CHAPTER III

WATER POLLUTION CONTROL BENEFITS

Introduction

The purpose of this chapter is to review and evaluate estimates of national damages due to water pollution and of the benefits of federal water pollution control policy, and to arrive at some judgment as to the magnitude of benefits likely to be realized in the implementation of the Federal Water Pollution Control Act amendments of 1972 (FWPCA-72). This law calls for all industrial dischargers to have controlled their discharges consistent with the best practical treatment methods (BPT) by 1977 and further to achieve the best available treatment technologies (BAT) by 1983. Municipal treatment systems are to meet similar requirements, secondary treatment by 1977 and the best practicable waste treatment technology by 1983.[1]

The BPT and BAT requirements apply to point sources of pollution. The principal mechanism for dealing with nonpoint sources of pollution such as erosion and agricultural and urban runoff is the requirement for the "development and implementation of area-wide waste treatment management plans" as required by Section 208 of the FWPCA-72. Estimation of the benefits of controlling nonpoint sources is made difficult both because of

[1]Amendments to the Act passed in 1977 allow for modifications of the BAT requirements and for various extensions of the 1983 deadline for BAT for industry.

the lack of information on the effects of nonpoint source pollutants on water users and because of the difficulty in predicting the degree of required control which is likely to emerge from the Section 208 planning process. The benefits of nonpoint source control will not be covered in this report.

Ideally one would like to be able to derive estimates of the <u>incremental</u> benefits achieved by compliance with each stage of the FWPCA-72, that is, for BPT in 1977 and BAT in 1983. However there are several problems in deriving estimates of incremental benefits from the studies and the data presently available. First, the FWPCA-72 are not the first effort to control water pollution. Rather they represent a major change in federal and state policies which were established in 1965 and which were having some effect on water quality as implementation slowly proceeded. Although there were substantial weaknesses in the 1965 law, especially with respect to incentives and the enforcement effort, it is likely that there would have been some improvement in water quality after 1972 even without the new amendments. Several of the studies reviewed in this chapter take 1972 water quality levels as the starting point for estimating the benefits of achieving full compliance with the standards established under the FWPCA-72. These studies are likely to overestimate the incremental benefits associated with the Act, since they attribute all of the subsequent improvement in water quality to the FWPCA-72.

A second set of problems concerns how to determine the incremental benefits attributable to the implementation of each stage of the FWPCA-72. First, if the benefit function is nonlinear, its exact form must be known in order to determine what portion of the total benefits can be attributed to achieving the BPT standards of 1977. Furthermore, the relative stringency of the 1977 and 1983 standards varies substantially across polluting substances and for any substance across industrial categories. Thus there is no simple aggregate relationship between the degree of control which was to be achieved in 1977 and that to be expected in 1983. Rather an analysis must proceed on a case-by-case basis looking at individual pollutants and industries. Only one of the studies reviewed here (Unger, 1975) attempted to make separate estimates of the benefits of implementing each stage of the Act. Except for this, we must be satisfied with estimates of the benefits of full compliance with the Act.

Some of the studies have attempted to estimate benefits of improvement from some base year, say 1972. Others have focused on the damages due to pollution levels actually experienced in 1972. There are at least two reasons why estimates of damages might be taken as upper-bound estimates of the benefits of full compliance with the 1983 standards. First, these standards call for strict control of discharges and in some cases will result in the elimination of certain types of discharges. And second, if the benefit function is nonlinear, that is, the first clean-up efforts produce the largest benefits, the bulk of benefits will have been achieved (and damages avoided) as the 1983 standards are approached and attained.

We will proceed by estimating benefits by category of effects. In contrast with the air pollution benefits, there are substantial differences among the studies reviewed here in the way effects and benefits are classified. I have chosen to classify point source pollution control benefits in the following manner:

1. <u>Recreation</u>

   These are benefits to individuals who actually use waterways for recreational activities such as fishing, swimming, boating, or water fowl hunting. This category should also include activities such as hiking, picnicking, and nature observation which are frequently engaged in near water bodies. However, none of the studies reviewed here attempted to estimate benefits to these activities.

2. <u>Nonuser Benefits</u>

   This category includes amenity, aesthetic, and ecological benefits which are not directly associated with activities on or adjacent to the water body or with diversionary uses of the water. This category could also include preservation benefits, option values, and changes in property values which reflect households' willingness to pay to be near high quality water bodies.

3. <u>Diversionary Uses</u>

   a. <u>Drinking water and health</u>: To the extent that point sources of pollution result in chemical, bacterial, or viral contamination sources of drinking water, controlling that pollution may reduce risks to human health.

b. <u>Treatment Costs for Municipal Water Supplies</u>: Pollutants present in intake water may force suppliers to incur higher treatment costs for reasons other than, or in addition to, the protection of health.

c. <u>Household Benefits</u>: To the extent that point sources of pollution affect water hardness, costs to households could be reduced by controlling these substances.

d. <u>Industrial Treatment Costs</u>: Control of pollution may reduce costs of treating industrial process and cooling water.

4. <u>Commercial Fisheries</u>

Where pollution has reduced the biological productivity of fisheries or resulted in the closure of shellfish beds and other fishery resources, abatement can result in increased producer rents and/or lower prices of fisheries products to consumers.

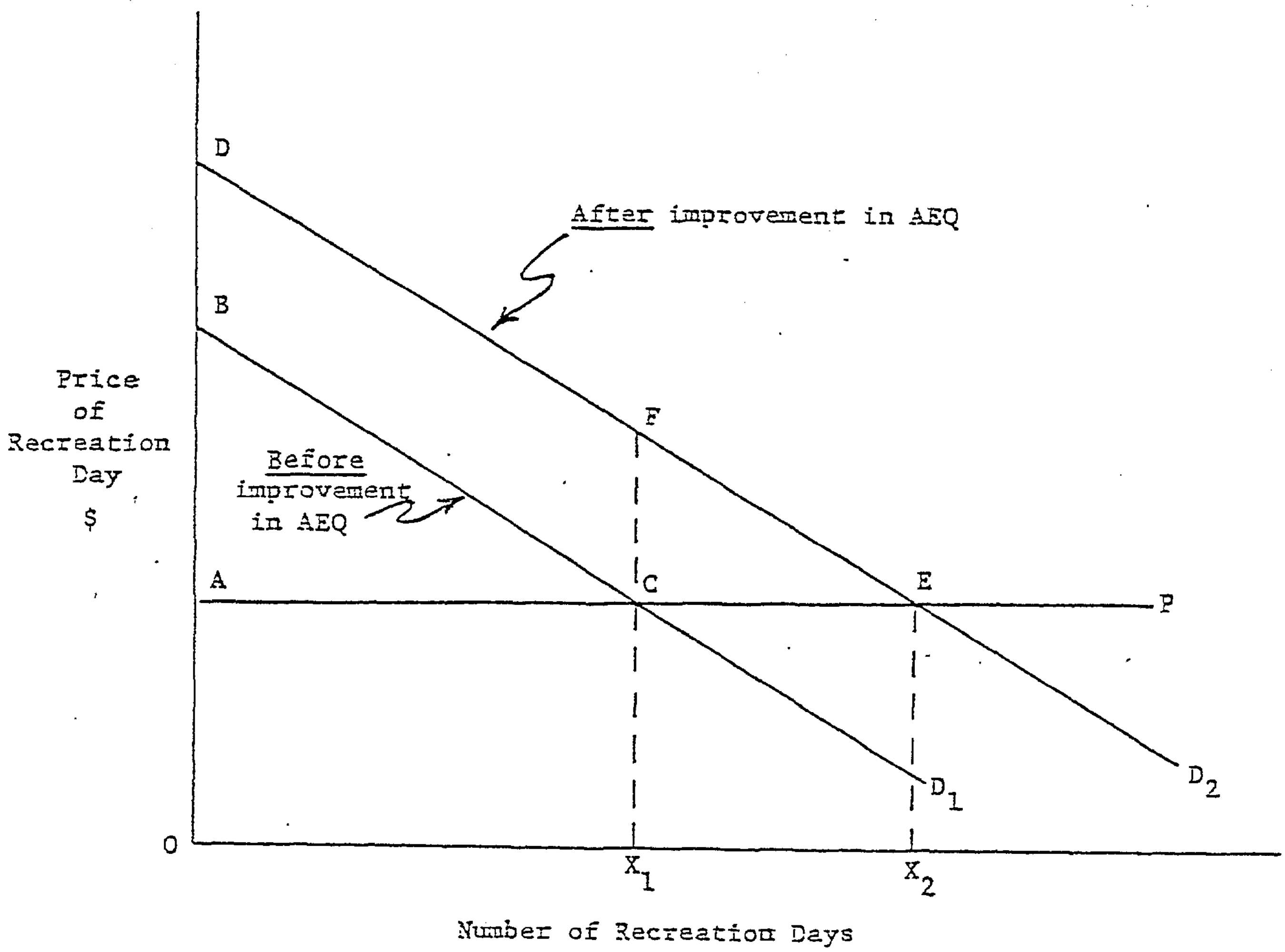
<u>Recreation</u>

It will be helpful first to review the conceptual basis for defining and measuring the benefits of improved water quality for recreationists. Consider a single recreation site such as a lake, park or wilderness area. There is a demand function for the use of this recreation site which relates the quantity of recreation services demanded, measured in recreation days, to the price of these services income, and other socioeconomic variables. This demand function can also be interpreted as a marginal willingness to pay or inverse demand function, relating the marginal value of a recreation day to the quantity of recreation days. An inverse demand curve can be plotted holding income, the prices and availability of substitutes, and the quality of this recreation site constant. In Figure 2, D_1 is the demand curve for visits before water quality is improved. Suppose the price of admission to this site is $0A per day. The actual recreational use or quantity demanded will be OX_1. The value of this recreation site, given the initial water quality, is the consumers' surplus as measured by area ABC.

Assume that water quality is improved at this site. Users would be willing to pay more at the margin to use this improved site at given use levels; and at the given price, use would increase. In economic terms the effect is to shift the demand curve to the right. The new demand curve is shown by D_2. The net economic benefit of this improvement in water quality is the increase in willingness to pay as measured by the area between the two demand curves, BCED.

The net benefit can be divided into two categories. The first is the increase in value to those OX_1 users who were using the facility even at the original level of water quality. This is the area BCFD. This area represents their increased willingness to pay to maintain present use rates at this recreation site rather than do without. In addition, the greater attractiveness of this site relative to alternative recreation sites and alternative consumption activities results in an increase in recreation days at this site equal to $X_2 - X_1$. The net benefit

Figure 2



D
After improvement in AEQ
B
Price of Recreation Day $
F
Before improvement in AEQ
A
C
E
P
D_1
D_2
0
X_1
X_2
Number of Recreation Days

associated with this increase in use is the area CEF. This increase consists of both greater use rates by original users and new users who are attracted to this site by the improvement in water quality.

To implement this theoretical approach requires first, a way of estimating demand functions for a recreation site, and, second, a way of predicting changes in the demand curve when water quality at the site changes. Of course, the problem of demand estimation would be straightforward if the normal practice were to charge an entry fee and if fees varied substantially. But the typical practice for publicly provided recreation sites is to charge a zero price or only a nominal entry fee. Without variation in the entry fee, it is not possible to estimate demand functions through normal econometric procedures. However, it may be possible to infer how a given group of people would respond to changes in the entry price by examining data on how different groups of people respond to differences in monetary travel costs. This is the basic hypothesis of the so-called Clawson-Knetsch (C-K) travel cost method of demand estimation.[2]

It must be emphasized that the C-K method is site-specific, that is, it yields a demand function for a specific recreation site rather than for recreational activities in general. The site demand is a derived demand and depends on the ability of the

[2]For an explanation of the C-K methodology and a discussion of problems in its application to estimating water quality benefits, see Freeman (1979), Chaster 8.

site to "produce" the desired activities. While this may reduce the usefulness of the C-K method for some purposes, for example, predicting total recreation activity over time, it is precisely the site-specific nature of the method which makes it attractive for estimating the economic value of water quality improvements for particular water bodies. The C-K approach cannot be used to estimate the demand function for generalized recreation experiences aggregated over sites.

The so-called participation model is an alternative approach to the analysis of recreation and water quality benefits which involve less stringent data requirements, assumptions, and estimation procedures than the C-K technique. The approach is to estimate reduced form equations relating participation in specific recreation activities by a given population to the socio-economic characteristics of that population and to the supply and quality of recreation opportunities available. These less stringent data requirements can be considered advantages, but they entail the loss of ability to infer values from the empirical analysis.

If reduced form population-specific participation equations can be estimated, it would be possible to predict the increase in participation to be expected with an increase in the supply of recreation opportunities or with an improvement in ambient water quality. If the value of a recreation day of a particular type could be inferred from other sources, then one component of recreation benefits can be estimated by multiplying the increase in recreation days by the assumed value per day. However this would not capture the increased utility associated with the pre-existing level of use, that is, the area BCFD in Figure 2. This omitted component of benefits could be quite important.

A participation model of this type was used by Davidson, Adams, and Seneca (1966) to predict the increase in water recreation attributable to improving water quality in the Delaware Estuary. These authors used data from the 1959 Nationwide Outdoor Recreation Survey to estimate regression equations for participation in boating, swimming, and fishing. The availability of water for recreation was measured by the area in acres of water of recreational quality within the study area. These area variables were significant in the estimated regression equations. Actual socioeconomic data for 1960 and projected values for these variables for 1975 and 1990 were combined with the estimated reduced form equations to predict recreation activity levels in the 11 county area around the Delaware Estuary for those years. The variables for availability of water area were those actually observed at the time of the study, excluding the Delaware Estuary itself. This gave an estimate of recreational activities over time assuming that degraded water quality in the Estuary prevented recreation there.

Then it was assumed that the water quality of the Delaware would be improved sufficiently to allow water-based recreation in the Estuary. In other words, an improvement in water quality was assumed to be equivalent to an increase in the area of water available for recreation, in order to make use of the information contained in the reduced form equations. The projected increase in the availability of water area was used to predict new levels of recreational activity. The difference between the "with" and "without" predictions was attributed to the water quality improvement. Davidson, Seneca, and Adams did not employ a unit value or shadow price for recreation days to compute benefits. Rather they computed the unit value which would be required to make benefits equal the costs of control. A value of $2.55 per day in 1959 dollars was sufficient to make benefits equal costs. Water quality entered the analysis only through a judgment as to whether or not river waters were suitable for recreation. Factors such as variation of water quality within the Estuary, differences in the aesthetic attributes of the shoreline and surrounding areas at different points in the Estuary, and problems of access to the water played no role in the model.

The participation approach could be used either to predict the changes in recreation at a point in time, or, as in the case of the Davidson, Adams, Seneca study, to make projections of changes in recreation over a long span of time. In the latter case, estimates are subject to all of the kinds of limitations inherent in long-term economic projections. In particular, these projections ignore the possible effects of changing tastes, increasing income, leisure time, and the impact of improved opportunities on participation rates through the "learning by doing" phenomenon.

This technique for relating water quality to recreation behavior is only as good as the data contained in the survey instrument. The survey data must include information on the availability of recreation opportunities including type of water body, indicators of water quality, other site characteristics such as facilities and improvements, and accessibility. Ideally the survey should record not only levels of participation but some measure of the costs of travel from the residence to the recreation site actually chosen.

The National Commission on Water Quality commissioned four studies of benefits, three of which included various components of recreation activities. Each study estimated the benefits of improving water quality from 1972 levels in 1980 and in 1985, the latter assuming full attainment of the objectives of the FWPCA-72. In each case the estimates were based on projections of population, income, and other variables to the relevant year.

One of these studies, carried out by the National Planning Association (1975), utilized a recreation participation model to estimate the increase in participation in fresh water fishing and boating that might be attributed to projected improvements in water quality. These were the only activities for which the available data permitted the estimation of the relationship between participation and water quality. The data were from the National Recreation Survey of 1970.

On the basis of the estimated relationship between participation and water quality, the National Planning Association predicted that participation in boating would increase by between 50 and 115 million activity days per year by 1985. Fresh water recreational fishing was predicted to increase by between 26 and 67 million days per year by 1985. NPA then applied unit values of $12.12 and $10.06. per day in 1978 dollars to boating and fishing activities respectively. The same technique was used to estimate increases in activity levels for the year 1980. The results are shown in Table 10. It should be noted that is method will lead to an underestimate of total benefits for two reasons. First, some water based activities such as water skiing, canoeing, and sailing have been omitted due to lack of data. And second, this technique captures only those benefits accruing to additional participation, and neglects benefits due to increased utility for existing participants. As indicated before, this omission could be significant.

The second study, by Battelle Memorial Institute (1975), predicted the change in swimming participation in the U.S. on the basis of the reduction in miles of public beaches closed to swimming because of coliform bacteria contamination. It was estimated that about 13% of the total miles of lake, river, and ocean beaches in the U.S. were closed to swimming either permanently or periodically because of water pollution under existing conditions. The study attempted to distinguish between net increases in swimming activity and activities diverted from other beaches because of changes in the availability of swimming sites. The former were valued more highly ($3.03 per day versus $1.09 per day in 1978 dollars). The benefits associated with 1980 levels of water quality, population, income, etc. were estimated to lie

TABLE 10

NATIONAL RECREATION BENEFITS AS ESTIMATED FOR THE NATIONAL COMMISSION ON WATER QUALITY

(in 1978 dollars)

	Millions of dollars Per Year	
	1980	1985
Fresh Water Recreational Fishing (National Planning Association)	$264- $639	$267- $677
Boating (National Planning Association)	371- 842	603- 1,399
Swimming at Public Beaches (Buttelle Memorial Institute)	173- 571	191- 631
Marine Recreational Fishing (Bell and Canterbery)	2,459	3,997
Totals	$3,266-$4,511	$5,058-$6,705

Source: National Commission on Water Quality (1976), p. III-286.

between $173 and $571 million per year, in 1978 dollars. 1985 benefits were estimated to lie between $191 and $631 million per year.

The third study, by Bell and Canterbery (1975), estimated the impact of changes in water quality on marine fisheries, both recreational and commercial. The results for commercial fisheries will be discussed below. Bell and Canterbery used secondary data to derive relationships between water quality and biological productivity, and between productivity and the number of participants and days of sports fishing. The estimates covered ten species of fish and shellfish on the East Coast, Gulf Coast and West Coast. A household production function model was used to derive a relationship between expenditures on fishing (for example, gear, travel, etc.) and the consumer surplus associated with the activity. Time as an input was valued at the foregone wage rate. This will lead to an overestimate of benefits if the true opportunity costs of time is less than the wage rate. In fact some evidence suggests that the opportunity cost of time outside of the work place may be only one-quarter to one-third of the wage rate.[3]

Bell and Canterbery estimated that implementation of the FWPCA-72 would lead to increases in marine sports fishing valued at $2.46 billion per year in 1980 and at $4.0 billion in 1985, both in 1978 dollars. These figures are also shown in Table 10.

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[3] See Freeman (1979), pp. 204-209.

Adding the four components of recreation benefits covered by the National Commission on Water Quality Studies gives total benefits in 1980 of between \$3.3 and \$4.5 billion. The range for 1985 is between \$5.1 billion and \$6.7 billion per year.

Heintz, Hershaft, and Horak (1976) estimated the national damages (or benefits lost) due to water pollution to four recreational activities, fishing, boating, swimming, and water fowl hunting. Estimates were derived for 1973. The data on recreation activity levels came from the 1970 surveys by the Bureau of Recreation and the U.S. Fish and Wildlife Service. Activity levels were projected to 1973 on the basis of population growth. The explanation of their technique will be framed in terms of the benefits of eliminating water pollution. We will go into their technique in some detail in order to show some of the problems that arise in attempting estimates of national benefits from the available data. These problems include very limited information on the relationships between changes in water quality and recreation activities and on the value of recreation as a function of water quality, and the difficulties in extrapolating from limited data on narrowly defined regions to national estimates.

The benefit measure derived by Heintz, Hershaft, and Horak has three components: a travel cost savings for existing recreationers as more accessible sites become available, an increase in recreation activity, and an increase in the utility or welfare associated with the existing level of recreation activity.

In order to estimate the reduction in travel costs when pollution is eliminated, Heintz, Hershaft, and Horak had to obtain three key pieces of information. The first is the percentage of recreationists who shift the location of their recreation activity as water quality changes. The source of this parameter is a survey of recreationists in Green Bay, Wisconsin conducted by Ditton and Goodale.[4] Recreationers were asked, "What would you do if water conditions deteriorated at the place you do most of your boating, fishing, and swimming?" Possible responses were:

--move to a location on Green Bay;
--move to a location not on Green Bay;
--stay in same location but participate less frequently;
--would not bother me;
--stop participating entirely.

The second key parameter is the percentage change in travel cost for those who actually shift. This was apparently derived from a survey of recreationists at the Rocky Mountain National Park in Colorado. Respondents were shown photographs of streams with different water qualities. And asked to indicate how their plans would vary with changes in stream quality, the study showed that a given percentage change in water pollution would result in an approximately equal percentage change in distance traveled to

[4] I do not have access to this report. The following description is based on Heintz, Hershaft, and Horak (1976).

engage in recreation activities.

The third key piece of information is the changes in water quality experienced by recreationists across the country. Heintz, Hershaft, and Horak used a proxy for this a measure of the change in the number of miles of waterways classified as polluted. Thus the model does not treat water quality as a continuous variable but as a dichotomous variable, that is, polluted or not polluted.

These three pieces of information were used in the following manner.[5] It was assumed that all U.S. recreationists would respond to a reduction in pollution in the same way as the Green Bay sample. Travel costs per recreation day were taken from the 1970 national surveys of hunting, fishing and recreation. The percentage reduction in travel costs for those changing behavior was taken from the Rocky Mountain Park survey. And it was assumed that a 41% reduction in polluted stream miles would result in an equal percentage decrease in total travel by recreationists. The decrease in travel cost was computed by multiplication as follows:

$$\begin{bmatrix}\text{Number of}\\\text{Recreation}\\\text{Days}\end{bmatrix} \times \begin{bmatrix}\text{Travel}\\\text{Cost}\\\text{Per Day}\end{bmatrix} \times \begin{bmatrix}\text{Percent of}\\\text{Recreationists}\\\text{Shifting}\end{bmatrix} \times \begin{bmatrix}\text{Percent}\\\text{Reduction}\\\text{In Travel}\\\text{Costs}\end{bmatrix}$$

The second component of benefits, that due to the change in activity levels, was also based on information from the Green Bay Survey. The percentage responding "stop participating entirely"

[5] For details of the computations, see Heintz, Hershaft, and Horak (1976).

was taken as a measure of the change in national recreation activity levels.

Finally, the estimate of the change in utility was found by first predicting the proportion of recreationists who would not move to a different site or stop their recreation. Again, this was based on the Green Bay survey. Then, a monetary value for this utility loss was assumed. This figure, $5.75 per day in 1973, was taken from the survey of recreationists in the Rocky Mountain National Park.

The results of these calculations show that for fishing and hunting, the decrease in travel cost is the major component of estimated benefits; while for boating and swimming, the major benefit comes from increased utility of existing activities. Over 40% of the total benefits come from fishing; while water fowl hunting makes a minor contribution to the total. Using the consumer price index, these figures can be converted to 1978 dollars. Heintz, Hershaft and Horak estimate benefits to lie in the range $3.7-$18.5 billion per year with the most likely point estimate being $9.2 billion. This works out to just over $40 per capita for the U.S. population in 1978.

This estimate and the computations on which it is based can be criticized on the basis of both the use of the data and the underlying implicit model. There are three major problems with using data from surveys such as those from Green Bay and the Rocky Mountain National Park to estimate national benefits. First, the nature and magnitude of the change in water quality are not specified in the survey questions. The question may conjure up quite different pictures of deteriorated water conditions in different individuals. Thus it is not possible to establish a quantitative link between a policy which affects discharges and water quality in a specified way and the responses of recreationists to those changes.

Second, the questions are hypothetical, and there is no assurance that respondents would behave in the way they said they would if the postulated changes in water quality actually occurred. Responses to hypothetical questions are more likely to be accurate predictors of behavior when the respondent is presented with an accurate and detailed description of the hypothetical situation. But the vagueness of the questions makes it less likely that responses will be good predictors of actual behavior.

Finally, the surveys are specific to the locations in question, and responses are conditioned upon existing water quality in the survey area, the availability of alternative recreation sites within that general area, their water qualities, and the socioeconomic characteristics of the population. Other parts of the country will have different availabilities of substitute sites and different population characteristics. These differences must be taken into account in developing predictions of the behavior of the national population.

More fundamental criticisms can be directed at their basic model. Unlike the model of Figure 2, the model implied by their method of calculation is based on the demand for participation in a recreation activity rather than recreation at a specific site. The problem is that their treatment of the roles of site characteristics and travel cost as determinants of demand is wrong. Their model assumes a demand curve for the activity conditional on the accessibility and quality of alternative sites. This is D_1 in Figure 3. Travel cost, presumably some average across sites, is treated as a proxy for price and taken as given at P_1. This leads to an equilibrium of OX_1 days of participation. They argue that an improvement in water quality will shift the demand curve out, say to D_2, and lower the average travel cost, say to P_2. If this is correct, then the benefits would be measured by the travel cost savings to original participants, ABHI, plus the consumer surplus to additional days of participation because of the lower price, GIF, plus the utility gain to original participants because of improved water quality, CDGH. These three areas correspond to their descriptions of their three components of benefits.[6]

Their basic error is to treat travel cost as exogenous and as determining participation. Rather realized travel cost per day of participation is endogenous, being determined by the interactions among demand for participation, availability of alternative sites, their qualities, and their distances from the residences of recreationists. An improvement in water quality need

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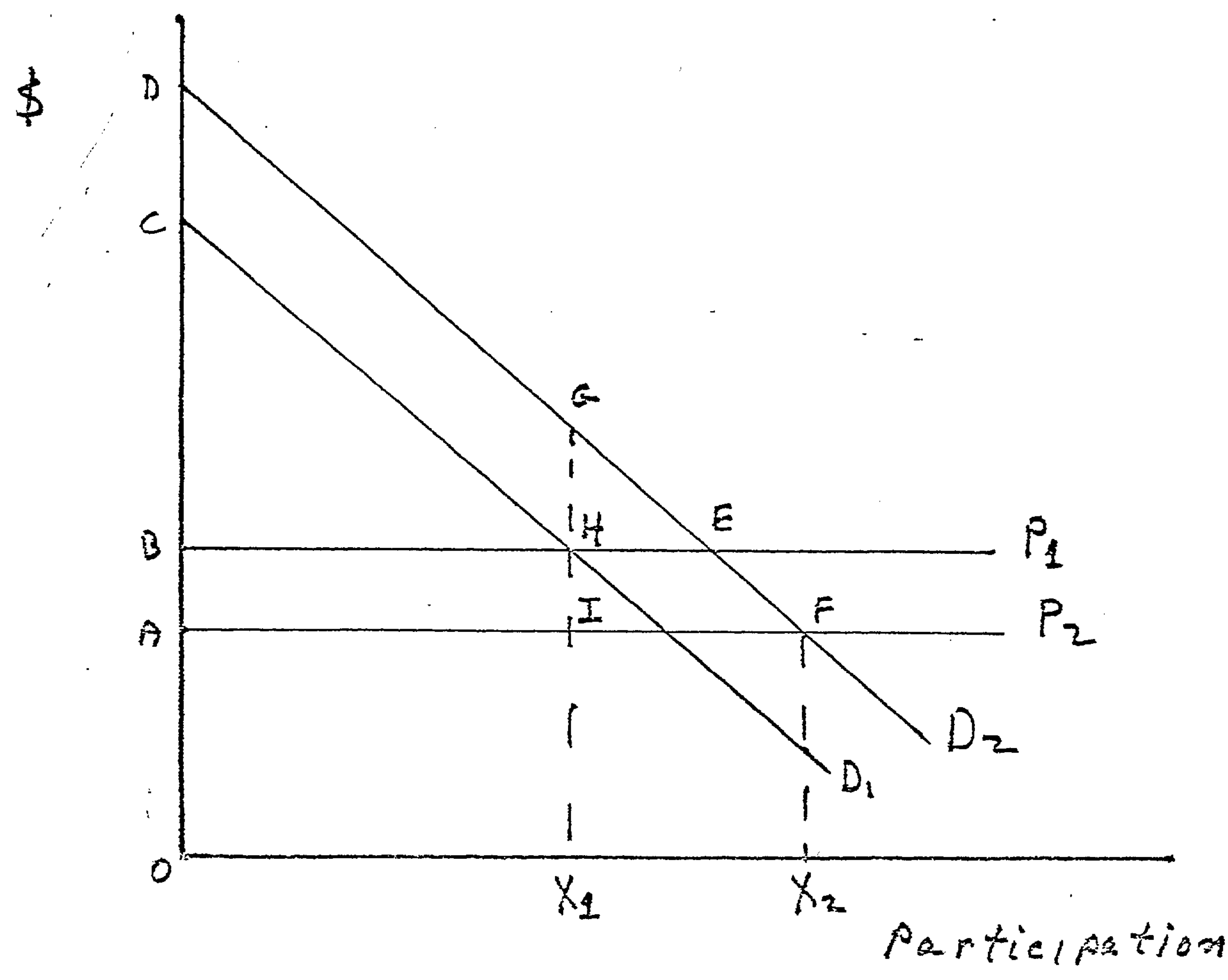
[6] Their actual computation of the second component of benefits does not correspond to the model described here. The utility gain to additional participation is actually computed as a fraction of the area ABHI. They do not offer a clear explanation for this.

Figure 3



not decrease travel cost. It could increase it if the improvement made a more distant site more attractive than closer sites being used before the quality change.

The correct model of demand for recreation participation would treat the demand curve of Figure 3 as an inverse demand curve. Willingness to pay would be a function of the number and quality of sites, their location,and travel cost per mile. Specification and estimation of this demand relationship would be very difficult since the function must fully capture substitution relationships among sites. The equilibrium would be where marginal willingness to pay, net of travel costs, is zero. An improvement in water quality would shift this curve out. Benefits would be measured by the area between the old and new curves.

In summary there are theoretical, and computational errors in the Heintz, Hershaft, and Horak approach to estimating benefits. And their method places excessive reliance on weak survey data which is too region specific to be used reliably to estimate national benefits. Thus their estimates cannot be considered reliable.

Unger (1975) also estimated national recreation benefits using substantially the same data and methodology. The principle differences were as follows:

--Unger estimated benefits for 1977, 1983, and 1985;

--Unger distinguished between fresh water and ocean swimming and used an estimate by Tihansky (1974) for the latter;

--Unger included an additional component of benefits for increased activity.

The benefit estimates for 1977, 1983, and 1985 reflect both changes in the water quality from the base year (1972) and increases in population and income. The additional benefits for ocean swimming are quite small, amounting to only about $0.1 billion per year in 1985. Unger's total recreation benefits for all categories in 1978 dollars are:

1977		1983		1985	
Range	Best	Range	Best	Range	Best
$1.9-15.0 billion	$7.0 billion	$3.9-24.1 billion	$12.2 billion	$5.9-32.2 billion	$16.8 billion

Because these estimates are based on the same method and data (specifically the Green Bay survey), they are subject to the same criticisms and limitations as those by Heintz, Hershaft and Horak.

There have been two recent estimates of the benefits of improving recreation opportunities for specific river basins. While it is dangerous to extrapolate from one river basin with its perhaps unique characteristics to the nation as a whole, these studies may provide some support for at least order of magnitude estimates of national benefits.

Gramlich (1977) used a willingness to pay survey of households in the Charles River Basin in Massachusetts to estimate the benefits of achieving swimmable quality water throughout that river. Gramlich's estimate lies in the range of $12.9 to $32.1 million per year in 1978 dollars. The best estimate is $22.6 million per year. This amounts to about $22 per capita for the population within the watershed. If every person in the U.S. had this willingness to pay, national benefits would be about $4.8 billion per year. Gramlich also asked his respondents to state their willingness to pay for an improvement in all rivers in the United States to swimmable quality. Extrapolating from these responses Gramlich estimated that the total benefits to all Americans of improving water quality to the swimmable level in all rivers would be $1.8 billion per year in 1978 dollars.

In the second study, Walsh, et al. (1978) showed residents in the South Platte River Basin of Colorado pictures of streams of different water quality. Unlike the Charles River, the principal source of pollution in the South Platte River is heavy metals from mining and refining activities. Recreation users indicated a willingness to pay of $64.92 per year for an improvement in water quality which would permit recreation activities. Users were also asked a question about willingness to pay to preserve of the option of future use. Responses to this question averaged $25.89 {all values in 1978 dollars). Since it is conceptually difficult to distinguish the option value from the use value for known users, the best estimate of willingness to pay for users is the sum of these two--that is, $90.81 per year. This amounts to $6.03 per activity day.

Non users were also asked their willingness to pay to preserve the existence of a natural undegraded waterway and to bequeath clean water to future generations. The sum of these resposes averaged to $48.05 per household for non users.

We have reviewed several estimates of national recreation benefits based on different methods and data. Table 11 reproduces the benefit estimates for 1985 from each of the three major studies by category. All values are in 1978 dollars. The Heintz, Hershaft, and Horak damage estimates are included on the assumption that as a first approximation achieving the 1985 objectives will mean elimination of the adverse effects of pollution. In this respect they may tend to overestimate true benefits. But these estimates are biased downward in comparison with those of the National Commission on Water Quality and Unger in that they do not reflect the influence of population and income growth on recreation behavior and potential benefits.

These estimates span a range from approximately $1.8 billion per year (Gramlich's estimate of the benefits of achieving swimmable waters) to $32.2 billion per year (Unger's upperbound estimate for 1985). We turn now to developing synthesis estimates in each category.

The National Commission on Water Quality made separate estimates for fresh water and marine sports fishing while Heintz, Hershaft, and Horak, and Unger estimated aggregate fishing benefits. These latter studies used faulty method and poor data, so their estimates must be discounted. The Commission's estimate for fresh water is based on a recreation participation model which captures only the benefits to new activity. Adding benefits to existing users could double the estimate. The Commission's lower bound and most likely point estimate (the midpoint

Table 11

Benefits By Category For 1985
(in billions of 1978 dollars per year)

	Heintz, Hershaft and Horak Range (Best Estimate)	Unger Range (Best Estimate)	National Commission On Water Quality
Fresh Water Fishing	$1.8-7.5 (4.0)	$2.5-15.1 (7.8)	$.3-.7
Marine Sports Fishing			4.0
Boating	$1.0-5.2 (2.5)	$1.1-7.5 (3.5)	$.6-1.4
Swimming	$.8-5.4 (2.6)	$2.2-8.9 (5.1)	$.2-.6
Water Fowl Hunting	$.1-.4 (.2)	$.1-.7 (.4)	(no estimate)

of their range) should be doubled to reflect this. I place the upper bound estimate at $4.0 billion per year to give some weight to range of estimates provided by Heintz, Hershaft, and Horak, and Unger. Benefits to fresh water recreational fishing are judged to be in the range of $0.6 to $4.0 billion per year in 1978 dollars. The most likely point estimate is $1.0 billion per year.

In developing the estimate of marine sports fishing benefits for the National Commission on Water Quality, Bell and Canterbery used an unrealistic value of time. I assume that the true opportunity cost of time is one-third the wage rate. This affects only one component of their estimate. I assume that the effect is to reduce their estimate by about 25%. Thus the most likely point estimate is $3.0 billion per year in 1978 dollars. I judge the range to be $2.0 to $5.0 billion per year. This gives some weight to the Heintz, Horak, and Hershaft, and Unger estimates for total fishing.

I judge the National Commission estimates of boating benefits to be based on a more reliable model than the others. However they must be adjusted to reflect benefits to existing users. I do this by doubling their lower bound and midpoint estimates. Thus I estimate boating benefits to be in the range of $1.2 to $2.8 billion dollars per year in 1978 dollars. The most likely point estimate is $2.0 billion per year.

It is difficult to place much confidence on any of the estimates of swimming benefits. The Heintz, Hershaft, and Horak estimates are inherently biased upward. I judge the benefits to lie in the range of \$0.2 to \$2.0 billion per year in 1978 dollars. The most likely point estimate is \$0.5 billion per year. Water fowl hunting benefits are relatively insignificant according to Heintz, Hershaft, and Horak. I judge the benefits to lie in the range of \$0.1 to \$0.3 billion per year. The most likely point estimate is \$0.2 billion per year.

The estimates described here are summarized in Table 12. Total recreation benefits for achieving the 1985 water quality objectives are estimated to lie in the range of \$4.1 to \$14.1 billion per year in 1978 dollars. The most likely point estimate is \$6.7 billion per year.

We do not have a firm basis for determining what portion of this total can be attributable to achieving the BPT standards or what portion has been realized by actual water quality improvements as of 1978. On the one hand, many people have argued that the marginal benefits of achieving BAT will be substantially smaller than the benefits of achieving BPT. On the other hand, as of 1978, not all point sources were in full compliance with BPT standards.[7] Taking these factors into account, a reasonable but crude estimate is that perhaps half of this total, or roughly \$3.4 billion per year, has been achieved by actual water quality improvements as of 1978.

7/ See Freeman (1978), pp. 48-53.

Table 12

Synthesis Estimates of National Recreation
Benefits To Be Realized In 1985
(in billions of 1978 dollars per year)

	Range	Most Likely Point Estimate
Fresh Water Fishing	$ .6-4.0	$1.0
Marine Sports Fishing	$2.0-5.0	$3.0
Boating	$1.2-2.8	$2.0
Swimming	$ .2-2.0	$ .5
Water Fowl Hunting	$ .1- .3	$ .2
Total	$4.1-14.1	$6.7

Non User Benefits

This category includes all welfare gains experienced by and reflected in the willingness to pay of people not making direct use of water bodies or diverted water. This includes what have been called aesthetic benefits, ecological benefits, preservation values, and option values in various studies in the literature. Non user benefits are difficult to define in quantitative terms and to measure; and because they are not linked to observable activities such as recreation, it is difficult to determine value and willingness to pay by observation.

Two approaches to determining nonuser benefits have been employed in the literature. They are property value studies and survey/questionnaires. Property value estimates may capture both aesthetics and the value of proximity for active recreationers. Thus there may be an element of double counting if these are counted as nonuser benefits and added to recreation user benefits. However property values do not appear to be a significant component of national benefits, so this problem is relatively unimportant as a practical matter.

Dornbusch, in a series of studies culminating in his report to the National Commission on Water Quality (Dornbusch, 1975), estimated the relationship between changes in water quality and changes in property values over time. He estimated these relationships for 17 localities and used them to estimate the national benefits for given predicted improvements in water quality. He estimated benefits in 1980 would be $74.7 million, and in 1985 to be $92.5 million per year, both in 1978 dollars. However it is difficult to know how much credence to give to these estimates. The equation estimated by Dornbusch is not derived from either of the theoretical models that have been developed as a basis for benefit calculation.[8] It should be noted that even if property value benefits have been correctly measured, they capture only those benefits accruing to the relatively small percentage of the population which owns property in the vicinity of water bodies.

Heintz, Hershaft, and Horak (1976) cited two willingness to pay surveys dealing with nonuser or aesthetic benefits. One dealt with the willingness to pay to preserve a salmon fishery on the Fraser River in British Columbia. Willingness to pay was $223 per household; and this amounted to 54% of the estimate of recreation benefits per household associated with the fishery. This value may strike the reader as implausibly high. However salmon may be an especially desirable and highly valued game fish species. In any event, what is of importance here is the ratio between user and preservation values.

A similar questionnaire administered in the southeastern U.S. found aesthetic benefits to range from 50-150% of the benefits of recreation fishing. The survey of willingness to pay for preservation and bequest motives by Walsh, *et al*. (1978) found a similar relationship between nonuser and user benefits. Heintz, Hershaft, and Horak used the ratio of aesthetic to recreation benefits (.54) from the Fraser River study and applied it to

[8] See Freeman (1979), Chapter 6, esp. pp. 148-151.

their estimate of fishing benefits to derive with an estimate of aesthetic benefits to the U.S. of $2.2 billion per year in 1978 dollars.

This is a tenuous empirical basis from which to estimate national nonuser benefits. Nevertheless, utilizing the synthesis estimate of recreation fishing benefits of $4.0 billion per year presented above and assuming that aesthetic and ecological non-user benefits are 50% of this, we can compute our own estimate. To reflect the uncertainty in the estimate, I give a range of $1-5 billion per year in 1978 dollars. The most likely point estimate is $2.0 billion per year.

Diversionary Uses

Drinking Water and Health: Until very recently most of the concern about the health effects of polluted drinking water has been focused on bacterial and viral diseases such as infectious hepatitis, salmonellosis, and gastroenteritis. Two estimates of the benefits of controlling bacterial and viral diseases have been prepared for the Environmental Protection Agency. But they differ by more than two orders of magnitude.

Unger (1975) based his estimate of the benefits of achieving the objectives of the FWPCA-72 in 1985 on a review of the causes of water borne disease outbreaks in the U.S. compiled by Craun and McCabe for EPA. These investigators found that reported cases of water borne disease averaged to less than 3,000 per year in the period 1960-71. Unger adjusted these figures for under-reporting and applied a value per case based on medical cost and lost earnings. The disease control benefits of attaining the 1985 goals were estimated at $3 million per year in 1975 dollars.

Heintz, Hershaft, and Horak (1976) combined data from three other studies prepared for the Environmental Protection Agency to estimate that existing levels of water pollution induced between one and two million cases of disease and 1600 deaths per year. These figures apparently were not derived from statistical analyses of disease rates, but rather come from data on the incidence of these diseases and some judgment as to the portion caused by drinking water contamination. The main categories of death were gastroenteritis, hepatitis, and salmonellosis. Applying unit values for morbidity similar to those of Unger, and valuing mortality at $100,000 to $250,000, Heintz, Hershaft, and Horak estimated the benefits of eliminating drinking water pollution to lie between $320 and $967 million per year in 1973 dollars. About half of this total is attributable to preventing mortality. If avoiding mortality is valued at $1 million, the Heintz, Hershaft and Horak estimate would rise to between $1.68-2.14 billion per year.

The Heintz, Hershaft, and Horak estimate of the incidence of water borne disease seems implausibly high. Unger estimated that in 1977 approximately 115.7 million people utilized municipal drinking water from surface sources. The Heintz, Hershaft, and Horak estimate implies that between one and two percent of this group contracts a drinking water related disease each year. I take the Heintz, Hershaft, and Horak estimate to be an upper bound. Thus the benefits of controlling viral and bacterial disease transmitted through municipal drinking water are estimated to lie between $3 million and $2 billion per year. To reflect my judgment that the Heintz, Hershaft,and Horak figure may err substantially on the high side, I take $.5 billion per year as the most likely point estimate of benefits of controlling contagious disease.

Recently there has been increasing concern about the health effects of chemical contamination of drinking water. Page, Harris, and Epstein (1976) found evidence linking contamination of surface drinking water supplies in Louisiana with higher cancer mortality. Harris, Page, and Reiches (1977) found similar evidence linking drinking water contamination and cancer mortality in the Ohio River Valley. The National Academy of Sciences (1978) concluded that chloroform in drinking water increases the risk of death due to cancer.

Unger (1975) estimated the benefits of eliminating chemical contamination of surface waters to be $182 million per year in 1975 dollars. This figure was derived by estimating the costs of removing chemicals from drinking water supplies by activated carbon filtration. This is an appropriate basis for estimating benefits if all drinking water supplies are actually filtered through activated carbon and the sole purpose of the filtration is to remove these chemical contaminants. Elimination of the

the chemical contamination of surface waters would lead to a cost savings of this magnitude in municipal water supply treatment.

In fact very few municipal systems presently use activated carbon filtration. And although EPA is considering regulations to require cities above a certain size to undertake filtration the primary target is the trihalomethanes which are formed by the combination of free chlorine from disinfection with naturally occurring organic compounds.[9] Thus eliminating chemical contamination of intake water due to point source pollution would not affect the need or desirability of activated carbon filtration.

The appropriate method for estimating the benefits of preventing chemical contamination of drinking water intakes is to estimate dose-response functions and apply these to present estimates of exposure. I am not aware of any quantitative estimates of dose-response functions at ambient concentrations which could be used for this purpose.[10]

If 1,000 people died each year from chemical contamination of drinking water, and if the statistical value of life is $1 million, potential benefits would be $1.0 billion per year. I take this to be an upper bound estimate. The lower bound estimate is zero. The most likely point estimate is assumed to be

[9] Personal communication from Clifford Russell, Resources for the Future, Inc., Washington, D.C.

[10] The work by Page and others cited above used dummy variables to distinguish between water drawn from surface sources presumed or known to be contaminated and ground water sources presumed or known to be "clean."

$0.2 billion per year. These are purely subjective estimates and are included only to suggest the possible seriousness of the problem.

Combining the figures for chemical contamination and contagious disease yields a range of health benefits of $0.0 to $3.0 billion per year. The most likely point estimate is $.7 billion per year. Actual control efforts undertaken as of 1978 are likely to have had a substantial effect on contagious diseases. However the effective control of chemical contaminants will occur primarily during the second stage of achieving BAT treatment requirements. It seems reasonable to conclude that perhaps one-third and no more than one-half of these potential benefits had been realized as of 1978.

Treatment Costs for Municipal Water Supplies: The presence of point source pollutants at the intake points of municipal water supply systems increases the degree of treatment required to remove suspended solids and substances affecting odor and taste. If the point source pollutants were eliminated, it would be possible to reduce municipal supply treatment costs accordingly. These cost savings should be counted as a benefit of pollution control.

Unger (1975) and Heintz, Hershaft, and Horak (1976) have provided estimates of the benefits based on similar data and methodology. They used the same sources to estimate that about 40% of municipal water supply treatment costs are attributable to point source pollutants, and that costs could be reduced by 40%

if these pollutants were controlled at the source.[11] Heintz, Hershaft, and Horak applied this proportion to an estimate of municipal water treatment costs in 1973 to obtain an estimate of damages due to pollution of $.41 billion per year in 1973 dollars (or $.6 billion in 1978 dollars). Unger used a different basis to estimate treatment costs in 1977 and to project costs to the years 1983 and 1985. He estimated the benefits of meeting the 1985 water quality objectives to be $.993 billion in 1975 dollars (or $1.2 billion per year in 1978 dollars).

On the basis of these two studies, I estimate that municipal water supply benefits lie in the range of $.6-$1.2 billion per year in 1978 dollars. The most likely point estimate is $.9 billion per year.

Household Benefits: Water hardness and the presence of dissolved solids in the municipal water supplies may impose a variety of costs on households. If the hardness and dissolved solids are due at least in part to point source pollution, then controlling these sources will reduce these costs and lead to corresponding benefits. Tihansky estimated damages to households due to mineral contamination of water. Tihansky's work is the basis of benefit estimates of both Unger and Heintz, Bershaft, and Horak. These two studies used different bases for extrapolation and different assumptions regarding the contribution of man-made point

[11] The sources were Bruce Barker, and Paul Kramer, "Water Quality Conditions in Illinois," in Statewide Water Resource Development Plan, 1972, Illinois Department of Transportation, and Henry C. Bramer, The Economic Aspects of the Water Pollution Abatement Program in the Ohio River Valley, Ph.D. Dissertation, University of Pittsburgh, 1960. See Heintz, Hershaft, and Horak (1976), pp. III-38 and III-39.

source pollution to total damages. Unger estimated the benefits to households in 1985 of controlling point source pollution to be $88 million per year in 1975 dollars ($107 million in 1978 dollars). Heintz, Hershaft, and Horak estimated that damages were $346 million per year in 1973 dollars (or $508 million in 1978 dollars). Based on these two studies I estimate that the benefits lie in the range of $.1-.5 billion per year in 1978 dollars. The most likely point estimate is $.3 billion per year.

Industrial Treatment Costs: Heintz, Hershaft, and Horak (1976) and Unger (1975) used many of the same sources to estimate the impact of point source pollution on industrial treatment costs for process water, boiler feed water, and cooling water. Heintz estimated damages in 1973 to be $.3 billion per year (or $.4 billion in 1978 dollars). Unger estimated the benefits of achieving water quality objectives in 1985 to be $.63 billion per year in 1975 dollars (or $.76 billion in 1978 dollars). On the basis of these studies, I estimate that benefits to industry lie between $.4 and $.8 billion per year in 1978 dollars. The most likely point estimate is $.6 billion per year.

Commercial Fisheries

The most comprehensive estimate of the benefits of improved commercial fisheries opportunities was done by Bell and Canterbery (1975) for the National Commission on Water Quality. They utilized secondary data to develop biological productivity functions and used these to estimate the impact on productivity of changes in water quality. These predictions were then combined with an economic model to predict changes in prices, quantities, consumer surpluses and factor incomes. The study was limited to marine fisheries. They estimated that the benefits of achieving the objectives of the FWPCA-72 in 1985 would be $575 million per year in 1975 dollars (or $696 million in 1978 dollars).

Heintz, Hershaft, and Horak (1976) cited earlier estimates of damages carried out between 1970 and 1973. These were then adjusted to the 1973 base year. Damages and/or benefits were estimated to be approximately $100 million per year. These were about evenly divided between marine and fresh water fisheries. I do not have access to these earlier studies, so evaluation is not possible.[12]

The National Academy of Sciences (1979) examined the impact of chemical contamination of fish and Food and Drug Administration contamination limits on commercial fisheries. The Academy limited its study to the impact of contamination by polychlorinated biphenyls (PCBs). The National Academy estimated that reducing the allowable content of PCBs from the present 5mg/kg would result in a loss of landed value of about $1 million for marine fisheries and $7 million for fresh water fisheries. Lowering the allowable tolerance to 1 mg/kg would result in the loss of another $10 million in landed values. Because of the availability of substitutes and because resources can be reallocated, the true economic damage would be less than the loss in landed value. Thus these figures must be interpreted as an upper bound

[12]Unger (1975) used the same sources.

estimate of economic damages.

Because of the omission of fresh water fisheries and the impacts of some forms of chemical contamination of fish, the Bell and Canterbery figure is probably an underestimate of the total damages to all commercial fisheries due to man-made pollutants. However it seems unlikely that these other categories would be more than an additional 100 million per year. Thus we estimate that the potential benefits to commercial fisheries of achieving the 1985 objectives lie in the range of $.4-1.2 billion per year in 1978 dollars. The most likely point estimate is $.8 billion per year.

Summary

The results of the preceding analysis are summarized in Table 13. Total benefits to the nation of meeting water quality objectives in 1985 are estimated to lie in the range of $6.6 to $25.8 billion per year in 1978 dollars. The most likely point estimate is $12.0 billion per year. Of this total, almost 55% is attributable to recreation alone, and almost 75% of this total is due to the combined categories of recreation, aesthetics, ecology, etc.

It would be more useful for policy analysis if the total figure could be allocated between the attainment of the 1977 BPT goals and the 1983 BAT goals. The available data do not permit this. However, on a very crude subjective basis, it is probably reasonable to attribute something like one-half of this total to the water quality improvements that had been attained by 1978.

Table 13

Summary Of National Benefits of Meeting 1985
Water Quality Objectives By Category
(in billions of 1978 dollars per year)

	Range	Most Likely Point Estimate
Recreation	$4.1-14.1	$6.7
Non-User Benefits: aesthetics, ecology, property values	1.0- 5.0	2.0
Diversion Uses		
Drinking Water-Health	0.0-3.0	0.7
Municipal Treatment	0.6- 1.2	0.9
Households	0.1- 0.5	0.3
Industrial Supplies	0.4- 0.8	0.6
Commercial Fisheries	0.4- 1.2	0.8
Total	$6.6-$25.8	12.0

References to Chapter 3

Battelle Memorial Institute, Assessment of the Economic and Social Implications of Water Quality Improvements on Public Swimming, Columbus, Ohio, 1975.

Bell, Frederick W., and Canterbery, E. Ray, An Assessment of the Economic Benefits Which Will Accrue to Commercial and Recreational Fisheries from Incremental Improvements in the Quality of Coastal Waters, Florida State University, Tallahassee, 1975.

Davidson, Paul, F. Gerard Adams, and Joseph Seneca, "The Social Value of Water Recreational Facilities Resulting from an Improvement in Water Quality: The Delaware Estuary," in Allen V. Kneese and Stephen Smith, eds., Water Research, Johns Hopkins University Press, Baltimore, 1966.

Dornbusch, David M., The Impact of Water Resource Quality Improvements on Residential Property Prices, 1975.

Freeman, A. Myrick, III, The Benefits of Environmental Improvement: Theory and Practice, Johns Hopkins University Press, Baltimore, 1979.

________, "Air and Water Pollution Policy," in Paul Portney, ed., Current Issues in U.S. Environmental Policy, Johns Hopkins University Press, Baltimore, 1978.

Gramlich, Frederick W., "The Demand for Clean Water: The Case of the Charles River," National Tax Journal, 30, No. 2 (June, 1977) 183-194.

Harris, Robert H., R. Talbot Page, and Nancy Reiches, "Carcinogenic Hazards of Organic Chemicals in Drinking Water," in Origins of Human Cancer, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1977.

Heintz, H.T., A. Hershaft, and G. Horak, National Damages of Air and Water Pollution, a report submitted to the U.S. Environmental Protection Agency, 1976.

National Academy of Sciences, Non-fluorinated Halomethanes in the Environment, Washington, 1978,

__________, Polychlorinated Biphenyls, Washington, 1979.

National Commission on Water Quality, Staff Report, Washington, 1976.

National Planning Association, Water-Related Recreation Benefits Resulting from P.L. 92-500, Washington, 1975.

Page; R. Talbot, Robert Harris, and Samuel Epstein, "Drinking Water and Cancer Mortality in Louisiana," Science 193, No. 4247 (July 2, 1976), 55-57.

Tihansky, Dennis P., "Recreational Welfare Losses from Water Pollution," Journal of Environmental Quality, 3, no. 4 (1974), 335-342.

__________, Economic Damages to Household Items for Water Supply Use; Environmental Protection Agency, Washington, 1973,

Unger, Samuel G., National Benefits of Achieving the 1977, 1983, and 1985 Water Quality Goals, a report submitted to the U.S. Environmental Protection Agency, 1975.

Walsh, Richard G., et al., Option Values, Preservation Values and Recreational Benefits of Improved Water Quality: A Case Study of the South Platte River Basin, Colorado, Environmental Protection Agency, Research Triangle Park, 1978.