THE DAMAGES TO RECREATIONAL ACTIVITIES FROM PCBs IN NEW BEDFORD HARBOR

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INTRODUCTION

The PCB contamination of New Bedford Harbor has lowered the use value of recreational resources in the New Bedford Harbor area. In the case of beach use, the economic loss is measured as the present value of the reduction in willingness-to-pay for access to beaches which recreationists view as less desirable because of PCBs. For recreational fishing, the damages are measured as the increase in costs incurred by recreational fishermen who want to fish in the Harbor area but must travel farther to avoid contaminated areas. These increased travel costs are a measure of the recreational fishermen's minimum willingness-to-pay for fishing in areas uncontaminated by PCBs.

This report estimates the present value of damages to beach use to be between \$8.3 million and \$11.4 million and the damages to recreational angling to be approximately \$3.1 million. Total damages for injury to these recreational resources are estimated to be between \$11.4 and \$14.5 million. Part I of the report presents the evidence for beach use damages and Part II for recreational angling. Part III gives the present value, in 1985 dollars, of the joint damages to beach use and fishing.

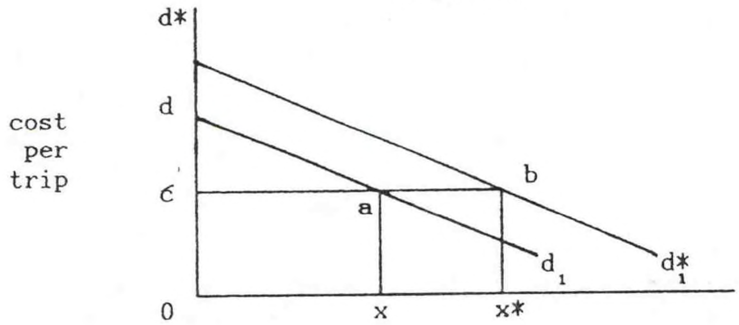
I. THE DAMAGES TO BEACH USE

A. Framework

The contamination of New Bedford Harbor with PCBs has resulted in elevated levels of PCBs near beaches in the greater New Bedford area. This analysis is an approach to estimating the damages caused by the reduction in environmental quality at various beaches.

In the simplest case, when there is only one beach, a reduction in the quality of the beach influences the demand for the beach. A change in the demand for the beach implies a change in the user's willingness to pay for access to the beach. This analysis is described graphically in Figure 1.

Figure 1



Let $d^*d_1^*$ be the demand curve for going to the beach in the absence of PCB contamination. The consumer's net willingness to pay for access to the beach can be approximated by the area d*bc, the area under the demand curve and above the price. Now the presence of PCBs reduces the demand for visits to the beach to dd_1. The new willingness to pay for access is dac. The reduction in willingness to pay for access to the beach is dabd*, the damage to an individual beach goer from contamination by PCBs.

When several beaches are contaminated, this straightforward analysis holds as long as individuals use only one beach, that is the same beach, both before and after the quality change. Then we can compute aggregate benefits for quality changes at all beaches by adding areas under individual demand curves.

However, when an individual visits more than one beach, the analysis becomes more complicated. The complication is caused by the fact that the level of contamination at one beach influences the demand for other beaches. Consider the two beach case, the number of beaches to be analyzed for New Bedford. The demand for beach 1 depends not only on the environmental quality at beach 1, but also on the quality at beach 2; similarly for beach 2. Then the conceptually correct measure of value for a change in the contamination at both sites should be calculated as follows (see the appendix for a derivation of this result):

the change in the area under the demand curve at beach 1 induced by the quality change at beach 1, assuming quality at beach 2 at its initial level

+

the change in the area under the demand curve at beach 2 induced by the quality change at beach 2, assuming quality at beach 1 at its new level.

This definition of damages encompasses the sequencing of quality changes. It requires the evaluation of beach 1 at the original environmental quality for beach 2 and the evaluation of beach 2 at the subsequent quality at beach 1. The same kind of sequencing applies in the case of multiple price changes. (See, for example, Just, Hueth and Schmitz.) As is shown in the first part of the appendix, the same reasoning occurs when the recreationist chooses among many beaches, only two of which are polluted.

There are two problems which arise in the practice of this method. The first problem, which arises in any situation, is that the demand curves we observe are Marshallian or income-constant demand curves, not the Hicksian or utility-constant demand curves used in the development of the approach. The second problem, an artifact of the New Bedford study, is that we only observe (or estimate) each demand curve at the initial and subsequent quality levels at all beaches. That is, we miss the sequencing of quality changes. Both of these problems are explained in the appendix.

The standard approaches for estimating the recreational benefits for environmental quality typically rely on variations in quality across sites. (See Smith and Desvousges, and Kling, Bockstael, and Strand, for example.) In the case of PCBs in New Bedford Harbor, this approach is not feasible. Because PCBs are not perceptible to water recreationists, people tend to use other information to learn that sediments in the vicinity of New Bedford beaches are polluted with PCBs.

The approach taken in this report differs from standard approaches due to the absence of observable changes in behavior induced by changes in PCB levels at different beaches. The basic approach is as follows:

A. Estimate the 'with PCBs' demand function for contaminated beaches using survey data for planned beach visits for 1986.
B. Estimate the 'without PCBs' demand function for contaminated beaches using responses to the interviewer's question for 1986.
C. Calculate the costs of PCBs calculating the benefits of beach access under A and under B and subtracting A from B.

While the general approach involves steps A – C, the credibility of the results depends most crucially on the details of the implementation. The first part of the appendix demonstrates that for complete assessment of damages, one need only estimate demand changes for beaches perceived to be polluted, rather than for all of the beaches.

B. New Bedford Area Beaches

There are a number of town, state, and local beaches in the New Bedford area. Exhibit 1 presents the approximate location of these beaches. These beaches vary considerably in their physical and aesthetic characteristics. A brief summary of these characteristics is presented in Exhibit 2. This beach information was developed from site visits and discussions with local and state officials. East and West Beaches, the only beaches in the town of New Bedford, are the two most urban beaches in the area, and have nearly identical features. Each beach extends right up to a major road and has either a long jetty or a pier at one end. Both of these beaches are visited primarily by local citizens and summer residents. Two of the three state beaches in the area -- Demarest Lloyd in Dartmouth, and Horseneck Beach in Westport -- are large, state reservations with numerous facilities, varied natural features, and extensive beaches. Both beaches are used by local, regional, and state visitors. Fort Phoenix, in Fairhaven, is the third state beach in the area. It is smaller and somewhat more developed than the other two state beaches, and is used primarily by local citizens and summer residents.

The town beaches in Fairhaven and Dartmouth are fairly similar to one another. In general, they are relatively undeveloped and primarily attract neighborhood visitors. Some of these local beaches are quite small. The towns of Fairhaven and Dartmouth also have a few informal and local beaches that are also small in size and that have few or no facilities. There are several informal beaches along West Sconticut Neck that have limited public access.

The sediments near several of these beaches have been contaminated with PCBs. Exhibit 3 shows the PCB sediment concentrations measured in the Acushnet River Estuary. The beaches that appear to be affected by concentrations from 2 to 10 ppm PCBs are Fort Phoenix, East Beach, West Beach, Jones Beach, and beaches along West Sconticut Neck (Shell Beach).

In the analysis below, the focus will be on the damages at East, West, and Fort Phoenix beaches. While some households may perceive that other beaches may have been tainted, the analysis will be limited to the three mentioned beaches. The potential for affecting perceptions at other beaches implies that the damage assessment completed below may underestimate the true damages incurred.

C. Sources of Data

The empirical work of this report is based upon a telephone survey of households in the New Bedford area. This survey, described in detail below, gathered detailed information about beach going and fishing activities and perceptions of PCBs. It was necessary to design and execute a survey because existing sources of data were not adequate for estimating damages for a variety of reasons.

To serve the purpose of recreational damage assessment, a data source must meet at least the following criteria:

1) The source must be site-specific; that is, it must give information about individual behavior at the specific site of concern.
2) The source must give information in sufficient detail to allow researchers to explain how behavior changes in response to costs of access and other important determinants of behavior.
3) The data must have been gathered in a systematic way, from one observation to another and from one time period to another.

If the first criterion is not met then the data cannot be used to infer damages at a specific site, because there is no information about changes in behavior at that site. If the second criterion is not met then there is no basis for inferring damages because it will not be possible to estimate the effects of the costs of access on individual quantity demanded. As the earlier discussion indicates, damage assessment requires that we measure how behavior changes in response to environmental quality, and also in response to cost changes.

For beach use and recreational swimming, statistics on attendance are available for some beaches. Ten of the beaches given in Exhibit 1 have some sort of annual attendance data. Thus there are some site-specific data. However, neither the second nor the third criterion is met. The data on attendance cannot be used to determine how people's beach attendance responds to cost increases because for any given year data are aggregated over people with different costs and do not show how many people travel different distances. Thus, even if the data were gathered systematically, and were free of obvious errors, they would not lend themselves to the task of damage assessment.

The beach attendance data also fail to meet the third criterion. The data are gathered in an unsystematic way, and they do not support reliable inferences about changes in aggregate attendance from one year to the next. There are two major sources of errors. The first is the variable and incomplete sample period during which data are gathered from year to year. The second is the variation in the sampling method over time and from beach to beach.

Variation in the sample period is evident from examining specific beaches. For instance, statistics are lacking at some beaches for the non-swimming months, while at other beaches statistics are missing for certain weeks during the summer. The three state beaches, Fort Phoenix, Demarest Lloyd, and Horseneck, have statistics for all the summer months from 1973 to 1985, but the latter two beaches are missing attendance figures for some (but not all) of the fall, winter and spring months from 1978 through 1984. In addition, during these non-summer months, attendance data at these three beaches were collected irregularly, usually only during fair weather weekends. Beach attendance data at East and West Beaches were compiled for 1971 through 1985, but were collected only during the summer season. Thus, there are no data available for beach visitation from early September through late June. Further, the number of weeks during the summer when attendance figures were collected is inconsistent from year to year. For instance, in 1984 attendance statistics were compiled during nine summer weeks, while in other years, attendance was collected for either 10, 11, 12, or 13 summer weeks.

Finally, the beach statistics collected for three of the town beaches -- Apponagansett, Round Hill, West Island (Fairhaven town beach) -- are incomplete because they are based on the number of car stickers sold to the residents each year, rather than on daily counts of cars or individuals. Thus, it is not possible to use these data to estimate total number of visits for the year because there is no information available on how often the sticker-owners visit the beach.

A second major shortcoming of the area beach attendance data is the variation in sample methods used at different beaches to measure attendance. Because of this variation in counting methodology, it is difficult to compare weekly or seasonal attendance figures between the state beaches and the New Bedford beaches. The state beaches compile daily visitation figures by counting the number of entrance tickets sold to cars. Total number of daily visitors are calculated by multiplying the number of tickets sold times the average number of persons per car. This average number of occupants per car is estimated for each beach once every three years, based on data collected during one summer's day. In addition, these state beaches also calculate the number of "non-paying" visitors. These include walk-ins, bicyclists, and vehicles that have purchased yearly seasonal passes. While this method has been used consistently at the state beaches during the past decade, attendance figures are inaccurate for several reasons. First, the average number of passengers per car used to calculate total number of visitors is estimated only once every three years, and is based on only one day in the summer. If this sampling day is not representative of the entire season, or if the average number of visitors changes significantly during the subsequent two years, then total beach attendance figures may be significantly over- or understated. Second, this method understates attendance totals because it does not count individuals who walk into the beach from non-entrance points.

The method used to count visitors is quite different at East and West Beach. At these New Bedford beaches, a city recreation employee (either a lifeguard, maintenance person or water safety instructor) estimates the total number of daily visitors by estimating the number of individuals who have come to the beach by mid-afternoon. This method may tend to either over- or underestimate attendance figures depending on the accuracy of the employee. Further, beach attendance estimates made at the end of the summer may be more accurate than estimates made earlier in the season because of the increased experience (and thereby increased accuracy) of the employee. In general only two employees at each city beach will estimate attendance during the entire summer season, thereby reducing some of this potential seasonal bias. However, the data for East and West beaches may be inconsistent from year to year because the employees estimating the number of people on the beach have changed from one year to the next during the past decade. Attendance figures at these beaches are also understated because attendance is estimated only once a day, and therefore does not take into consideration beach turnover.

Finally, the sampling methods used at all beaches also understate total attendance figures because they do not include individuals attending these beaches after hours (e.g., in early morning or evening) during the months when statistics are gathered.

Other than the data on beach attendance discussed above, there are no sources of data which could be used to estimate the damages of PCB contamination to beach use. As a consequence a survey of households in the New Bedford area concerning beach use in the area was designed and executed.

D. The Recreational Survey[1]

The data used for inferring damages to beach use and fishing in the New Bedford area are based on a telephone survey conducted by Decision Research Corporation (DRC) during March 1986. The instrument for this survey is attached to this report. The survey was conducted in accordance with established standards of the public opinion research industry. Interviewers questioned 545 New Bedford area households concerning their recreational habits, their knowledge of PCBs, and certain socioeconomic characteristics. Additional information concerning distances to various area beaches was derived from knowledge of the census tract where the household resided.

DRC began the telephone survey with a random sample of households with listed telephone numbers in the cities/towns of New Bedford, Fairhaven, and Dartmouth. The sampling procedure was designed to ensure that every household with a listed telephone number in the specified geographic area was equally likely to be included in the random sample. The sample list included name, address, telephone number, and census tract number for each household.

All interviews were conducted by trained and experienced interviewers at the DRC central interviewing facility in Boston. Prior to beginning the administration of the survey instrument, interviewers were thoroughly briefed on the skip patterns of the survey, the proper method of asking each question, and appropriate methods of probing for acceptable answers (e.g., specific numbers rather than qualitative responses). To avoid biasing the responses to survey questions, DRC interviewers are trained to maintain objectivity when asking questions. Furthermore, interviewers, coders, data processors, and supervisors were all unaware of the identity of DRC's client, and the intended use of the data. Thus, the survey personnel were not able to consciously bias the results of the survey to serve the client.

Five hundred forty-five (545) interviews were completed during the time period March 25 through March 31, 1986. Because of a large population of Portuguese-speaking residents in the New Bedford area, all respondents of Portuguese descent were given the option of having the interview conducted in Portuguese. Each survey participant met the following criteria: current resident of New Bedford, Dartmouth or Fairhaven; lived in the New Bedford area for a minimum of one year; at least 18 years of age; and, one of the members of the household who decides which beaches to visit (for questions pertaining to beaches) or where to saltwater fish (for angling questions).

Several precautions were taken to increase the chances that each household included in the sample would actually be contacted, and therefore, that the survey results would be representative of the New Bedford community. Surveys were conducted at various times of the day, evening, and over the weekend (20% weekday; 62% evening; and 18% weekend interviews). All working numbers included in the sample list were attempted three times, with attempts occurring on a different day of the week and during a different time of day (i.e., unsuccessful daytime attempts were called back during the evening on a different day). Interviewers were also instructed to record carefully specific times that respondents requested that they be recontacted, and supervisors closely monitored the callback times to ensure that interviewers placed calls at the specified times.

All completed surveys were checked by supervisors for completeness and accuracy immediately after each interview. All responses were coded and processed "in-house" by DRC. The execution of these tasks by DRC staff under close supervision ensured high levels of reliability and quality control. Data entry (with 100% verification) was conducted by an outside supplier.

E. Empirical Analysis

The costs of PCB contamination are computed for East and West Beaches in New Bedford and for Fort Phoenix Beach in Fairhaven. While these are not the only beaches potentially affected by PCB contamination, they are the main public beaches near the contaminated areas. In the following, I will use the survey returns to measure the costs of PCB contamination near East Beach, West Beach and Fort Phoenix to beach-going households in the greater New Bedford area.

The analysis proceeds with the estimation of two demand curves for each site: first, the current (with PCBs) demand curve and second, the "without PCBs" demand curve. These demand curves are assumed to approximate the behavior of households. They work by analogy. In showing how households respond to differences in costs among beaches, the demand curves show how households would pay for access to the beaches.

The Marshallian demand curves are of the form

$$x_{ij} = \begin{cases} g(z_{ij};b_j) + e_{ij} & g(z_{ij};b_j) + e_{ij} > 0 \\ 0 & g(z_{ij};b_j) + e_{ij} \leq 0 \end{cases}$$

where

j = East Beach, West Beach, Fort Phoenix;
x_{ij} = trips by i^{th} household to j^{th} beach;
b_j = vector of coefficients of demand function to be estimated for j^{th} beach;
e_{ij} = $N(0,s_j^2)$ random variable.

The vector of coefficients b_j will be estimated for each beach for the "with" and "without PCBs" cases.

Several problems need to be addressed in estimating these demand curves. First, most households interviewed attended only a few beaches, so that for each beach, there is a substantial number of zero visits. This problem is handled by estimating a Tobit model, which accounts for the piling up of observations about zero.[2] Second, for empirical reasons, East Beach and West Beach have been aggregated into one site. The basic reason for aggregation is the high correlation between the distance from any point in the greater New Bedford area to East Beach and the distance from the same point to West Beach. Exhibit 4 shows this correlation to be greater than .99. Such a high simple correlation would make separate estimation for each beach results highly imprecise. Further, as is evident from Exhibit 2, East and West Beach are similar enough in character to be considered perfect substitutes, making the aggregation quite acceptable conceptually. They are both located in residential areas along Rodney French Boulevard and are about one-half mile apart.

The demand by the i^{th} household for trips to the j^{th} beach is assumed to depend on the costs of getting to the j^{th} beach as well as costs of getting to substitutes for the j^{th} beach. The following beaches are considered to be the choice set for New Bedford area households:

Beach	Town
East Beach	New Bedford
West Beach	New Bedford
Fort Phoenix	Fairhaven
West Island	Fairhaven
Demarest Lloyd	Dartmouth

Beaches and households are dispersed over the three-town area. Substitutes for households in Dartmouth are not necessarily good substitutes for households in Fairhaven. For example, an increase in the cost of going to West Island would likely influence the demand for trips to Fort Phoenix by Fairhaven households, but would be unlikely to change the trip demand function for Fort Phoenix by Dartmouth households. This fact complicates the specification of the demand functions. What should be the determinants in each function? Specification is further exacerbated by the substantial collinearity among distances to the various beaches (see Exhibit 4). This collinearity, for example, makes it difficult to test reliably the hypothesis that West Island is a substitute for Fort Phoenix while Demarest Lloyd is not.

The following model specification is designed to handle the issue of site substitution and to contain the problem of collinearity of regressors. The demand for trips to East/West Beach and Fort Phoenix, both "with" and "without PCBs," is as follows:

$$x_{ij} = g(PEB, PFTP, PSUB, PASS, b_j) + e_{ij}$$

where

x_{ij} = trips by i^{th} household to j^{th} beach;
PEB = cost of getting to East Beach for the household;
PFTP = cost of getting to Fort Phoenix for the household;
PSUB = cost of the cheaper substitute, West Island or Demarest Lloyd;
PASS = 1 if the household has a pass to Fort Phoenix, 0 otherwise.
b_j = parameter vector for j^{th} beach, to be estimated.

Specifying PSUB as the cost of the cheaper substitute implies that West Island and Demarest Lloyd are perfect substitutes. Models with income and other socioeconomic variables performed about the same as the models here, and typically such variables are not significant demand shifters in recreational demand models. The role of income in such equations is especially problematic. Income is typically measured with substantial error. Perhaps the best argument that can be made for income in recreation demand equations is that when it works, it is probably a proxy for a variety of taste variables.

Each household's cost of getting to the respective beach is calculated as the roundtrip distance from the center of the census tract to beach, valued at $.084 per mile plus the cost of time. The cost of time is based on a simple mean of the after-tax opportunity cost of time of the household's spouses. The opportunity cost of time depends on the individual's occupation as explained in Exhibit 5. The opportunity cost of time is converted to an after-tax basis by multiplying by one less the marginal tax rate, explained in Exhibit 6. This figure is converted to an after-tax opportunity cost per minute, and multiplied by the number of minutes from the Census tract of the respondent to the beach of concern.[3]

Four versions of the basic demand function are estimated, one for East/West and for Fort Phoenix "with PCBs," and one for East/West and for Fort Phoenix "without PCBs." All equations are estimated on the same set of 495 observations. Only 495 of the 538 observations on beach users were used in the estimation of equations. Of the 43 observations given zero weights in the estimation, 41 were excluded because the respondents were unable to answer the question concerning planned trips or trips "without PCBs." These responses were coded as '999' for the dependent variable and were excluded from the estimation. Two observations were given zero weight because the respondents said they would go every day to East/West Beach.[4]

The set of 495 observations used in the estimation is selected from the 538 respondents who answered the question of whether they went to the beach in 1985. Households that did not go to any of the area beaches in 1985 were not asked question 7 about their planned trips to East/West and Fort Phoenix in 1986. Those households that were not asked the question were assumed to plan zero trips in 1986 for purposes of the estimation. Additional investigation shows that the inclusion of these households has negligible impact on the calculation of damages. Households are classified as aware of PCBs if they name PCBs as a contaminant of the New Bedford Harbor in question 10 or they believe the Harbor is contaminated with PCBs as revealed in question 11. Households that are not aware of PCBs are not asked question 14 about how many trips they would take if PCBs were removed from the Harbor. They are assumed to take their planned 1986 "with PCBs" trips even without PCBs.

Exhibit 7 gives the parameter estimates for the "with PCBs," the planned 1986 trips for the two beaches. Exhibit 8 gives parameter estimates for the "without PCBs." The resulting equations for the two beaches under the two circumstances are typical for cross-section work. Trips are influenced by own costs, other costs, and having a pass for Fort Phoenix. All of the own-cost coefficients have the anticipated negative sign, and are significantly less than zero at least at the 95 percent level of confidence. The substitute prices are significantly positive or not significantly different from zero. Households that had passes to Fort Phoenix had significantly higher demand for visits to Fort Phoenix and East/West Beach.

The damages from PCB contamination can be calculated from the own-price coefficients in Exhibits 7 and 8 and information on trips to the beaches in question. There are two parts to the damage calculation. First, damages for households within the survey must be calculated. Second, the damages from the sample must be expanded to the population.

To calculate damages from the contamination by PCBs, take the area under the demand curve for planned 1986 trips and compare it with the area under the demand curve for planned 1986 trips "without PCBs." It can be shown that the area under a linear demand curve is $x^2/(-2b)$ when x is the level of trip and b is the own-price coefficient for the beach in question.[5] Therefore, the damages for beach j are

$$d(j) = x_j'^2/(-2b_j') - x_j^{o2}/(-2b_j^o)$$

where the subscript prime (′) indicates trips and demand coefficients after PCBs are removed, and the superscript ought (o) indicates trips and demand coefficients for the 1986 activities planned with current levels of PCBs.

If all households sampled took the sample level of trips, then we could calculate sample damages by multiplying the damages per household by the number of sampled households. However, trips vary substantially across households, with the largest number of households taking zero trips. When trips vary across households, we could calculate each sampled household's damage from its observed trips, and sum across all sample households to calculate the damages among sampled households. The difficulty with using individual observations derives from the convex consumer surplus function. Observations on trips which are quite large, will comprise most of the sample household damages. A slight variation on this approach, which would reduce the variance of trips among households, would be to use the predicted value of trips. This approach also suffers from the substantial impact of large predicted trips. In either case, using individual observations rather than a measure of central tendency would result in higher damages.

The most conservative approach for calculating damages in the current case is to rely on the concept of a representative user and calculate the damages for this representative user. A robust estimate of trips for the representative user is the median. Damages are calculated only for those households who are aware of PCBs. In summary, annual damages for a chosen beach are calculated as follows:

Damages = benefits of access without PCBs − benefits of access with PCBs
$= HH \cdot [P(after,PCB) \cdot a' - P(before,PCB) \cdot a^o]$

where

HH = number of households in the New Bedford area

P(after,PCB) = proportion of sample households that visit after PCBs are removed and are aware of PCBs

P(before,PCB) = proportion of sample households that visit before PCBs are removed and are aware of PCBs

a', a^o are benefits of access without PCBs, and planned 1986 (with PCBs), for the representative user of the beach;

$a' \equiv x'^2/(-2b')$

$a^o \equiv x^{o2}/(-2b^o)$

x' = median trips, after PCB removal, among users of beach who are aware of PCBs

x^o = median trips, before PCB removal, among users of beaches who are aware of PCBs

b^o = own-price coefficient for beach where damages are assessed, before cleanup.

b' = own-price coefficient for beach after cleanup

The expression for the damages for a particular beach can also be written

$$HH \cdot P(t)[P(after|PCB) \cdot a' - P(before|PCB)a^{0}]$$

where

P(before|PCB) is the proportion of those aware of PCBs who visit the beach before PCB removal

P(after|PCB) is the proportion of those aware of PCBs who visit the beach after PCB removal

P(t) = proportion of households aware of PCB

Exhibit 9 shows the proportions P(before|PCB) and P(after|PCB) for East/West Beach and Fort Phoenix, as well as the median trips for each beach, before and after PCB removal.

From the median trips per user aware of PCBs, in Exhibit 9, I calculate the benefits of access at each beach, planned 1986 and without PCBs. These benefits of access are estimates of what the representative user would pay annually for the right to visit each beach. Aggregate benefits are calculated as the product of benefits per user and the number of users. The number of users is predicted as the proportion who visit the beach among those aware of PCBs (given in Exhibit 9) times the number of households aware of PCBs (78.2% of 51498).

The expansion of per-user damages to the population, raises two issues. First, damages added across beaches may under or overestimate the aggregate damages to a household that attends both beaches. The appendix shows that there is no reason to argue strongly in either direction. Consequently, I take the sum of the per-household damages at East/West and Fort Phoenix as the correct measure of damages to the household for removing PCBs from both beaches.

The second issue is that the per-household damage applies to those households that are aware of PCBs. In March 1986, 78.2 percent of households in the New Bedford area knew of PCBs. However, as perceptions change over time, gradually more people become aware of PCBs. Further, prior to 1986, fewer people were aware of PCBs. Exhibit 11 shows the proportion of the sample aware of PCBs each year from 1975 to 1986. This exhibit is derived from responses to question 12, which asked the household in what year it became aware of PCBs in the harbor. This exhibit shows that in 1975 only 8.55 percent of the households were aware that the harbor contains PCBs.

The damages of PCB contamination per household should be expanded only to the proportion of households aware of PCBs, as given by Exhibit 11, between 1979 and 1986. However, it is reasonable to believe that the proportion aware of PCBs will continue to grow after 1986. This sort of growth phenomenon is modelled most plausibly with the logistics growth function. This function will allow us to predict how the proportion of the population aware of PCBs will grow in the future. Using observations in Exhibit 11, I have estimated the following logistics growth function[6]

$$P(t) = \{1 + \exp[2.85 - .35t]\}^{-1}$$

where P(t) is the proportion of the households aware of PCBs, and t is the number of years into the future from 1975. This equation will allow the future proportion of households aware of PCBs to be predicted.

Using the proportions in Exhibit 11 for the years 1979-1986, and the predicted proportions from the equation above for the years 1987-2085, I determine the number of households in any year who are aware of PCBs. Assuming the number of households remains constant at the 1985 estimate of 51,498 for the New Bedford area, I estimate the number of households aware of PCBs. The present discounted value of damages can be calculated in two steps:

1) annual damages = number of households aware of PCBs X damages/household
   = P(t)D(1986)
2) present discounted value of damages
   = sum of annual compounded damages, 1979-1985
   plus sum of annual discounted damages, 1986-2085

$$= \sum_{t=1979}^{2085} (1 + r)^{1986-t} P(t)D(1986)$$

where r is the discount rate. With a discount rate of r = .03, the damages to beach use are $11.4 million in 1985 dollars, discounted to 1986.

F. Capacity

An inherent difficulty in the use of survey responses is that each household responds independently of the plans of other households. In the beach survey, households make their plans for beach visits assuming that adequate parking will be available and that space on the beaches can be found. If many households respond positively to the absence of PCBs, individuals may not be able to realize their plans because sufficient capacity may not be available. When capacity is less than planned attendance, the benefits of access to beaches will be reduced. In turn, the damages from the presence of PCBs will be less than otherwise if capacity constrains the responses to the removal of PCBs.

The magnitude of the effect of capacity constraints on benefits depends in part on how the excess demand is managed. In the absence of excess demand and without physical damage from use, open access to beaches is the optimal strategy, and one can calculate damages without concern over allocating use. When capacity constraints exist, open access is no longer the most efficient strategy. Benefits of access depend on how use is allocated. The greatest benefits can be achieved through a pricing scheme which sets the price of entrance equal to the level where individual plans are realized precisely at the level of capacity. Other methods of allocating use will be less efficient and will bring less benefits. The role of optimal management and its effect on benefit-cost outcomes is well developed in benefit-cost literature.

The question of whether the physical capacity of a beach is adequate to handle the aggregate demand for a beach is not simple. Much of the difficulty results from variation in seasonal demand. A given physical capacity may suffice to handle demand distributed uniformly across a year, yet be quite inadequate to handle the same annual aggregate demand which occurs on two or three days a year. The matter is more complicated still, in that the pattern of seasonality is endogenous, subject to change with the imposition of capacity constraints. For example, an individual may realize that a beach will be filled to capacity on July 4, and decide to shift his visit to another day. While changing the day of the visit may mean a diminution of benefits, it will not result in lost benefits for the day. In effect, a careful analysis of the effects of capacity constraints requires knowledge of how households distribute their use over the seasons of the year and how they would change their distribution in response to rationing schemes, prices and capacity constraints. An analysis which assumes that households do not readjust their use in response to constraints is likely to overstate the effects of capacity constraints.

To assess the relationship between capacity and aggregate attendance with and without PCBs at Fort Phoenix and East/West Beach, we need information on physical capacity and the distribution of annual use. The survey data pertain to annual use only, and give no insight into seasonal use patterns.

There are no data on attendance at East and West Beaches except for the peak summer weeks. However, some idea of the distribution of use of area beaches can be gained by looking at the monthly distribution of attendance at Fort Phoenix, Demarest Lloyd and Horseneck. Peak use days occur in the months of May through September. Exhibit 12 shows the mean proportions of annual use that occur in the peak period for the three beaches for the years for which complete records are available. The percent of off-peak use for Fort Phoenix is quite a bit higher than for Horseneck and other reported beaches. The basic reason for the greater off-peak use for Fort Phoenix is its proximity. Fort Phoenix also has the attraction of the remnants of the fort. East and West Beach fit the Fort Phoenix case better than other area beaches. East and West are quite accessible for walking and sunbathing in off-peak months. Based on the data on Fort Phoenix and Horseneck Beach, I assume that 85 percent of the use of East and West beaches occurs during the peak summer months. For Fort Phoenix, I use 70 percent, the mean use occurring during peak summer months.

To conclude the capacity issue, we need to estimate the number of beach days typically available during the peak five-month period from May through September. The capacity of beaches is roughly determined by parking capacity, which provides an upper limit on daily use, and the number of days on which the beaches are usable. The relevant constraint here is weather. Some indication of the weather is given in the bathhouse records for the City of New Bedford Recreation Commission. Records are available for the nine weeks from June 29 to August 31, 1986 (except for the week ending August 10). During this period there were 33 days recorded as fair. Supposing that during May, June, and September there were 27 additional fair days, we would have 60 beach days per year. This is a considerable underestimate of capacity, however, because even when days are not so fair during the summer, people go to the beach.

On each potential beach day, capacity is approximately determined by the number of parking spaces. This is only approximate for several reasons. Households can change their transportation mode. The number of people per vehicle may increase. And drivers may park further away. But assuming that parking provides the constraint to visits on the 60 beach days, we can estimate summer capacity from knowledge of the number of parking places. Exhibit 2 shows that there are about 645 parking places at East/West and about 450 at Fort Phoenix. A turnover rate of three per day is assumed, based on the survey responses to length of stay at the area beaches. The median length of stay at East, West, and Fort Phoenix is about two hours per visit. Consequently, I estimate capacity for the summer beach visits as:

East/West	116,100
Fort Phoenix	81,000

To compare these estimates of capacity with estimates of actual attendance, we need to calculate attendance for those aware of PCBs as well as the attendance for those who are not aware. Let xn be median trips to the beach in question by users of the beach who are not aware of PCBs. Then an estimate of aggregate trips before PCBs are removed is

$$HH\cdot[P(t)P(\text{before}|PCB)x^{0} + (1 - P(t))P(\text{visit}|\text{no PCBs})xn]$$

where HH is the population of households and P(visit|no PCBs) is the proportion of households not aware of PCBs that visit the beach. To calculate estimated attendance for the "without PCBs" case, I substitute x' for x^0 and P(after|PCB) for P(before|PCB). Estimates of aggregate summer attendance are given in the last two rows of Exhibit 13.

Comparing the estimates of summer attendance here with the estimates of capacity above, we can see that there is no capacity constraint prior to the removal of PCBs, but there may be a capacity constraint after the removal of PCBs. The relevant question is thus what is the estimated impact of this capacity constraint on the damages attributable to PCB contamination?

I will undertake an analysis of the effect of capacity based on the constraints on the representative user taking median trips. I assume that when capacity constrains use, each user of the beach is affected in the same way by having trips to the site rationed based on the relationship between capacity and aggregate summer visits. Naturally, a capacity constraint will reduce representative consumer's surplus. For the linear demand function, it can be shown that a user who plans to take x trips but is rationed to the quantity kx will have consumer's surplus equal to $x^2[1-(1-k)^2]/(-2b)$. This is simply a portion $(1-(1-k)^2)$ of the original benefits of access, and this portion equals one when there is no rationing (k=1).[7]

In the case of rationing at East/West Beach and Fort Phoenix, there are several complicating factors. First capacity constraints will not affect all trips, only those taken during the summer when capacity is assumed to be constraining. For this analysis I assume that 85 percent of East/West beach use occurs during the peak summer season, while 70 percent of Fort Phoenix use is peak period demand. Consequently, a proportionate reduction in demand because of the capacity constraint will influence 85 percent of trips of the representative use at East/West and 70 percent at Fort Phoenix. In effect the k for each beach is given by

$$k = 1 - p + pr$$

where k = the proportion of desired trips realized
p = proportion of annual use occuring in summer and subject to rationing
r = the proportional reduction due to rationing.

In the analysis below I will assume that

r = summer aggregate capacity/planned aggregate summer visits.

A second issue that must be addressed is the effect of capacity constraints on households unaware of PCBs. Their trips will also be constrained, and their benefits of access reduced in the same way as households that are aware of PCBs. This reduction in the value of access for users unaware of PCBs must be subtracted from the increased value of access gained by users aware of PCBs. And since the proportion of households aware of PCBs grows over time, the capacity constraint will grow more severe, and the effect on benefits of access by all households will increase. The benefits of access for users of each beach not aware of PCBs are given in Exhibit 14.

When capacity constrains use, the annual damages from PCBs must be calculated as follows:

Damages =

change in benefits of access for households aware of PCBs

\+

change in benefits of access for households unaware of PCBs

Because the capacity constraint reduces use, and removal of PCBs does not increase demand for those households unaware of PCBs, access benefits for those households are reduced and reduce the damages imposed by PCBs. The calculations of damages for each beach are made as follows:

$$D(\text{beach}, t) = HH \cdot P(t)[p(\text{after}|\text{PCB})a' - P(\text{before}|\text{PCB})a^{o}]$$
$$+ HH(1 - P(t))[P(\text{visit}|\text{no PCB})(an' - an^{o})]$$

where (as before)

HH = households

P(t) = proportion of households aware of PCBs

P(after|PCB) = proportion of households aware of PCBs who attend the beach after PCBs removed

P(before|PCB) = proportion of households aware of PCBs who attend the beach before PCBs removed

a^{o}, a' = constrained benefits of access, before and after PCBs removed, for users of beach aware of PCBs

P(visit|no PCB) = proportion of households <u>not</u> aware of PCBs who visit a particular beach

an^{o}, an' = constrained benefits of access for users of beach unaware of PCBs.

Damages are added across beaches, as before. The damages change every year. For each year, the damage calculation requires first an estimate of aggregate attendance unconstrained, with and without PCBs. Then aggregate attendance is compared with capacity. When capacity is constraining, benefits of access are revised, and the damages computed as given above. As in the unconstrained case, the present discounted value of damages is the sum of damages compounded since 1979 and the sum of annual damages discounted from 1986 to 2085:

$$\text{present discounted value of damages} = \sum_{t=1979}^{2085} D(t)(1+r)^{-t}$$

where

$$D(t) = D(\text{East/West},t) + D(\text{Fort Phoenix},t).$$

Based on the estimates of capacity given above and the estimates of summer use calculated in Exhibit 14, I compute the present value of damages to be $8.3 million in 1985 dollars, discounted to 1986 in the presence of capacity constraints.

II. DAMAGES TO RECREATIONAL FISHING

A. Framework

Saltwater angling is a popular activity throughout Buzzards Bay. Individuals fish both from the shore and from boats. Several charter fishing companies operate out of New Bedford and Apponagansett Harbors. Captain Leroy, Inc. is a charter fishing company that operates two boats on a regular daily schedule from Fairhaven, from April to October. Several other small companies have boats that leave from Davis and Tripp Marina in Dartmouth.

Anglers catch a wide variety of bottom-feeding and migratory species in New Bedford Harbor. From the shore, the catch may include various groundfish, such as flounders, tautog and scup. Charter parties travel out as far at Cuttyhunk and the Elizabeth Islands. They often pursue bluefish and stripers, along with a wide variety of groundfish.

The initial administrative actions in response to the discovery of PCBs in New Bedford Harbor were directed at fishing. In 1977 the Massachusetts Department of Public Health issued health warnings against the consumption of lobsters and bottom fish taken from portions of New Bedford Harbor. In a regulation issued September 25, 1979, the Department of Public Health formally banned the taking of any fish except baitfish inside the hurricane barrier, and banned the taking of bottom fish in area II, between the hurricane barrier and the imaginary line from Ricketson's Point to Wilbur Point.

Evidence about the impact of PCBs on recreational fishing comes from two sources: a telephone survey of households in the New Bedford area and conversations with about 15 local anglers. Both sources of evidence reveal that anglers typically are aware of the PCB problem. Conversations with local anglers revealed several types of behavioral response to the PCB problem:

- anglers fish less often;
- anglers fish further south, away from the most contaminated waters of New Bedford Harbor; and
- fish caught in the Harbor are not eaten, but thrown back.

The phone survey of area households corroborates the anecdotal information provided by local anglers. The recreational fishing questions were asked of 428 households. Seven of those households were not asked beach questions because no one was available to answer questions about beach activities. Of those seven angling households, five were aware of PCBs in the sense of responding to the questions concerning what substances were contaminating the harbor by naming PCBs or responding "yes" to the question about whether they believed that PCBs were damaging the harbor. The other 421 households who were asked recreational fishing questions were households who revealed themselves aware of PCBs in the questions regarding beach use. Of those 421 households, 78 had participated in saltwater fishing in 1985. Consequently, the survey sample of recreational anglers aware of PCBs is 83 households. The angling participation rate for households aware of PCBs is 83/426 = .195.

PCB contamination of New Bedford Harbor waters imposes damages on the public because it results in contamination of fish at levels above public health standards and, as a consequence, removes Area I from all fishing and Area II from bottom fishing. Anglers are aware that they should avoid certain fishing areas and that they should not eat some kinds of fish. To measure the damages to recreational fishing, I analyze the demand for fishing in the New Bedford area. Complete measurement of damages would require estimation of demand function for fishing in Areas I and II, with and without PCBs. It is not possible to estimate such demand functions from a survey of the population of the New Bedford area only, because such a survey does not provide enough variation in the cost of access to fishing. Fishing is much less site specific than beach going, and anglers typically move about during a fishing trip.

To measure the damages from PCB contamination, I consider the cost savings to anglers as a consequence of eliminating PCBs from the New Bedford Harbor and eliminating the ban on bottom fishing in Area II. This is consistent with damage measurement in the beach section, which takes damages from contamination by PCBs as the benefits of removing PCBs.

Consider two polar cases in measuring the damages of PCBs removal. In Case I, removal of PCBs induces anglers simply to shift their trips from outside of Area II to inside Area II, resulting in cost savings of $\Delta x \Delta c$, where Δc is the reduction in per trip costs from having the closer fishing grounds available in the absence of PCBs. The other extreme is that the lower cost results in Δx additional trips. The additional consumer's surplus from these lower costs can be approximated by $\Delta x \Delta c/2$. This measure would be valid if fishing in Area II were distinct from other areas in the general vicinity.

The following analysis computes damages for households aware of PCBs who fished in New Bedford waters in 1985. It does not attempt to infer the losses to households who have given up fishing or who have substituted to fishing completely outside of the New Bedford area.

B. Empirical Analysis

Damages can be computed from estimates of the aggregate number of trips taken at a higher cost and the mean increase in cost. The telephone survey provides evidence on the aggregate number of trips affected. From the telephone survey, 15.2 percent of respondents were aware of PCBs and went recreational fishing in 1985. This figure is greater than the state-wide average participation rate of 11.2 percent in 1980 for Massachusetts and 13.9 percent in 1980 for Rhode Island, but New Bedford is closer to the water and would be expected to have a higher rate.[8]

The increase in trips in Area II if PCBs were removed can be estimated from the responses to questions 18 and 21 in the survey. Question 18 asked the respondents how frequently they fished in Area II in 1985, and question 21 asked how frequently they would fish in the same area in the absence of PCBs. As shown in Exhibit 15, the median responses were 6 in 1985 and 12 in the absence of PCBs. The exhibit also shows that 65 percent of the fishing households fished in Areas I and II in 1985, and that 77 percent would fish there in the absence of PCBs. Assuming that the proportion of angling households (83/426 = .195) does not increase in response to PCB removal, I calculate the increase in aggregate trips in Area II as follows.

$$\Delta x = HH \cdot P(t)P(fish)\{P'(\text{Area II}|fish)x' - P^{o}(\text{Area II}|fish)x^{o}\}$$

where

Δx = aggregate change in trips
HH = aggregate households = 51498
P(t) = proportion of households aware PCBs = .782
P(fish) = proportion of households aware of PCBs who fish in the New Bedford waters = .195
$P'(\text{Area II}|fish)$ = proportion of anglers aware of PCBs who fish in Area II {Prime (′) for without PCBs; ought (o) for 1985}
x', x^{o} = median trips per angler aware of PCBs in Area II.

Using the data shown in Exhibit 15, I calculate the aggregate increase in trips to be 41935 with the removal of PCBs.

To demonstrate the potential magnitude of damages I show the savings in costs that would occur if these trips were moved from the Area III - Area II border to Fort Rodman/East Beach area, or to Fort Phoenix, whichever is closer. This is an underestimate of cost savings, because without PCBs anglers could fish anywhere in Area I. For anglers fishing from shore I assume that households who live closer to East Beach move their trips to the East Beach area from the Apponagansett area, while households who live closer to Fort Phoenix move their trips to the Fort Phoenix area from the West Island area. For some households, this implies no cost adjustment because they are currently closer to the site where they fish. Taking into account the fact that some households do not have to travel further, I calculate a mean roundtrip increase in distance of 3.6 miles. The costs of this mileage adjustment are $.084 per mile travel cost and the opportunity cost of time, which is a mean of $4.70 per hour for angling households. Travel in this area appears to average 40 miles per hour, or 1.5 minutes per mile. Consequently, the adjustment costs for households fishing from shore who are making their adjustments by driving further are $.72 per trip, on average.

To calculate the cost savings to boating anglers, I assume that the boating anglers motor south two miles from mid-way down Sconticut Neck to the imaginary line from Wilbur Point to Ricketson's Point. For a typical bass boat, traveling about 15 miles per hour and using four gallons per hour, the fuel cost of moving the four miles round trip would be $1.22. Traveling the four miles would take about 16 minutes, valued at $4.70 per hour, would be $1.25. The sum of the cost savings per trip for boating anglers would be $2.47. About half of all private boat trips and fishing from shore (non-charter and party boat trips) are typically boat trips.[9] Consequently, the mean adjustment cost per trip would be $1.60.

The total damages any year are the product of the mean adjustment costs and the aggregate number of trips affected:

$$\text{damages} = \Delta c \cdot \text{number of trips affected},$$

where Δc, the increase in costs, is $1.60.

Given these estimates, the damages incurred in any one year by recreational anglers are $1.60 per trip times the number of annual trips (41,935) that are moved in response to the PCB contamination. For 1986, the damages are estimated to be \$67,100. This estimate of damages, the cost savings, is valid when all fishing in the New Bedford area is similar, and Area II is distinct only by being cheaper. This seems a conservative magnitude for the 6000 plus households who would fish in Area II and are aware of PCBs.

To conclude the angling analysis, the damages from 1979 to 1985 must be compounded to 1986, and the damages from 1987 to 2085 must be discounted to 1986. It is assumed that the same path of adjustment in awareness to PCBs among anglers occurs at the same rate as among the population in general. The present value of damages to recreational fishing is

$$\sum_{t=1979}^{2085} (1 + r)^{1986-t} \, DF(t) = \$3.1 \text{ million}$$

where $r = .03$, and DF(t), the damages to recreational fishing, depend on the proportion of households aware of PCBs. This proportion is calculated from Exhibit 11 and the logistics growth function estimated from Exhibit 11.

This estimate of damages is conservative in that it ignores several behavioral changes and calculates the cost of only one change: avoiding certain areas. It seems quite likely that higher costs are imposed on those who quit angling because of PCB contamination.

III. CONCLUSION: THE PRESENT VALUE OF DAMAGES TO BEACH USE AND RECREATIONAL ANGLING.

The present value of damages from PCB contamination to recreation activity in the New Bedford area is the sum of damages to beach use and recreational fishing. The present value of damages are without capacity constraints

beach use	$ 11.4 million
recreational angling	$ 3.1 million
Total damages	$ 14.5 million

These damages are conservative in many respects, for example, in not covering activity changes at some beaches, in not counting as damaged any summer visitors, and in not dealing with a variety of averting actions in recreational fishing.

In the presence of capacity constraints, the present value of damages are

beach use	$ 8.3 million
recreational angling	$ 3.1 million
Total damages	$ 11.4 million

FOOTNOTES

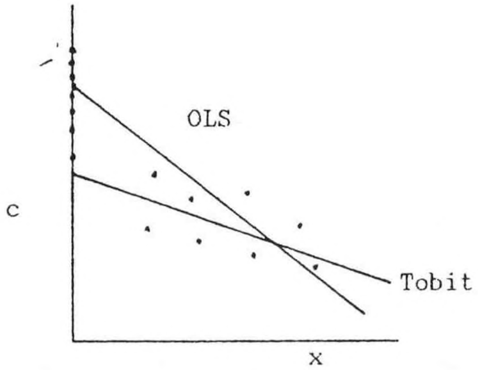
[1] The information on the survey was provided by Decision Research Corporation.

[2] The Tobit model is an approach to estimating functions which take only zero or positive numbers. For recreational applications, the model is

$$x = zb - e \qquad zb - e > 0$$
$$x = 0 \qquad zb - e \leq 0$$

where ε is assumed normal with zero mean, constant variance. This model is explained in detail in Maddala, Ch. 6. It recognizes that when price (or other appropriate variable) gets high enough, quantity demanded goes to zero, and stays there. Estimating Tobit models rather than ordinary least squares (OLS) usually results in more elastic recreational demand models. (See, for example, the results of Smith and Desvousges, 1985.)

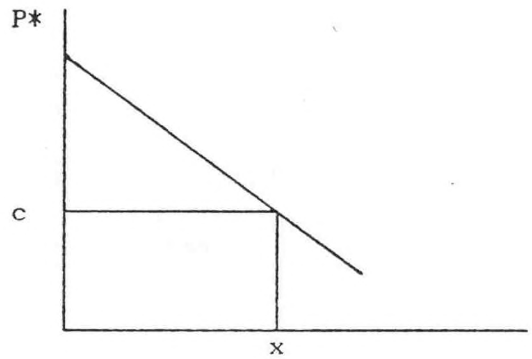
The effect of using a Tobit estimation procedure which recognizes the nonnegative nature of recreational demand can be seen by looking at observations in price quantity space, all else equal.



The OLS model will treat the zeroes and positive demands the same, and fit a function which minimizes squared deviations from a line drawn through all the points. The Tobit procedure fits a model which explains whether people take trips at all, and given that thay take these trips, what their demand curve is like. The graph shows that the OLS model estimates a slope too steep for participants, and will overestimate consumer's surplus for participants.

[3] The survey (question 6) sought from each respondent the estimated time to travel to the beach of concern. When a household gave a response to this question, the individual time was used. To provide estimates for those individuals who did not respond to the questions about time, I used the following procedure. Time from the i^{th} Census tract to the j^{th} beach is the mean of all observations for that Census tract - beach combination if there are at least three respondents who give their perceived time in that cell. If there are fewer than three respondents, I assume that a one way trip takes seven minutes startup time and travelling occurs at 40 miles per hour.

4 There are many ways to select the sample from the set of 538 beach observations. One could analyze the planned trips using only the set of households who went to the beach in 1985, and analyze the "without PCBs" trips using only those housholds aware of PCBs. One could use the subset of observations of households who went to the beach in 1985 and know about PCBs. There are several other ways of selecting the observations to use in the analysis. I have chosen the approach that seems least likely to create sample selection errors.

5 

This result is derived as follows: Let the i^{th} individual's demand curve be

$$x_i = a_i + bc_i$$

where a_i is the constant term and other arguments of the demand curve. A price of P* will reduce quantity demanded to zero:

$$0 = a_i + bP_i^*$$

or

$$P_i^* = -a_i/b$$

Consumer's surplus, the shaded triangle below the demand curve above the cost is

$$(P_i^* - c_i)x_i/2 = \left[\frac{-a_i}{b} - c_i\right] x_i/2$$

$$= \left[\frac{-a_i}{b} - \frac{x_i}{b} + \frac{a_i}{b}\right] \frac{x_i}{2}$$

$$= -x_i^2/(2b)$$

where the second line follows from the fact that $x_i = a_i + bc_i$ or $c_i = (x_i - a_i)/b$

6 The equation $P(t) = \{1 + \exp(2.85 - .358t)\}^{-1}$ is estimated from the data in Exhibit 11 by the following OLS equation

$$\mathrm{LOG}[P/(1-P)] = c_0 + c_1 t$$

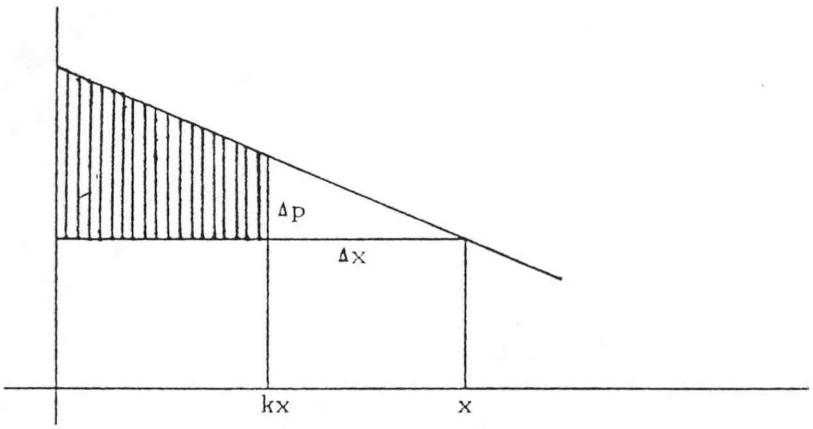
where t = 1 for 1975, 2 for 1976 and so forth. The t-statistics for the estimated coefficients exceed 20 and the $R^2 = .98$.

7 To demonstrate this result, note that in the figure below $-x^2/2b$ is the surplus when the trips are taken. Let kx be the constraint on trips. Then the person realizes surplus equal to $-x^2/(2b) - \text{abs}(\Delta x \, \Delta p/2)$. For a linear demand curve $\Delta p = \Delta x/b$, so that surplus becomes $x^2/(-2b) - (\Delta x)^2/(-2b)$. The reduction in trips, Δx equals

$$\text{old trips} - \text{new trips} = x - kx$$
$$= (1 - k)x$$

So that surplus becomes

$$\frac{x^2}{-2b} - \frac{(1 - k)^2 x^2}{-2b} = \frac{x^2}{-2b}\left[1 - (1 - k)^2\right]$$



The shaded area is the surplus under rationing at kx.

8 1980 Survey of Hunting, Fishing and Wildlife-Associated Recreation, Table 10.

9 For example, in 1985, in the North Atlantic region, 54.7 percent of non-charter boat trips (that is, trips from shore, structure, private or rental boats) were from private or rental boats. See National Marine Fisheries Service, U.S. Department of Commerce: Marine Recreational Fishery Statistics Survey, Atlantic and Gulf Coats, 1985 (June 1986) Table 33, p. 68.

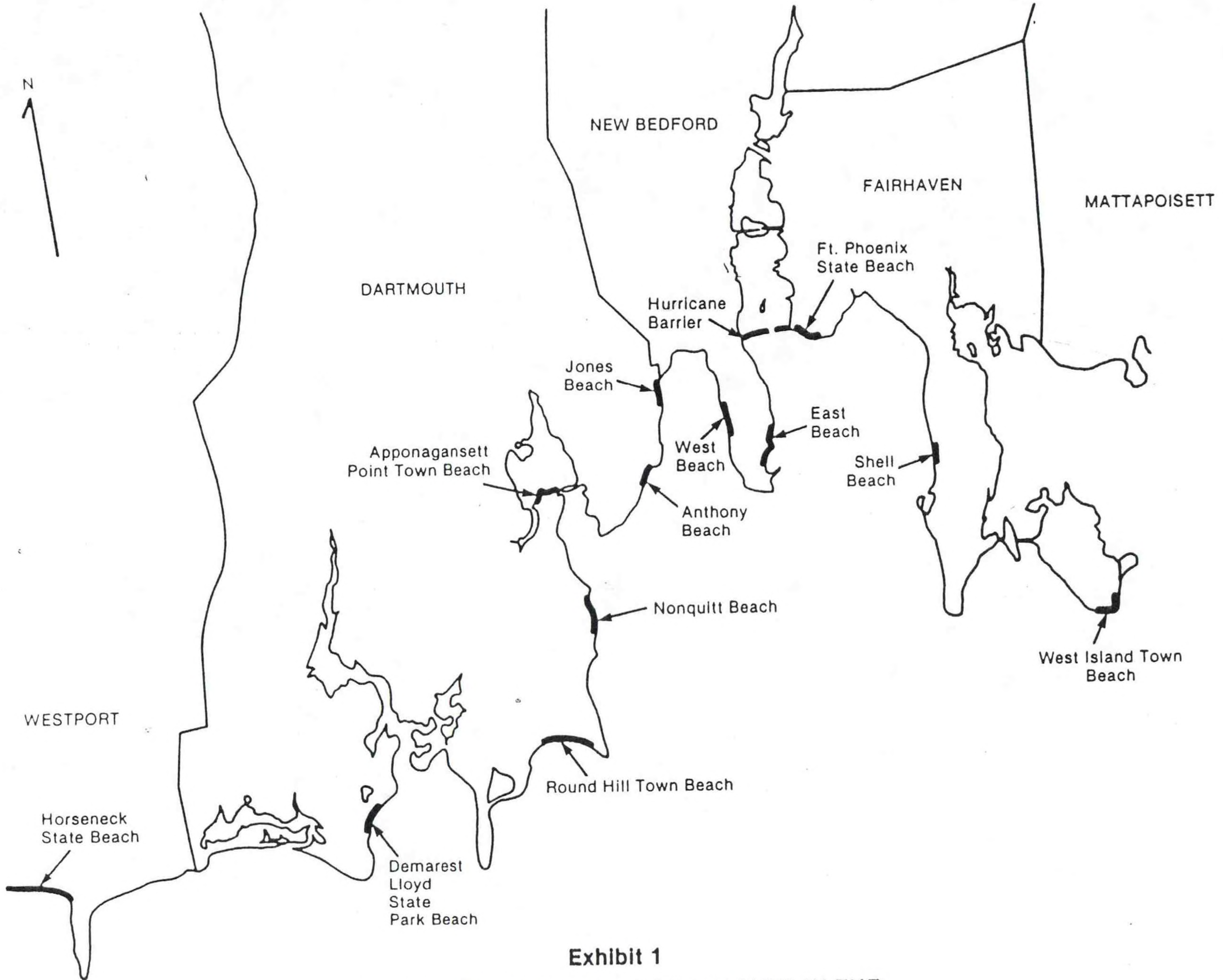


Exhibit 1

APPROXIMATE LOCATION OF BEACHES IN THE NEW BEDFORD AREA

Exhibit 2

SUMMARY OF CHARACTERISTICS OF BEACHES IN THE NEW BEDFORD AREA
Source: Christine Ruf, Industrial Economics, Inc.

Town/Beach	Jurisdiction	Attendance	Fee	Approximate Dimensions	Physical Characteristics	Other Characteristics
NEW BEDFORD						
East Town Beach	Town	'71-'86	No	.25 mi x 125 ft of beach	3 free pkg lts (300 cars) and along streets (100 cars); concession std.; swingset; lifeguard; bath & shower; cement pier (-25' x 75')	Extremely urban; right next to busy road; visitor stratification by age on beach; can walk or take bus ($.30) 75% sand, 25% cobbles.
West Town Beach	Town	'71-'86	No	.5 mi x 100 ft of beach	Pkg on streets and in Nagelwood Park (245 cars); bath house; concession std. across st.; long jetty at end of beach w/ boat ramp; lifeguard	Somewhat nicer than East Beach but still very urban; on a busy road; stratification by age; can walk or take bus, 75% sand, 25% cobbles.
FAIRHAVEN						
Fort Phoenix	State	'73-'86	$3 per vehicle per day; $20 per season.	21 acres 2,400 ft. bch	Bath house; pkg lot (450 cars); concession; plygrd; grassy fld; tennis cts; basktbl court; lifeguard	Nice beach and view; lots of seaweed on shore; woods in back; big rock outcrops; quiet; 70% sand; 30% boulders/cobbles.
West Island	Town	900 - 1,100 car stickers per year	$5 per seasonal sticker; resid. & renters only	.75 mi x 500' beach; -.5 mi x 50' dune	Dirt pkg lot (-100 cars) 2-story lkout tower; lifeguard	Very nice & open; feeling of isolation (at end of ngbhd st) 75% sand; 25% boulders/cobbles.
Informal beaches: (along West Sconticut Neck, e.g. Shell Beach)	N/A	N/A	No	var. length; width from 20' to 75'	No facilities; limited access; occasional pkg. on nearby street	Beaches range from all sand to all cobble; lots of jetties.

Exhibit 2
(continued)

SUMMARY OF CHARACTERISTICS OF BEACHES IN THE NEW BEDFORD AREA

Town/Beach	Jurisdiction	Attendance	Fee	Approximate Dimensions	Physical Characteristics	Other Characteristics
DARTMOUTH						
Demarest Lloyd State Park	State	'73-'83 (based on cars)	$3/day, $20/season, per vehicle	220 acres; 1,800 lin. ft. beach	Bathhouse; lfgd; picnic area; 2 pkg lots (450 cars)	Shallow water; nice beaches; good for birding; salt marshes
Round Hill	Town	Based on no. of stickers only	$5 seasonal sticker, resident only	1 mi x 75 ft	Pkg for 250-300 cars; picnic area; lfgds	N/A
Jones Beach	Town	Based on no. of stickers only	$5 seasonal stk. residents, $5/day/vehicle non-resident	.33 mi x 100 ft	Pkg for 150 cars picnic area	Small waves; This is known as a small children's beach.
Apponagansett Pt.	Town	Based on no. of stickers only	$5 seasonal stk. residents, $5/day/vehicle non-resident	.5 mi x 100 ft	Picnic area; parking for 100 cars; lifeguard; boat ramp	Rocky beach; little sand; good for shellfishing.
Anthony Beach	N/A	N/A	Must be club member	N/A	N/A	N/A
Nonquitt Beach	N/A	N/A	N/A	N/A	N/A	N/A
WESTPORT						
Horseneck Beach	State	'75-'85 (based on cars)	$3/day; or $20/season, per vehicle	594 acres; 10,000 ln ft of beach	Pkg for 2,000 cars, lifeguard; boat ramp; 100 campsites	Barrier dunes; salt marshes; nice surf; great view.

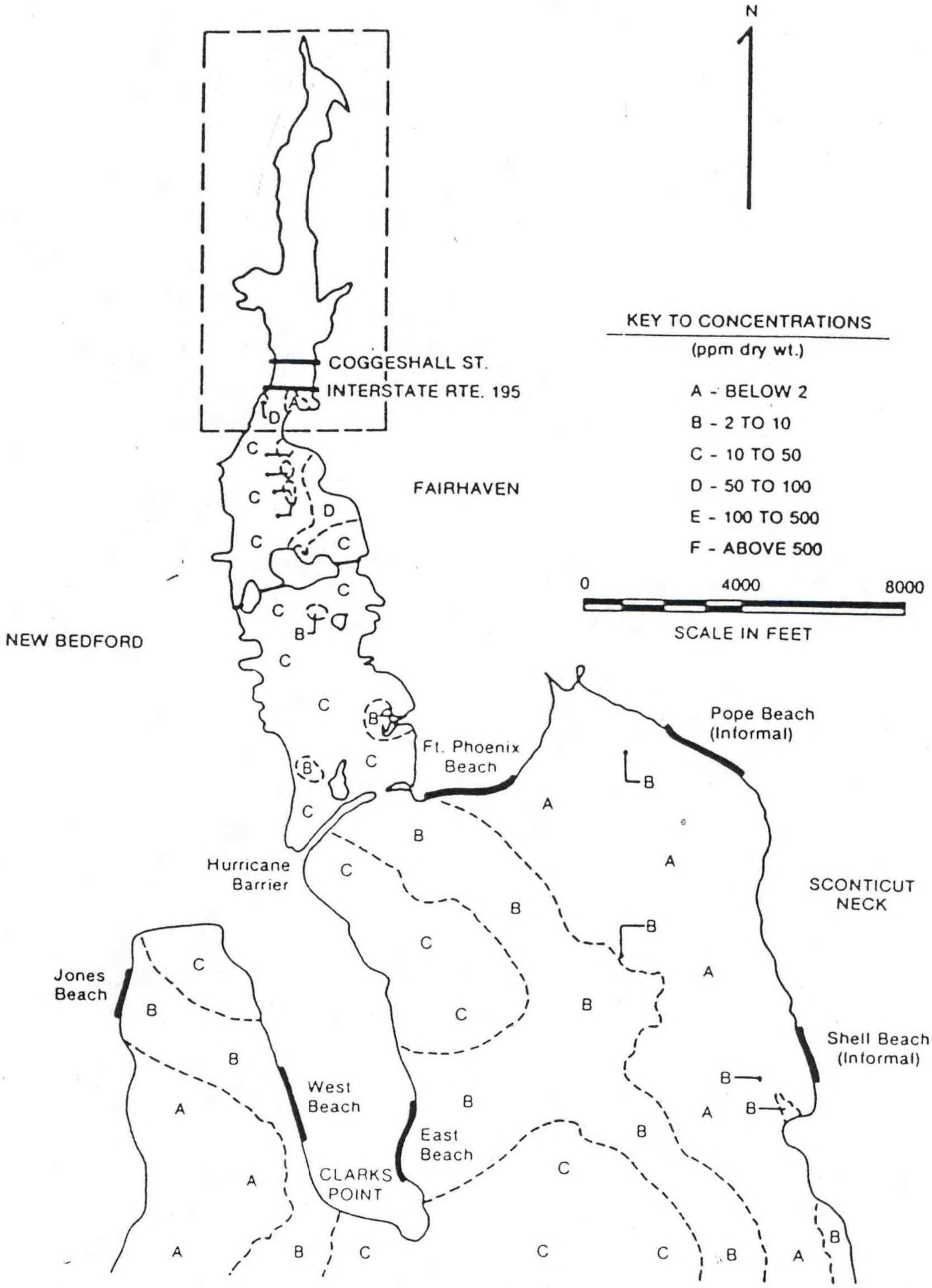


Exhibit 3

SEDIMENT CONCENTRATIONS, ACUSHNET RIVER ESTUARY
NEW BEDFORD, MASSACHUSETTS

Source: NUS Corporation, July 1984

Exhibit 4

SOME SIMPLE CORRELATION COEFFICIENTS AMONG DISTANCES FROM CENSUS TRACTS TO BEACHES

East Beach	–				
West Beach	.997	–			
Fort Phoenix	.570	.571	–		
West Island	.210	.207	.817	–	
Demarest Lloyd	.476	.507	–.133	–.392	–

Exhibit 5

PRE-TAX OPPORTUNITY COST OF TIME

Questionnaire occupation	Employment and Earnings source	Hourly rate
Salaried employee[a]	weighted average of (1) Executive, administrative and managerial and (2) technical, sales and administration support. Weights are numbers of workers in each group	$8.86
Self-employed	unweighted mean of major occupation groups	7.84
Professional	professional specialty	11.90
Tradesmen	precision production, craft and repair	9.68
Executive	executive, administration and managerial	12.33
Services	service occupations	5.33
Hourly worker	handlers, equipment cleaners, helpers and laborers	6.45
Education	technical sales and administrative	7.50
Homemaker, never worked, responses not elsewhere classified	minimum wage	3.35

[a] The opportunity cost of time for each occupation of the questionnaire is based on median earnings according to the categories listed for the occupation. The hourly rates are computed as median weekly earnings divided by 40 hours for the fourth quarter of 1984, as given in Employment and Earnings, Vol. 33, No. 1, January, 1986, Table A-75. The categories Homemaker, never worked, other and refused are assigned the Federal minimum wage.

Exhibit 6

MARGINAL TAX RATES[a]

Income Category	Marginal Tax Rate
Under $15,000	.192
$15,000 to $19,999	.229
$20,000 to $24,999	.264
$25,000 to $34,999	.315
$35,000 to $49,999	.385
$50,000 and over	.454
not reported	.229

[a] These rates are the average marginal rates that would be paid by a married couple, filing jointly with income in the given range, in 1985. The rates include the Massachusetts income tax of .05375.

[b] A household receives one less the marginal tax rate of each dollar earned. A person in a household with reported income less than $15,000 would receive almost 80% (1 - .192) of each dollars earned.

Exhibit 7

DEMAND COEFFICIENTS FOR PLANNED 1986 TRIPS:
WITH PCBs.[a]

Variables	Constant	PEB	PFTP	PSUB	PASS	Log likelihood	Number of observations
East/West	-11.96	-10.84	2.73	1.05	36.0	-841	495
	(1.5)	(4.73)	(.98)	(.40)	(2.8)		
Fort Phoenix	-3.7	.65	-2.94	.30	8.3	-620	495
	(1.6)	(1.0)	(3.4)	(.4)	(2.0)		

a Estimated with the University of Maryland SHAZAM package.

b Parentheses contain asymptotic t-statistics under null hypothesis of no association.

Exhibit 8

DEMAND COEFFICIENTS FOR 1986 TRIPS:
WITHOUT PCBs.[a]

Variables	Constant	PEB	PFTP	PSUB	PASS	Log likelihood	Number of observations
East/West	-6.9	-12.91	3.94	3.93	40.4	-1268	495
	(.8)[b]	(5.3)	(1.3)	(1.4)	(2.8)		
Fort Phoenix	-3.24	.88	-4.8	2.78	22.7	-1126	495
	(1.1)	(1.0)	(4.4)	(2.7)	(4.1)		

a Estimated with the University of Maryland SHAZAM package.

b Parentheses contain asymptotic t-statistics under null hypothesis of no association.

Exhibit 9

CALCULATION OF BENEFITS OF ACCESS, PLANNED 1986 AND WITHOUT PCBs

HOUSEHOLDS AWARE OF PCBs

	Proportion of Households Knowing about PCBs That Attend	
	East/West Beach	Fort Phoenix
1986 with PCBs	.275	.251
1986 without PCBs	.476	.518

	Median Trips per Household Among Households Planning to Attend the Particular Beach and Knowing about PCBs.	
	East/West Beach	Fort Phoenix
1986 with PCBs	10	5
1986 without PCBs	15	9

	Benefits of Access per User Aware of PCBs	
	East/West Beach	Fort Phoenix
1986 with PCBs	$4.61	$4.25
1986 without PCBs	$8.71	$8.44

Exhibit 10

ESTIMATED DAMAGES PER HOUSEHOLD
AWARE OF PCBs

East/West Beach	Fort Phoenix
$2.88	$3.31

Exhibit 11

PROPORTION OF SAMPLE HOUSEHOLDS AWARE OF PCBs, BY YEAR

Year[a]	Proportion Aware of PCBs
1975	.0855
1976	.130
1977	.143
1978	.176
1979	.207
1980	.299
1981	.397
1982	.493
1983	.605
1984	.737
1985	.775
1986	.782

[a] Based on question 12 which asked when the household became aware of PCBs.

Exhibit 12

MEAN PROPORTIONS OF REPORTED ANNUAL USE
OCCURRING DURING MAY TO SEPTEMBER

Fort Phoenix	Demarest Lloyd	Horseneck
.70	.96	.91

EXHIBIT 13

ESTIMATED SUMMER ATTENDANCE

FOR EAST/WEST AND FORT PHOENIX, 1986

	Annual Visits per Household	
	East/West	Fort Phoenix
1986 Planned	2.65	1.16
1986 without PCBs	6.08	3.83

	Aggregate Summer Visits	
	East/West (85% of annual)	Fort Phoenix (70% of annual)
1986 Planned	116,000	41,817
1986 without PCBs	266,141	138,066

EXHIBIT 14

CALCULATION OF BENEFITS OF ACCESS

FOR PLANNED 1986 USE: HOUSEHOLDS NOT AWARE OF PCBs

	Proportion of Households Not Aware of PCBs That Attend	
	East/West	Fort Phoenix
Planned 1986	.193	.168

	Median Trips per Household Among Households Not Aware of PCBs That Attend the Beach	
	East/West	Fort Phoenix
Planned 1986	12	5

	Benefits of Access per User Not Aware of PCBs	
	East/West	Fort Phoenix
Planned 1986	$6.64	$4.25

EXHIBIT 15

ANGLING HOUSEHOLDS AWARE OF PCBs

Proportion of Angling Households Fishing in Area II	
1985	.65
1986 - PCBs removed	.77

Median Trips in Area II Per Angling Household	
1985	6
1986 - PCBs removed	12

APPENDIX

Further Development of Concepts

1. Basic Measures.

Consider the m beach problem where visits to the m beaches are the first m components of the ($m < n$) n-dimensional vector x, the consumer's choice vector. Utility is given by $U = U(x,\alpha)$ where α_i is the exogenous quality index of site i, $i = 1,\ldots,m$. While α_i will have only one dimension, it is a simple bookkeeping problem to extend the analysis to several dimensions. Further, weak complementarity is assumed, so that when there are no visits to the i^{th} beach, the consumer is indifferent to quality at the i^{th} beach. (See Freeman: The Benefits of Environmental Improvements.) The problem is to calculate the benefits of changing the quality at some subset of the m sites; for convenience I analyze the case where quality changes at two of the m sites. In effect, I calculate the benefits (or costs) of changing the parameter vector from $(\alpha_1^0,\alpha_2^0,\bar{\alpha})$ to $(\alpha_1^1,\alpha_2^1,\bar{\alpha})$ where $\bar{\alpha} = (\alpha_3^0,\ldots,\alpha_m^0)$. That is, the first two components of the quality vector change, leaving the last m-2 in their original state. Benefits or damages are derived from the expenditure function, which is defined by

$$C(p^o,\alpha) = \min_x\{xp^o \mid U(x,\alpha) = U\} \tag{1}$$

where p^o is the vector of prices paid for x, and U is reference utility level, which is suppressed as an argument in $C(p,\alpha)$.

For people who visit both beaches, the benefits of a change in several components of α are given by

$$b = -\ [C(p^o,\alpha^1) - C(p^o,\alpha^o)] \tag{2}$$

where $\alpha^i = (\alpha_1^i,\alpha_2^i,\bar{\alpha})$, $i = 1,2$. The issue here is to show that the basic definition of benefit change, given by equation (2), can be estimated as areas under demand curves of sites 1 and 2 only. Expression (2) can be identically rewritten as

$$b = -[C(p^o,\alpha^1) - C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha}) + C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha}) - C(p^o,\alpha^o)] \tag{3}$$

by adding and subtracting $C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha})$. Using the notation for Hicksian demand curves $\partial C/\partial p_i = h_i(p,\alpha)$, and assuming weak complementarity between α_i and site i, we can write this as

$$b = \int_{p_1^o}^{p_1^*} h_1(p_1,p_2^o,\alpha_1^1,\alpha_2^1,\bar{\alpha})dp_1 - \int_{p_1^o}^{p_1^{**}} h_1(p_1,p_2^o,\alpha_1^o,\alpha_2^1,\bar{\alpha})dp_1$$

$$+ \int_{p_2^o}^{p_2^*} h_2(p_1^o,p_2,\alpha_1^o,\alpha_2^1,\bar{\alpha})dp_2 - \int_{p_2^o}^{p_2^{**}} h_2(p_1^o,p_2,\alpha_1^o,\alpha_2^o,\bar{\alpha})dp_2 \tag{4}$$

where p_1^*, p_1^{**}, p_2^*, and p_2^{**} are the choke prices for sites 1 and 2 respectively.[1] The choke prices depend on the quality vector and price vector, and therefore differ for the same site as demand curves shift. The functional dependence of p^* on α and p^o is implicit in what follows, but does not influence the construction. The result (4) is critical to welfare measurement. It states that the welfare effects of changes in the quality of several sites can be calculated as the sum of the areas under the appropriately located Hicksian demand curves for site one and site two. Expression (4) follows from (3) in two steps. First, the integral on the first line of (4) is

$$\int_{p_1^o}^{p_1^*} [h_1(p_1, p_2^o, \alpha_1^1, \alpha_2^1, \bar{\alpha})dp_1 - \int_{p_1^o}^{p_1^{**}} h_1(p_1, p_2^o, \alpha_1^o, \alpha_2^1, \bar{\alpha})]dp_1$$

$$= C(p_1^*, p_2^o, \alpha_1^1, \alpha_2^1, \bar{\alpha}) - C(p^o, \alpha_1^1, \alpha_2^1, \bar{\alpha}) - \left[C(p_1^{**}, p_2^o, \alpha_1^o, \alpha_2^1, \bar{\alpha}) - C(p^o, \alpha_1^o, \alpha_2^1, \bar{\alpha})\right]$$

$$= - [C(p^o, \alpha^1) - C(p^o, \alpha_1^o, \alpha_2^1, \bar{\alpha})] \qquad (5)$$

$$\text{because } C(p_1^*, p_2^o, \alpha_1^1, \alpha_2^1, \bar{\alpha}) = C(p_1^{**}, p_2^o, \alpha_1^o, \alpha_2^1, \bar{\alpha})$$

where the last equality holds by weak complementarity. That is, the cost function is not responsive to changes in α_1 when $x_1 = 0$ (or p_1 is so high that $x_1 = 0$). Hence the first two terms on the right hand side of (4) are equal to the first two terms on the right hand side of (3). A similar analysis shows that the second two terms on the right hand side of (3) equal the second two terms on the right hand side of (4).

This expression tells us that we can compute an individual's total benefits of quality changes at several sites by adding up changes in areas under Hicksian demand curves, as long as the demand curves have the appropriate quality arguments. Specifically benefits at site 1 are computed assuming α_2^1 (new quality at site 2), while benefits at site 2 are computed assuming α_1^o (old quality at site 1).

This result is a substantial help in calculating benefits. Intuitively, changes in the quality at one site influence an individual's use of other sites, and even purchases of non-recreational goods. The result in (4) states that we do not need to keep track of all the changes in behavior that are induced by a quality change at the i^{th} site. In fact, all we have to do is to find out how the demand curve at the i^{th} site shifts. This result is analogous to welfare measurement of multiple price changes, which is done by sequentially calculating the areas under the demand curves for the goods whose prices change. (See Just, Hueth and Schmitz.)

2. Aggregation Problems

In the New Bedford case, the nature of the situation makes it difficult to measure the sequencing properly. Discovery and public awareness of PCB contamination occurred over a short period of time. Hence we can observe

$(\alpha_1{}^0,\alpha_2{}^0)$, and hypothetically construct $(\alpha_1{}^1,\alpha_2{}^1)$ but consider it impossible to observe or construct hypothetically $(\alpha_1{}^0,\alpha_1{}^1)$ or $(\alpha_1{}^1,\alpha_2{}^0)$ (one beach clean, the other polluted). Consequently, we observe and hypothetically construct the following measure of benefits, aggregated across sites (when the α argument is assumed implicit):

$$b^o = \int_{p_1^0}^{p_1^*} [h_1(p_1,p_2^0,\alpha_1^1,\alpha_2^1) - h_1(p_1,p_2^0,\alpha_1^0,\alpha_2^0)dp_1$$

$$+ \int_{p_2^0}^{p_2^*} [h_2(p_1^0,p_2,\alpha_1^1,\alpha_2^1) - h_2(p_1^0,p_2,\alpha_1^0,\alpha_2^0)]dp_2 \qquad (6)$$

when it is assumed for simplicity that $p_1^* = p_1^{**}$, without influencing the result. Let b be the correct measure of damages with the appropriate sequencing of the quality variables, b^o the measured damage and a to be defined below. Since b^o is the measured damage, b the true damages, we look for the difference between b and b^o. Through tedious manipulations and repeated application of weak complementarity to (6), it can be shown that

$$b^o = b - (a - b) \qquad (7)$$

where a is a measure of benefits such as b^o above, but with the p_1^0 in $h_2(p_1^0,...)$ and p_2^0 in $h_1(.\ p_2^0..)$ replaced by p_1^* and p_2^*. Hence a is positive, and may exceed b^2. We see that b^o (observed benefits) differs from b, true benefits given in equation (4), all errors of estimation aside, as follows:

$$b^o - b = b - a \qquad (8)$$

We can express a as an unknown constant times b:

$$a = kb.$$

Then we can write b^o as

$$b^o = (2 - k)b$$

If k is less than 1, b^o overestimates b; if k is greater than 1, b^o underestimates b. There are no strong empirical or conceptual reasons to suppose that k is greater or less than one. (In fact, minimal conceptual work suggests that $k > 1$.) Without evidence, the most judicious approach is to assume that $k = 1$, so that $b^o = b$ (measurement errors aside).

3. The Hicksian vs. Marshallian issue

The discussion so far has been developed only in terms of Hicksian demand curves, whereas we observe behavior derived in principle, at least, from Marshallian demand curves. The differences between Hicksian and Marshallian measures of welfare for price changes have been explored in painful detail. The differences in the welfare effects of quality changes have not been similarly explored. For the case of interior solutions, there is no reason to anticipate any uncommon differences between the more correct measures of equivalent or compensating variations and the more easily calculated consumer's surplus measure.

One can see that strong income effects create the potential for disparities. The Hicksian demand for a site can be written

$$x_i = h_i(p,\alpha,u)$$

while the observed Marshallian is

$$x_i = f_i(p,\alpha,y).$$

The Hicksian and Marshallian are equal at the point where income equals the minimum expenditures needed to reach u or where $y = C(p,\alpha,u)$:

$$h_i(p,\alpha,u) = f_i(p,\alpha,C(p,\alpha,u))$$

Differentiating both sides with respect to α gives

$$\frac{\partial h_i}{\partial \alpha} = \frac{\partial f_i}{\partial \alpha} + \frac{\partial x_i}{\partial y}\frac{\partial C}{\partial \alpha}.$$

This expression tells us that the response of the Hicksian and Marshallian demand function differ by $(\partial x_i/\partial y)\cdot(\partial C/\partial \alpha)$, the income effect times the change in minimum cost with respect to quality. The difference between equivalent or compensating variation and consumer's surplus also depends computationally on the limit prices. But we can see that if the income effect is small, then the Hicksian and Marshallian functions will respond the same to quality changes and it is reasonable to assume that the surplus and the variations will be close. If the income effect is large, then one would have grounds for arguing that there are substantial differences. It seems quite plausible to argue that consumer's surplus is a good measure of either the willingness to pay for beach access or the amount beach users would have to be paid to relinquish access.

4. Introducing Additional Sites

What if more than two beaches are affected? Can we tell the direction of bias if the environmental quality at other beaches is influenced (as it almost surely is)? We can address this question by looking at the costs of quality changes at n sites, and seeing what happens if we measure welfare changes at less than n. Suppose that α changes from α^0 to α^1. Then the benefits (if an improvement) of this change are

$$b = -[C(p,\alpha^1) - C(p,\alpha^0)]$$

This can be written

$$b = -[C(p,\alpha^1) - C(p,\alpha_1^1,\ldots,\alpha_{n-1}^1,\alpha_n^0)$$

$$+ C(p,\alpha_1^1,\ldots,\alpha_{n-1}^1,\alpha_n^0) - C(p,\alpha_1^1,\ldots,\alpha_{n-2}^1,\alpha_{n-1}^0,\alpha_n^0)$$

$$+ C(p,\alpha_1^1,\ldots,\alpha_{n-2}^1,\alpha_{n-1}^0,\alpha_n^0) - C(p,\alpha_1^1,\ldots,\alpha_{n-3}^1,\alpha_{n-2}^0,\alpha_{n-1}^0,\alpha_n^0)$$

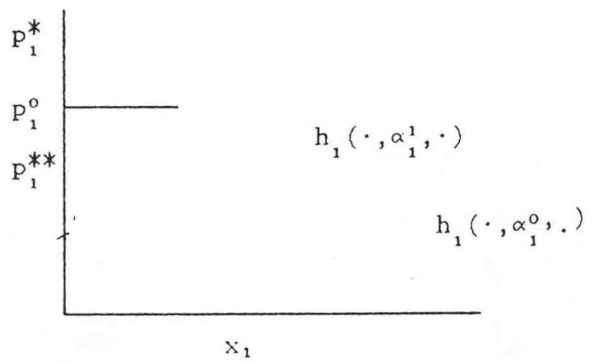
$$+ \quad \vdots$$

$$C(p,\alpha_1^1,\alpha_2^0,\ldots,\alpha_n^0) - C(p,\alpha^0)].$$

If all of the α's increase (i.e., there is an improvement everywhere) then it is reasonable to assume that each Hicksian demand curve shifts out as a result of its own improvement in quality. Hence, measuring the quality improvements at some sites underestimates the benefits of the improvement. Whether Hicksian demand curves shift out as a result of quality improvements is an empirical question whose answer depends on the strength of the income effect.

FOOTNOTES TO APPENDIX

1 This expression also holds if a person initially visits only one site or no sites. That is, $p_1^o \geq p_1^{**}$, or $p^o \geq p^{**}$. Here the argument is made for the case where $p_1^o \geq p_1^{**}$. In that case, the integral $\int_{p_1^o}^{p_1^{**}} h_1(p_1,\cdot)\, dp_1$ must be identically zero, because quantity demanded is initially zero and cannot change as price increases. Hence benefits for x_1 are simply $\int_{p_1^o}^{p_1^{*}} h_1(p_1,\cdot)dp_1$ or the shaded area in the figure below.



The same reasoning holds for x_2 or for both sites jointly.

2 Expression (7) can be demonstrated as follows:
Writing out b^o from (6), we have

$$b^o = \left\{ \int_{p_2^o}^{p_2^*} [h_2(p_1^o,p_2,\alpha_1^1,\alpha_2^1) - h_2(p_1^o,p_2,\alpha_1^o,\alpha_2^o)]dp_2 + \int_{p_1^o}^{p_1^*} [h_1(p_1,p_2^o,\alpha_1^1,\alpha_2^1) - h_1(p_1,p_2^o,\alpha_1^o,\alpha_2^o)]dp_1 \right\}$$

By integrating this expression for b^o, we have

$$\begin{aligned} b^o = \{ & C(p_1^o,p_2^*,\alpha^1) - C(p^o,\alpha^1) \\ & - C(p_1^o,p_2^*,\alpha^o) + C(p^o,\alpha^o) \\ & + C(p_1^*,p_2^o,\alpha^1) - C(p^o,\alpha^1) \\ & - C(p_1^*,p_2^o,\alpha^o) + C(p^o,\alpha^o) \} \end{aligned}$$

The second and fourth terms are b (see expression (2)), so b^0 is

$$b^{o} = b + \Big\{C(p_1^{o},p_2^{*},\alpha^{1}) - C(p_1^{o},p_2^{*},\alpha^{o}) - C(p^{o},\alpha^{1})$$

$$+ \; C(p_1^{*},p_2^{o},\alpha^{1}) - C(p_1^{*},p_2^{o},\alpha^{o}) + C(p^{o},\alpha^{o}) \Big\}$$

$$= b + \Big\{C(p_1^{o},p_2^{*},\alpha^{1}) - C(p_1^{o},p_2^{*},\alpha^{o})$$

$$+ \; C(p_1^{*},p_2^{o},\alpha^{1}) - C(p_1^{*},p_2^{o},\alpha^{1}) + b\Big\}$$

$$= b - \{a - b\}$$

where $a = - \Big\{C(p_1^{o},p_2^{*},\alpha^{1}) - C(p_1^{o},p_2^{*},\alpha^{o})$

$$+ \; C(p_1^{*},p_2^{o},\alpha^{1}) - C(p_1^{*},p_2^{o},\alpha^{o})\Big\}.$$

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