risk or to treat the condition. The discussion here relates to determining the economic value of a known statistical risk to life or to a particular illness; these methods can only be applied when there is sufficient scientific evidence to predict quantitative risks to life and health.

Mortality

When discussing the value of life it is important to make the distinction that we are not valuing a particular life, since for that particular individual it would have a virtually infinite value, but rather we are valuing a "statistical life". The general question is: what value do we place on a small reduction in small probabilities of death, not the value of avoiding certain death.

There are several methods of valuing risks to human life. The first method, called the human capital approach, values a statistical life as the present value of the expected future income of the persons at risk, possibly adjusted to include some non-market services the individual provides (house-keeping). This method has many problems including: valuing persons according to their economic productive capacity, while ignoring many other contributions people make valuing people differently depending on their age and occupation, thus placing very little value on children or people who are not employed; and ignoring the attitudes of the person at risk to the prospect of increased or decreased risk.

The second method is willingness to pay (WTP) studies. The value of a statistical life is the sum of the WTP for probability reductions divided by the expected number of lives saved. The methods used in these studies are similar to those described above; contingent valuation, averting behavior, and hedonic methods. The hedonic methods typically involve studies of the wage premium that must be paid to induce people to take on risky jobs. Estimates of the value of a statistical life have ranged widely, but there is some clustering of values in the $1.5 to $4 million range. (Cropper and Oates 1992; Moore and Viscusi 1990).

Morbidity

Morbidity or illness is also valued in two ways. First, there is an opportunity cost approach, akin to the human capital approach, where the value of the illness is the lost wages caused by the illness. Secondly, there is the WTP approach which uses the methodologies of contingent valuation or averting expenditures. The former is simple to calculate, but likely underestimates the true loss associated with illness. The latter is conceptually more sound, but suffers from all the problems associated with contingent valuation. Estimates are often provided for WTP to avoid "symptom days", which are simply days symptoms are suffered. An example of WTP estimates for symptom days include $1.39 to $42.00 for coughing. (Cropper and Oates 1992).

Omissions and Double-Counting

Two problems that may arise from using more than one method to estimate the benefits of any environmental improvement are omissions and double-counting. Omissions occur when some category of benefits is not captured by any of the methods being applied. For example, if the damage function method is used to estimate the benefits to commercial fishing of sediment remediation and the hedonic method is used to estimate property value benefits for lakefront properties, there is no measurement of benefits to ecosystem integrity nor to human health. On the other hand, if one uses contingent valuation to determine the full public value for a remediation project and also performs a hedonic study of likely property value increases, there is a risk of double-counting to the extent that the contingent valuation study incorporated notions of increases in property values. The design of a benefit study should include a listing of the full range of benefits that may arise from the project, a list of the benefits that will be captured by each method used, a check that double-counting will not arise, and some recognition of the benefits that will not be captured by the study.

V. CHALLENGES FOR BENEFIT VALUATION

While the discussion of economic valuation methods above identified advantages and disadvantages of the various methods, estimating the benefits of contaminated sediment remediation presents some particular challenges that should be considered before undertaking a benefit valuation study or assessing an existing study. These challenges and the limitations previously discussed mean that in many cases it will be difficult to rely on benefit-cost analysis as the primary basis for making policy decisions, simply because the analysis will be necessarily incomplete. Even in such cases, it may still be useful to analyse those benefits that can be quantified, so long as there is explicit recognition of those which cannot be so quantified.

Economic benefit estimation cannot begin until one has scientific data describing the biophysical benefits of the sediment remediation. If we do not know the extent to which a remediation project will reduce the concentrations of PTS in the water column, fish, or wildlife, we cannot value the health or recreational benefits to humans arising from remediation. If scientists cannot predict the extent to which the ecosystem will recover as a result of a sediment remediation project, we cannot estimate the economic value of that ecosystem recovery. In many cases it appears that our scientific knowledge is sufficiently limited, that it will be difficult to describe the biophysical effects of remediation, and therefore difficult to even begin the economic evaluation.

While there is a vast literature on the estimation of economic benefits of pollution control generally, there are few studies applying these methodologies to the remediation of contaminated sediment. This means that there are few models of the specific application of the general methodologies to the particular problem of contaminated sediment, and few existing estimates of the value of remediation that might be used for benefit transfer or for deriving a ball-park estimate of the benefits of a particular remediation project.

In the case of air pollution, a major benefit is reduced harm to human health. If one can describe a reduction in the concentration of one of the traditional pollutants and if one knows the local population density, there are formulas that will permit a reasonably accurate estimate of the physical health benefits of reducing air pollution concentrations in a particular location. In the case of contaminated sediment, local conditions may profoundly affect the rate at which PTS in the sediment are released on an ongoing or episodic basis: there are many different compounds of concern, the local ecology may determine the type of harm that a given release will cause, and local conditions will determine the extent to which it is necessary to worry about downstream effects of sediment redispersal. Because the biophysical effects of contaminants are so site-dependent, it is more difficult to predict the biophysical benefits, much less the economic benefits, of any particular remediation project than is the case with many air pollution or water pollution control projects. This reduces the opportunity to use benefit transfer and raises the cost of doing any particular assessment.

Even if there was a perfect quantification of the biophysical benefits of sediment remediation, most of the methods of economic evaluation are costly to implement. In addition, there are debates about the methodology of some techniques and serious criticisms have been levelled at some recent studies. (Portney 1994; Dunford 1999). This means that it is likely to be costly to perform a study in which one could have reasonable confidence, and even then there is no assurance that the results could not be attacked on some grounds. Perhaps this problem is no worse than that of the scientific methods used to determine the biophysical effects of remediation, but it may be not much better. If we can still debate the extent to which current concentrations of PTS in lake water are causing damage to various elements of the ecosystem, it seems unlikely that an estimate of the economic benefits of remediation will be beyond dispute. The more limited the available budget for analysis, the more controversial the results are likely to be.

Most contaminant sediment problems that have been known for some time and remain untreated will be costly to remediate; if remediation was inexpensive, it would likely have been done already. Furthermore, in many AOCs there is uncertainty about which parties may be liable for costs of remediation. A study that purported to determine the benefits of remediation could be used either to support or to postpone remedial action, depending on the outcome. It would not be surprising if the announcement of a study of the benefits of remediation would cause both those who might benefit from remediation and those who might be asked to pay to have an interest in the outcome of the study, and to try to influence it to their benefit. While a benefit study alone cannot determine the proper course for remediation and while few economists would recommend that a cost-benefit study by itself should decide what ought to be done, benefit estimation is another piece of evidence that can be used for various purposes by the parties involved with a contaminated site. It should be anticipated that the design of the study will attract considerable interest and input, both welcome and unwelcome.

VI. NECESSARY ACTIONS

Because of the scientific uncertainties about the biophysical effects of sediment remediation, the uncertainties involved in assigning economic values to those biophysical effects, and the lack of a clear and generally accepted framework for deciding what remedial action to take and when, one should not expect that economic evaluation of the benefits of sediment remediation will be a panacea for AOCs around the Great Lakes. In particular, it should not be assumed that an economic benefit valuation will be the first step in a comprehensive benefit-cost analysis that will produce "the answer". While benefit-cost analysis is a powerful framework for organizing available data, the results are only as useful as the quality of the data available for analysis, and as we have indicated, the data are often subject to considerable uncertainty.

On the other hand, an economic valuation of the benefits of a particular remediation project may be quite useful both for learning which categories of benefits are more important and which are less important, and for deriving even a rough idea of the magnitude of those benefits that can be estimated, relative to the costs that can be estimated. If the costs are $100 million and the estimated benefits are only $1 million, it would seem prudent to do more study before proceeding with the project, unless there is general agreement that the omitted benefits could easily make up the $99 million shortfall. If a preliminary analysis indicates that the only benefit category of any importance is sport fishing and if data on sport fishing are scarce, then gathering more data about local sport fishing may be a high priority. And if local representatives insist that remediation is highly valuable while the study suggests low values, the study may provide a basis for dialogue with local representatives about the reasons for the discrepancy, perhaps leading to a more refined study or to new perceptions.

This analysis suggests several action steps relating to the economic benefits of sediment remediation:

- Coordination should continue with the NEMW Institute/NOAA study of economic benefits in order to pursue case studies that could be used to refine the application of economic analysis to sediment remediation.
- Because successful analysis depends on a good foundation of scientific data, it is important that any economic benefit study begin with a pre-screening of proposed case study sites to determine whether they actually have the data available to do even a minimally successful study.
- The scoping studies that are under way should be pursued (the St. Clair River study is likely to be completed soon).
- Pilot studies, even partial rather than complete studies, could be used to develop a better understanding of which benefit categories are likely to be most important for remediation of contaminated sediment, and which categories are least relevant.

- Pilot studies could be used to develop a better understanding of which economic evaluation tools are most useful for the assessment of the benefits of sediment remediation, and which are least useful.

We note that grant programs, particularly in the United States, seem to recognize increasingly the need for site-specific work on economic benefits. Considerably more empirical data, on which an understanding of the economic benefits of sediment remediation can be based, should be available in the near future. It may be worthwhile to update this paper, building on the knowledge that has accumulated, and perhaps to develop a short manual to accompany it that would be of use to AOCs that continue to face difficult choices regarding contaminated sediment.

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