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Economic Benefits of Remediating the Sheboygan River, Wisconsin Area of Concern

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ABSTRACT. *This study estimates the economic benefits of remediation in the Sheboygan River, WI Area of Concern (AOC) using two distinct empirical methods. The methodology parallels that described by Braden* et al. *(2008). The results are mixed. Using hedonic analysis of property sales, for owner-occupied homes within a 5-mile radius of the Sheboygan River AOC, the overall estimated loss of value is $158 million (8% of market value). Of this total, only $49 million in losses for homes closest to the upper river segment has strong statistical support. The impacts are greatest proportionally for properties closest to the AOC. A survey-based method yields a mean estimate of $218 million (10% of property value) in willingness to pay for full cleanup of the AOC. If remediation were to induce recovery of property values, then the local communities could benefit through increased property tax revenues.*

INDEX WORDS: *Hedonic analysis, conjoint choice, benefits estimation, Area of Concern, Sheboygan River.*

INTRODUCTION

This paper presents estimates of the community economic benefits from remediation of the Sheboygan River, WI Area of Concern (AOC). This is one of 43 contaminated areas designated by Canada and the U.S. in 1987 for priority remedial actions (http://www.epa.gov/glnpo/aoc/index.html). The study was undertaken to identify economic benefits that the community might realize from AOC remediation. It involves analyzing the residential property market to discern impacts of the AOC on prices, and surveying homeowners to determine

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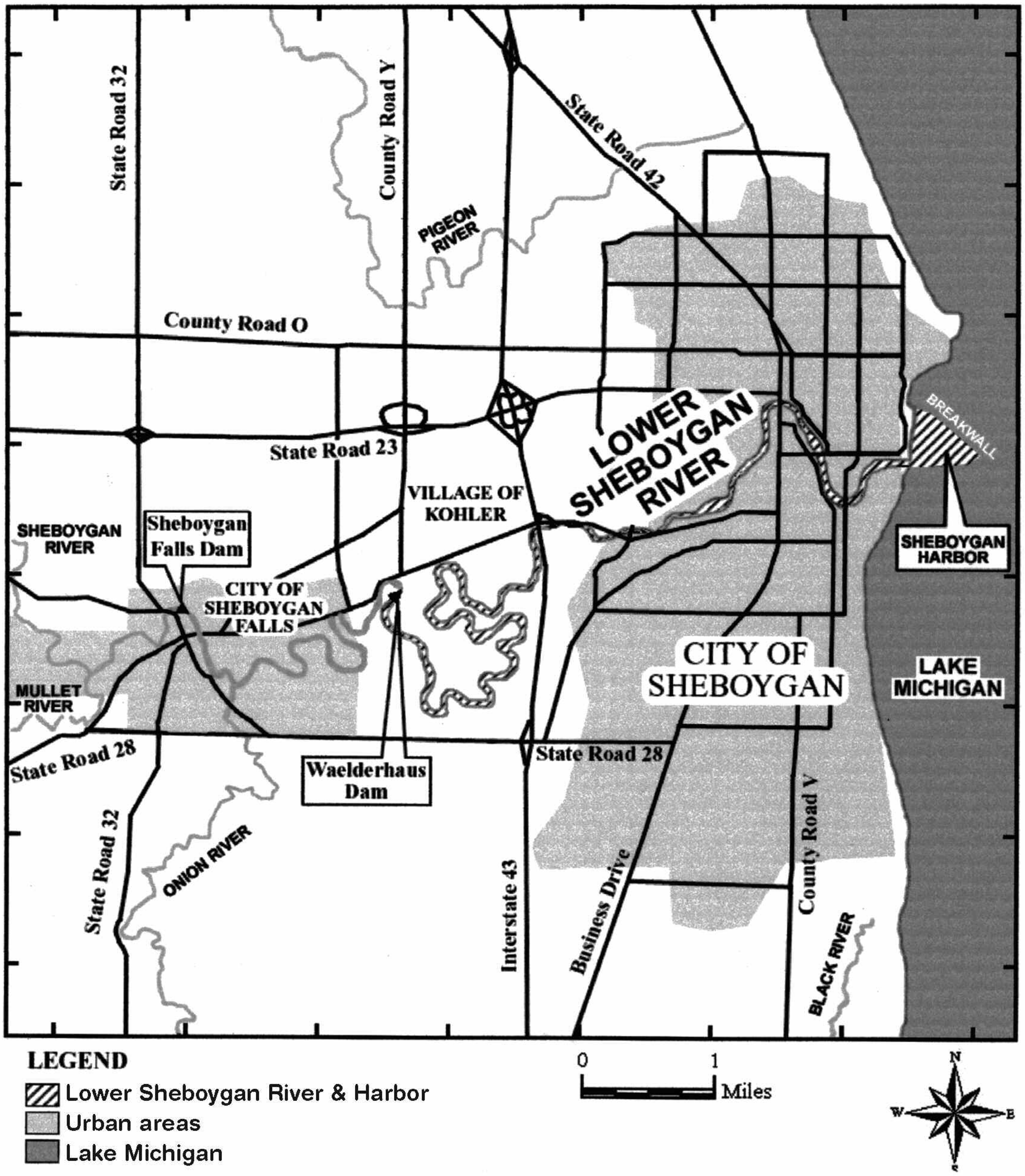

FIG. 1. Thematic map of the Sheboygan River AOC[a].

[a]As defined by USEPA, the AOC extends from the breakwall in Lake Michigan to Sheboygan Falls Dam. Remediation was begun in 2006 for the segment west of the Waelderhaus Dam. The cross-hatched segments correspond to the AOC as defined in the survey. The market-based analysis also includes the "upper river" segment between the two dams.

their attitudes toward the AOC and willingness to pay more for homes if the AOC is cleaned up. Similar motives and methods underlie the companion study of the Buffalo River, NY AOC by Braden *et al.* (2008), where they are discussed in more detail.

The Sheboygan River, WI AOC lies on the western shore of Lake Michigan, approximately 60 miles (97 km) north of Milwaukee, WI. The AOC encompasses approximately 14 miles (22.6 km) of the river, from the Sheboygan Harbor breakwater in Lake Michigan up to the Sheboygan Falls Dam. A schematic map appears in Figure 1. The website of

TABLE 1. Census statistics for the Sheboygan River AOC area.

	City of Sheboygan Falls	City of Sheboygan	Village of Kohler	Town of Wilson	Town of Sheboygan Falls	Town of Sheboygan	Town of Lima	Total
Population (2003)[a]	6,995	49,263	1,945	3,301	1,683	7,348	2,931	73,466
Median Age	39.6	35.4	39.8	41.5	40.4	37.7	39.1	36.68 [b]
Total Housing Units	2,826	21,762	792	1,323	675	2,245	1,029	30,652
Occupied Housing Units	2,745	20,779	737	1,235	657	2,148	1,008	29,309
Owner-occupied Housing Units	1,579	10,727	630	962	326	1,776	724	16,724
Median Value of Owner-occupied Units ($)	$111,600	$89,400	$144,400	$134,600	$122,900	$135,800	$118,500	$102,667 [b]
Average Household Size	2.58	2.55	2.65	2.62	2.61	2.85	2.88	2.6 [b]
Median Household Income (1999$)	47,205	40,066	75,000	59,241	50,489	60,846	53,023	44,623 [b]

Source: U.S Bureau of the Census (2001), except as noted
[a] American Community Survey, U.S. Bureau of the Census (2003)
[b] Weighted average of the jurisdiction medians

the U.S. Environmental Protection Agency (USEPA), Great Lakes National Program (http://www.epa.gov/glnpo/aoc/sheboygan.html) describes the AOC and its environmental challenges in greater detail.

Based on physical characteristics, the Sheboygan River AOC is divisible into three sections. The lower river (*LR*) extends 3 miles from the Kohler Landfill to the breakwater in Lake Michigan. The middle river (*MR*) extends 7 miles from the Waelderhaus Dam to the Kohler Landfill. The upper river (*UR*) extends approximately 4 miles from the Sheboygan Falls Dam to the Waelderhaus Dam. The bulk of the officially-recognized contamination originated in *UR* from a small engine manufacturing plant. The *MR* flows through land closely associated with an international manufacturing company and used for a horse farm, a tree nursery, golf courses, a hunting and fishing club, and a private wildlife area, as well as for the manufacturing facility and a landfill. The *LR* passes through parkland, commercial and industrial areas in the City of Sheboygan, and a harbor before discharging into Lake Michigan. In the early part of the current decade, a large resort development was built in the City of Sheboygan just south of the harbor.

The AOC impinges on seven different local jurisdictions: the cities of Sheboygan and Sheboygan Falls, the Village of Kohler, and the townships of Lima, Sheboygan, Sheboygan Falls, and Wilson. In 2005, a $28 million remediation project began in the *UR* (M. Tuchman, USEPA/GLNPO, personal communication, 2005). The only activities planned in *LR* and *MR* consist of monitoring and limited dredging at an estimated cost of $12 million.

Sheboygan Data

We collected data for single family residences purchased in 2002 through 2004 and located within 5 miles of the Sheboygan River AOC. The mixed urban-rural character, elongated shape of the AOC, and highly decentralized and variable real estate assessment practices in the region presented distinctive challenges for defining the study area. The towns of Lima and Wilson presented special challenges. Assessment data had to be collected from incomplete paper files. Because of this difficulty and because the Sheboygan River is not physically present in either jurisdiction, in each of these two townships, we collected data for only the sixteen sections closest to the AOC. For the other jurisdictions, all purchased properties within five miles of the AOC were included in the data set. Census demographic statistics for these jurisdictions appear in Table 1.

The assessment data were of uneven quality between jurisdictions. There was a high incidence of missing observations for the structural characteristics of individual properties. As a result, the usable structural characteristics were limited to the acreage of the property, the size and age of homes, and the numbers of full- and half-baths. In all, 2,168 property records included at least these attributes. All sale prices were converted to 2004 dollars using the house price index for the Sheboygan metropolitan area computed by the Office of Federal Housing Enterprise Oversight (OFHEO) (2005). Jurisdiction dummy variables capture the cumulative effects of public services, tax rates, and other community variables. Distances to the AOC and to other prominent features of the local landscape, including high-

TABLE 2. *Variables for Sheboygan area single-family home purchase data, 2002–2004[a].*

	Housing Attribute Variables	Mean (Median)	Std. Dev.	Min.	Max.
saleprice	Sales price of parcel (2004$)	129,961 (108,217)	71,008	25,000	754,100
acres	Acreage of parcel (ac)	0.28 (0.17)	0.49	0.08	9.12
age & agesq	Age of home & age squared (yrs.)	54.4 (52)	33.24	0.0	161.0
sfla	Size of living area (ft^2)	1528.89 (1393)	580.71	750	6467
fullbath	Full-bathrooms (no.)	1.34 (1)	0.57	0	5
halfbath	Half-bathrooms (no.)	0.34 (0)	0.49	0	2
	Location Variables	N	% of Total		
CSF	=1 if in City of Sheboygan Falls	175	8.07		
CS	=1 if in City of Sheboygan	1,597	73.66		
VK	=1 if in Village of Kohler	128	5.9		
TW	=1 if in Town of Wilson	68	3.14		
TSF	=1 if in Town of Sheboygan Falls	22	1.01		
TS	=1 if in Town of Sheboygan	159	7.33		
TL	=1 if in Town of Lima	19	0.88		
LR	=1 if closest to LR segment, 0 otherwise	1,614	74.45		
MR	=1 if closest to MR segment 0 otherwise	211	9.73		
	Distance Variables	Mean (Median)	Std. Dev.	Min.	Max.
airport	Dist. to Sheboygan Airport (mi.)	6.09 (6.53)	1.46	0.51	9.28
notriver	Dist. to closest stream, not AOC (mi.)	1.22 (1.04)	0.67	0.00	4.17
evrgnwood	Dist. to Evergreen Park (mi.)	2.81 (2.62)	1.62	0.17	9.35
rwaysite	Dist. to closest railroad (mi.)	2.36 (1.92)	1.42	0.14	10.52
shoreline	Dist. to L. Michigan shoreline (mi.)	1.73 (1.14)	1.64	0.03	10.15
hwyx	Dist. to closest highway interchange (mi.)	1.95 (1.88)	0.63	0.13	5.06
landfill	Dist. to Kohler Landfill (mi.)	2.66 (2.37)	0.85	0.66	8.66
uwsheb	Dist. to Univ. campus (mi.)	2.48 (2.40)	0.89	0.32	9.05
aoc	Dist. to AOC (mi.)	1.23[b] (1.08)	0.82	0.01	4.91

[a]N = 2,618; all located within 5 miles of AOC.
[b]Mean for *LR* subsample equals overall mean. Means for *MR* and upper river subsamples are 2.11 mi. and 0.57 mi. respectively.

ways, railroads, other rivers, and the central business district, are also included. Definitions for these variables and their summary statistics for our sample are presented in Table 2.

In addition to the assessment and spatial data, 850 of the home buyers in the assessment data set received a mail survey that was identical, except for local descriptive information, to the one described in more detail by Braden *et al.* (2008). The survey instrument elicited household demographic and attitudinal information, and used conjoint choice questions to elicit consumer trade-offs between home size, the environmental condition of the river, distance to the river, and home price. The survey sample systematically over-represented jurisdictions with small numbers of home transactions in an effort to realize a statistically-significant survey subsample for each one. After adjusting for 11 undeliverable surveys, the overall response rate was approximately 48%. Of the 410 surveys returned, 40 did not respond fully to all questions. The analysis is based on the 370 complete responses.

Due in part to the stratification across jurisdictions, the mean home price is approximately 18% higher and the mean home age approximately 14 years less for the survey sample than for the sale sample. In terms of mean market price, size, and age, the homes owned by the response sample closely match the mail sample. A test of equivalence of the distribution by jurisdiction of the response sample relative to the mail sample fails to reject the null hypothesis at the 2% level of significance.

Relative to the overall population for the region, our ability to make comparisons is limited by the fact that the census does not report many summary

TABLE 3. Descriptive statistics for survey demographic, attitudinal, and perception data[a].

A. Demographic data:

	Modal Category and (Mean Value [a])	% of Responses in Modal Category
Number of bedrooms	3 (2.9)	56.36%
Year home purchased	2003	39.79%
Type of home	"Single Detached"	79.63%
Household size (no. people)	2 (2.8)	37.08%
Household income	"$40,000–$60,000" ($78,067)	25.68%
Respondent Age	"25-34" (43.7)	31.07%
Years lived in Sheboygan County	"26 years or more" (16.75)	42.97%
Frequency of Sheboygan River viewing per year	"26 or more times" (22.9)	62.86%

B. At the time you bought your current home, how important was each of the following factors to you?

	Very important 5	4	3	2	Not at all important 1
Size of house	32.83%	34.34%	23.74%	7.32%	1.77%
Quality of neighborhood	67.76%	23.68%	7.30%	0.25%	1.01%
Proximity to polluted sites	30.87%	21.43%	25.51%	12.76%	9.44%
Proximity to water resources	15.01%	19.59%	31.81%	18.83%	14.76%
Proximity to employment & shopping	22.28%	32.41%	29.37%	12.15%	3.80%
Price of home	58.79%	29.65%	10.05%	0.75%	1.26%
Property taxes	41.96%	33.42%	18.59%	4.27%	1.76%

C. At the time you bought your current home, how strongly did you agree or disagree with these statements?

	Strongly Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Strongly Disagree
The river is attractive	15.93%	45.95%	21.41%	13.32%	3.39%
The river enhances the quality of life	17.9%	39.74%	27.62%	11.84%	2.89%
The river is important to the local economy	22.55%	37.93%	28.38%	8.49%	2.65%
The river is environmentally safe	3.95%	15.0%	29.74%	29.21%	22.11%
The river is a likely area for new development	18.04%	36.6%	28.12%	10.08%	7.16%

[a] Answers were categorical. Except for type of home, sample means are calculated from the mid-points of the categories. All homes were purchased in years 2002, 2003, or 2004.

demographic statistics for the sub-sample of homeowners, and the fact that our study area does not correspond exactly to census jurisdiction boundaries. The loose comparisons we can make are as follows: a) using an OFHEO (2005) housing price index for the Sheboygan SMSA, the price-adjusted year 2004 median property value for our sale sample ($92,810) is less than the median ($119,593) calculated as a weighted average of the census median values for the communities in our sample, while the adjusted median value ($116,156) in the survey responses is just 3% less than the census median; b) the census median income ($44,623) is in the survey's modal range ($40,000 to $60,000); c) the weighted average median resident age in the census (36.7 years) is greater than the modal range (25 to 34 years) in the survey responses; and d) the census mean household size (2.6 people) is less than the survey median (2.84).

Attitudes toward the AOC and Housing

Survey respondents were asked to rate factors that influence their housing choices and express attitudes toward specific aspects of the Sheboygan River. Their responses are summarized in Table 3. Since only homeowners are in the survey, the household incomes in the survey are higher than that of the general population. The demographic data reveal that more than 40% of respondents had lived in Sheboygan for at least 26 years. More than 60% of the sample reports encountering the river 26 or more times each year. In choosing a house, the quality of the neighborhood and the price of the home are rated very important by nearly 90% of respondents. Among the queries in the survey, only proximity to water resources is rated "very important" by less than half of the sample. With a relative abundance of water resources in the area, this relative indifference to water resources is perhaps unsurprising, but it may also reflect a selection effect in that relatively few respondents reside adjacent to water bodies. A plurality of respondents expresses mild agreement with most of the descriptors of the Sheboygan River used in the survey. The exception is "environmentally safe" where "no opinion is the modal response. For the respondents who express opinions, the preponderant sentiments is that the river is attractive (61%), economically important (60%), environmentally unsafe (51%), important to the quality of life in the community (58%), and a likely area for redevelopment (55%).

Economic Impacts of Contamination and Benefits of Cleanup

This section presents results from both market-based and survey-based methods of valuing the economic impacts of the Sheboygan River AOC. The companion study by Braden *et al.* (2008) provides readers with a more detailed discussion of the analytical methods and models.

Hedonic Analysis Based on Distance

The analysis of the residential real estate market is based on hedonic price theory. We estimate a form of the hedonic price model in which sales price is assumed to be a linear function of property characteristics. To allow for nonlinear effects of some location characteristics on prices, we logarithmically transform all variables that describe the distance of a home to a nearby feature of interest. This transformation means that a small change in distance must impact housing prices differently depending on the initial location. This conforms to our expectation that the AOC affects nearby housing values more severely compared to properties further away. We also use logarithmic transformations of the variables for house size (ln*sfla*) and lot size (ln*acres*). As with distance, economic theory leads us to expect the marginal impacts of these variables to diminish as the respective sizes increase. The logarithmic specification imposes this condition. Linear, quadratic, and inverse specifications also were estimated, but the results either violated theoretical expectations or yielded insignificant results for the distance variables. Overall, the models did not differ appreciably in adjusted-R^2. Tests for influential outliers failed to identify any that would explain these anomalies. Rather, the inconsistencies between specifications almost certainly reflect data limitations that preclude controlling for the number of bedrooms, fireplaces, garages, and other factors that typically vary with home size.

As indicated in Table 4 by an R^2 of 0.6790, the model explains the data well. The prefix "ln" associated with some of the explanatory variables in Table 4 indicates a logarithmic transformation. All of the included parcel characteristic variables are reasonable in sign and significant at the 1% level. For the structural variables, house and lot size contribute to price at positive but decreasing rates, and age has a negative but diminishing effect.

For neighborhood effects, the "base" jurisdiction in the model is the Town of Sheboygan Falls (*TSF*). *TSF* is a rural area north and east of the City of Sheboygan Falls (*CSF*), at the western end of the AOC. The jurisdiction dummies included in the model represent changes in property prices *relative to TSF*. The jurisdictional effects might reflect, for example, differences in public services, tax rates, schools, and other community features. After controlling for home and location characteristics, the jurisdiction dummies are significantly positive for the City of Sheboygan Falls and the Village of Kohler (*VK*) but insignificant at the 10% level for all other jurisdictions.

The location-related variables measure the straight-line distances between each home and geographic features of potential importance to homeowners. Nine features are included in the model: the AOC, major highways, Evergreen Park (a large community park in the City of Sheboygan), the Sheboygan Campus of the University of Wisconsin (UW-Sheboygan), the Lake Michigan shoreline, rivers other than the Sheboygan River, the Sheboygan County Airport, railways, and the Kohler Landfill. Except for the railways and rivers other than the Sheboygan River, all of the distance coefficients are significant at the 5% level or better. The significant positive coefficients of the Kohler Landfill and the highway variable mean that house values increase with distance—i.e., proximity depresses house values. The coefficients for distances to

TABLE 4. Hedonic property value results[a].

	Coefficient	Std. Err.	t	P>|t|	95% Conf.	Interval
			Housing characteristics			
fullbath	19,522.77	2,298.78	8.49	0.000	15,014.70	24,030.84
halfbath	11,548.75	2,007.16	5.75	0.000	7,612.57	15,484.94
ln*sfla*	77,256.83	4,252.41	18.17	0.000	68,917.55	85,596.12
age	–536.63	109.10	–4.92	0.000	–750.59	–322.67
agesq	0.282	0.817	0.35	0.726	–1.300	1.864
ln*acres*	21,386.86	2,218.80	9.64	0.000	17,035.64	25,738.07
			Location variables			
CSF	48,428.56	10,514.21	4.61	0.000	27,809.44	69,047.68
CS	–187.81	15,300.47	–0.01	0.990	–30,193.12	29,817.49
VK	120,703.20	14,952.48	8.07	0.000	91,380.31	150,026.10
TW	7,940.65	15,607.56	0.51	0.611	–22,666.89	38,548.19
TS	19,468.20	13,410.13	1.45	0.147	–6,830.01	45,766.40
TL	8,837.64	14,573.01	0.61	0.544	–19,741.06	37,416.34
			Distance variables (non–AOC)			
ln*landfill*	82,600.81	17,368.46	4.76	0.000	48,540.03	116,661.60
ln*evrgnwood*	–7,317.33	2,329.53	–3.14	0.002	–11,885.71	–2,748.95
ln*airport*	–29,861.07	8,629.41	–3.46	0.001	–46,783.95	–12,938.19
ln*notriver*	–3,286.54	1,969.81	–1.67	0.095	–7,149.47	576.40
ln*shoreline*	–9,593.60	2,070.33	–4.63	0.000	–13,653.66	–5,533.53
ln*hwyx*	18,748.77	4,450.41	4.21	0.000	10,021.20	27,476.34
ln*uwsheb*	–90,057.83	15,654.76	–5.75	0.000	–12,0757.9	–59,357.74
ln*rwaysite*	–733.77	4,892.28	–0.15	0.881	–10,327.88	8,860.33
			Distance variables (AOC)			
ln*aoc*	6,761.05	2,590.38	2.61	0.009	1,681.13	11,840.97
ln*aoc*LR*	–1,489.57	3,709.98	–0.40	0.688	–8,765.10	5,785.97
*lnaoc*MR*	–2,690.14	4,513.16	–0.60	0.551	–11,540.77	6,160.50

[a]n = 2,168; R^2 = 0.6790

Evergreen Park, the airport, the shoreline, UW-Sheboygan, and other rivers are significantly negative, implying that proximity adds to property values.

The model also includes dummy variables to examine potential differences in the effect of specific sections of the Sheboygan River on the proximity variable. There are reasons to believe that the effects of the AOC may differ across three segments of the river. First, the upper river is separated from the lower river by a dam and this dam defines the boundary of active remediation in the upper river. Secondly, a major landfill and interstate highway separate the middle river segment from the lower river segment. Furthermore, development patterns are such that housing units are dispersed further from the AOC in the middle segment, but very close to the river in the lower and upper segments. As such, we interact the variable indicating the distance from the AOC with two dummy variables, one indicating whether the house is closest to the lower river segment (*LR*) and the second indicating whether the house is closest to the middle river segment (*MR*). Thus, a change in sales price due to a percentage change in distance from the AOC is given by:

β_{lnaoc} for homes closest to the upper river,

$\beta_{lnaoc} + \beta_{lnaoc*MR}$ for homes closest to the middle river,

$\beta_{lnaoc} + \beta_{lnaoc*LR}$ for homes closest to the lower river,

where β represents the coefficient estimate in Table 4.

According to the model estimates, distance from the AOC has a significant, positive effect on housing values for properties located nearest the upper

TABLE 5. Economic impacts associated with the Sheboygan River AOC.

Panel A: Property Value Effects from Hedonic Market Analysis			
	Impact Zone		
	Properties Closest to Lower River (*LR*)	Properties Closest to Middle River (*MR*)	Properties Closest to Upper River (*UR*)
Number of single-family properties	12,433	1,641	2,650
Mean loss (std. dev.) (2004$)	$8,235 ($3,378)	$4,057[c] ($2,838)	$18,420 ($6,924)
Total value loss ($10^6 \times$ 2004$)[a]	$102.4	$6.7[c]	$48.8
[std. err.]	[$87.9]	[$8.5]	[$18.7]
{95% conf. int.}	{–$69 to $274}	{–$10 to $23}	{$12 to $85}
Total assessed value ($10^6 \times$ 2004$)	$1,384	$182	$294
Total value loss / Assessed value	7.3%	3.8%	16.3%
Total adjusted ass'd value ($10^6 \times$ 2004$)	$1,486	$189	$342
Total value loss / Adjusted ass'd value	6.8%	3.7%	14.0%
Panel B: Willingness to Pay for Full Cleanup from Survey Analysis[b]			
Household WTP for full-cleanup (std. dev.) (2004$)	$13,067 ($3,949)	$13,650 ($5,471)	$12,481[e] ($6,117)
Aggregate WTP for full-cleanup ($10^6 \times$ 2004$) [d]	$162.5	$22.4	$33.1[e]
[std. err.]	[$49.1]	[$9.0]	[$16.2]
{95% conf. int.}	{$65 to $258}	{$4 to $39}	{$1 to $64}

[a] Total across all segments is $158 million; only $48.8 million for *UR* differs significantly from zero.
[b] Standard errors estimated by bootstrap method.
[c] Underlying coefficient estimates are not statistically significant.
[d] Total across all segments is $218 million.
[e] For survey analysis, homes in *UR* region were linked to the *MR* segment due to impending cleanup in the *UR*.

river segment, indicating that the residential property market in the western portion of the study area continued to discount proximity to the AOC in the 2002–2004 period despite announced plans for contaminant remediation in the upper river. The interaction terms which allow different price gradients for the middle and lower river segments are not individually significant. However, an F-test for the sum of the coefficients for the lower river is statistically significant at the 10% level (i.e., the F-statistic for the test H_0: $\beta_{lnaoc} + \beta_{lnaoc*LR} = 0$ equals 3.06, p-value = 0.0805), while the F-test for the sum of the coefficients for the middle river indicates a price gradient that is not statistically significant (the F-statistic for the test H_0: $\beta_{lnaoc} + \beta_{lnaoc*MR} = 0$ equals 0.85, p-value = 0.3581). The interaction effects thus indicate that the price gradient is steepest for the upper river and least steep (and statistically not significantly different than zero) for the middle river, with the gradient for the lower river segment lying between these two estimated gradients (also see Fig. 2).

While there is economic reasoning to allow the price gradients to vary by river segment based on local "on-the-ground" conditions, statistically one could justify dropping these terms and just estimating a single gradient. Thus, for robustness, we estimated a model which restricts the price gradient to be the same for all locations. The resulting coefficient estimate is 6087.79 (σ = 2082) and is statistically significant at the 1% level. We choose, however, to maintain the interaction terms in the discussion of the economic impacts based on the economic justification for their inclusion and because they will produce more conservative estimates of the total capital losses associated with the AOC. For comparison sake, we also compute the total capital losses based on the single price gradient just reported.

Figure 2 illustrates the changes in the marginal impact of the AOC as distance from the AOC increases. Because we transform the distance variables by logarithms, the marginal impacts diminish rapidly as distance increases. The graph in Figure 2 truncates at 2 miles because the estimated marginal effects at greater distances are less than 0.1% per 0.1 mile. The estimated coefficient for β_{AOC} indicates that a 1% increase in distance from the AOC for homes in the upper river would result in a ($6,761/100) = $67.61 increase in the average

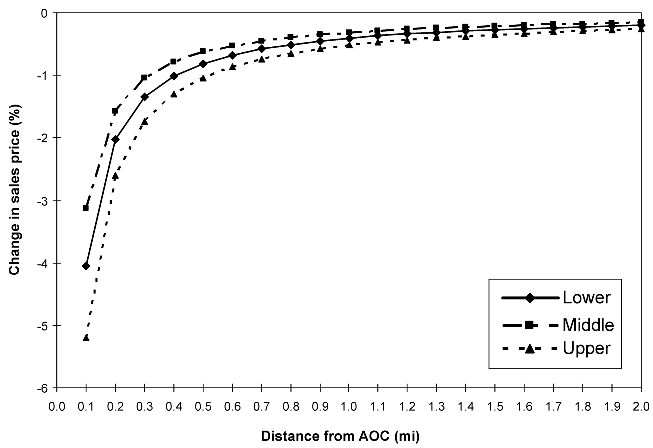

FIG. 2. Marginal impacts as percent of average sales price within 2 miles of the Sheboygan River Area of Concern, by river segment from hedonic model[a].

[a]The total impact on average property values at a particular distance from the river is cmputed as the sum of the estimated marginal impacts beginning 5 miles from the river and moving toward the specific location. At distances greater than 2 miles, the estimated marginal impacts approach zero and are now shown.

price. Thus, extrapolating linearly, at a distance of 1 mile (1.6 km) from the AOC, increasing the distance by 0.1 mile (10%) would increase the average price by $676. This marginal effect is $527 for homes nearest the lower river and $497 for homes nearest the middle river (although the latter estimate is based on a price gradient that is not significantly different than zero). However, for a home located adjacent to the river (0.2 miles), increasing distance by 0.1 mile would increase the average price by $2,035 to $3,380, depending on the river segment. This marginal price represents between 1.6% and 2.6% of the mean sales price for our sample of $129,961.

Of primary interest is the realized total capital loss associated with the AOC. To compute this from the hedonic model, we predict the increase in the price of the house if it was hypothetically moved from its current location to a hypothetical "boundary" distance from the AOC that is just far enough away so that there is no price effect from the AOC (see Braden *et al*. 2008 for a more detailed discussion of this logic and its empirical implementation). For properties immediately adjacent to the river, this realized capital loss is between $15,925 and $26,449, or 12% to 20% of mean sales price in the sample depending on the river segment considered. For homes located 2 miles from the AOC, the realized capital loss is in the 3% to 5% range.

Panel A of Table 5 reports the mean of the capital losses for properties in our sample. The selected model produced overall estimates of welfare impact in the middle of the range observed across different model specifications. Also reported is the total capital loss as a percent of the total assessed value of all properties within 5 miles of the AOC. The percentage impacts are likely to be an overstatement because assessed values typically are less than actual sales prices. As indicated in Table 5, in the lower river area where the density of properties is the greatest, the mean loss is $8,235. In percentage terms, this loss is approximately 7% of the mean assessed price of all homes in the area. The properties located closest to the upper river are relatively closer to the AOC, in general, than are the properties closest to the middle or lower segments. Consequently, the logarithmic specification results in a greater mean property value loss for the upper river than for the other sections. The percentage property value losses for homes nearest the middle river are around 4% but based on insignificant estimates. Homes located nearest the lower river dominate the sample and their percentage discounts approximate the full sample mean.

The estimated aggregate property value losses for the entire impact area also appear in the upper panel of Table 5. There are 16,724 households in the area: 2,650 nearest the upper river, 1,641 nearest the middle river, and 12,433 households nearest the lower river. We multiply each section's mean loss by the number of nearest households within five miles—for example, 2,650 times approximately $18,420 for upper river households, producing a total loss of $48.8 million associated with that segment.

Due to the large number of households in the lower river area, the total estimated mean property value loss is greatest there—in excess of $102 million. Households nearest the middle river are the fewest in number and generally farthest from the AOC, so their total loss based on the mean value is least—$6 million to $7 million. However, the 95% confidence intervals for the estimates for both *LR* and *MR* encompass zero, leaving only the $48.8 million estimate for *UR* properties with strong statistical support. (The underlying coefficient estimates for *LR* are significant at the 10% level but not at the 5% level.) Considering all segments together, the estimated mean total property value losses are approximately $158 million. If, instead, we compute the total losses based on the model in which we constrain the AOC impacts to be the same along all river segments—i.e., the model with no interaction terms between distance to the AOC and the segment of the AOC—the total property value loss is $172 million.

Analysis of Housing Choices

This section focuses on the conjoint choice housing survey. Once again, we follow the methods described more fully in Braden *et al.* (2008). We first estimate the respondent's utility function for housing using the Random Utility Model (RUM). Then, based on the utility estimates and following reweighting to compensate for sample statification, we compute the maximum willingness to pay for a change in the environmental condition of the river.

The attributes varied in the conjoint choice questions are the size of the home (*HOUSE*, in ft^2), the distance to the AOC (*DIST*, in mi), the environmental condition of the AOC (*ADD* = more pollution; *PART* = partial cleanup; *FULL* = full cleanup), and home *PRICE* (in 2004 dollars). *DIST* and *HOUSE* are transformed to natural logarithms to allow for nonlinear effects. For comparison to the hedonic results, we focus here on how much more homeowners would be willing to pay for homes if *FULL* prevails as the environmental condition.

The Sheboygan survey defined the AOC as beginning at the Waelderhaus Dam and extending to the mouth of the harbor. In effect, the upper river segment was excluded. This was a pragmatic effort to minimize confusion about the status of the upper river, which was about to undergo remediation at the time the survey was administered. There had been a good deal of publicity about the impending cleanup. Since the upper river was excluded from the AOC in the survey, distances to the truncated AOC are accordingly greater for the homes closest to *UR*. *UR* respondents were expressing WTP for cleanup in the *MR* and *LR* segments.

The random effects conjoint choice model estimates appear in Table 6. The random effects estimator compensates for potential correlation between the multiple responses provided by each survey respondent (Haaijer *et al.* 1998). The Wald-χ^2 test indicates that the overall model is significant at the 1% level. The log likelihood for the random effects estimator is significantly higher (less negative) than for the general conditional logit model (–1324.72 vs. –1378.91). The log likelihood test for the existence of correlation within individuals shows that we can reject the null hypothesis at the 1% significance level. Thus, an individual's own responses are significantly related to each other, supporting the use of the panel estimator.

TABLE 6. *Results for random effect conditional logit model of home choice*[a].

Variable	Coefficient	Std. Err.	|t|	P>|t|
ln*HOUSE*	5.07897	0.42919	11.83	0.00
ADD	–1.40679	0.13879	–10.14	0.00
PART	0.14428	0.10677	1.35	0.18
FULL	0.87625	0.10343	8.47	0.00
ln*DIST*	–0.00682	0.02031	–0.34	0.74
ln*DIST*ADD*	–0.02773	0.03508	–0.79	0.43
lnD*IST*PART*	0.01643	0.03212	0.51	0.61
ln*DIST*FULL*	–0.05388	0.02705	–1.99	0.05
PRICE	–0.00003	0.00000	–12.64	0.00
*HIGH**ln*HOUSE*	–1.42694	0.62163	–2.30	0.02
*HIGH*ADD*	–0.32794	0.21364	–1.54	0.13
*HIGH*PART*	0.05814	0.15758	0.37	0.71
*HIGH*FULL*	0.16076	0.14881	1.08	0.28
*HIGH*PRICE*	0.00001	0.00000	3.85	0.00
*MID**ln*HOUSE*	1.55785	0.52379	2.97	0.00
*MID*ADD*	0.08699	0.15829	0.55	0.58
*MID*PART*	–0.00060	0.12787	0.00	1.00
*MID*FULL*	0.01756	0.11880	0.15	0.88
*MID*PRICE*	–0.00004	0.00004	–1.12	0.26
ASC	1.09100	0.13746	7.94	0.00
Number of obs	2856			
Number of groups	370			
Obs per group: min	1			
avg	7.7			
max	8			
Wald $\chi^2(19)$	360.22			
Prob > χ^2	0			
Log likelihood	–1324.729			

[a] Variable definitions: *HOUSE* = house size (ft^2); *ADD* = Additional pollution; *PART* = Partial cleanup; *FULL* = Full cleanup; *DIST* = Distance to the AOC (mi.); *PRICE* = Price of home (2004$); *ASC* = Alternative Specific Constant (= 1 for current home, 0 otherwise).

The *ASC* variable, indicating whether the current home is chosen, is highly significant although not large in magnitude Each attribute variable occurs in the model alone and in interactions with other variables. Both the Delta and Bootstrap methods were used to generate standard errors with consistent results. The variables *HOUSE, PRICE, ADD*, and *FULL* are significantly positive at the 1% level. *PART* is insignificant. The joint hypothesis test for all variables including *FULL* is significant (H_0: $\beta_{FULLT}+\beta_{lnDIST*FULL}+\beta_{HIGH*FULL}+\beta_{lnDIST*FULL} = 0$; $\chi^2(1) = 32.19$; p-value = 0.00). Hypothesis tests for

DIST and the joint significance of *DIST* and its interaction with the environmental condition variables are not significant, with the exception of *DIST* + *DIST*FULL* (H_0: $\beta_{DIST} + \beta_{DIST*FULL} = 0$; $\chi^2(1) = 4.12$; p-value = 0.04). *DIST* interacts negatively with *FULL*, implying that proximity to the AOC increases utility when the river is clean. The negative and significant interaction of *HIGH* and *HOUSE* implies that high-income respondents place less value on house size than middle- and low-income respondents—probably because their homes are already larger. The positive coefficient on *MID*HOUSE* means that middle-income respondents place above-average value on added housing space. The positive and significant coefficient on *HIGH *PRICE* implies that high income households require larger than average price increments to influence their choices.

The conjoint choice estimates are translated into dollar values following the procedures described by Braden *et al.* (2008). We focus on the full cleanup results for comparability to the hedonic results and report only mean values because median values were not very different. By segments, the estimated mean WTP for full cleanup are $13,067 (*LR*), $13,650 (*MR*), and $12,481 (*UR, based on cleanup of the MR and LR*). The weighted average across all segments is approximately $13,037. These results are in the middle of those produced by other model specifications. Multiplying the respective segment values by the number of households produces the aggregate impact estimates shown in the lower panel of Table 5. The total WTP is $218 million. Of this total, $162.5 million (75%) is attributable to homes closest to the *LR*.

Comparison of Hedonic and Conjoint Choice Estimates

The estimated property value losses from the AOC total $158 million (mean value of $9,447/home; 7% of mean property value) of which only the $48.8 million portion (mean value of $18,420/ home; 14% of mean property value) related to homes nearest the *UR* segment has a 95% confidence interval that does not include zero. The conjoint results imply a weighted mean willingness to pay for full cleanup of approximately $13,037 (10% of the sales sample mean price) which translates to an estimated total WTP for full cleanup of $218 million. Of the latter total, 75% is attributable to homes nearest the lower river segment. The upper river segment accounts for $33.1 million in WTP for cleanup which is less than the estimated property value loss in that area.

A comparison of the estimated marginal values of home size provides additional insight into the difference in total values. The hedonic model estimates a value of approximately $55/ft^2 at the sample mean size while the conjoint analysis produces a value of approximately $105/ft^2. The small number of home attributes available for inclusion in the hedonic model may have imparted bias in the coefficient estimate for home size. In any case, the conjoint survey responses yield a significantly greater estimate of marginal value relative to the market-based estimates.

Revenue Implications

To illustrate the revenue implications of the potential increases in residential property values, we offer a calculation based on the lower-bound increases in property values estimated with the hedonic model for owner-occupied properties closest to the middle and lower river segments. The calculation focuses on these segments because they have not yet undergone remediation. Based on a review of rates prevailing in Sheboygan County communities in 2005, an overall property tax rate of 2.5% of market value is a reasonable approximation. Applying this rate to the hedonic estimates for segments *LR* and *MR* totaling $109 million (albeit, the estimates from both segments are based on statistically-insignificant coefficients) implies an aggregate annual revenue collection of $2,725,000. Assuming further that local governments could issue 15-year revenue bonds paying a 5% annual coupon interest with a 2% cost of bond issue, these revenues would suffice to repay principal and interest on a bond worth approximately $27.7 million. This calculation should not be interpreted as a specific estimate of revenues that Sheboygan County jurisdictions could commit to AOC remediation. It is based on full and immediate realization of lost property values that do have strong statistical support. Clearly, it would be unwise to count on these estimates. In addition, it does not account for other local needs for funds, assumes that multiple jurisdictions could act jointly, and may not accurately depict bond market conditions.

CONCLUSIONS

This study sought to discover how contamination of the Sheboygan River, WI has affected property values in the area and to estimate the potential for economic gains that might accompany remediation. We collected data for and applied two distinct empirical methods to assess the economic benefits of AOC remediation through effects on the value of residential real estate. All impacts were measured in 2004 dollars. The hedonic analysis of single-family owner-occupied property sales within a five-mile radius of the Sheboygan River AOC, after controlling for selected structural, community, and spatial effects, indicates an overall loss of value of $158 million (8% of adjusted assessed market value) due to their proximity to the AOC. However, only the $48.8 million loss for properties closest to the upper river segment has strong statistical support. The survey-based analysis of willingness to pay for cleanup produces an overall estimate of $218. Three-quarters of the WTP is attributable to homeowners closest to the *LR* segment. The upper river segment alone produces statistically significant estimates in both analyses: $48.8 million in price discounts from the hedonic analysis and $33.1 million in WTP for full cleanup from the survey. The WTP for *UR* households relates to the condition of the *MR* and *LR* segments, and this may account for a WTP estimate that is less than the price discount for properties in the *UR*.

Several other studies have estimated the economic impacts of AOCs on surrounding property values (see Braden *et al.* 2008 for a full description). The estimated impacts range from less than 1% of property values for the Ashtabula River AOC (Lichtkoppler and Blaine 1999) up to 17% of the mean property value for homes located very close to the Grand Calumet Harbor AOC (McMillan 2003). The results reported here are in the mid-range of those produced by the earlier studies, and the proportional effects are very similar in magnitude to those reported in Braden *et al.* 2008 for the Buffalo River AOC.

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