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ASSESSMENT OF DAMAGES BY PCB CONTAMINATION TO NEW BEDFORD HARBOR AMENITIES USING RESIDENTIAL PROPERTY VALUES

Prepared for:

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National Oceanic and Atmospheric Administration
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Rockville, Maryland 20852

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I. EXECUTIVE SUMMARY

In this analysis, the effect of PCB contamination on the value of amenities provided by New Bedford harbor is tested using a repeat sale study of residential housing values. The repeat sale approach examines how residential property values near a resource change when it becomes polluted by comparing houses which have sold repeatedly. The reduction in residential property values reflects the reduced value of the harbor amenity and serves as a measure of the resulting economic loss to society.

The repeat sale study suggests that PCB contamination in the harbor has statistically significantly reduced housing values there. In the most polluted areas, PCB Zone I, the adjusted value of nearby houses averages $5500 or 9.5 percent less than equivalent homes near cleaner waters. In PCB Zone II, the adjusted prices of repeat sales averages $6400 per house or 15 percent less than equivalent homes near cleaner water. Examination of different functional forms, different controls for inflation and interest, and multiple specifications suggests these results are robust.

Calculating total damages from these figures yields estimates ranging from $27.3 to $39.7 million. Over two thirds of these damages occur in the outer harbor compared to one third in the more polluted inner harbor. The relative share of the damages are higher in the outer harbor partly because there are more affected homeowners near the outer harbor and partly because the

losses per household appear to be slightly higher outside the hurricane barrier. The value that renters, visitors, and homeowners in multifamily neighborhoods may place on the reduced amenities are not counted in these estimates. The omission of the damages to these other parties makes the estimates of this report inherently conservative.

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I. INTRODUCTION

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The purpose of this analysis is to measure the economic value of the loss of amenities in New Bedford Harbor as the result of polychlorinated biphenyls (PCBs). The harbor, as a public resource, is not sold in a market place and so has no market price. Thus, we cannot use market prices for harbors to show how much the value of the harbor has declined. However, it is possible to use market prices of nearby residential homes to measure the value of the harbor to residents because the sales prices of these houses can reflect the value of proximity to the harbor. Thus, if the harbor is valuable, otherwise similar homes close to the harbor will be worth more than homes further away. By carefully controlling for differences between homes, we can isolate the individual contribution of PCB contamination to the value of residences. If the PCB contamination truly affects residential property values, then homes close to the contamination will fall in value once the pollution occurs compared to homes further away. By measuring how the market values for residential properties near the harbor changed once the PCBs were discovered, we can estimate a value of the PCB damage from repeat sales of properties.

A harbor is a resource which economists call a "public good", a service or output which more than one person can consume at a time. Other familiar examples of public goods include parks, clean air, and national defense. Large numbers of consumers can enjoy the benefits of a public good without interfering with each other. Because a public good is jointly consumed, the value of

a public good is the sum of what all the consumers of the good are willing to pay. For example, if Mr. Smith will pay $5, Mrs. Jones will pay $3, and Mr. Kine will spend $6 to catch fish in the harbor, the total value of the harbor would be the sum of the values of the three users (5+3+6= $14). Thus, the use value of the New Bedford harbor to society, is the sum of the values that each individual user would place on harbor use. Similarly, if pollution reduces the value of the harbor, the damage is the sum of the reduced harbor values to all the users.

In this analysis, we measure the magnitude of the value of the damage from the PCB contamination to nearby residential owners living in single family neighborhoods. That is, we measure the losses felt by only a portion of the people who live nearby the harbor. In addition to the people in this study (homeowners in single family neighborhoods), there are many people living nearby who are not included in this study. For example, all nearby renters and selected homeowners who live in predominantly rental multifamily neighborhoods are not counted. People who live further away but occasionally visit the New Bedford harbor area are also excluded from the sample. We exclude all these people from the study because their values would be difficult to quantify using the repeat sale methodology. Nonetheless, it seems reasonable to expect that whatever results we find for our sample reflect impacts felt by these other groups as well. These additional potential losses to renters, visitors, and excluded homeowners, however, are not counted in this study.

In addition to the use values measured in this study, some resource economists also argue that there are important nonuse values to a natural resource such as existence, bequest, and option values. These nonuse values reflect the concerns of citizens who care deeply that natural resources are preserved for their own sake, for future human generations, and for future uncertain times. Unfortunately, because these nonuse values do not imply observable behavior on the part of the concerned citizens, these values are difficult to quantify or detect. We make no attempt to quantify or include nonuse values in this analysis.

Although the residential property values of all the towns surrounding New Bedford City may have been impacted by the contamination, we restrict ourselves to the towns which border the harbor. Prudence and available time and budget constraints have limited the study to three towns: New Bedford, Dartmouth, and Fairhaven. Based on information from sampling and the results of this study, limiting the analysis to these three towns has not biased the results. That is, we have no evidence to suggest the contamination is affecting the residential values of shoreline towns further away from the harbor than Fairhaven or Dartmouth or towns further in the interior

In this study, we develop a *repeat sale methodology* to measure PCB pollution damages. Residential properties which sold more than once over the last sixteen years are compared. Pairs of sales for properties near the polluted harbor which have

sold before and after the pollution became well known are compared against other properties. We then test whether the PCB pollution affected the change in value of the properties near the pollution.

An alternative approach in the literature is the hedonic method. With the hedonic method, one takes a cross section of houses and tries to explain the variation in house prices by the characteristics of each house. By including measures of pollution, one can test whether the pollution contributed to the spatial price pattern of market sales. Unfortunately, it is difficult to know whether the pollution or some other spatially correlated variable may be causing the observed spatial price effect. To extend the power of the hedonic model, one could perform an hedonic regression both before and after the pollution event. This latter test resembles the repeat sale analysis. The difference between the methods, however, is that the hedonic test tries to control for house characteristics with a statistical model whereas the repeat sale test controls for house characteristics by carefully sampling paired observations. The repeat sale method, by more carefully controlling for the differences in housing characteristics, is a more fine tuned experimental instrument than the hedonic method for measuring this kind of intertemporal phenomenon. We consequently rely solely on the repeat sale approach in this analysis.

Inflation and changing interest rates have a large effect on real estate prices. In any intertemporal housing analysis, one

must adjust for these factors. In this study, we rely upon the GNP residential non-farm price deflator to control for inflation in housing prices. To control for interest rate effects, we rely upon the New Bedford Institution of Savings June mortgage interest rates. Because these indices may not control for interest and inflation perfectly, we also explore alternative price deflators and mortgage interest rates.

Examining the change in real values across our sample between sales, reveals that real housing prices have increased over the period of the sample by about 5% or almost $1900. This upward trend obviously does not imply, by itself, any adverse impacts from pollution. However, comparing the market sales of owner occupied units in our sample from the New Bedford harbor area with homes in all of Massachusetts, we find that New Bedford homes have fallen behind the state average by an average $3600 or 2.5% between paired sales. If this relative effect were characteristic of all owner occupied housing in the entire New Bedford region, it would represent a relative reduction of about $96,800,000 ($3600 * 26,875 units) in property values.

These aggregate figures can be suggestive but they are not strong evidence for the presence or absence of a pollution effect. It is not possible to attribute either the real increase or the relative decrease in the aggregate market value of owner occupied homes in the New Bedford region, just to PCB pollution. There are other reasons why the average level of homes in the New Bedford area have increased in real value or fallen in relative value over this time period. For example, both interest rates

and regional growth rates are important factors which have changed dramatically over this time period. These changing background events indicate that aggregate averages simply will not be able to provide reliable indications of the true effect of the PCB contamination on residential property values. In order to associate a loss in residential property values specifically to the PCB contamination of the harbor, we must find more direct evidence that the PCBs contribute to a decline. Specifically, we must determine if there is a decline in house values associated with the time the PCBs became widely known and if the decline is more evident in houses which are closer to the PCB pollution. Only this relative comparison between paired sales in the sample will provide strong evidence for the presence or absence of a pollution effect.

In the next section , we describe the methodology of the repeat sale approach. The results of the analysis are then shown and discussed in Section IV. The pollution results are summarized in Section V and the resulting damage estimates are computed.

III. REPEAT SALE METHODOLOGY

In this study, we intend to use the reduction in market value of homes near the PCB contamination of the harbor as a measure of the reduced value of harbor amenities due to pollution. The basic logic behind this approach is quite simple. Homes are more

valuable when they are located near public resources which people value positively (see Freeman [1979a]). If the value of the resource drops for some exogenous reason such as pollution, the value of being near it will also drop. Thus, one can measure the reduction in the use value of the resource through the reduction in the property values of nearby residences.

The repeat sales approach was first suggested in the writing of Robert Lind [1974]. Lind noted that if there were enough buyers of every type, the value of a change in the environment would be reflected in the change in property values of directly affected properties. Thus, for example, if pollution in a harbor diminished the value of access to that harbor, the value of this change would be reflected in the reduction in property values of homes near the water resource. Given Lind's condition of sufficient buyers, the total value of the harbor pollution would be reflected in the reduction of property values of the homes near the harbor. Similarly, if the polluted harbor were restored, the model would predict that housing values near the harbor would increase by the value of the restoration.

One topic which received a lot of subsequent attention in the literature was the stringency of Lind's requirement of sufficient buyers. Polinsky and Rubinfeld [1977] and Polinsky and Shavell [1975, 1976] wrote a series of articles discussing the implications of whether or not there were many alternative buyers. The conclusion of this literature largely supports Lind. When there are enough potential buyers (the so-called "open city"), the value of the resource is reflected in the change in

property values of the affected properties. However, when the number of buyers are limited (the "closed city"), the change in value of the affected properties is not an adequate measure of the resource change. In the closed city case, an environmental improvement would be underestimated by the change in property values. Similarly, a decrease in environmental quality would be worth more than the reduction in property values would suggest if there were insufficient buyers. Thus, to the extent that the open city assumption is questionable, the change in property value approach is inherently a conservative measure of public resource contamination.

The repeat property sale approach suggests that if a harbor is damaged, the value of that damage will be reflected in the change in residential value of units nearby the harbor. If residents obtain less utility from using the harbor once harbor contamination occurs, the residents will pay less for access once they are aware of the contamination. This reduction in access value will then be visible in the pattern of residential property values. Properties will fall in value once knowledge of the contamination becomes public. Properties nearer the damaged resource will fall in value more than properties further away. The fall in private residential property values thus provides a careful monetary measure of the reduction in value of the public resource.

To measure changes in property values over time, we use repeat sales, the market values of homes which have sold more

than once. Repeat sales are important in this context because using the same house to measure values before and after the pollution event controls for the myriad of housing characteristics which differ from house to house. If different houses are being compared, it is always possible that the differences of the other housing characteristics may be causing the change in property values. To make sure that the houses are in fact the same, it is important to control for any physical change in the houses over the period of comparison.

Another issue of importance is how to define the pollution event. Housing values will only reflect housing characteristics which home buyers are aware of. Thus, if the PCBs were in the harbor but nobody knew they were there, the housing values would not reflect their presence. PCB contamination in sediments is in fact difficult for the typical home-owner to detect. Thus, it is likely that home-owners were not aware of the PCBs until they were discovered and publicized. The effect of PCBs on residential market prices is only expected once the contamination of the harbor became widely known. Thus the pollution event for the housing market was not the date that the physical contamination occurred but rather the date when the contamination became widespread public knowledge.

The exact date that the public became fully informed of the PCB contamination in the New Bedford harbor is difficult to determine. The physical release of PCBs probably occurred over a long time period. The initial discovery of PCBs in the harbor came in 1976. However, the understanding that the PCB problem

was serious enough to affect the use of the harbor may not have been apparent to the public until September, 1979 when the Massachusetts Department of Public Health restricted use of parts of the harbor area specifically because of PCB contamination. Further public debate about health risks and cleanup probably increased awareness through 1980 and 1981. It seems reasonable to assume that widespread knowledge of the contamination of the harbor did not occur until late in 1979. However, the exact date which marks the beginning of widespread public knowledge is not clear. We consequently explore different pollution event dates for the repeat sale analysis to test the sensitivity of the results to the pollution event date. If the effect is due to PCBs, we should expect the pollution effect to diminish as the event date moves away from the late 1979-1980 period.

If PCBs are the cause of any reduction in property values, property values after the event should be depressed compared to sales values before the event. Thus, if we have a myriad of real estate repeat sales, those pairs of sales before and after the event should reflect the PCB effect. Any changes in prices in pairs of sales which happened entirely before the event and or entirely after the event, presumably reflect other factors or trends. Thus, one clue concerning the cause of property value changes lies in the timing of changes. The PCB effect is expected to be strongest in the pairs which straddle the event, one sale before and sale one after the event. In order to capture this effect, we mark all pairs which straddle the

pollution event with a dummy variable called EVENT. EVENT measures the change in property values of pairs which straddle the pollution event compared to all the other pairs which do not.

We explore two spatial measures of pollution in the analysis: PCB regulatory zones (PCBZONEI,PCBZONEII) and proximity to an inner harbor site with high PCB measures (PROXHOT). The regulatory zones, PCBZONEI and PCBZONEII, were established in September, 1979 by the Massachusetts Department of Public Health to protect the public health from PCB exposure. These zones restrict the fishing and other activities which can occur in each area. PCBZONEI, which corresponds to the inner harbor, is the most restrictive zone, excluding swimming, lobstering, and all fishing. PCBZONEII, which extends from the hurricane barrier out approximately four miles, is less restrictive prohibiting just lobstering and bottom fishing. PCBZONEIII contains the lowest traces of PCB contamination within the restricted area. Only lobster fishing is prohibited in PCBZONEIII. PCBZONEIV is the outer area of the New Bedford harbor stretching into Buzzard's Bay which has no PCB contamination. The regulatory zone measures are attractive proxies for pollution because they are well known having been publicly announced. Several places in PCBZONEI are also posted. The zones are also helpful because they demarcate the boundaries of lost use and they establish a specific moment of public awareness.

The proximity (PROXHOT) measure to the "PCB hot spot" represents a crude proxy for the concentration of PCBs. The hot spot, in this case, is the location in the upper inner harbor

where unusually high PCB concentrations were found. The underlying assumption of this measure is that users believe that the highest PCB concentrations center in the upper inner harbor and that they fall as one gets further from this area. Actual measures of PCB sediment concentrations may not precisely follow this distance gradient, but they clearly do tend to decline with distance from the upper inner harbor. Thus, a citizen unfamiliar with a precise map of sediment concentrations, might use proximity to the upper inner harbor as a rough measure of his pollution exposure. The proximity measure is the inverse of the distance in miles from the hot spot. Because it is an inverse, it has a nonlinear quality suggesting that as one approaches the hot spot the pollution levels rise more quickly. For example, a user going from two miles to one mile from the hot spot would experience a lot more additional pollution than one going from ten miles to nine miles.

Combining our concern that the pollution effect be found in more polluted zones and that the effect be evident only when the pollution became widely known, we use an interaction variable to measure the pollution effect. The interaction variable is the product of a timing variable and a spatial variable. The timing variable, the pollution event, measures only effects which occur before versus after the pollution event. The spatial effect, the PCB Zones, measures only effects on houses closer to the PCB pollution problem. By using the product of the two variables as our pollution variable, we measure only pollution effects which have both the expected spatial and timing effect of

the PCBs.

In this analysis, we explore only homes which have sold more than once in the market. We use repeat sales in order to control for the many other characteristics of houses that affect market value. Even with repeat sales, however, housing characteristics can change because people make physical changes in their homes. Since the time frame we are exploring stretches in some cases as long as fifteen years, this is sufficient time for significant changes to occur. Further, it is clear from inspection of the Fairhaven records, that home improvements are more likely to occur just before and just after sales. It is therefore important to control for housing improvements in repeat sale analyses.

In order to measure the effect of harbor contamination on property values, a formal model of the relationship between property values and the public resource must be specified. Theory does not give us a precise prescription for the appropriate functional form to use to measure the relationship between housing prices and housing characteristics. Technically, there are an infinite number of functional forms which could be explored for this analysis. Halvorsen and Pollakowski [1981] recommend using flexible functional forms so that the data determine the functional form. Cassel and Mendelsohn [1985], however, point out some of the practical difficulties with this general strategy especially for purposes such as measuring the value of a specific characteristic.

Instead of using a flexible functional form in this study, we explore two popular functional forms: linear and semilog equations. These forms are familiar in that many analyses of housing characteristics use one of these forms. Secondly, each of these functional forms conforms to a simple intuition about the relationship between a public resource and nearby properties. The linear model assumes that the value of access is simply something that can be added to a property. The value of access, in this model, would be the same whether the rest of the house was worth $40,000 or $80,000. In the semilog model, the value of access is assumed to be proportional to the value of the home. That is, access to the public resource increases the value of the home by some proportion. In this case, the absolute value of access would be twice as high for the $80,000 house compared to the $40,000 house.

With the linear model, we are assuming that the value of a house is a linear function of its characteristics:

$$(1) \qquad V = a_0 + a_1 z_1 + a_2 z_2 + \ldots + a_n z_n ,$$

where V is the sales value of the home, z_i is the ith characteristic of the home, and a_i is the ith estimated coefficient of the model. The change in market value of the house with a change in the level of characteristics is a constant in the linear model. That is, the marginal value (p_i) of each characteristic z_i is a_i. Changes in property values can be

measured by comparing sales in one time period compared to another. Thus, if we compare V_0 to v_1, we would expect that the change in sales values to be:

$$(2) \qquad V_1 - V_0 = a_1 (x_{11} - x_{10}) + \ldots + a_n (x_{n1} - x_{n0}) \quad ,$$

where the subscript on x_{ij} refers to characteristic i and time j. The coefficients, a_i, are assumed to be the same in the above equation before and after the event. If the characteristics are the same in both time periods, the effect of the characteristic cancels out in this model. Only variables which change across time periods will have non-zero coefficients in the change model. The change in property value approach is consequently ideal for situations where pollution levels noticeably change over time. Only the pollution variables and other changing factors belong in the equation. With the linear model, the pollution effect is assumed to be independent of the magnitude of other changes and the initial value of the home.

The semilog model has the following form:

$$(3) \qquad \log (V) = a_0 + a_1 z_1 + a_2 z_2 + \ldots + a_n z_n \quad ,$$

where log(V) refers to the natural logarithm of market sales value and all other variables are the same as in equation (1). Looking across houses in the market, the marginal price for each characteristic z_i is proportional to the value of the house in the semilog equation:

$$p_i = a_i V \quad .$$

Changes in property values should now fit the following form:

$$(4) \qquad \log (V_1/V_0) = a_1(z_{11} - z_{10}) + \ldots + a_n(z_{n1} - z_{n0}) \quad .$$

As with the linear model, we assume that the coefficients remain unchanged in the model. If a characteristic is unchanged, then it cancels out in this model. Only variables which change between time periods belong in this empirical model. Note that the effect of a reduction in an amenity is assumed to be proportional to the value of the house in equation (4).

IV. DATA

The properties included in this analysis represent a sample of single family homes in Fairhaven, Dartmouth, and New Bedford which sold at least twice since 1969. Properties which were used for commercial or multifamily uses were excluded. Empty lots were excluded from the analysis because repeat sales on such lots tended to involve the building of a house between sales. Sales which were between family members, associated with foreclosures, or for the amount of $1 were all excluded on the grounds that they did not represent arms-length transactions. All pairs of sales which were closer than 60 days were also dropped. Although many of these sales were for the same price and thus may reflect true market transactions, some properties changed in market value dramatically in a very short time implying that at least one sale was probably not arms-length. Sales of porperties which were subdivided were also dropped from

further analysis because it is difficult to determine the value of each of the original pieces of property. Independently, Mr. Mr. McLaughlin, representing Belleville, also reviewed the record of property sales. In a communication with the court, Mr. McLaughlin identified some 70 properties which he felt violated the above requirements. Of these, approximately 20 were originally in our sample. Just to be certain that the sample includes only valid sales, we exclude these additional 20 properties from the study as well.

The value of properties is measured using actual market sales data. Data on all properties with a sale reported on the Fairhaven assessor's tape were collected for the initial sample. Because only sales in the last five years were coded onto the tape, the sample includes almost all sales after 1980 but only a fraction of sales before 1980. Additional properties which sold between 1969 and 1979 were also obtained from Fairhaven in order to test for the importance of balancing the sample. This latter set were collected randomly by the first letter of the street address. For all properties, we collected information about the history of sales. That is, records from the Fairhaven assessor's office and the Bristol County Record of Deeds were examined to get a complete history from 1969 to 1985 of market sales. Similar data were collected for the towns of Dartmouth and New Bedford. A sample of these sales was then checked using the Property Sales Report to State Tax Commission for the State of Massachusetts. Except for one property whose sale value was rounded to the nearest thousand dollars, the sales values and

dates corresponded perfectly.

The repeat sale data set includes all single family, owner-occupied properties located in single family neighborhoods. The total number of repeat sales which we examined which sold more than once and which had complete data is 1030. The required data includes a complete address, dates of sales, and amounts of sales. Over half of the properties with a sale after 1980 had been sold at least once before in the 1969-85 time period. In addition, for many of the properties, we also have information about the physical characteristics of the dwelling.

Most of the properties with repeat sales include only a single pair of sales (57%). Many properties thus involve more than one pair (43%) and a few properties have more than three sales (15%). Properties which sold more than twice result in multiple adjacent pairs. For example, a property which sold three times, say in 1970, 1979, and 1984 was viewed as having two pairs of sales. One pair would be the comparison of market values between 1970 and 1979. The other pair would be a comparison of sales between 1979 to 1984. The fraction of the sample (43%) which had more than two sales thus accounted for 60% of the final pairs.

One important issue in the design of the data collection concerns the scope of the geographic zone to include in the study. In particular, it was important to determine how far inland the value of access to the water extended. Because of the joint consumptive nature of public resources, the total value of

the resource is the sum of what all users would pay for access to the site. Thus, if we limited our inquiry too sharply, we could underestimate the value of the resource and the damage caused by any decline in resource value. Luckily, extending the scope of the analysis too far will not bias the results upward because the distant properties mistakenly included in the data set should have no expected effect. Extending the scope of the boundaries of the analysis too far, however, may reduce the reliability of the results by introducing properties which are inherently different from shoreline properties. Thus, if the geographic scope is extended too far inland, it may reduce our ability to discern the effect of the pollution on the properties which are truly affected.

Previous studies of the value of water quality suggest that properties as far as 4000 feet away may be affected by the proximity to the resource (see Brown and Pollakowski [1977], Dornbusch and Barragher [1973]). Brashares [1985], however, found that the value of homes as far away as three or four miles were affected by the water quality of public lakes. It would appear that the distance from which the use value of a public water body is no longer reflected in residential property values depends upon the data set and the overall value of the relevant water body.

Analyzing post-1980 property values in Fairhaven and Dartmouth, reveals that housing prices decline with distance from shore. That is, the distribution of residential prices with

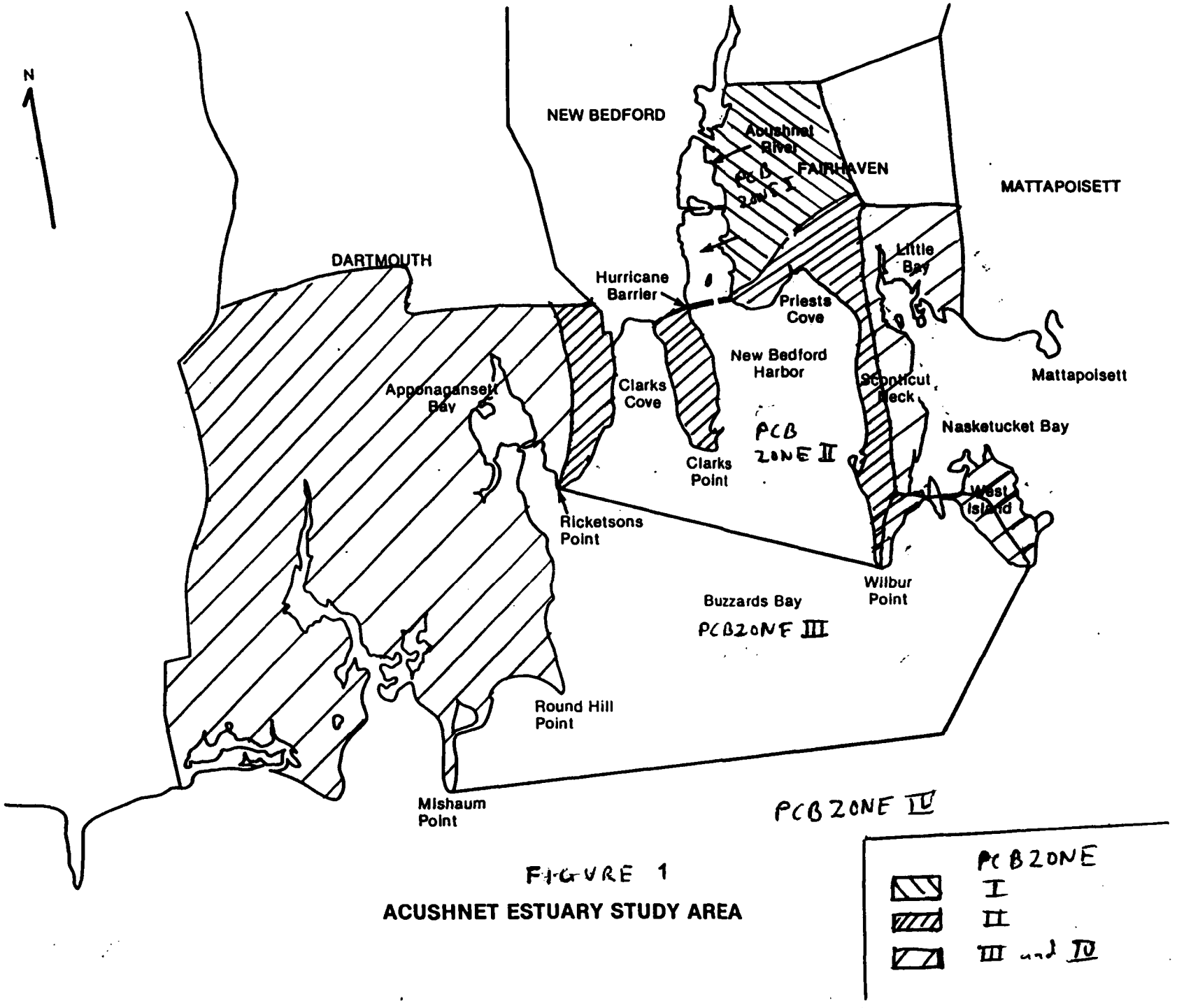

FIGURE 1

ACUSHNET ESTUARY STUDY AREA

respect to distance from the shore suggests that proximity to the shoreline is positively valued. This relationship becomes less clear beyond two miles from the water. Thus, we limit our analysis to properties within two miles of the shoreline. Accordingly, we limit our damage estimates to properties within two miles of the relevant shoreline.

Altogether, we have 652 pairs of sales from Fairhaven, 389 from Dartmouth, and 189 from New Bedford. The total size of the sample is 1230 pairs of sales. One reason that we have more observations for Fairhaven than any other city is that there are more owner occupied homes in single family neighborhoods near the water in Fairhaven than in the other towns. The geography and spatial distribution of Fairhaven homes is such that a high proportion of the town is close to the shoreline. The additional observations collected to increase the proportion of pre 1980 sales were all collected in Fairhaven. This too has contributed to the higher sample size in Fairhaven than the other towns. We do not expect that the method of sample collection has biased our results because all pollution zones are represented in the Fairhaven data. Thus, with respect to the critical pollution effects, the sampling method has been essentially random.

In this analysis, we measure changes in housing characteristics using data from building permits. From each town, we collected data from the town building department on each of our repeat sale properties. The building permit identified the location of the building, the type of improvement, the date, and the nominal value of the improvement. The real value of the

improvement was computed by dividing the recorded nominal value of each improvement by the residential GNP deflator. We include the real value of all improvements, IMPROVE, which occurred between sales as an independent variable in the analysis.

V. REPEAT SALE RESULTS

In this section, we describe the results of completing several multiple regressions following the format described in the previous section. In Table 1, we list the variables used in the analysis along with their means, standard deviation, and definition.

We present regression results for two functional forms. The linear housing model results in a multiple regression equation with DIFFERENCE, the difference in prices between pairs of sales, as the dependent variable. The semilog model results in a multiple regression with LOGRATIO, the log of the ratio of later divided by earlier prices, as the dependent variable.

In order to control for inflation, we adjust all nominal prices using the GNP non-farm residential deflator. Thus, unless otherwise stated, all prices are measured in real terms and the deflator is the GNP non-farm residential index.

In order to control for changes in interest rates, the difference in the interest rates (INTEREST), from the earlier to the later sale, is included as an independent variable. We use

TABLE 1

VARIABLES USED IN THE REPEAT PROPERTY SALE ANALYSIS

NAME	MEAN	STANDARD DEVIATION
DEFINITION		
DARTMOUTH	.34	.47
Dummy (1,0) for whether the property is located in Dartmouth.		
DIFFERMASS	-4352	21000
Later market sale minus earlier market sale in dollars using Massachusetts price deflator.		
DIFFERENCE	1030	16600
Later market sale minus earlier market sale in dollars using the GNP residential non-farm price deflator.		
EVENT	.28	.45
Dummy (1,0) for whether earlier and later sale bracket 1980 not including sales occurring in 1980. Intended to measure whether timing is consistent with pollution effect.		
EVPCBZONE1	.06	.24
Dummy (1,0) for whether sale brackets 1980 and also has its nearest water in PCB Zone I. It is the product of EVENT times PCBZONE1.		
EVPCBZONE2	.08	.27
Dummy (1,0) for whether sale brackets 1980 and also has its nearest water in PCB Zone II. It is the product of EVENT times PCBZONE2.		
EVPROXPCB	.11	.31
Product of PROXPCB and EVENT. Attempts to capture both the timing and spatial component of the PCB pollution damage.		
EVPROXSHOR	1.84	7.01
Product of PROXSHOR and EVENT. Reflects the change in the distance gradient with respect to the shoreline associated with the timing of PCBs.		
HIGHSCHOOL	2.43	2.74
The change in the percent in the Census tract of adults who completed high school measured between 1970 and 1980 weighted by the length of sale.		
IMPROVE	.529	2.86
Value in thousands of dollars of improvements measured in real 1985 dollars between first and second sale.		

INCOME -1691 1352

The change in the median family income in the Census tract measured in real 1985 dollars measured between 1970 and 1980 weighted by the length of sale.

INTEREST 2.32 3.25

The difference in annual effective mortgage interest rates between sales. The rates reflect mortgages on conventional existing homes offered in June each year by the New Bedford Institution of Savings. A value for 1982 was interpolated using national mortgage interest rates.

INTERESTNAT 1.88 2.46

The difference in annual effective mortgage interest rates between sales. The rates reflect the national average mortgage rate on conventional existing homes reported by the National Home Loan Bank Board.

LENGTH1 1.19 2.52

Time, in years, between first and second sale times PCBZONE1, a dummy for whether the property is in PCB Zone I. Average length between sales in PCB Zone I is 4.37 years.

LENGTH2 1.18 2.55

Time, in years, between first and second sale times PCBZONE2, a dummy for whether the property is in PCB Zone II. Average length between sales in PCB Zone II is 4.48 years.

LENGTH3-4 1.94 2.91

Time, in years, between first and second sale times PCBZONE3-4, a dummy for whether the property is in PCB Zone III or PCB Zone IV. Average length between sales in PCB Zones III and IV is 4.18 years.

LOGRATMASS -.038 .29

The log of the ratio of second divided by first sales in pair using adjusted prices deflated by the Massachusetts index.

LOGRATGNP .028 .31

The log of the ratio of second divided by first sales in pair using real prices deflated with the GNP residential deflator.

OWNER 1.21 2.67

Change in the percent of owner occupied dwellings in a Census tract between 1970 and 1980 weighted by the length of sale.

PCBZONE1 .27 .45

Dummy (1,0) for properties whose nearest water lies inside PCB Zone I.

PCBZONE2 .26 .44

Dummy (1,0) for properties whose nearest water lies inside PCB Zone II.

PCBZONE3-4 .47 .49

Dummy (1,0) for properties whose nearest water lies inside PCB Zone III or PCB Zone IV.

PROXPCB .41 .50

Inverse of distance in miles between nearest water and location near Aerovox plant where high PCB concentrations found in sediment.

PROXSHORE 6.1 10.73

Inverse of distance in miles between residence and nearest water using closest roads measured from town maps. The mean value of distance from the shore was .47 miles.

UNEMPLOY .84 1.17

Change in the unemployment rate in a Census tract between 1970 and 1980 weighted by the length of sale.

the June mortgage interest rate of the New Bedford Institution of Savings to represent annual interest rates. In order to test the robustness of this indicator, we also try using the annual national single family conventional existing mortgage rate published by the Federal Home Loan Bank. Although we settle on using the difference in interest rates as the explanatory variable for interest rate changes, we did try the ratio of interest rates as well but found the ratio less effective than the difference in explaining residential price changes. In order to control for physical changes in the residence, we include IMPROVE as an independent variable in the equation. IMPROVE is the cost of the recorded improvement.

In order to control for underlying trends in housing sale prices by area, we introduce a measure of the time between sales. Housing prices could be trending in neighborhoods for many reasons including depreciation (-), regional growth (+), homeownership tenure (+), and demographic changes (-/+). Because each of the pollution zone areas may have a different underlying trend, we include a separate length measure for each: LENGTH1, LENGTH2, AND LENGTH3-4 to capture the influence of trends in PCB Zone I, II, and III-IV.

Finally, to control for effects which just happened to be correlated with 1980, we use a dummy variable EVENT. Thus the net effect of all sales which happened before and after 1980 (whether in the polluted zone or not) is reflected in this term.

In order to control for explicit changes in the quality

of neighborhoods over the study period, we include some objective measures of neighborhoods gathered from Census tract information. Since the issue in the analysis is changes in neighborhood quality, the study focuses upon changes in the levels of these variables measured in 1970 and again in 1980. Unfortunately, the data, especially for just single family neighborhoods, span only a few Census tracts. Further, the tract variables tended to be correlated with one another. These two factors limit the number of neighborhood change variables which could be included in the regression. In experiments with various measures, we found that the percent of adults graduating from high school to be the most consistent neighborhood change indicator. The precise variable included in the regression is the change in the percent of adults who graduated high school between 1970 and 1980 for the Census tract. Changes in median income, percent owner occupied, percent single family, and percent unemployed were all explored but found to be insignificant or the wrong sign.

The coefficients which measure pollution effects in this study are the interaction terms between EVENT and the pollution zones PCB Zone I and PCB Zone II. These interaction terms, EVPCBZONE1 and EVPCBZONE2, have both the timing and the spatial features to be pure PCB effects. As our measure of the pollution effect, we compare properties which are close to the PCB pollution and which sold before and after the pollution became known against all other sales. In addition to these interaction terms, we also explore another measure of pollution, EVPROXPCB, which is the interaction term between EVENT and the proximity to

the PCB hot spot, PROXPCB.

We begin by displaying the regressions for predominantly single family neighborhoods. This area includes Dartmouth, Fairhaven, and the peninsula of New Bedford. Several regressions were explored with different specifications. Upon dropping independent variables which were insignificantly different from zero, we arrived at the parsimonious regressions in Tables 2 and 3. These results encompass two pollution measures and two functional forms (difference and logratio).

As can be seen in Table 2, the coefficients of the independent variables have their expected sign and are generally significantly different from zero. For example, IMPROVE has a positive coefficient and is very significant. The size of the coefficient suggests that housing value increases about 2.1% or about $1080 for every thousand dollars spent on improvements. INTEREST is negative and highly significant as expected. When nominal mortgage interest rates rise, the real price of houses fall. This reflects in part a positive association between the nominal rate and the real rate of interest. It also may reflect bureaucratic liquidity constraints as banks fail to adjust their residential qualification requirements with higher interest rates. Thus, fewer buyers qualify for any given house as the interest rates rise thus depressing home values.

LENGTH1 and LENGTH3-4 are negative and statistically significant suggesting that houses in each of these zones have had a negative downward trend in prices over the study period.

TABLE 2

REPEAT SALE MULTIPLE REGRESSION[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM: VARIABLE	LOGRATIO	LINEAR
CONSTANT	.089 (6.41)	4470 (6.12)
IMPROVE	.021 (6.85)	1076 (6.68)
INTEREST	-.041 (10.38)	-2711 (13.18)
LENGTH1	-.027 (4.73)	-1024 (3.49)
LENGTH3-4	-.019 (4.13)	- 839 (3.55)
EVENT	.252 (6.90)	16900 (8.90)
EVPCBZONE1	-.103 (1.85)	-5616 (1.94)
EVPCBZONE2	-.150 (2.98)	-6338 (2.43)
HIGHSCHOOL	.015 (3.41)	490 (2.12)
ADJ R^2	.177	.218
$ERROR^2$	81.72	2.210×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

LENGTH2 was tried in alternative regressions but found to be near zero and so was dropped. The zero coefficient on LENGTH2 implies that sales of houses in PCB Zone II have no observable long run trend in real prices over the study period.

HIGHSCHOOL has a positive significant coefficient suggesting that houses in Census tracts which had increasing fractions of highschool graduates increased in value. Because many of the Census variables are highly correlated with each other, one should not interpret the HIGHSCHOOL coefficient too literally. It probably is acting as a proxy for a general increase in socioeconomic status for a neighborhood. EVENT is significant and positive suggesting that there was an overall increase in real prices for homes which sold before and after 1980 in the New Bedford region. Part of the explanation for this phenomenon is the broad boom in housing prices in the Northeast and especially in the Boston metropolitan area at this time.

The pollution terms, EVPCBZONE1 and EVPCBZONE2, are negative and significant in both regressions. Relative to the price increases in the New Bedford shoreline region, real housing prices in PCB Zone I and PCB Zone II fell after 1980. The size of the coefficients suggest a loss in housing value of 10.3% or $5600 per house in PCB Zone I and 15.0% or $6300 per house in PCB Zone II.

In Table 3, EVPROXPCB is substituted for EVPCBZONE1 and EVPCBZONE2 as the pollution measure. This substitution has little impact upon the coefficients of the other independent

TABLE 3

REPEAT SALE MULTIPLE REGRESSION[a]

POLLUTION VARIABLE: EVPROXPCB

FUNCTIONAL FORM: VARIABLE	LOGRATIO	LINEAR
CONSTANT	.082 (6.00)	4197 (5.90)
IMPROVE	.021 (6.81)	1076 (6.68)
INTEREST	-.042 (10.77)	-2765 (13.54)
LENGTH1	-.022 (4.46)	- 892 (3.47)
LENGTH3-4	-.010 (3.04)	- 495 (2.65)
EVENT	.200 (6.50)	14400 (9.03)
EVPROXPCB	-.054 (1.44)	-2320 (1.19)
HIGHSCHOOL	.012 (2.86)	375 (1.66)
ADJ R^2	.173	.216
$ERROR^2$	82.02	2.214×10^{11}

[a] There are 1027 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

variables which remain the same as in Table 2. The pollution coefficient for EVPROXPCB is negative in both regressions but not as significant as the pollution zone measures. The size of the coefficient suggests that houses one mile from the hot spot are worth 5% ($2300) less and that houses one-half mile from the hot spot are worth 10% ($4600) less compared to houses more distant from the PCB hot spot.

Earlier studies of pollution effects sometimes concentrate upon how the access gradient to the resource changes with the advent of pollution (see Dornbusch and Barragher [1972] and Feenberg and Mills [1980]). Unfortunately, these studies focus entirely upon changes in the slope of the gradient and completely ignore changes in the overall level of prices. They consequently miss the important pollution zone effects found in Table 2. In Table 4, we examine how prices of access to the water change before and after the pollution. In addition to the zone measures of pollution EVPCBZONE1 and EVPCBZONE2, we also include measures of the value of proximity to the nearest water. EVPROXSHOR measures the change in the value of being close to the shore before and after the pollution event. Of course, the value of being close to the shore is only expected to drop near the polluted waters. EVPROXSHPCB is an interaction term between EVPROXSHOR and the sum of PCBZONEI and PCBZONEII. It measures the change in the value of proximity to the shore in the two PCB polluted zones. As can be seen in Table 4, the value of EVPROXSHOR increases after the pollution event and the change is significant. The value of EVPROXSHPCB, however, falls after the pollution event. Whereas

TABLE 4

REPEAT SALE MULTIPLE REGRESSION WITH DISTANCE TO SHORE[a]

POLLUTION VARIABLE: EVPCBZONE1, EVPROXSHPCB, AND EVPCBZONE2

FUNCTIONAL FORM: VARIABLE	LOGRATIO	LINEAR
CONSTANT	.094 (6.73)	4751 (6.54)
IMPROVE	.021 (6.92)	1086 (6.80)
INTEREST	-.041 (10.53)	-2737 (13.42)
LENGTH1	-.026 (4.56)	- 953 (3.27)
LENGTH3-4	-.019 (4.22)	- 862 (3.67)
EVENT	.210 (5.47)	14260 (7.17)
EVPCBZONE1	-.065 (1.14)	-3440 (1.15)
EVPCBZONE2	-.114 (2.14)	-4296 (1.55)
EVPROXSHOR	.010 (3.30)	616 (4.04)
EVPROXSHPCB	-.009 (2.59)	-525 (3.04)
HIGHSCHOOL	.013 (3.00)	372 (1.61)
ADJ R^2	.185	.231
$ERROR^2$	80.57	2.166×10^{11}

[a] There are 1027 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

proximity to the shore is more desirable in the less polluted water, it is less desirable nearer the PCB polluted water. For example, compare a home which is one quarter mile from the shore with a home which is two miles from the water. Suppose both homes are in the polluted zone. The closer home has a proximity value of 4 and the more distance home has a proximity value of

water, the closer home fell in value by $1800 (3.5 x 525) more after the pollution event. On top of this gradient shift, there is also the pollution zone damages which in PCB Zone II is equal to another $4300 or 11%. The results in Table 4 consequently support the findings of a PCB effect of the magnitude revealed in Table 2. In addition to all homes in the PCB pollution zones dropping in value, homes in the pollution zone closer to the water dropped in value slightly more than homes further away from the water. The relative value of being close to water has dropped in PCB Zones I and II.

In order to provide a complete picture of the scope of regressions estimated, selected alternative models are displayed in Appendix A. Note that although the coefficients change across these specifications, that the overall level of damages remains about the same. In Tables A-1 and A-2, alternative Census variables are introduced in the regressions. These variables tend to be insignificant.

Table A-3 repeats the regression in Table 2 using a Massachusetts deflator. The Massachusetts deflator is based on the average sale price of single family homes in Massachusetts

from 1969 to 1985 collected by the Multiple Listing Service. These sales were then used as an index to adjust all nominal dollars. Since the statewide average sales prices adjust for inflation, regional growth, and interest rates, these factors are all controlled fby the deflator. Because this index does reflect state wide forces which may or may not be appropriate for the New Bedford region, it is not clear whether it is a superior or inferior index. However, the Massachusetts index is surely a different index from the GNP residential deflator with mortgage interest rates and in this sense is a good test of the robustness of the results with respect to the deflator method.

Examining Table A-3, most of the coefficients of the independent variables have the same sign and significance as in Table 2. The significance of interest rates has been greatly reduced but this is expected since the deflator already controls for interest rate effects. The coefficient on EVENT has changed sign and is insignificant with the Massachusetts deflator. The large boom in housing prices detected in the general New Bedford area after 1980 happened across the entire state. Relative to the rest of the state, overall prices did not increase in New Bedford after the pollution event, they actually decreased. The coefficient on EVPCBZONE1 is slightly smaller and less significant than in Table 2 but the coefficient on EVPCBZONE2 is slightly larger and more significant. A significant pollution effect is found in both models (Tables 2 and A-3). Although the distribution of damages across the two pollution zones changes slightly with the different deflator, the overall level of

damages is slightly higher in the Appendix table.

We also have information on single family homes in the multifamily part of New Bedford along the Acushnet River. Because these neighborhoods are dominated by renters in triplexes, it is not clear that our model of single family neighborhoods can explain housing prices in this area. We repeat the regressions shown earlier for single family neighborhoods including New Bedford rental neighborhoods which are near the harbor. The results are shown in Table A-4. *HIGH SCHOOL* lost significance in the regressions including rental neighborhoods. Other neighborhood Census variables also performed poorly when the rental New Bedford data is included, suggesting that the model does not fit the rental neighborhood closely. The pollution variables are also affected with EVPCBZONE1 and EVPCBZONE2 moving towards zero and becoming less significant.

Although the inclusion of the rental neighborhoods of New Bedford has the attractive feature of providing more observations, the rental neighborhood appears to be sufficiently different that it does not conform to the tendencies of the single family neighborhoods in the rest of the sample. We therefore feel that the model without the rental portion of New Bedford provides a more accurate picture of the intertemporal housing market.

Another alternative regression explored was to use national mortgage interest rates instead of those of the New Bedford Institution of Savings. Table A-5 uses the national rates

published by the Federal Home Loan Bank Board. Note that the national interest rates result in slightly larger and more significant coefficients on the interest rate variable. The pollution effects are also affected; they are slightly smaller and less significant. The local interest rates, however, are conceptually more appropriate for this analysis, since it is the local rates which are expected to affect local housing prices. Thus, the analysis focuses on using the New Bedford Institution of Savings mortgage rates over the national average.

Although we focus on the implementation of the regulatory zones by the Massachusetts Health Department as the pollution event (1980), pieces of information about the PCBs in the harbor became available across a wider time horizon beginning in 1976 and following through at least 1982. Thus, it is reasonable to ask whether or not other dates might serve as pollution events. It is also important to demonstrate that the effects which we label as pollution effects were not evident before the pollution became known. In Appendix B, we display a set of regressions with the same specification as Table 2 except the pollution event is defined as a different year in each regression. Beginning in 1974, and extending to 1983, we explore ten different years as potential pollution events.

The results of the analysis of alternative pollution event years is supportive of a PCB effect. Beginning in 1974 and carrying through to 1978, EVPCBZONE1 and EVPCBZONE2 are positive and usually significant. That is, before the PCB pollution was known (1976) and before, we would argue, the PCB pollution was

widely known (1979), the pollution measures tend not to show a pollution effect. In fact, they indicate an underlying phenomenon working in the opposite direction perhaps tempering the true magnitude of the pollution effect. In 1979, the pollution coefficients have mixed signs and are not significantly different from zero. It is only with the pollution event year reaching 1980 that one observes consistent negative signs in the pollution coefficients. The negative coefficients on EVPCBZONE1 and EVPCBZONE2 remain negative and significant after 1980. In fact, the coefficients actually become larger implying that some of the damage may have continued into later years than just 1980. Thus, it is possible that not all of the damage caused by the PCB problem was accounted for in 1980. There is suggestive evidence that the maximum impact may have occurred in 1982. However, to be conservative, we remain with the pollution event date that is closely tied with the closure of the harbor.

VI. DAMAGE ESTIMATES

In order to predict the size of damages associated with the contamination of New Bedford harbor, we extrapolate from the sample of homes examined in this study to all single family homes in Dartmouth, Fairhaven, and New Bedford. Because we found that our model was not as effective in describing the price patterns found in predominantly multifamily parts of New Bedford, we limited our damage estimates to just single family neighborhoods. There are several plausible damages, then, which are not included

in our damage calculations. First, we explicitly ignore the impact of the PCB pollution on rental properties even though two-thirds of the units in New Bedford are rental units. We count only damages to home-owners from the PCB pollution. Second, we only examine homeowners in single family neighborhoods. All the homeowners in PCB Zone I who live in New Bedford are not included in these estimates. Three, we only include residents who live within two miles of the harbor. To the extent that people from further away are affected by the PCB contamination, their losses are excluded.

Controlling for trend effects and other factors, we rely on EVPCBZONE1 and EVPCBZONE2 as measures of pollution. EVPCBZONE1 and EVPCBZONE2 require the PCB damages to be consistent with both time and space. The data support a finding of a pollution effect (see Section III). Across several specifications, houses near polluted waters dropped in value. Although several different regressions all support this finding, we settle on Table 2 to actually calculate final damages.

Because we do not know whether the linear or semilog model of housing prices is truly best, we calculate damages using both functional forms. Thus, we use both the difference and the logratio models of Table 2 to calculate damages. Houses in PCB Zone I are associated with a linear damage effect equal to about $5600 per house and a proportional effect of 10.3 percent (see Table 2). Houses in PCB Zone II are associated with a linear damage effect equal to about $6300 per house and a proportional

effect of 15 percent.

In order to estimate the damages from PCBs given that EVPCBZONE1 is the measure of pollution, we must determine the number of homes and the value of these homes near PCB Zones I and II. According to data from the 1980 US Census, there are about 1690 owner occupied dwellings in Fairhaven in the Census tracts associated with PCB Zone I (we ignore the 1420 homes found in this area in New Bedford). The corresponding figures for owner occupied homes in PCB Zone II are 1100 for Fairhaven, 830 for New Bedford, and 900 for Dartmouth. The value of these homes was computed from the sample. The average sale in Dartmouth in PCB Zone II in 1985 dollars was $81,000. In Fairhaven, the average sale was $59,000 in PCB Zone II and $78,500 in PCB Zone I. In New Bedford, the average sale price was $66,000 for PCB Zone II (and $54,000 for PCB Zone I). Note that we are only including homes from the three towns which are in the plots analyzed in this study. Thus no home is further than two miles from the nearest water and the average distance from the nearest water is about a half mile. Further, no homes in New Bedford in PCB Zone I are included in these estimates.

In the logratio model, the coefficient for EVPCBZONE1 and EVPCBZONE2 has to be transformed to reflect a percentage reduction in value. The following formula from Halvorsen and Palmquist [1980] changes the coefficient c to a measure of the percentage change effect from this dummy variable:

$$\text{percentage change} = \exp(c) - 1 \quad .$$

The percentage change in sales value from being in PCB Zone II (c=-.15) is 13.9 percent and for PCB Zone I (c=-.105), it is 9.8 percent.

With the logratio model, damages are expressed in terms of percentage drops in housing value. Multiplying the percentage reduction in value (for example, .139) times the value of relevant owner occupied housing yields total damages. With the difference model, damages are expressed in terms of dollars per house. Total damages are calculated with these figures by multiplying the per house loss by the number of houses in each area. The results are displayed in Table 5.

Total owner occupied damages are 27.3 million dollars in the difference model and 39.7 million dollars in the logratio model. Total damages tend to be higher in PCB Zone II (over two thirds of all damages) than PCB Zone I. This distribution of damages is mostly due to the predominance of single family homes in single family neighborhoods in PCB Zone II. There is also a slightly larger per house pollution effect in PCB Zone II. Despite the higher pollution in PCB Zone I, the reduction in use value is probably greater in PCB Zone II because of the more pristine original condition of PCB Zone II waters and the greater access homes enjoy to the outer harbor.

Comparing cities, half of the damages appear to be in Fairhaven. The damages are greatest in Fairhaven because of the predominance of single family homes in this town near the water.

TABLE 5

ESTIMATE OF DAMAGES IN MILLIONS OF 1985 DOLLARS FROM PCB POLLUTION

PCB ZONE	DARTMOUTH	FAIRHAVEN	NEW BEDFORD	TOTAL
REPEAT SALE DIFFERENCE MODEL: EVPCBZONE1 AND EVPCBZONE2[a]				
I	...	9.5	...	9.5
II	5.7	6.9	5.2	17.8
TOTAL	5.7	15.4	5.2	27.3
REPEAT SALE LOGRATIO MODEL: EVPCBZONE1 AND EVPCBZONE2[b]				
I	...	13.0	...	13.0
II	10.1	9.0	7.6	26.7
TOTAL	10.1	22.0	7.6	39.7

[a] The damage estimates are based on per house figures presented in Table 2. See the text for a detailed description of the calculation.

[b] The damage estimates are based on percentage reduction estimates presented in Table 2.

New Bedford, despite its much larger size, contains mostly rental homes and rental neighborhoods which are not counted in these estimates. Consequently, the New Bedford damages are the smallest of the three towns. Dartmouth has more moderate damages compared to Fairhaven because more homes in Dartmouth are more than two miles from the water or are near PCB Zones III and IV.

APPENDIX A

ALTERNATIVE SPECIFICATIONS OF THE REPEAT SALE MULTIPLE REGRESSION MODEL

TABLE A-1

ADDITIONAL CENSUS DATA[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM:	LOGRATIO	LINEAR
CONSTANT	.091 (6.12)	4537 (5.89)
IMPROVE	.021 (6.85)	1080 (6.69)
INTEREST	-.041 (10.24)	-2701 (13.03)
LENGTH1	-.027 (4.61)	-1030 (3.33)
LENGTH3-4	-.021 (3.93)	-879 (3.21)
EVENT	.253 (6.93)	16960 (8.91)
EVPCBZONE1	-.104 (1.86)	-5676 (1.96)
EVPCBZONE2	-.159 (3.01)	-6491 (2.37)
HIGHSCHOOL	.014 (3.04)	490 (1.96)
INCOME	.001 (0.15)	137 (0.26)
UNEMPLOY	.009 (0.94)	268 (0.54)
ADJ R^2	.176	.217
ERROR^2	81.64	2.209×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

TABLE A-2

ADDITIONAL CENSUS DATA[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM:	LOGRATIO	LINEAR
CONSTANT	.090 (5.99)	4516 (5.78)
IMPROVE	.021 (6.82)	1080 (6.67)
INTEREST	-.041 (10.29)	-2707 (13.06)
LENGTH1	-.027 (4.34)	-1016 (3.14)
LENGTH3-4	-.019 (3.43)	-817 (2.91)
EVENT	.252 (6.89)	16930 (8.88)
EVPCBZONE1	-.103 (1.84)	-5645 (1.95)
EVPCBZONE2	-.150 (2.88)	-6220 (2.29)
HIGHSCHOOL	.015 (2.43)	493 (1.57)
INCOME	-.001 (0.11)	60 (0.10)
OWNER	-.001 (0.12)	-20 (0.06)
ADJ R^2	.176	.217
$ERROR^2$	81.72	2.210×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

TABLE A-3

NOMINAL VALUES ADJUSTED BY THE MASSACHUSETTS DEFLATOR[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM: VARIABLE	LOGRATIO	LINEAR
CONSTANT	.042 (3.09)	1816 (1.88)
IMPROVE	.013 (6.69)	870 (6.44)
INTEREST	-.002 (0.62)	- 881 (3.23)
LENGTH1	-.029 (5.50)	-1970 (5.05)
LENGTH3-4	-.022 (5.04)	-1660 (5.29)
EVENT	-.038 (1.08)	583 (0.23)
EVPCBZONE1	-.072 (1.35)	-4264 (1.11)
EVPCBZONE2	-.196 (4.08)	-10930 (3.15)
HIGHSCHOOL	.010 (2.35)	695 (2.26)
ADJ R^2	.136	.137
$ERROR^2$	74.65	3.893×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by a Massachusetts deflator (statewide single family sales) to $1985.

TABLE A-4

RENTAL NEW BEDFORD DATA ADDED[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM:	LOGRATIO	LINEAR
VARIABLE		
CONSTANT	.120 (8.26)	5138 (7.23)
IMPROVE	.025 (8.27)	1005 (7.00)
INTEREST	-.046 (11.48)	-2746 (14.15)
LENGTH1	-.018 (3.38)	- 580 (2.28)
LENGTH3-4	-.018 (3.69)	- 740 (3.10)
EVENT	.259 (6.53)	16600 (8.55)
EVPCBZONE1	-.016 (0.30)	-2260 (0.86)
EVPCBZONE2	-.133 (2.43)	-5285 (1.98)
HIGHSCHOOL	.005 (1.20)	88 (0.41)
ADJ R^2	.180	.210
ERROR^2	113.4	2.711×10^{11}

[a] There are 1178 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and all of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

TABLE A-5

NATIONAL MORTGAGE INTEREST RATE[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

FUNCTIONAL FORM: VARIABLE	LOGRATIO	LINEAR
CONSTANT	.093 (6.73)	4636 (6.47)
IMPROVE	.022 (7.11)	1102 (6.97)
INTEREST	-.061 (12.42)	-3831 (14.84)
LENGTH1	-.024 (4.24)	- 850 (2.95)
LENGTH3-4	-.014 (3.06)	- 569 (2.43)
EVENT	.242 (6.95)	15700 (8.66)
EVPCBZONE1	-.094 (1.73)	-5177 (1.83)
EVPCBZONE2	-.120 (2.43)	-4738 (1.84)
HIGHSCHOOL	.017 (3.85)	559 (2.46)
ADJ R^2	.210	.248
$ERROR^2$	78.48	2.128×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

APPENDIX B-1

HISTORICAL REPEAT SALE ANALYSIS[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

POLLUTION EVENT:	1974		1975	
FUNCTIONAL FORM:	LOGRATIO	LINEAR	LOGRATIO	LINEAR
VARIABLE				
CONSTANT	.091 (6.44)	4497 (6.03)	.083 (5.81)	4170 (5.57)
IMPROVE	.022 (7.07)	1092 (6.63)	.021 (6.84)	1068 (6.52)
INTEREST	-.024 (7.77)	-1503 (9.09)	-.026 (8.23)	-1558 (9.42)
LENGTH1	-.024 (3.51)	- 745 (2.06)	-.017 (2.45)	- 506 (1.37)
LENGTH3-4	-.000 (0.09)	456 (1.83)	.008 (1.68)	903 (3.45)
EVENT	-.179 (4.63)	-12400 (6.06)	-.222 (5.76)	-15150 (7.45)
EVPCBZONE1	.032 (0.52)	4111 (1.26)	.081 (1.30)	6990 (2.14)
EVPCBZONE2	-.011 (0.21)	5482 (1.86)	.139 (2.56)	11640 (4.05)
HIGHSCHOOL	.023 (4.84)	828 (3.24)	.019 (3.95)	699 (2.78)
ADJ R^2	.175	.189	.171	.195
σ^2 ERROR	81.95	2.302×10^{11}	82.37	2.278×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

APPENDIX B-2

HISTORICAL REPEAT SALE ANALYSIS[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

POLLUTION EVENT:	1976		1977	
FUNCTIONAL FORM:	LOGRATIO	LINEAR	LOGRATIO	LINEAR
VARIABLE				
CONSTANT	.084 (6.02)	4198 (5.75)	.095 (6.82)	4852 (6.59)
IMPROVE	.022 (6.95)	1079 (6.86)	.022 (7.02)	1095 (6.67)
INTEREST	-.025 (7.86)	-1493 (9.12)	-.020 (6.19)	-1283 (7.42)
LENGTH1	-.017 (2.40)	- 430 (1.16)	-.020 (3.09)	- 656 (1.77)
LENGTH3-4	.010 (2.09)	1140 (4.41)	.006 (1.28)	874 (3.34)
EVENT	-.248 (6.69)	-17850 (9.22)	-.205 (5.92)	-13870 (7.59)
EVPCBZONE1	.108 (1.77)	9234 (2.91)	.117 (1.98)	9290 (2.98)
EVPCBZONE2	.147 (2.71)	13596 (4.79)	.116 (1.98)	10160 (3.62)
HIGHSCHOOL	.018 (3.91)	664 (2.71)	.014 (2.98)	268 (1.11)
ADJ R^2	.181	.218	.172	.191
ERROR^2	81.29	2.211×10^{11}	82.22	2.287×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

APPENDIX B-3

HISTORICAL REPEAT SALE ANALYSIS[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

POLLUTION EVENT:	1978		1979	
FUNCTIONAL FORM:	LOGRATIO	LINEAR	LOGRATIO	LINEAR
VARIABLE				
CONSTANT	.096 (6.73)	5015 (6.64)	.096 (6.70)	5240 (6.90)
IMPROVE	.021 (6.76)	1071 (6.41)	.020 (6.42)	1014 (6.07)
INTEREST	-.021 (5.75)	-1287 (6.73)	-.038 (8.93)	-2312 (10.25)
LENGTH1	-.026 (3.88)	-1030 (2.92)	-.029 (4.66)	-1298 (3.93)
LENGTH3-4	.002 (0.36)	530 (1.99)	-.009 (1.94)	-427 (1.70)
EVENT	-.137 (3.81)	-9606 (5.04)	.114 (2.90)	7952 (3.82)
EVPCBZONE1	.133 (2.24)	10500 (3.34)	.080 (1.33)	7953 (3.82)
EVPCBZONE2	.066 (1.25)	7565 (2.70)	-.015 (0.30)	-1729 (0.64)
HIGHSCHOOL	.010 (2.21)	120 (0.50)	.010 (2.10)	185 (0.78)
ADJ R^2	.148	.163	.150	.166
σ^2 ERROR	84.64	2.367×10^{11}	84.37	2.358×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

APPENDIX B-4

HISTORICAL REPEAT SALE ANALYSIS[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

POLLUTION EVENT:	1980		1981	
FUNCTIONAL FORM:	LOGRATIO	LINEAR	LOGRATIO	LINEAR
VARIABLE				
CONSTANT	.090 (6.41)	4470 (6.13)	.082 (5.86)	4291 (5.84)
IMPROVE	.021 (6.85)	1076 (6.69)	.021 (6.69)	1047 (6.45)
INTEREST	-.041 (10.38)	-2711 (13.18)	-.029 (9.20)	-1755 (10.50)
LENGTH1	-.027 (4.73)	-1024 (3.49)	-.024 (4.25)	- 977 (3.33)
LENGTH3-4	-.019 (4.12)	-839 (3.55)	-.016 (3.74)	-874 (3.82)
EVENT	.252 (6.90)	16920 (8.90)	.206 (6.16)	14060 (8.05)
EVPCBZONE1	-.103 (1.85)	-5616 (1.94)	-.126 (2.34)	-8609 (3.07)
EVPCBZONE2	-.150 (2.98)	-6338 (2.43)	-.113 (2.23)	-7843 (2.96)
HIGHSCHOOL	.015 (3.41)	490 (2.12)	.011 (2.38)	245 (1.06)
ADJ R^2	.177	.218	.172	.205
$ERROR^2$	81.72	2.210×10^{11}	82.18	2.249×10^{11}

[a] There are 1030 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

APPENDIX B-5

HISTORICAL REPEAT SALE ANALYSIS[a]

POLLUTION VARIABLE: EVPCBZONE1 AND EVPCBZONE2

POLLUTION EVENT:	1982		1983	
FUNCTIONAL FORM:	LOGRATIO	LINEAR	LOGRATIO	LINEAR
VARIABLE				
CONSTANT	.071 (4.94)	3502 (4.73)	.066 (4.82)	3627 (5.04)
IMPROVE	.020 (6.44)	996 (6.18)	.020 (6.50)	976 (6.13)
INTEREST	-.023 (7.23)	-1262 (7.73)	-.022 (7.06)	-1240 (7.66)
LENGTH1	-.023 (4.25)	- 986 (3.57)	-.019 (3.67)	- 784 (3.62)
LENGTH3-4	-.017 (3.99)	-1105 (4.94)	-.012 (3.14)	-718 (3.62)
EVENT	.201 (6.02)	15800 (9.13)	.266 (6.88)	19330 (9.56)
EVPCBZONE1	-.148 (2.71)	-11644 (4.09)	-.173 (2.81)	-13660 (4.24)
EVPCBZONE2	-.074 (1.48)	-8160 (3.17)	-.006 (0.10)	-7080 (2.40)
HIGHSCHOOL	.010 (2.25)	247 (1.08)	.005 (1.21)	- 6 (0.03)
ADJ R^2	.175	.220	.205	.237
σ^2 ERROR	81.95	2.203×10^{11}	78.94	2.156×10^{11}

[a] There are 1081 pairs of sales in these multiple regressions from the towns of Dartmouth, Fairhaven, and the single family part of New Bedford. T-statistics are presented in parentheses. The dependent variable for each regression is adjusted by the GNP residential deflator to $1985.

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