MULTI-SITE ECONOMIC BENEFITS OF SEDIMENT REMEDIATION AT GREAT LAKES AREAS OF CONCERN

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Final Report to the Illinois-Indiana Sea Grant Program
Under project AOM NA06 OAR4170079 R/CC-06-06

1. Project Goal

The broad goal of this research was to accelerate informed decision-making about contaminated sediment remediation in the Great Lakes. The research aimed to be directly applicable to the remedial action plans (RAPs) prepared for each Great Lakes Area of Concern (AOC) and to the lakewide management plans (LaMPs) prepared for each of the Great Lakes. The research had two subsidiary objectives: (1) to quantify the economic benefits of contaminant clean-up for communities adjacent to Great Lakes Areas of Concern (AOC) and (2) to educate the public and elected officials about the economic benefits of clean-up.

2. Narrative/Accomplishments

The following accomplishments relate to the "Description of Investigations" in the original project proposal.

(a) *Collect and characterize studies.* We have collected and coded 45 economic studies of noxious sites, including AOCs. These studies yield more than 120 individual estimates of economic impact. The coded database is being provided electronically to IISG along with this report.

(b) *Complete analysis of Sheboygan River AOC.* The Sheboygan analysis was completed in March 2007. A manuscript reporting on this study has survived second review review at *J. Great Lakes Research* and is in revision for further consideration. The current version of that manuscript is included here as Appendix A. The value estimates from that study are included in the database note in section (a) above.

(c) *Estimate meta-value function.* The analysis of the data collected in part (a) is presented in Appendix B of this report. This manuscript is in revision for submission to an appropriate scholarly journal.

(d) *Derive benefits-transfer function*. The benefits transfer methodology is described in Appendix C.

(e) *Compute basin-wide benefits.* Appendix C also presents the results of the benefits transfer process.

2. Impacts

Information about the Sheboygan study was posted on the Great Lakes webpage maintained by the Northeast Midwest Institute, with whom the University of Illinois partnered in the study. The Institute updated information on the website as the study progressed including the posting of project summaries, event information, and news releases.

The project team presented information on many phases of the project as follows:

John B. Braden. "Buried Treasure: The Economy of Brownfields." Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 3, 2006; Department of Agricultural and Applied Economics, University of Wisconsin-Madison, February 10, 2006; Department of Agricultural Economics, Michigan State University, March 7, 2006; Kwansei Gakuin University (Japan), April 5, 2007; National Chung Ching University (Taiwan), April 9, 2007; National Taiwan University, April 12, 2007.

John B. Braden. "The 'Great' Lakes." Dial Club at the University of Illinois, Urbana, February 6, 2006.

John B. Braden. "Economic Benefits of AOC Remediation." Presentation at a public forum sponsored by the Sheboygan River Partnership, Maywood Environmental Park, Sheboygan, WI, February 9, 2006.

John B. Braden, DooHwan Won, Laura O. Taylor, Nicole Mays, and Allegra Cangelosi. "Economic Benefits of AOC Remediation: New Evidence from Buffalo and Sheboygan." International Association of Great Lakes Research Annual Meeting, Windsor, ONT, May 22-26, 2006.

John B. Braden. "Sunken Treasure? New Evidence about the Economic Value of Contaminated Site Remediation." Great Lakes Science Advisory Board, International Joint Commission, Windsor, ONT, October 5, 2006.

John B. Braden. "Sunken Treasure? New Evidence about the Economic Value of Contaminated Site Remediation." University of Michigan/Great Lakes Environmental Research Laboratory Workshop on Great Lakes Health, Ann Arbor, October 5, 2006.

John B. Braden, Xia Feng, and DooHwan Won. Waste sites and property values: A meta analysis. Association of Environmental and Resource Economists, Orlando, FL, July 27, 2008.

The project team provided regular updates on project developments to local, state and federal stakeholders, community groups and concerned citizens in person, via email, phone and postal mail. Particular attention was paid to maintaining contact throughout the project's duration with the Sheboygan River Partnership, University of Wisconsin Extension, Wisconsin Department of Natural Resources, and Wisconsin Sea Grant. Project representatives visited Sheboygan in, February 2006, and September 2006.

A public forum to disseminate the findings for Sheboygan was held at the Blue Harbor Resort & Conference Center (725 Blue Harbor Drive, Sheboygan, WI) from 2:00 pm to 3:30 pm on Thursday, September 21, 2006. It featured a presentation by Dr. John Braden concerning the results of the two-year study on the economic value of cleaning up the Sheboygan River Area of Concern (AOC). Other speakers included Sheboygan Mayor Juan Perez, Wisconsin State Senator Joe Leibham, Marc Tuchman with EPA's Great Lakes National Program Office, James McNelly with the Wisconsin Department of Natural Resources, Jon Gumtow with the Sheboygan River Basin Partnership, and Nicole Mays with the Northeast-Midwest Institute. David Ullrich, Executive Director of the Great Lakes and St. Lawrence Cities Initiative, moderated the event. Jim Hurley attended on behalf of Wisconsin Sea Grant. Overall, more than 45 people attended.

3. Performance Measures

<u>Performance Measures and Descriptions</u>
Measure 1: Economic and societal benefits derived from the discovery and application of new sustainable coastal, ocean, and Great Lakes products from the sea.

None – not applicable.

Measure 2: Cumulative number of coastal, marine, and Great Lakes issue-based forecast capabilities developed and used for management.

2007 Actual:
2 new estimation models completed and used to forecast economic benefits of remediation in Sheboygan River AOC

2008 Actual:
1 new estimation model of noxious site impacts; 1 new forecast model of economic benefits of remediating U.S. Great Lakes AOCs

Measure 3: Percentage/number of tools, technologies, and information services that are used by managers (NOAA and/or its partners and customers) to improve ecosystem-based management.

2007 Actual:
4 tools and services provided
1 applied to study of tax increment financing for remediation
1 applied to USEPA assessment of SuperFund legislation

2008 Anticipated:
1 meta-analysis model of the property value impacts of contaminated sites
1 benefits transfer model for unstudied contaminated sites

4. Partners

List partners in each of the following areas within the time period covered by this annual report. Partners are those who are co-funding/participating on projects or activities with Sea Grant.

Federal	Regional	Local & State	NGOs	International	Industry/Business	Academic Institutions	SG Programs	Other
USEPA - GLNPO		Cities of Sheboygan & Sheboygan Falls, Village of Kohler	Northeast-Midwest Inst.	International Joint Commission – Great Lakes Science Advisory Board	Marggraf Meetings	University of Illinois at Urbana-Champaign	IL-IN Sea Grant	
USDA - CSREES		Wisconsin DNR	Sheboygan River Basin Partnership		Associated Appraisals	Georgia State University & North Carolina State University	WI Sea Grant	
			Great Lakes & St. Lawrence Cities Initiative		Tellen Co.	University of WI Extension		
					Barbieur Appraisals			

5. Publications List (print or electronic)

Please list all publications according to the categories below that were produced during this reporting period.

Peer-Reviewed Journals/Articles/Book Chapters:

Braden, J.B., L.O. Taylor, D. Won, N. Mays, A. Cangelosi, and A.A. Patunru. "Economic Benefits of Remediating the Sheboygan River, WI Area of Concern." *J. Great Lakes Research*, in revision for third review, July 2008.

Technical Reports:

Braden, J.B., L.O. Taylor, D. Won, N. Mays, A. Cangelosi, and A.A. Patunru. "Economic Benefits of Sediment Remediation." Report to the Great Lakes National Program Office, USEPA, under grant no. GL-96553601, December 2006, 121+ pp. (www.nemw.org/EconBenReport06.pdf)

Proceedings/Symposia:

Braden,J.B., D. Won, L.O Taylor, N. Mays, and A. Cangelosi. "Economic Benefits of AOC Remediation: New Evidence from Buffalo and Sheboygan." Great Lakes in a Changing Environment: Abstracts of the 49th Annual Conference on Great Lakes Research, International Association of Great Lakes Research, Windsor, ONT, May 2006, p. 20.

Won, D., J.B. Braden, and L.O. Taylor. "The Economic Impact of Contaminated and Nozious Sites: A Meta Analysis." Abstracts, Third World Congress of Environmental and Resource Economists, Kyoto, July 2006.

Braden, J.B., X. Feng, and D. Won. "Noxious Sites and Property Values: A Meta-analysis." Association of Environmental and Resource Economists, Orlando, FL, July 2008.

Thesis/Dissertations:

DooHwan Won, "Essays on the Economic Value of Environmental Cleanup." University of Illinois, PhD awarded, October 2007.

Videos/CDs/DVDs:
Handbooks/Manuals/Guides:
Press Releases:

NEWS RELEASE – September 19, 2006, Northeast-Midwest Institute, Washington DC. "Sheboygan Area **Homeowners** to Benefit from River Clean-up"

Newsletters/Periodicals:
Other (e.g. websites, such as SGNIS):

http://www.nemw.org/greatlakes.htm#sheboygan

Newspaper articles:

Emmitt B. Feldner. "Clean river could raise property values." *Plymouth Review Beacon* and *Sheboygan Falls News*, February 21, 2006.

Eric Litke. "River cleanup to help home values." *Sheboygan Press*, September 23, 2006.

Joelle Steffen. "Clean river boosts values." *Plymouth Review Beacon*, September 26, 2006.

Manuscripts in development for scholarly publication

Braden, J.B., X. Feng, and D. Won. "Waste Sites and Property Values: A Meta-analysis."

Braden, J.B., X. Feng, and D. Won. "Economic Impacts of Great Lakes Areas of Concern: A Benefits Transfer Analysis."

6. Students Supported

Students supported by any Sea Grant funds (i.e., hourly support, tuition and/or stipend).

Category	# of new students	# of continuing students	# of Degrees Awarded

Sea Grant Supported MS/MA Graduate Students			
Sea Grant Supported PhD Graduate Students		3*	1
Sea Grant Supported Undergraduate Students			
Other (e.g. high school)			
TOTAL			1

- One doctoral student produced a dissertation based on this project. The other two were appointed for shorter periods to conduct specific tasks while pursuing dissertation research in other fields.

Appendices

Appendix A

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

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

ABSTRACT: This study estimates the economic benefits of remediation in the Sheboygan River, WI Area of Concern using two distinct empirical methods. The methodology parallels that described by Braden *et al.* (2008). Within a five-mile radius of the Sheboygan River AOC, after controlling for numerous structural, community, and spatial effects, an analysis of market values shows that single-family residential property prices are depressed by approximately $109 million (7% of market value) due to their proximity to the AOC. The impacts are greatest proportionally for properties closest to the AOC and, collectively, for those located in the most populous areas. A survey-based method yields a median estimate of $184 million (10% of property value) in willingness to pay for full cleanup of the AOC. If remediation were to induce full recovery of a conservative estimate of property value losses, $109 million, local jurisdictions could expect increased property tax revenues of $2.7 million per year.

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

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

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 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 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 westward three miles from the Lake Michigan breakwater to the Kohler landfill. The middle river (*MR*) extends seven miles from the Kohler landfill to the Waelderhaus Dam. The upper river (*UR*) extends approximately four miles from the

Waelderhaus Dam Sheboygan Falls Dam. The bulk of the officially-recognized contamination originated in *UR* from a small engine manufacturing plant. The *MR* flows through land owned by 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. The industrial facility abuts the river near the landfill. The *LR* passes through parkland, commercial, and industrial areas in the City of Sheboygan, and a harbor before discharging into Lake Michigan. Early in the present decade, a large resort 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 with extensive dredging began in the *UR* (Tuchman 2005). The only activities planned in *LR* and *MR* consisted 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 five 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 data for the structural characteristics of individual properties. As a result, the usable structural characteristics were limited to the acreage of the property, size and age of home, and the numbers of full- and half-bathrooms. 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 highways, 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 homebuyers 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 sub-sample for each one. After adjusting for 11 undeliverable surveys, the overall response rate was approximately 48%. Of the 410 surveys returned, 40 were incomplete. The analysis is based on the 370 complete responses.

Due in part to the stratification across jurisdictions, the mean home price are approximately 18% higher and the mean home age approximately 14 years less for the survey response sample than for the sale sample. In terms of mean market price, size, and age, the homes owned by the response sample closely matches 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.

Our ability to make comparisons to census demographic statistics for the area is limited by the fact that the census does not report many summary 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 a county-level housing price index prepared by the OFHEO, the price-adjusted year 2004 median property value for our sale sample ($92,810) is less than the $102,667 calculated as a weighted average of the census median values for the communities in our sample as well as the adjusted median value of $116,156 in the survey responses; b) the census weighted 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). Since all survey respondents are homeowners, the incomes in the survey should exceed those of the general population.

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 Tables 3. 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 report 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. A plurality of the respondents expressed 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 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 most affects the value of homes nearest the river. 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. Tests for influential outliers failed to identify any that would explain these anomalies. Rather, the inconsistencies almost certainly reflect data limitations that precluded controlling for the number of bedrooms, fireplaces, garages, and other factors that typically vary with home size. Overall, the models did not differ appreciably in adjusted-R^2.

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 rate, 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 linear 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, 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 AOC, 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 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 river on the distance variable. There are reasons to believe that the effects of the AOC may differ across three segments of the Sheboygan River. First, the upper-river is separated from the middle river by a dam that bounds the active remediation in the upper river. Secondly, a major landfill and interstate highway overpass separate the *MR* from the *LR*. Furthermore, housing units closest to the *MR* are dispersed further from the AOC than in the lower and upper segments. Accordingly, we interact the variable indicating the distance from the AOC with two dummy variables, one indicating whether the house is closest to the *LR* and the second indicating whether the house is closest to the *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 *UR*. This indicates 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 the price gradients for the *MR* and *LR* segments to differ from that of the *UR*, are not individually significant. However, an F-test for the sum of the coefficients for the *LR* 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 *MR* 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 (see Figure 2).

While there are economic reasons 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, 6087.79 (σ = 2082), is statistically significant at the 1% level. We choose, however, to maintain the interaction terms based on the economic justification for their inclusion and because their inclusion 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 the distance variables are transformed by logarithms, the marginal impacts diminish rapidly as distance increases. The graph in Figure 2 truncates at two 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 one percent 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 price. Extrapolating linearly, at a distance of one 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 from 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.

To compute the realized total capital loss associated with the AOC from the hedonic model, we predict the increase in the price of a 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 two miles from the AOC, the realized capital loss is in the 3% to 5% range.

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 five 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% because they are generally further from the river. Homes located nearest the LR dominate the sample and their 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—for example, 2,650 times approximately $18,420 for upper river households producing a total loss of $48 million associated with that segment.

Due to the large number of households in the lower river area and their general proximity to the AOC, the total property value loss is greatest there—in excess of $102 million. Households nearest the middle river are the fewest in number and generally furthest from the AOC, so their total property value loss is least—$6 million to $7 million, although this is based on coefficient estimates that do not differ significantly from zero. Considering all segments together, the estimated total property value losses are approximately $157 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 mean property value losses are $172 million.

On the assumption that remediation already underway will reduce or eliminate the residential price reductions near the *UR*, it is useful to compute the total losses for the lower river and middle river homes alone as a guide to potential future remedial work. There are 14,074 households closest to these two segments. Their total property value losses, based on mean values, sum to approximately $109 million. Again, the $7 million in *MR* impacts is based on estimates that do not differ significantly from zero.

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 stratification, we compute the maximum willingness to pay for a change in the environmental condition of the river. The attributes included 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 impose 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 pragmatic effort to minimize confusion about the status of the *UR*, 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 *UR* was excluded from the AOC in the survey, distances to the truncated AOC are accordingly greater for the homes closest to *UR*.

The estimates produced by a random-effects panel estimator 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 rejects the null hypothesis at the 1% significance level. Thus, an individual's own responses are significantly related each other, supporting the use of the panel estimator.

The *ASC* variable indicates whether the current home is chosen. 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 *ASC*, *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). This joint expression is negative, implying that distance away from the AOC decreases utility when the river is clean; equivalently, a clean river would make closer properties more desirable. 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 are not very different. By segments the estimated mean WTP for full cleanup are $13,067 (*LR*), $13,650 (*MR*), and $12,481 (*UR*). The weighted average 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 $217 million. It includes the $22 million point estimate for *MR* that is based on coefficients that, together, are not significantly different from zero.

Comparison of Hedonic and Conjoint Choice Estimates

Compared to properties in the sales sample located at least five miles from the river, the hedonic results indicate that the AOC reduces value of a home nearest the lower river by a mean of $8,235. This equals approximately 7% of the sample mean market value. The weighted sample mean impact is $9,447, also approximately 7% of the average market value. The conjoint results imply a weighted mean willingness to pay for full cleanup of approximately $13,037. This is equivalent to 10% of the mean price in the sales sample. Restricting the analysis to the middle and lower sections of the river alone, to allow for current remediation in the upper river segment, produces total estimated property value losses of $109 million using the hedonic model and a WTP for full cleanup of \$184 million from the survey responses. Of the latter amount, \$22 million derives from a statistically insignificant coefficient for the *MR*.

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 hedonic 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 an illustrative calculation based on the lower-bound increases in property values estimated with the hedonic model. 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 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 the lost property values, and this may not be realistic. 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. We collected data for and applied two distinct empirical methods to assess the owner-occupied residential property value impacts. All impacts were measured in 2004 dollars. Within a five-mile radius of the Sheboygan River AOC, after controlling for numerous structural, community, and spatial effects, owner-occupied single-family residential property prices appear to be depressed on the order of $157 million (8% of adjusted assessed market value) due to their proximity to the AOC. The impacts are greatest for properties closest to the river and concentrated in the more populated areas nearest the lower river. Excluding properties closest to the upper river, where remediation is already underway, the survey-based estimates of willingness to pay for full cleanup of the middle and lower AOC segments are $184 million based on median or mean values. The comparable estimates (lower and middle river areas only) from the hedonic analysis are $109 million. A 2.5% property tax rate applied to an increase of $109 million in the property tax base would raise $2.7 million annually.

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 are very similar to those reported in Braden *et al*. 2008 for the Buffalo River AOC.

ACKNOWLEDGEMENTS

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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 (2000), except as noted

[a] American Community Survey, U.S. Bureau of the Census (2003)

[b] Weighted average of the jurisdiction medians

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 five 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.

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.

Table 4. Hedonic property value results[a]

	Coefficient	Std. Err.	t	P>|t|	95% Conf. Interval	
Housing characteristics						
fullbath	19522.77	2298.78	8.49	0.000	15014.70	24030.84
halfbath	11548.75	2007.16	5.75	0.000	7612.57	15484.94
ln*sfla*	77256.83	4252.41	18.17	0.000	68917.55	85596.12
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*	21386.86	2218.80	9.64	0.000	17035.64	25738.07
Location variables						
CSF	48428.56	10514.21	4.61	0.000	27809.44	69047.68
CS	-187.81	15300.47	-0.01	0.990	-30193.12	29817.49
VK	120703.20	14952.48	8.07	0.000	91380.31	150026.10
TW	7940.65	15607.56	0.51	0.611	-22666.89	38548.19
TS	19468.20	13410.13	1.45	0.147	-6830.01	45766.40
TL	8837.64	14573.01	0.61	0.544	-19741.06	37416.34
Distance variables (non-AOC)						
ln*landfill*	82600.81	17368.46	4.76	0.000	48540.03	116661.60
ln*evrgnwood*	-7317.33	2329.53	-3.14	0.002	-11885.71	-2748.95
ln*airport*	-29861.07	8629.41	-3.46	0.001	-46783.95	-12938.19
ln*notriver*	-3286.54	1969.81	-1.67	0.095	-7149.47	576.40
ln*shoreline*	-9593.60	2070.33	-4.63	0.000	-13653.66	-5533.53
ln*hwyx*	18748.77	4450.41	4.21	0.000	10021.20	27476.34
ln*uwsheb*	-90057.83	15654.76	-5.75	0.000	-120757.9	-59357.74
ln*rwaysite*	-733.77	4892.28	-0.15	0.881	-10327.88	8860.33
Distance variables (AOC)						
ln*aoc*	6761.05	2590.38	2.61	0.009	1681.13	11840.97
ln*aoc*LR*	-1489.57	3709.98	-0.40	0.688	-8765.10	5785.97
*lnaoc*MR*	-2690.14	4513.16	-0.60	0.551	-11540.77	6160.50

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

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.) [std. err.]	$8,235 ($3,378) [373]	$4,057 ($2,838) [195]	$18,420 ($6,924) [84]
Total mean value loss (10^6 x 2004$)[a]	$102	$7	$48
Total assessed value (10^6 x 2004$)	$1,384	$182	$294
Mean value loss / Assessed value	7.3%	3.8%	16.3%
Total adjusted ass'd value (10^6 x 2004$)	$1,486	$189	$342
Mean value loss / Adjusted ass'd value	6.8%	3.7%	14.0%
Panel B: Willingness to Pay for Full Cleanup from Survey Analysis			
Household WTP for full-cleanup [std. err.]	$13,067 [807]	$13,650[b] [1,331]	$12,481 [690]
Aggregate WTP for full-cleanup (10^6 x 2004$)	$162	$22 [b]	$33

[a] Total across all segments is $157 million.

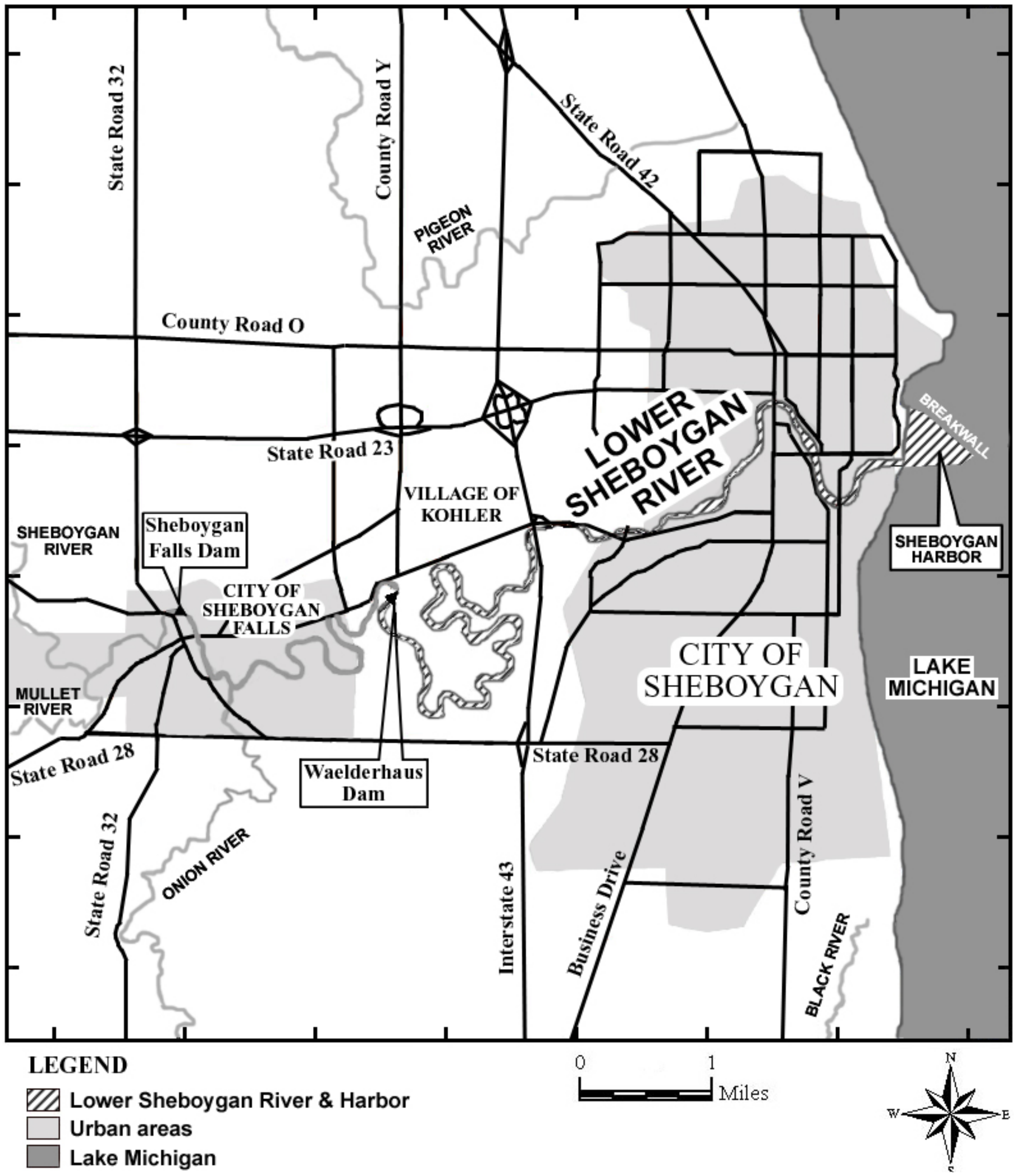
[b] Based on a coefficient not significantly different from zero.

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			

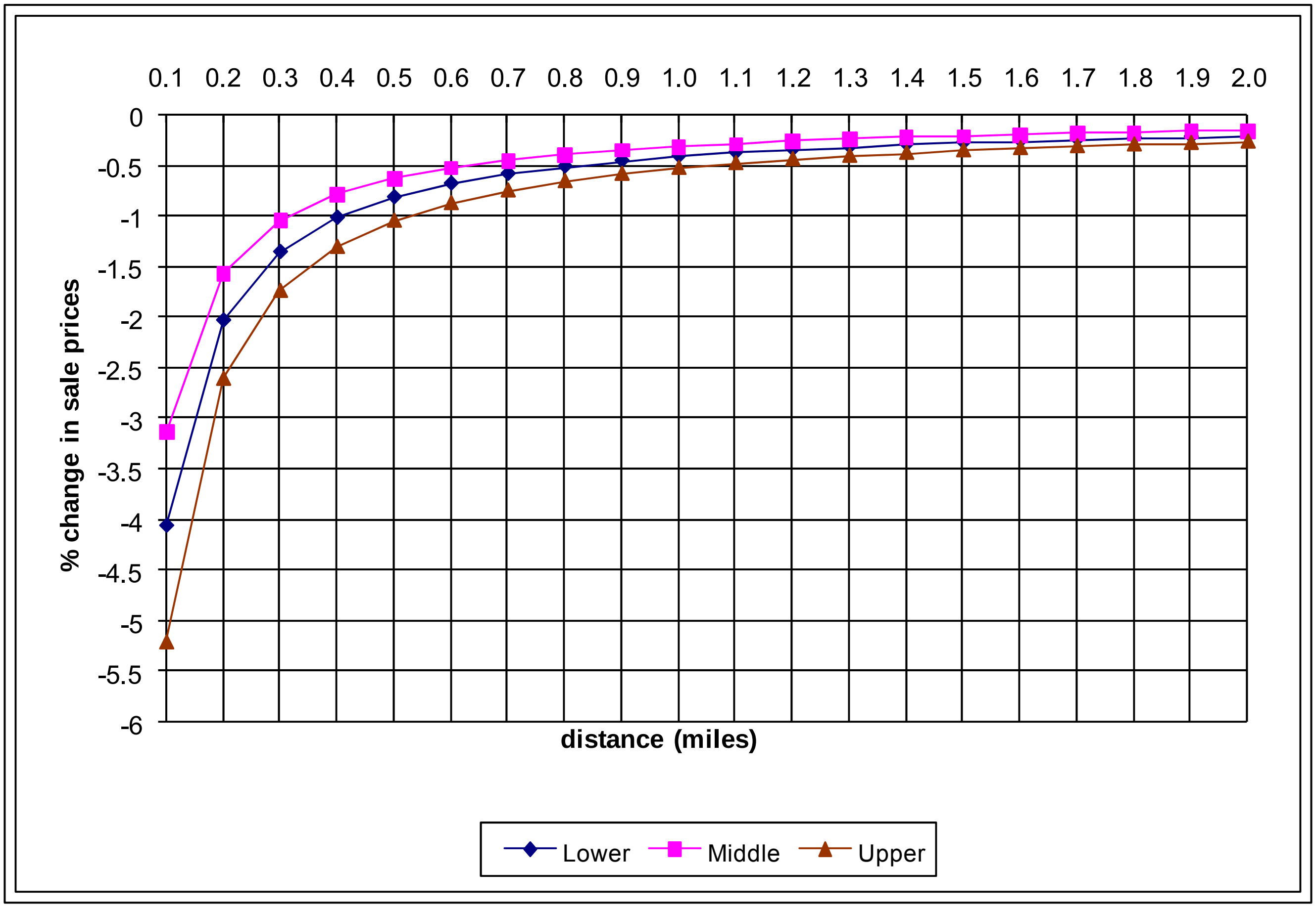
[a] Variable definitions: *HOUSE* = house size (ft^2); *ADD* = Additional pollution; *PART* = Partial cleanup; *FULL* = Full cleanup; *DIST* = Distance to the AOC (mi.); *PRICE* = Price of home (2004$); *ASC* = Alternative Specific Constant (=1 for current home, 0 otherwise).

Figure 1. Schematic 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.

Figure 2. Marginal impacts as percent of average sales price for properties within 2 miles of the Lower Sheboygan River



Appendix B

Waste Sites and Property Values: A Meta-analysis†

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Waste Sites and Property Values: A Meta-analysis

Abstract

This paper presents a meta-analysis of the literature measuring the economic impact of sites harboring waste materials on real estate values. This assessment is timely in view of recent studies suggesting that some of the most contaminated waste sites in the United States have idiosyncratic or no discernable effects on nearby property values. We develop a common measure of impact – the estimated proportionate effect on property values – and apply explanatory variables including characteristics of the study sites, the data collected, the methodology used, and exogenous variables representing temporal and market conditions. A sample of 46 studies yields 142 distinct estimates of property value effects, of which 129 observations survive outlier diagnostics. The estimation results are highly robust and significant across estimators and specifications. They suggest that all classes of waste sites affect real estate prices, but sites classified as hazardous, especially aquatic hazardous sites, lead to the greatest discounts. The estimated impacts of nonhazardous waste and nuclear sites are not statistically different from one another. Surprisingly, studies of sites included on the EPA's National Priority List estimate generally smaller impacts (although still statistically significant) than do studies of non-NPL hazardous waste sites. The estimates for sites in Canada and Mountain, Middle Atlantic, and South Atlantic states exceed those for other regions. Larger study areas and aggregated data, such as census block observations, are associated with lesser estimates.

1. Introduction

Over the past 20 years, the U.S. Environmental Protection Agency (EPA) has located and analyzed the risks associated with tens of thousands of hazardous waste sites.[1] By the early 1990s, more than $10 billion had been collected from a tax on chemical feedstocks to help pay for remediation of the contaminated sites considered most hazardous. In addition, by 1995, polluters who were found responsible for the contamination had committed more than $11 billion dollars toward cleanup (U.S. Environmental Protection Agency 1996). Nevertheless, hundreds of sites remain on

[1] Once contaminated sites are discovered, they are entered into the Superfund Information System (USEPA 2008b), also known as CERCLIS. EPA then evaluates the potential for a release of hazardous substances from the site using the Hazard Ranking System (USEPA 2008a). The severely hazardous sites are put on National Priority List (NPL) for cleanup. In addition to terrestrial sites, 43 severely-contaminated aquatic sites in the Laurentian Great Lakes Basin have been designated as Areas of Concern under the terms of the Great Lakes Water Quality Agreement between the U.S. and Canada (International Joint Commission 2006).

the National Priority List (NPL) and thousand more have been recommended for remediation. The potential costs of cleanup are daunting, and the pressure to ensure a return on investment is accordingly great. The potential for external impacts of these sites on the usefulness and value of neighboring properties elevates the issue from a private to a public concern. For property owners and local officials alike, the possibility of recovering lost property values, both on- and off-site, is often an important motivation for cleanup.

This paper presents a meta-analysis of the literature measuring the economic impact of waste sites on real estate values. Efforts to measure these impacts have focused on the market prices of properties potentially subject to harm. The usual hypothesis is that preferences concerning local environmental conditions, including the presence of waste materials, are capitalized into property values. Following Ridker's (1967) pioneering study of air quality impacts, dozens of articles and reports have tested the effects of geographically-defined waste sites. The literature has grown to the point where quantitative assessment to discover regularities is now possible. This paper provides such an assessment of 46 hedonic property value studies of the economic impact of waste sites.

This assessment is timely in view of recent studies suggesting that some of the most contaminated sites in the United States – those selected for the National Priority List (NPL) under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as the Superfund Law) – have idiosyncratic (Kiel and Williams 2007) or no (Greenstone and Gallagher forthcoming) discernable effects on nearby property values. NPL sites are supposedly those that present the greatest risk to human health. An absence of measurable offsite effects would weaken the case for actions to promote remediation, such as those called for under CERCLA.[2] However, the results of the studies by Greenstone and Gallagher (forthcoming) and Kiel and Williams (2007) are at odds with prevailing interpretations of the pertinent literature. Four previous publications assess the literature on the property value impacts of contaminated sites: three are qualitative (Faber 1998, Kiel and Boyle 2001, and Simons 2006) and the fourth (Simons and Saginor 2006) uses formal meta-analytical techniques. The latter study is closest in spirit to this paper, but the two differ in several respects. First, Simons and Saginor (S&S) commingle studies of likely positive environmental influences from parks, water bodies, and clean air together with studies of the negative effects likely to accompany not only NPL sites, but also high-voltage power lines, pipelines, nuclear sites, railroad easements, shopping centers, sex offenders, rental properties, confined animal facilities and other sources of air pollution. S&S use a single distance variable to capture the effect of proximity to a site plus dummy variables to distinguish the different types of site. In contrast to S&S, our analysis focuses on negative influences alone—in particular, sites that contain regulated waste materials: nonhazardous landfills, terrestrial sites contaminated by hazardous materials (both NPL sites and non-NPL sites), aquatic sites contaminated by hazardous materials, and nuclear sites.[3] We also limit the sample of studies to those that explicitly use standard market-based hedonic methods, while S&S also included surveys and case studies. Furthermore, we control for more potential influences on study findings: changes over time in institutions, knowledge and preferences; and features of the individual sites, studies, data sets, and study methodologies. We also do not limit the analysis to residential properties; we include the few studies that analyze effects on commercial and industrial

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[2] For over two decades, federal agencies have been required by Presidential Executive Orders to analyze the benefits and costs of significant regulatory proposals and actions and to show that the benefits justify the costs (Executive Office of the President 2007).

[3] Of these categories, nuclear sites alone are not regulated principally under environmental statutes. They are included here because they closely resemble hazardous waste sites in that materials known to pose risks to humans are stored onsite.

real estate. Finally, several recent additions to the literature, including studies of aquatic hazardous wastes sites, have not previously been included in meta-analyses.

In focusing on studies of nearby property values, we do not mean to suggest that property values fully capture the externalities associated with these sites. Among the economic impacts unlikely to be embedded in property values are those expressed through bio-transport and bio-accumulation and affecting, for example, water-based recreation and fishing activity.

We hypothesize that hedonic studies of waste sites reveal systematic discounts in the prices of neighboring properties, with larger discounts for hazardous sites than for nonhazardous landfills. In a similar spirit, Smith and Desvousges (1986) found that 77% of survey respondents in Boston were unwilling to live within five miles of a nuclear power plant compared to 67% for landfills and 52% for coal-fired electric generating plants. We make no attempt to distinguish the specific mechanisms underlying the external impacts, which might range from quantifiable physical impacts (Gayer *et al.* 2000) to stigmatization (Dale *et al.* 1999; Messer *et al.* 2006). Whatever the means, we hypothesize that the market discounts proximity to all waste sites, but different types of waste sites have distinct effects.

The next section briefly reviews meta-analysis and the hedonic valuation method used by all of the studies reviewed here. The paper continues with a description of the meta-model, the data, the empirical results, and conclusions.

2. Meta-analytic and Hedonic Models

Meta-analysis is a statistical method used to integrate and summarize research results from many studies addressing a common subject. It highlights points of agreement and disagreement. First used in psychological research (Glass 1976), meta-analysis has become widely accepted in the behavioral, social, health, and economic sciences (Stanley 2001), including environmental economics (Nelson and Kennedy 2008).

The studies analyzed here are all drawn from the hedonic property value literature. In brief, following Freeman (2003) and Taylor (2003), the market equilibrium prices of housing are assumed to be described by a hedonic price function

$$P = P(S,N,A) \tag{1}$$

where the price of a home P is a function of vectors of structural S, neighborhood N, and environmental A variables, respectively. The marginal cost of an additional unit of a particular characteristic equals the equilibrium marginal willingness to pay (MWTP) for it, and both equal the partial derivative of the hedonic price function. The partial derivative of the hedonic price function with respect to an environmental variable is the basis of all price impact estimates in the literature reviewed here.[4] Although the price impact of a waste site is most likely to be negative, it is often interpreted as a positive willingness to pay for elimination of the negative impacts. Here, we adopt this interpretation – a positive *MWTP* indicates the magnitude of the price discount and, accordingly, the presumed potential for offsite property value gain from remediation.

Most hedonic studies of localized disamenities use the distance from such a site as a proxy for exposure to negative externalities. Under certain conditions (Taylor 2003), the marginal price of an additional unit of distance measures the MWTP to avoid the disamenity. Several distinct attributes of a site might affect location decisions. For example, a home located both near a contaminated site and adjacent to a busy highway could be affected by both "neighborhood"

[4] Estimation of the hedonic price function and the marginal implicit attribute prices constitute the "first-stage" of the method outlined by Rosen (1974). They characterize the intersection of marginal willingness to pay and marginal supply costs. For non-marginal changes in attributes, however, marginal values might change along the respective demand and supply curves. Estimation of the welfare effects of such changes would require so-called "second-stage" estimation of the underlying demand function. Serious econometric challenges of identification confront second-stage estimation (Taylor 2003), so virtually all applied studies settle for a lower-bound approximation of the true welfare value. The approximation consists of the estimated marginal value times the magnitude of the change in the attribute.

attributes. By controlling for these other attributes, and assuming that the contamination is the influential feature of the site of interest, the economic effect of the contamination is assumed to be embedded in the distance to that site.

In lieu of distance, some studies use the number of waste sites within a study area as a measure of the density of exposure (Ketkar 1992) or use a dummy variable to indicate the presence of a contaminated site (e.g., Gunterman 1995; Ho and Hite 2000). In these instances, the marginal price effect of an additional contaminated site, or the presence of a contaminated site, is the MWTP to avoid the waste site.

Virtually all studies restrict the geographic scope of the price effects. The assumption is that property prices beyond a particular perimeter are unaffected and, thus, serve as a benchmark for comparison. The summary measure of impact is the price differential between an "average" home at or beyond the perimeter and the identical home located at the sample mean distance from the waste site. This equals the integral of the hedonic price function from the mean distance to the perimeter holding all other variables at the sample means. We label this measure as ΣMWTP. A hedonic price function that is linear in distance yields a constant MWTP while the marginal estimates in a nonlinear specification vary with distance.

The hedonic property value model has been implemented in two distinct ways. The original and most-used approach employs cross-sectional data on property sales (e.g., Freeman 1974). The second approach analyzes repeat sales using panel data techniques (e.g., Palmquist 1982). This approach typically examines changes in the property market before and after a shock, such at the discovery or elimination of contamination. It has the advantage of reducing the need for detailed structural and neighborhood data, as long as those variables remain stable over time. Changes in the environmental condition of interest are represented by discrete dummy variables and MWTP is calculated for a change in the dummy variable. Even though there are differences in the meaning of MWTP between the standard single-period hedonic price model and the repeat-sales model, their theoretical bases and the functional forms used in estimation are very similar.

In addition to the market-based hedonic model, discrete choice methods have been applied to housing choices in the presence of disamenities (e.g., Cropper *et al*. 1993, Braden *et al.* 2004 and 2006a,b[5]). Although these applications also focus on property values, the theoretical basis for the estimation of willingness to pay differs from hedonic studies.[6] The different theoretical basis motivates their exclusion here.

3. Meta-analysis Model

The first requirement of meta-analysis is a comparable measure of outcomes. This serves as the left-hand-side variable in the meta-function to be estimated. Because the studies reviewed here differ in time and place, we need an indicator that is robust to inflation and differences between local markets. Following Nelson (2004), for each study *i*, we use a measure of relative impact – the marginal proportional price effect ($MPPE_i$):

$$MPPE_i = \frac{(\sum MWTP)_i}{P_i}.^{7} \qquad (2)$$

Recall that $(\Sigma MWTP)_i>0$ indicates the potential to recover external economic value from elimination of the waste site. We hypothesize that $MPPE_i$ depends on three classes of influences: site characteristics, the nature of properties affected, and the methods of analysis:

$$MPPE_i = f\,(site\ characteristics,\ data\ characteristics,\ methodology) \qquad (3)$$

[5] These studies report parallel applications of market-based hedonic methods and survey-based discrete choice methods. For this paper, their hedonic results alone are included.
[6] Discrete choice model starts with estimating indirect utility function while the other two model estimate hedonic price function of housing. In addition, it is based on hypothetical choices, not real market data.
[7] As noted earlier, hedonic models use either a continuous distance variable and or a discrete variable, such as an added contaminated site, as the instrument measuring environmental exposure. In either case, the reported MWTP is an average for the area studied.

The variables used here to capture these influences are defined in Table 1 and described below.

Site Characteristics

Type of disamenity. Our sample contains studies of non-hazardous sites (*Nonhaz*), hazardous waste sites, either terrestrial (*Terr*) or aquatic (*Aquatic*), and nuclear power plants (*Nuclear*). Non-hazardous sites include sanitary landfills and recycling centers. Terrestrial hazardous waste sites include hazardous waste landfills, inactive industrial sites where hazardous materials remain, and hazardous waste incinerators. Aquatic hazardous sites are river or harbors contaminated by hazardous substances. Since proximity to water has often been found to have pronounced effects on property prices (Luttik 2000), we separate aquatic hazardous sites to determine whether the literature reveals distinctive effects for waste sites as well. Nuclear sites include nuclear power plants, railroad easements where nuclear materials are transported, and radioactive material storage sites. Virtually all nuclear power plants store radioactive waste materials on-site. These four categories are mutually exclusive. By including studies of sites that store waste materials but are not classified as hazardous, we can perform a crude test of the hazard classification.

Geographic Location. Previous studies have detected regional differences in property markets (Simons and Saginor 2006). To learn if the literature indicates regional differences in the effects of waste sites, we include variables for the region(s) to which each study applies. Two studies (Lim and Missios 2007; Zegarac and Muir 1998) use Canadian data and the rest are linked to U.S. census regions: Pacific, Mountain, West Northcentral, East Northcentral, Middle Atlantic, New England, West Southcentral, East Southcentral, and South Atlantic. One study (Folland and Hough 1991) examined sites in multiple regions.

NPL. NPL designation indicates the most hazardous sites regulated by EPA. With the notable exceptions of Kiel and Williams (2007) and Greenstone and Gallagher (forthcoming), virtually all studies have found that NPL status significantly influences nearby housing values. The literature varies on whether remediation reverses negative price effects (e.g., Kiel 1995, McCluskey and Rausser 2003a).

On-site employment (Job). We hypothesize that *MPPE* is affected by the presence of job-creating economic activity at the site. On-going employment at a waste site may attract residents and offset the disamenity effect (e.g., Nelson 2004).

Stage of Cleanup (Stagei, i=0, 1, 2, 3*).* It seems likely that the discovery and confirmation of contamination (stages 0 and 1) would negatively affect nearby property values, but plans for and actions accomplishing remediation (stages 2 and 3) could mitigate the negative effects. To examine these conjectures, following Kiel and McClain (1995, 1996) and Kiel and Zabel (2001), we divide the cleanup process into the four noted stages and assign the *MPPE* estimate(s) from each study of an NPL site to one of those stages depending on the status during the period represented by the data. However, there are no standard definitions of status that have been applied across sites. Individual studies are often unclear about that status. [8] Thus, considerable judgment is required to assign a site status that allows the testing of these hypotheses. The studies of *Nonhaz* and *Nuclear* sites are not readily categorized in these ways, so they are subsumed in the case where all of the *Stage* variables take on zero values.

Cleanup. As a bivariate alternative to the cleanup stage variable, we also test a dummy variable *Cleanup* which distinguishes hazardous waste site studies conducted before cleanup from those undertaken afterwards.

[8] The studies of aquatic hazardous sites all come from the Great Lakes, where a standardized categorization has been developed by the International Joint Commission. The Great Lakes Areas of Concern (AOCs) are described at http://www.epa.gov/glnpo/aoc. The stages include nomination of the site as an AOC, formal designation as an AOC, completion of a remedial action plan, and delisting following remediation.

Data characteristics

Property type (Residen). The *Residen* variable controls for whether the estimated price impacts are for residential or non-residential properties. Commercial and industrial properties are more likely than residential properties to be located near waste sites and thus may reveal greater price impacts (Ihlanfeldt and Taylor 2004).

Individual parcel data (*Ind_sale). Ind_sale* controls for the use of sales data for individual parcels as opposed to assessment data for individual parcels or aggregate value data (e.g., for census blocks). In our sample, five studies used census data and two relied on assessment data. Individual sales data avoid the potential for lags and approximations in property assessments as well as the averaging and potential inaccuracy inherent in self-reported census data.

Geographical range (*Mean_Dt*)*.* As most nonlinear property value models imply, the proportional impact of a waste site is probably greatest for properties nearest to the site. Other things equal, data drawn from a larger geographic scale should yield a lesser *MPPE*. The mean distance from each property to the site of each study (*Mean_dt*) controls for this effect.

Number of sites (*M_Site*). This variable tests for whether the presence of multiple waste sites in a study affects the magnitude of the measured *MPPE*.

Sample size (Sample). The studies analyzed range in sample size from a minimum of 25 observations to a maximum of 70,328 observations. Variation in sample size may affect the statistical precision and significance of the estimates.

Neighborhood characteristics. Dummy variables reflect whether the studies included specific types of neighborhood control variables. *Demoecon* indicates whether a study controlled for some economic features such as the income or poverty level; *Access* represents the inclusion of controls for transportation accessibilities; and *Industry* reflects whether industrial activity data were included in some way, such as with distance to the center of employment concentration or whether the study site is in an industrial zone. Twenty of the 46 studies included economic controls, 25 controlled for accessibility, and four controlled for industrial activities.

Time Trend (Time). Over time, as new information emerges and experience accumulates, levels of concern may change. *Time* controls for this possibility. *Time* is measured in annual increments beginning with the year of the data (1966 = 0) used in the earliest study in the data set (Havlicek *et al.* 1971). For studies that use data from multiple years, if the years are bunched together and the study is not a before-after analysis, then the middle year of the interval is chosen to compute *Time*; for before-after analyses, the event year is chosen. The longest intervals in individual studies are 21 years (1968 to 1988) (Mendelsohn *et al*. 1992) and 18 years (Ihlanfeldt and Taylor 2004). Most other multi-year studies cover periods of less than 10 years.

Mortgage Rate (*Mort_rt*). To control for economic market conditions, we also include the national annual average interest rate for a conventional 30-year mortgage.

Methodological variables

Model Type (Linear). In their meta-analyses of air quality and airport noise, respectively, Smith and Huang (1995) and Nelson (2004) found that linear functions yielded larger values than other functional forms such as log-log, log-linear, and linear-log. Most of the studies analyzed here use some combination of linear, log-linear, log-log and linear-log models. To preserve degrees of freedom, we use only a single dummy variable to distinguish linear from nonlinear models.

Type of environmental variable (Discre). Some studies represent the environmental condition through a count or dummy variable reflecting discrete, and often substantial, changes in the environmental condition. Others use a continuous distance variable to capture incremental changes in exposure to a static condition. The *Discre* variable captures the potential differences between continuous and discrete representations of the environmental condition.

Publication (Publish). Smith and Huang (1995) suggest that peer-reviewed publication may indicate higher analytical quality and larger measured impacts. We control for these possibilities by distinguishing studies published in peer-reviewed outlets from those found in the "grey literature." The notoriety of a site could also contribute to the significance and magnitude of impact (Kiel and Williams 2007), but there is no obvious way to control for notoreity.

Significance. The *MPPE* variable measures magnitude but not significance. We include a dummy variable (*Sig*) to control for the statistical significance of the environmental variable used in each study. Other things equal, we expect significant estimates to be larger in magnitude.

Spatial Autocorrelation (Sar). In spatial data, failure to control for spatial autocorrelation can produce biased and inconsistent estimates. Among the 46 studies reviewed, only two (Brasington and Hite 2005 and Gawande and Jenkins-Smith 2001) address this issue. The dummy variable *Sar* tests whether controlling for spatial autocorrelation affects estimates of *MPPE*.

4. *Data*

A web-based journal search identified more than 70 papers using property value models to study waste sites. Some are theoretical studies without empirical evidence. Others report only appreciation rates or lack sufficient information to calculate *MPPE* (e.g., Kiel and McClain 1995b; Greenberg and Hughes 1993; McCluskey and Rausser, 2003b; Smith and Desvousges 1986; Zeiss and Atwater 1989). In the end, 46 studies provide enough information to calculate *MPPE*s. These studies are denoted by asterisks in the reference list. Among them, seven deal with aquatic hazardous sites (Zagarac and Muir 1998; McMillen 2006; Mendelsohn *et al.* 1992; Chattopadhay *et al.* 2005; Braden *et al.* 2005; Braden *et al*. 2006a, 2006b), five address nuclear sites (Nelson

1981; Gamble and Downing 1982; Folland and Hough 1991; Clark *et al*. 1997; Gawande and Jenkins-Smith 2001), and 12 deal with non hazardous sites (e.g., Bleich *et al*. 1991). The rest focus on terrestrial hazardous waste sites. Some of the studies estimate more than one *MPPE* value. Overall, there are 142 observations of *MPPE* from the 46 studies.

The studies range in time from Havlicek *et al*. (1971) to Lim and Missios (2007). All of the papers except Adler *et al.* (1982); Zagarc and Muir (1998); Ready (2005); Braden *et al* (2006a, 2006b); Ho and Hite (2005); and Hite (2006) were published in refereed journals. The papers by Adler, Zagarc and Muir, and Braden *et al.* were written for governmental agencies or nongovernmental organizations while the others are working papers. Even though the latter studies have not cleared peer-review, we judged the methods, data, and results to be sound.

The average radius of the study areas is just over 6.5 miles. The sample mean of the average distance from the closest waste site is 3 miles.[9] Unless a site undergoes remediation, we expect a positive *MWTP* and *MPPE* estimate, indicating that property values are discounted. As shown in Table 1, the average *MPPE* of the sample of 142 observations is a discount of approximately 6.37%. The estimated *MPPE*s vary from -83.68% to 174.01%. Negative coefficients reflect increases in property values near a target site. This could happen following elimination of a disamenity or from failure to control for factors that offset the effect of a disamenity, such as the employment effects of a nuclear installation (Clark *et al.* 1997; Folland and Hough 1991). The most negative estimate (-83.68%) relates to the effect of landfills in Columbus, OH on the property values in census block groups with poverty rates greater than 16% (Hite

[9] Excluding the estimates associated with non-hazardous sites would reduce the observations from 142 to 107. If we exclude the non-hazardous sites, the mean MPPE is 8.27%, the mean radial distance of study area is 7.57 miles, and the mean distance to the closest waste site is about 3.48 miles.

2006).[10] Some waste sites produced no statistically significant price effect (Nelson 1981; Adler *et al.* 1982; Bleich *et al.* 1991)

5. Empirical Results

Regression Diagnostics

First, we estimate a robust OLS model with the full sample of 142 observations. As shown in the "Robust OLS with Outliers" results in Appendix Table A-1, the estimated model has a very low adjusted-R^2 value. This suggests a need for regression diagnostics to identify outliers. Since an outlier may be an observation with large residuals, the first method identified observations with standardized residuals greater than two in absolute value. This criterion isolated eight outliers. A second method is Cook's D (Cook and Weisberg 1982). This measures the overall influence of each observation on the regression coefficient estimate and identified ten outliers. The third, DFITS (Belsley, Kuh, and Welsch 1980), reveals unusual observations by combining leverage and the studentized residual. Here, it identifies 10 outliers, four of which were also identified by Cook's D and four of which stood out in residuals detection. Combining all three methods isolates 13 observations. These outliers are excluded in our final model estimation, reducing the number of observations to 129. Table 1 lists the summary statistics of the resulting sample. The mean *MPPE* decreases from 6.37% to 4.49%.

A t-test of the overall sample mean *MPPE* shows that it is significantly different from zero. Because we are interested mainly in whether the different site types and sites at different cleanup stages differ from each other, we also test for equality between group *MPPE* means. Table 2 shows summary statistics of *MPPE* by both type of sites and cleanup stages. Terrestrial hazardous waste sites dominate the sample, accounting for 76 of 129 observations. For these sites, using t-tests, the null hypothesis that mean *MPPE* equals zero is rejected at the 0.001 level for *Terr* and

[10] Hite (2006) provides very little in the way of explanation for this surprising result.

Aquatic and at the 0.05 level for *Nonhaz*. The null hypothesis is not rejected at the 0.05 level for *Nuclear*.[11] We are also interested in whether each group mean *MPPE* by type of sites differs from the overall sample mean *MPPE*. From the results shown in the table, the mean *MPPE*s of *Aquatic* (15.937) and *Nuclear* (-0.489) are significantly different from the overall sample mean while the means for *Terr* and *Nonhaz* are not.[12] This implies that the effects of aquatic and nuclear sites may be significantly different from those of non-hazardous landfills and terrestrial hazardous waste sites while the effects of the latter two categories are not significantly different. A homogeneity test of equal variance between the different types of sites confirms differences between the types of site at the 0.01 significance level.[13]

Another issue of interest is how cleanup status affects *MPPE* estimates. Only terrestrial hazardous waste sites and aquatic sites are subject to formal cleanup processes, so we can only analyze the issue for the 90 observations in these two categories. From Table 2, it is apparent that most of the observations are in Stage 1 where contamination is acknowledged but no cleanup plan has been developed. The average *MPPE*s of each stage for the *Terr* and *Aquatic* sites are 4.569 (*Stage_0*), 4.610 (*Stage_1*), 6.979 (*Stag_ 2*), and 5.702 (*Stage_3*). T-tests of the null hypothesis that each of the mean *MPPE*s is zero are rejected for stages 0, 1, and 2.[14] However, none of stage mean *MPPE*s are significantly different from the overall sample mean *MPPE* at the 95% level. This implies that different cleanup stages do not contribute significantly to variation of the overall

[11] Respectively, the t-statistics and p-values for *Terr* are 4.47 and 0.0000; for *Aquatic*, they are 4.97 and 0.0003; the values for *Nonhaz* are 2.00 and 0.054; and the values for *Nuclear* are -0.261 and 0.780.

[12] The t-statistics and p-values for Aquatic are 3.57 and 0.003; for Nuclear, they are -2.66 and 0.026.

[13] Bartlett's test for equal variances: χ^2 (3) = 10.729, Prob> χ^2 = 0.013.

[14] The t-statistics and p-values for Stage 0 are 2.181 and 0.072; Stage 1 values are 4.26 and 0.0001; Stage 2 values are 4.005 and 0.0005, and Stage3 values are 1.506 and 0.154.

sample mean *MPPE*. Nevertheless, a homogeneity test demonstrates that the variances of the stage *MPPE*s differ from each other at the 0.001 level.[15]

A multicollinearity test of the explanatory variables excluding outliers produced VIF scores well below 10, indicating no appreciable multicollinearity. The Breusch-Pagan test for heteroskedasticity of the variance reject the null hypothesis (p=0.0475) of constant variance in the error term, which means robust OLS is required to correct standard errors.

Estimation Models

Some studies provide multiple estimates of *MPPE*. Without adjustment, the more estimates a study provides, the more importance it would assume in the meta-analysis. Several approaches are available to control for this effect. One is to use only one estimate from each study so that each study has the same weight in meta-analysis (Stanley 2001). We applied this approach using the following rules: (1) If a study produced more than one result, use the estimate for residential properties in cleanup stage 1 or, if that estimate is not available, then use the estimate for stage 2; and (2) If multiple estimates are given for the same stage, then use the smallest estimate. These rules produced 46 observations – one per study for our final sample: 12, 23, 7, and 5 observations, respectively, for *Nonhaz*, *Terr*, *Aquatic*, and *Nuclear* sites. Among the 30 observations for *Terr* and *Aquatic,* 2, 17, 8, and 3 observations, respectively, are for *Stage_0*, *Stage_1*, *Stage_2*, and *Stage_3*. By eliminating nearly two-thirds of the estimates, this approach greatly diminishes the potential explanatory power of the model. The estimation results are reported in Appendix Table A-1 (Robust OLS One Per Study).

Two other approaches to the weighting problem preserve sample size. One is to weight each estimate by the inverse of the number of estimates from the source study (Mrozek and Taylor. 2002). This causes each study to be weighted evenly, although individual estimates are not. The

[15] Bartlett's test for equal variances: $\chi^2(3) = 16.902$ Prob> $\chi^2 = 0.002$.

other approach takes explicit account of panel characteristics in the data using fixed effects or random effects models (Smith and Kaoru 1990). Generally, a fixed effect model is preferable since it does not require the assumption that the individual effects, which are incorporated into the error term, are uncorrelated with the explanatory variables. However, the fixed effects model reduces the degrees of freedom since it requires the addition of many dummy variables. The point estimates from fixed effects model lack reliability when the within variation (variation across time) remains small or even constant and renders impossible the estimation of the coefficients of time invariant variables. If the individual effects are uncorrelated with the explanatory variables, a random effects model yields consistent and efficient estimates while the estimates from a fixed effects model are consistent but not efficient (Johnson and DiNardo 1997). In order to conserve degrees of freedom, we apply the random effect model.

As a first step in applying these different weighting schemes, we include only the site characteristics as independent variables. The site characteristics are intrinsic and unaffected by researchers' judgments. Table 3 reports the results of robust OLS estimation (R1), random effects panel estimation (P1) and weighted least squares (W1 to W4) applied to 129 observations. The Breusch and Pagan Lagrange Multiplier test for random effects cannot reject the null hypothesis at the 0.05 significance level ($p=0.065$), implying that a pooled OLS model is appropriate. In terms of the adjusted-R^2 values, both the Robust OLS model and WLS models improve upon the panel model with the WLS model preferred. Since some of site variables are consistently insignificant for all three basic models (OLS, Panel, and WLS), we estimated three more WLS specifications using WLS: W2 excluding 'job'; W3 excluding 'job' and replacing stage variables with a single dummy 'cleanup'; and W4 excluding 'job' and any stage variables or 'cleanup'. All four WLS models show a significant positive effect of *Aquatic* on *MPPE*, indicating that on average aquatic sites have a higher price discount than other types of sites. Quite a few regional indicators, e.g., *Pacific*, are significant. These findings imply that the type of site and site location by region affect estimates of property value impacts.

Next, using the same methods, a variety of models are estimated with additional explanatory variables reflecting the data characteristics and analytical methods used. Table 4 displays the results of the full models. By the nature of meta-analysis, the specific magnitudes of the coefficients are not important (Boyle *et al*. 1994), so we focus on signs and significance.

The Breusch and Pagan Lagrangian multiplier test for random effects fails to reject the null hypothesis (p=0.378), so the pooled OLS is preferred to panel random effect model. Based on a comparison of adjusted-R^2 values, all the WLS models are superior to the robust OLS and panel model. Again, FW1 includes full set of variables; FW2 drops *Job, Industry, Time, Mort_rt,* and *Discre* because these variables are consistently insignificant across models; FW3 drops these five variables too and also replaces the three stage variables with 'cleanup'; FW4 drops the five variables and all stage-related variables. Across the four WLS models, although FW1 has the highest adjusted-R^2, FW4 seems to perform as well as FW1 because it has fewer explanatory variables with only a slight reduction in adjusted-R^2. This reaffirms the negligible affect of cleanup stages and is consistent with the bi-variate analysis which found that the group mean *MPPE*s by cleanup stage are not significant different from the overall sample mean MPPE. Given the consistency between the WLS models, in what follows, we focus on model FW4.

Interpretation

For all models, omitted classes of categorical variables are embedded in the constant term. The negative and significant coefficients of the constant terms thus reflect studies of nonhazardous sites in the East Northcentral region. The results for other site types and regions are properly interpreted by adding their coefficients to the constant term. In this type of analysis, the absolute magnitudes of the results are not particularly meaningful. The sign and significance of the coefficients are the interpretable features.

Overall, the results are robust. Most of the variables have the same signs across the models. Many variables that are significant in FW4 are also significant in one or more of the other models.

The FW4 results indicate that the type of site is very important. *Terr* and *Aquatic* are positive, consistent in magnitude, and highly significant in all six models, implying that studies of these classes of hazardous sites yield generally larger estimates of proportionate impact than studies of nonhazardous sites. Although positive, *Nuclear* is not significant, implying that estimates for nuclear sites are not statistically distinct from the omitted category, *Nonhaz*. The estimated effects of aquatic sites are generally larger than for any other class and the difference is statistically significant. These regression results differ from the simple ANOVA comparisons of sample means, which suggest equivalence of *Terr* and *Nonhaz*. The inclusion of the *NPL* variable distinguishing subsets of *Terr* may account for the separation apparent in the regression results.

Geographic location matters in all models. In FW4, sites in the Pacific, West Northcentral, East Southcentral, and South Atlantic regions and Canada are associated with greater estimates of impact compared to those in the East Northcentral region. Studies of sites in mountain states produce significantly smaller estimates. *M_site* is significant but has an unexpected negative sign, suggesting that multiple sites mute the effects on nearby property values. This finding may reflect structural differences of neighborhoods in the vicinity of clusters of waste sites.

Interestingly, the variable *NPL* is negative and significant. This indicates that studies of NPL sites, other things equal, tend to generate *smaller* estimates of *MPPE* relative to non-NPL hazardous sites. A joint hypothesis test on *Haz* and *NPL* significant and positive effects. The negative effect of *NPL* designation is contrary to expectation.

Concerning the data features, *Residen, Ind_sale*, and *Access* all are positive and significant at the 0.01 level. Thus, studies that use residential properties rather than commercial properties, or individual housing sales data rather than census or individual assessment data, or that control for other accessibility features, generate greater estimates of *MPPE*. The coefficients of *Mean_Dt* and *Demoecon* are negative and significant. The sign for *Mean_Dt*, in particular, is expected because of the dilution effect of larger geographic areas. Sample size seems unimportant.

Methodologically, *Publish* and *Sig* are consistently positive and significant in almost all models. The positive signs indicate, not surprisingly, that published and significant results tend to be greater in magnitude.[16] The coefficient of *Sar* is positive but insignificant. *Linear* is insignificant, implying little difference between the estimates from different functional forms.

Logistic Analysis

Kiel and William (2007) examine factors that make the coefficients of the environmental variable significant in each estimated model. Following their lead, we generate a new dependent variable (*Exp_sig*) which equals one for statistically significant and theoretically appropriate estimates of the environmental variable and zero if the estimated coefficient is either insignificant or theoretically unexpected.[17] Across 129 observations, the mean of *Exp_sig* is 0.597. We analyze *Exp_sig* with both an ordinary logit model and a random effect logit model. The latter compensates for possible correlation between multiple estimates from each study. The independent variables are the same as in full model. Table 5 shows the regression results.

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[16] Or in other words, we may say that studies with higher estimates tend to be published.

[17] The expected alternative hypothesis is that housing values increase as distance to a waste site increases. However, if the environmental variable is the inverse of distance, then the sign should be negative.

Based on the likelihood ratio χ^2 and their corresponding p-values and Log Likelihood, the ordinary logit models perform better than the random effects logit. The large p-value of the random effect logit model indicates that the null hypothesis of no variation among the multiple estimates within one study cannot be rejected and that the ordinary logit model is preferred. However, the results from the two models are essentially consistent and robust in terms of signs, magnitude, and significance. Because the two sets of models measure different things and different variables, it would be incorrect to compare the results from logit model with those from the previous models using nominal values of MPPE as the dependent variable. For the same variable, whether the sign is positive or negative has a different meaning. For example, in the logit model, *Nuclear* has a significant negative sign. This indicates that studies of nuclear sites are less likely than those of non-hazardous sites to produce statistically significant and expected estimates of MWTP.

The estimates in Table 5 suggest that studies of nuclear sites, of sites in New England, controlling for socio-economic features and industrial activities, or using a discrete environmental variable are less likely to produce statistically significant and expected effects on property values. Studies that are published, address aquatic sites, NPL sites, or sites in the Mountain, Middle Atlantic, East South Central, and South Atlantic regions, that focus on residential properties, and that use individual parcel sales data, and that control for geographic scale, other accessibilities, and spatial autocorrelation are more likely to produce estimates for the environmental variable that are statistically significant and have the expected effect on property values.

6. Discussion and Conclusions

This paper analyses the results of previous studies that have estimated the effects of waste sites on the market value of nearby real estate. These disamenities are hypothesized to negatively influence adjacent property values. Their remediation should reduce those impacts. Our analysis across distinct types of studies and sites provides insight into the effects of sites characterized by different types and degrees of risk associated materials deposited at those sites as well as into the effects of study characteristics.

Most of our key findings are robust across different empirical models. Here we point out a few of the more important ones. First, studies of river or harbor contamination produce systematically larger *MPPE* estimates than studies of terrestrial hazardous sites, and both of those classes produce larger estimates than studies of nuclear sites and non-hazardous waste sites, which are not statistically differentiable. The importance of aquatic attributes is loosely consistent with Luttik's (2000) observation that water features are highly influential for house prices. It implies that property owners may be especially concerned about the contamination of water, where it may be perceived to be more mobile and open to public exposure.

Nuclear sites tend to produce *MPPE* estimates not different from the effect associated with nonhazardous sites. This lack of differentiation may reflect greater on-site employment opportunities that may attract residents to live near nuclear power plants or a general comfort level with the risk levels at these highly regulated installations.

Surprisingly, cleanup stages do not seem to affect *MPPE* estimates consistently and significantly. In addition, other things equal, studies of sites on the EPA's National Priority List for cleanup produce systematically smaller estimates of impact than studies of terrestrial hazardous sites not on the NPL. This finding might reflect market expectations that sites on the NPL are or will be remediated with greater certainty than non-NPL sites. In other words, since property values embody both current use values and future economic prospects, the fact that NPL sites are given priority for remediation may more than offset the fact that these sites are among the most hazardous at the time they are placed on the list. The finding also suggests that, in focusing on

NPL sites, Kiel and Williams (2007) and Greenstone and Gallagher (forthcoming) may have examined samples that are less likely to reveal significant external effects. The very act of NPL listing may set in motion endogenous effects on expectations that serve to reduce those impacts.

Not surprisingly, the geographic size of a contaminated site appears to have significant influence on estimates of *MPPE*. Due to diminishing effects with distance from a site, smaller average effects are associated with studies of larger areas. Studies undertaken in some areas, such as West North Central, East South Central, South Atlantic states, and Canada, produce systematically greater *MPPE* estimates than have been found for other regions. Finally, studies of commercial properties and unpublished studies, which also are more likely to report insignificant estimates, are associated with smaller *MPPE* estimates.

Our results have at least two implications for future study of the effects of waste sites on nearby properties. One is that reliance on average or median property values measured at census block or tract scale may impart bias toward smaller estimates of impact that are less likely to be statistically significant. Studies of individual parcels within a mile or two of the waste site are more likely to reveal significant nonzero effects. Second, there is little evidence that a change in the status of a site, from discovery through remediation, produces significant and predictable effects on property values. This may imply either inertia or hysteresis in real estate markets. Whatever the underlying cause, it is a sobering discovery for those who would like to believe that removal of the disamenity will reliably lead to economic improvement. Many hedonic property value studies infer such an obversion, but the literature taken as a whole does not support it.

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Table 1. Variable Description and Summary Statistics

Variable	Definition	N=142 Mean	N=142 Std. Dev.	N=129 Mean	N=129 Std. Dev.
Mppe	Marginal property price effect (both significant and insignificant)	6.365	23.35	4.488	8.98
Mppe_sig	Significant marginal property price effect, 0 if insignificant	5.412	22.46	3.831	8.47
Nonhaz	1 if a nonhazardous site, otherwise 0	0.246	0.43	0.225	0.42
Terr	1 if a terrestrial hazardous waste site, otherwise 0	0.585	0.49	0.589	0.49
Aquatic	1 if an aquatic hazardous waste site, otherwise 0	0.099	0.30	0.109	0.31
Nuclear	1 if a nuclear or radioactive site, otherwise 0	0.070	0.26	0.078	0.27
M_Site	1 if multiple sites, otherwise 0	0.415	0.49	0.395	0.49
Pacific	1 if study site is in Pacific region, otherwise 0	0.035	0.18	0.023	0.15
Mountain	1 if study site is in Mountain region, otherwise 0	0.021	0.14	0.023	0.15
WN_Cent	1 if study site is in West Northcentral region, otherwise 0	0.042	0.20	0.047	0.21
EN_Cent	1 if study site is in East Northcentral region, otherwise 0	0.282	0.45	0.256	0.44
Mid_Atl	1 if study site is in Middle Atlantic region, otherwise 0	0.120	0.33	0.132	0.34
New_Eng	1 if study site is in New England region, otherwise 0	0.239	0.43	0.264	0.44
WS_Cent	1 if study site is in West Southcentral region, otherwise 0	0.092	0.29	0.101	0.30
ES_Cent	1 if study site is in East Southcentral region, otherwise 0	0.021	0.14	0.023	0.15
S_Atlant	1 if study site is in South Atlantic region, otherwise 0	0.155	0.36	0.140	0.35
Canada	1 if study site is in Canada, otherwise 0	0.049	0.22	0.054	0.23
NPL	1 if site is in NPL list, otherwise 0	0.197	0.40	0.209	0.41
Job	1 if site includes job-generating activities otherwise 0	0.197	0.40	0.217	0.41
Stage0	1 if a potentially contaminated site is proposed but not recognized by public, otherwise 0	0.049	0.22	0.054	0.23
Stage1	1 if contamination is recognized but no plan for cleanup yet otherwise 0	0.310	0.46	0.326	0.47
Stage2	1 if site has a cleanup plan, otherwise 0	0.197	0.40	0.202	0.40
Stage3	1 if site has been fully or partially cleaned up, otherwise 0	0.127	0.33	0.116	0.32
Cleanup	1 if it is post-cleanup period, otherwise 0	0.127	0.33	0.116	0.32
Residen	1 if residnetial property data are used, otherwise 0	0.873	0.33	0.884	0.32
Range	Geographical range (miles of radius from site to property studied)	6.524	7.24	6.668	7.19
Sample	The sample size of study	4290.676	11709.31	4581.7	12231.5
Mean_dt	Mean distance from site to properties (miles)	3.070	4.50	2.979	3.73
Ind_sale	1 if individual sales data are used, otherwise 0 (census, assessed, county data)	0.894	0.31	0.891	0.31
Demoecon	1 if soci-economic data are included(eg.,income, poverty, school quality etc), otherwise 0	0.493	0.50	0.488	0.50
Access	1 if other acessibility data are included (eg.,highway,airport etc), otherwise 0	0.570	0.50	0.566	0.50
Industry	1 if industrial activities data are included (eg., industry zone etc), otherwise 0	0.113	0.32	0.101	0.30
Time	Time trend of data year starting at 1966=0	22.254	6.85	22.023	6.59
Mort_rt	Annual national average conventional single-family mortgate rate	9.325	1.91	9.409	1.90
Publish	1 if a study is published in a journal, otherwise 0	0.887	0.32	0.907	0.29
Linear	1 if regression is linear, otherwise 0 (log-log,log-linear,inverse etc)	0.211	0.41	0.217	0.41
Discre	1 if a discrete variable (eg.,before/after etc.) is used for environmental change, otherwise 0	0.141	0.35	0.140	0.35
Sig	1 if the distance estimate is significant, otherwise 0	0.697	0.46	0.705	0.46
Exp_sig	1 if the distance estimate has both expected sign and is significant, otherwise 0	0.585	0.49	0.597	0.49
Sar	1 if spatial autocorrelation is controlled in the model, otherwise 0	0.063	0.24	0.070	0.26

Table 2. Test of Equivalence of Group Mean MPPE

	By Type (N=129)					By Cleanup Stage (N=90)*				
Type	Obs	Mean	Std. Err.	95% Conf. Interv.		Stage	Obs	Mean	Std. Err.	95% Conf. Interv.	
Nonhaz	29	3.148	1.700	-0.334	6.629	Stage0	7	4.569	2.095	-0.557	9.694
Terr	76	3.546	0.794	1.964	5.127	Stage1	42	4.610	1.082	2.425	6.795
Aquatic	14	15.937	3.206	9.010	22.863	Stage2	26	6.979	1.743	3.390	10.567
Nuclear	10	-0.489	1.872	-4.723	3.745	Stage3	15	5.702	3.785	-2.417	13.821

** Since the cleanup processes applied to Terr and Aquatic sites do not apply to Nonhaz and Nuclear sites, the former categories together contain only 90 observations.*

Table 3. Meta-Analysis Results-Site Characteristics Only (Dependent Variable: MPPE)

	Robust OLS		Panel		Weighted Least Squares							
	R1		P1		W1		W2		W3		W4	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Constant	2.221	3.279	0.651	2.908	0.228	3.448	-0.266	2.810	0.090	2.726	0.095	2.687
Terr	6.071 *	3.477	7.216 **	3.195	7.587 **	3.638	7.814 **	3.425	7.079 **	3.123	7.076 **	3.099
Aquatic	10.785 ***	3.515	11.378 ***	4.325	11.414 ***	3.648	11.550 ***	3.542	10.745 ***	3.400	10.774 ***	3.355
Nuclear	-1.756	2.217	-0.702	5.471	0.559	2.453	0.224	2.770	-0.057	2.711	-0.056	2.705
M_site	-6.884 ***	2.333	-4.611	2.886	-5.328 ***	2.071	-5.117 ***	1.984	-5.651 ***	1.868	-5.646 ***	1.860
Pacific	-5.071 **	2.288	-5.717	7.950	-6.116 ***	2.366	-6.432 ***	2.117	-6.571 ***	2.050	-6.578 ***	2.041
Mountain	2.428	4.355	1.928	7.353	2.635	4.126	3.094	3.884	3.208	3.823	3.197	3.780
Wn_cent	-3.693	3.097	-2.689	4.333	-4.724	3.638	-4.302	3.518	-4.088	3.330	-4.092	3.316
Mid_atl	5.642 **	2.186	5.994 *	3.307	6.398 ***	2.104	6.265 ***	2.096	5.737 ***	1.958	5.723 ***	1.880
New_eng	0.816	1.807	0.550	2.944	0.936	1.446	0.919	1.446	0.949	1.343	0.938	1.273
Ws_cent	-4.923 *	2.424	-5.788	4.511	-4.970 **	2.505	-5.675 ***	2.074	-5.764 ***	1.983	-5.729 ***	1.776
Es_cent	2.797	3.127	2.060	7.085	2.551	3.071	1.673	2.531	1.988	2.374	1.985	2.370
S_atlant	-0.096	2.185	-1.806	4.139	-0.928	1.707	-0.636	1.669	-0.031	1.555	-0.029	1.544
Canada	12.641 **	4.864	13.492 **	5.380	13.368 ***	4.523	13.749 ***	4.313	13.198 ***	4.275	13.203 ***	4.307
NPL	1.784	2.128	-2.020	2.675	-0.069	2.429	-0.160	2.419	0.544	1.925	0.557	1.848
Job	-1.814	2.105	-0.450	3.016	-1.321	2.182						
Stage0	-2.168	2.413	-5.444 *	3.136	-3.673	2.631	-3.633	2.543				
Stage2	-1.329	2.231	1.056	2.607	-0.319	2.097	-0.030	2.020				
Stage3	-1.579	2.310	0.274	2.706	-0.062	2.521	-0.095	2.526				
Clean									0.115	2.347		
N	129		129		129		129		129		129	
K	18		18		18		17		15		14	
Adj. R-Sqr	0.350		0.323		0.417		0.421		0.424		0.429	

*Note: * indicates significance level at 0.1; ** indicates significance level at 0.05; *** indicates significance level at 0.01.*

Table 4. Meta-analysis Estimation Results with Selected Models (Dependent Variable: MPPE)

	Robust OLS		Panel Model		Weighted Least Squares							
	FR1		FP1		FW1		FW2		FW3		FW4	
	Coef.	Rob. SE	Coef.	Rob. SE	Coef.	Rob. SE	Coef.	Rob. SE	Coef.	Rob. SE	Coef.	Rob. SE
Constant	-52.182 ***	17.875	-43.435 ***	17.184	-59.684 ***	18.248	-44.348 ***	10.207	-43.915 ***	10.154	-42.949 ***	9.922
Terr	15.512 ***	4.230	12.641 ***	3.362	16.501 ***	4.265	14.873 ***	3.650	14.245 ***	3.336	14.049 ***	3.263
Aquatic	22.664 ***	4.406	20.787 ***	5.144	23.477 ***	4.178	22.050 ***	4.416	20.929 ***	3.919	21.219 ***	3.944
Nuclear	7.269	4.642	2.203	7.448	6.837	4.956	2.159	4.114	2.420	4.198	2.230	4.218
M_site	-5.251 *	2.727	-2.348	3.614	-3.808	2.801	-2.829	1.905	-3.233 *	1.789	-3.127 *	1.708
Pacific	5.138	6.474	7.031	10.299	5.509	6.930	8.246	6.247	7.077	5.838	6.386	5.651
Mountain	16.947 ***	5.587	12.000	9.527	14.985 ***	5.150	12.493 **	5.144	12.780 **	5.228	12.495 **	5.083
Wn_cent	-8.419 *	4.610	-4.630	5.118	-8.474 *	4.491	-7.006 *	3.629	-6.524 *	3.433	-6.327 *	3.408
Mid_atl	9.853 ***	2.682	9.730 **	4.355	10.920 ***	2.496	10.532 ***	3.049	10.013 ***	2.876	9.837 ***	2.826
New_eng	3.518	2.461	1.592	3.142	3.706 *	2.181	1.752	1.435	1.609	1.339	1.268	1.238
Ws_cent	1.054	4.157	1.830	5.885	0.027	4.445	-1.725	3.932	-2.365	3.562	-2.272	3.490
Es_cent	7.879	5.029	8.364	9.929	8.828 *	5.220	11.952 ***	3.393	12.250 ***	3.458	11.514 ***	3.219
S_atlant	6.742 ***	2.023	7.189	4.889	6.772 ***	2.032	8.215 ***	1.829	8.769 ***	1.844	8.831 ***	1.763
Canada	15.353 **	6.340	15.764 ***	5.885	17.146 ***	6.538	16.642 ***	5.824	16.596 ***	5.845	16.828 ***	6.093
NPL	-5.769 **	2.774	-5.673 **	2.786	-7.364 **	3.007	-5.985 **	2.396	-5.840 **	2.298	-5.452 **	2.144
Job	-0.883	3.209	-0.412	3.257	-0.484	3.318						
Stage0	-2.179	2.931	-4.256	3.384	-3.000	2.920	-3.192	2.545				
Stage2	-0.763	2.330	1.091	2.877	-0.794	2.381	-0.513	1.759				
Stage3	-0.369	3.113	0.261	3.308	0.611	3.484	1.817	2.466				
Clean									2.155	2.244		
Residen	16.123 ***	3.454	16.452 ***	5.506	16.258 ***	3.140	16.362 ***	3.014	16.412 ***	3.022	16.141 ***	2.854
Mean_dt	-1.205 ***	0.461	-1.012	0.630	-1.089 **	0.483	-1.005 ***	0.351	-0.975 ***	0.338	-0.916 ***	0.323
Sample	-8.06E-05	7.54E-05	-9.77E-05	1.20E-04	-6.39E-05	8.74E-05	-4.73E-05	7.71E-05	-4.38E-05	7.39E-05	-3.11E-05	7.14E-05
Ind_sale	10.225 ***	3.907	9.978	6.393	11.640 ***	4.091	12.910 ***	3.355	13.163 ***	3.442	12.815 ***	3.322
Demoecon	-4.363 ***	1.627	-6.410 *	3.703	-5.399 ***	1.532	-6.305 ***	1.495	-6.236 ***	1.457	-6.259 ***	1.419
Access	6.767 ***	2.242	6.673 **	3.241	7.151 ***	2.285	7.233 ***	2.217	6.872 ***	2.128	6.305 ***	1.969
Industry	-0.492	3.316	0.147	4.855	0.128	2.716						
Time	0.337	0.259	0.128	0.258	0.381	0.273						
Mort_rt	0.670	0.525	0.013	0.600	0.828	0.579						
Publish	8.026 **	3.540	11.253 **	4.712	10.409 ***	3.479	10.057 ***	3.720	9.692 **	3.754	9.820 **	3.819
Linear	0.512	2.772	0.731	3.032	0.308	2.867	0.076	2.767	-0.725	2.499	-1.091	2.480
Discre	-2.945	3.775	-1.782	4.717	-1.579	3.876						
Sig	3.257 **	1.557	2.814 *	1.621	2.507	1.624	3.274 **	1.523	3.635 **	1.472	3.585 **	1.468
Sar	-2.491	4.410	1.943	7.635	0.168	4.571	4.020	3.011	3.897	3.039	3.723	2.955
N	129		129		129		129		129		129	
K	32		32		32		27		25		24	
Adj. R-Sqr	0.504		0.467		0.569		0.564		0.568		0.568	

*Note: * indicates significance level at 0.1; ** indicates significance level at 0.05; *** indicates significance level at 0.01.*

Table 5 . Logit Estimation Results

	Logit			Random Effect Logit		
Exp_Sig	Coef.		Std. Err.	Coef.		Std. Err.
Constant	-51.3792	***	15.543	-51.3832	***	15.544
Terr	2.6745		1.867	2.6749		1.867
Aquatic	19.0788	***	6.092	19.0804	***	6.093
Nuclear	-22.1273	***	6.033	-22.1291	***	6.033
M_site	3.1146		1.988	3.1146		1.988
Pacific	-2.2304		.	-6.2366		15428.940
Mountain	13.8653	**	5.649	13.8668	**	5.649
WN_Cent	11.7823		303.073	11.7831		303.234
Mid_Atl	33.3538	***	9.452	33.3564	***	9.453
New_Eng	-2.7799	*	1.664	-2.7799	*	1.664
WS_Cent	-3.1721		3.659	-3.1719		3.659
ES_Cent	12.6790	**	5.181	12.6799	**	5.182
S_Atlant	9.6903	***	3.705	9.6913	***	3.705
Canada	2.8430		2.158	2.8430		2.158
NPL	5.2242	***	1.919	5.2248	***	1.919
Job	-0.6937		1.149	-0.6939		1.149
Stage0	-2.7578		1.757	-2.7581		1.757
Stage2	2.3914		1.960	2.3914		1.960
Stage3	-0.8401		1.416	-0.8403		1.416
Residen	7.1006	**	2.864	7.1013	**	2.864
Mean_dt	0.5822	**	0.295	0.5823	**	0.295
Sample	-3.85E-04		2.38E-04	-1.14E-04		2.54E-04
Ind_sale	13.3080	***	4.780	13.3090	***	4.780
Demoecon	-5.4473	**	2.267	-5.4479	**	2.267
Access	3.6771	*	2.091	3.6773	*	2.092
Industry	-9.1291	***	3.513	-9.1294	***	3.513
Publish	28.5122	***	7.976	28.5144	***	7.977
Linear	0.5871		1.296	0.5872		1.296
Discre	-11.1226	***	3.604	-11.1234	***	3.604
SAR	16.5546	***	4.668	16.5558	***	4.668
N	129			129		
Pseudo R^2	0.495			0.552		
LR χ2	86.18			22.15(Wald χ2)		
Prob>χ2	0.000			0.814		
Log Likelihood	-43.887			-43.887		

*Note: * indicates significance level at 0.1; ** indicates significance level at 0.05;*
*** indicates significance level at 0.01.

Table A-1. Other Meta-model Estimates

	Robust OLS With Outliers			Robust OLS One Per Study		
MPPE	Coef.		Std. Err.	Coef.		Std. Err.
Constant	-29.363		32.469	-68.128	*	35.360
Terr	20.574	**	8.727	27.816	**	10.508
Aquatic	15.978		13.873	62.182	***	19.510
Nuclear	5.143		11.836	-28.697	*	13.413
M_site	-14.950	**	6.927	4.833		9.225
Pacific	3.406		13.055	27.725	**	10.021
Mountain	23.887		16.285	6.162		17.676
Wn_cent	-7.141		8.538	20.490		15.253
Mid_atl	3.274		7.603	14.551		10.063
New_eng	0.184		4.611	4.936		9.480
Ws_cent	8.535		7.503	-7.051		12.154
Es_cent	-17.399		17.496	-5.049		19.269
S_atlant	17.638	***	6.703	26.454	**	11.921
Canada	16.432		10.131	26.895	*	14.691
NPL	-6.942		9.631	11.016		10.787
Job	-3.875		5.894	18.159		13.834
Stage0	-1.575		6.450	-4.051		17.452
Stage2	-3.467		9.982	-33.917	**	14.411
Stage3	4.164		16.997	-55.009	***	16.868
Residen	20.234	*	11.086	26.437	**	10.596
Mean_dt	-0.422		0.623	0.359		0.764
Sample	0.000	*	0.000	0.000		0.000
Ind_sale	5.299		8.359	28.410	*	13.866
Demoecon	-11.098	**	5.586	-20.809	**	9.336
Access	-5.714		6.477	10.100		7.440
Industry	13.869		12.821	15.191		19.581
Time	0.381		0.577	-0.069		0.521
Mort_rt	-1.036		1.628	-5.029	**	2.033
Publish	13.642		10.533	41.491	***	13.321
Linear	-8.568		7.111	4.021		15.438
Discre	3.689		5.618	18.680		11.283
Sig	6.387		5.471	-1.788		8.878
Sar	-10.671		13.866	30.288	**	12.405
N	142			46		
K	32			32		
Adj. R-Sqr	0.121			0.396		

Appendix C

Economic Impacts of Great Lakes Areas of Concern: A Benefits Transfer Analysis

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Economic Impacts of Great Lakes Areas of Concern: A Benefits Transfer Analysis

ABSTRACT

Contamination by toxic compounds is a common denominator for the 43 Great Lakes Areas of Concern (AOCs) recognized by the International Joint Commission. Remediation of the sites in U.S. waters alone is estimated to cost up to $4.5 billion. We use meta-analytic and spatial analysis techniques in a “benefits transfer” exercise to forecast the impacts on residential real estate prices of 23 U.S. AOCs. The analysis relies on year 2000 census housing and price information. The estimated impacts on median home values sum to approximately $1.7 billion in 2000 dollars (equivalent to $2.7 million in 2005 dollars). This estimate almost certainly underestimates the impacts on average home values, and it does not include the potential property value impacts of eight of the largest AOCs. Nevertheless, it is well within the range of the estimated costs of remediation. Evidence in the literature is mixed about whether remediation would recover the lost economic values.

KEYWORDS: Benefits transfer, meta-analysis, hedonic method, Great Lakes, Areas of Concern

Economic Impacts of Great Lakes Areas of Concern: A Benefits Transfer Analysis

INTRODUCTION

Under the Great Lakes Water Quality Agreement of 1978, the U.S. and Canada have designated 43 sites in the Great Lakes Basin as priority areas for pollution remediation. Known as Areas of Concern (AOCs), 26 of the sites are in solely in U.S. waters, 12 are under Canadian jurisdiction, and 5 are bi-national sites. The AOCs were designated primarily because they contain unusually high concentrations of toxic chemicals (most commonly, polychlorinated biphenyls – PCBs). Many also suffer from inadequately treated wastewater, pollution from nonpoint sources, and degraded habitat.

In the U.S., by 1999, more than $600 million had been spent on remediation projects (Sediment Priority Action Committee 1999). An additional $250 million was authorized in 2002 by the Great Lakes Legacy Act (P.L. 107-303). By 2003, the Canadian government had expended C$1.9 billion (equivalent to approximately U.S.$1.5 billion) (International Joint Commission 2003). Nevertheless, by 2008, only two Canadian sites had met criteria for removal from the list of AOCs and two others were recognized as Areas in Recovery. In the U.S. zone, Oswego, NY was removed from the list of AOCs in 2007 and the Presque Isle Bay, PA achieved "Area in Recovery" status in 2002 (http://www.epa.gov/glnpo/aoc). In 2005, a Presidential task force placed the cost of remaining remediation work in U.S. AOCs at $1.5 billion to 4.5 billion, depending on the level of decontamination (Great Lakes

Regional Collaborative 2005). In the absence of concrete evidence that cleanup can produce economic benefits, the daunting costs dominate public debates. Those debates would be more balanced, and presumably more energetic, if investments in cleanup have strong potential to produce positive economic returns.

This paper uses meta-analytic results and spatial-analytic benefits transfer techniques to estimate the effects of the AOCs on nearby residential property values. This exercise is a first step toward quantifying the potential gains from remediation. It provides insight into what has been lost as a result of these contaminated sites; however, it cannot claim to reveal the values that might be recovered through remediation, nor does it provide an overall estimate of the economic effects of Great Lakes contamination. In the Great Lakes region, toxic contamination comes from a variety of sources: deposition of airborne emissions, ongoing discharges from point and nonpoint sources, uptake of legacy contamination in sediments, and recycling of persistent chemicals through the food web (EPA 1997). The mobility and longevity of the contaminants means that many of their effects are basin-wide and cumulative across sources; thus, estimates limited to the AOCs provide pieces of a larger puzzle. However, the contaminants and their effects are especially concentrated in the AOCs, so these are very important pieces.

Fourteen categories of "beneficial use" impairments are recognized in the U.S. Great Lakes (Great Lakes Information Network 1995). Some of them, such as degradation of benthos, affect humans indirectly if at all while others, such as beach closings, have obvious and direct effects. Whatever the underlying reasons, the fact that a location has been put on a government list of contaminated and/or seriously degraded sites induces caution about the potential risks involved. Surrounding properties may be stigmatized and their market value diminished as a result (Dale *et al.* 1999; Elliot-Jones 1999). The effects on real estate markets are especially noteworthy because the market prices at stake can be large and, through property taxes, public revenues can also be affected. However, it is not at all clear that the elimination of the contamination or degradation will restore property values to levels observed in their absence (Greenstone and Gallagher forthcoming; Kiel and Williams 2007; McCluskey and Rausser 2003).

Economic studies of the effects of localized toxic contamination have been conducted and published for seven Great Lakes AOCs (including one Canadian site) (Appendix Table A1). Two different methods of value estimation (Champ, Boyle, and Brown 2003) are reflected in these studies: "revealed-preference" (RP) analysis of real estate prices and "stated preference" (SP) surveys eliciting willingness to pay for remediation. For purposes of comparison, it is useful to consider the impacts as percentages of the contemporaneous mean or median value of local residential real estate. Percentages serve to normalize the measure of impact across locations and time. As shown in the table, the percentage estimates in these studies of property value discounts can exceed 10 percent in the immediate vicinity of an AOC, but they are in the 1 percent to 2 percent range for studies conducted at county (Lichtkoppler and Blaine 1999) or state (Stoll *et al.* 2002) scales.

There are too few studies of Great Lakes sites to support statistically-valid inference about other AOCs. Thus, in this study, we embed the Great Lakes information in the wider literature on the economic impacts of waste sites in an effort to forecast economic impacts using functional benefits transfer methods.

BENEFIT TRANSFER METHODS

Benefit transfer is the application of values and information derived from original research to predict outcomes in data contexts related to but not included among the background studies. For example, detailed studies of the impacts of waste sites A through S would be analyzed systematically, and the results of that analysis would be applied to comparable facts surrounding "policy site" T in order to forecast the impacts of that site. Following Rosenberger and Loomis (2003), the goal is to derive estimates of V_{Pj} for policy site j from the summary statistics of original research at study sites $i=1 \ldots I$, V_{Si}. Therefore, the study site values (V_{Si}) becaome transfer values (V_{Ti}) when applied to policy site j:

$$Ø(V_{Si}) => V_{Ti} \qquad (1)$$

Benefit transfer methods fit broadly into two categories: value transfer and functional transfer. Value transfer is the direct application of original summary statistics, such as per unit measures of willingness to pay, measures of elasticity, or other measures of marginal effects, to a policy site. An example would be to conclude from past studies that waste sites diminish nearby property values by an average of 5%, and to apply that summary statistic to sites where careful studies have not been done. Function transfer applies a statistical function created from data on the study sites, rather than a simple summary statistic, to the specifics of the policy site. For example, a demand function or a meta- analysis function might be applied to data from the policy site. Functional transfer is generally thought to generate more accurate estimates than value transfer methods because they take systematic account of the characteristics of the policy site. Rosenberger and Loomis (2003) list studies that were conducted to address the validity of benefit transfer using both value transfers and functional transfer and show that the latter usually perform better than value transfers. In this paper, we follow this rule and apply the meta-regression analysis function benefit transfer to predict the cleanup benefits of US AOCs.

META-REGRESSION FUNCTIONAL TRANSFER

Following Rosenberger and Loomis (2003), we define a meta-regression analysis transfer function as follows:

$$V_{Pj} = f_S(Q_{S|Pj}, X_{S|Pj}, M_{S|Pj}) \tag{2}$$

The above function states that the value for policy site *j* (V_{Pj}) is a function of data for each study site *i*. The variables can be quantity/quality variables (*Q*), site and data characteristics (*X*), and methodological variables (*M*) for each study and site *i*. Once estimated from the existing data, the resulting function is applied to new data for site *j* to produce a new value estimate specific to that site.

The first step in a meta-analysis functional transfer is a meta-analysis of study sites. Due to the small number of studies of AOCs, we begin instead with the meta-analysis of wastes sites, including AOCs, by Braden, Feng, and Won (2008c). The waste sites considered in that study include nonhazardous landfills, hazardous waste sites on land, and nuclear facilities, as well as hazardous waste sites under water. Their analysis is based on 142 observations drawn from 46 studies of such sites. For the entire sample of studies, the mean property value reduction is approximately 6% and the areas over which impacts are estimated average 6.7 radial miles in size. Exclusion of outlying estimates reduces the number of observations to 129 and the average proportional impact to 4.5%.

Braden *et al.* (2008c) estimate the functional relationship in (2) where the estimated percentage impacts on property values (*PPE*=proportional price effect) is the dependent variable. The explanatory variables are listed in Table 1 along with the coefficient estimates from their preferred specification. (Several other specifications and estimators were applied to the data, and the signs and significance of the explanatory variables were robust across specifications. The preferred weighted-least-squares model is among the most parsimonious, has the highest adjusted-R2 value, and produces conservative estimates of overall impact.

The results of the meta-analysis indicate that the economic impacts of waste sites are concentrated in the vicinity of the contamination. Prices within one mile of the site can be discounted by more than 10%. Furthermore, the meta-analysis does not find significant differences between the percentage impacts estimated by linear versus nonlinear specifications of the functional relationship with distance. However, most of the studies conclude that nonlinear functions are more consistent with economic theory and best fit the data.

The studies of aquatic sites produce estimates of economic impacts that are significantly greater than the full sample average – a difference of approximately 12 percentage points. Curiously, studies of sites included on the National Priority List for cleanup under the Superfund Law (42 U.S.C. 103) estimate *lesser* impacts on property values than studies of non-NPL hazardous waste sites. This finding may indicate expectations of faster remediation at NPL sites. In principal, remediation of waste sites should mitigate the economic impacts. Faster action should elevate the present value of the site relative to sites where action is likely to be slower.

Model Calibration and Assumptions

Armed with the estimated transfer function, the next step is to calibrate the function to the policy sites. The calibration process is illustrated in Table 1 for the Ashtabula, OH AOC. The Transfer Calibration column gives the variable values used in the transfer function. Since all of the policy sites are aquatic and in the U.S., Aquatic=1 while Canada=0. Following established practice (Rosenberger and Loomis 2003), methodological variables (*Sample, Ind_sale, Demoecon, Access, Publish, Linear, Sig,* and *SAR*) are set equal to the mean values in the meta-analysis data set.

Our major imposed assumptions for the calibration are as follows: (1) property types are limited to residential properties (*Residen*=1); (2) all AOCs are assumed to encompass multiple contaminated sites (*M_site*=1); (3) one or more of the contributing waste sites in an AOC is included on the NPL (*NPL*=1); (4) the average impacts apply only within a two mile radius around the boundary of an AOC; and (5) the mean radial distance for the impact zone is 1.41 miles from the boundary of the AOC; this is the mean distance if homes are distributed uniformly within the two-mile radius.

Policy Sites

Table 2 lists the 23 policy sites of interest. We judge these AOCs to be best suited to the transfer methodology. Eight U.S. sites (Clinton River, Detroit River, Rouge River, Saginaw Bay, and St. Clair River Michigan and Black River, Cuyahoga River, Maumee River Ohio are omitted. The reason for the omission is that all of them encompass huge areas. The hedonic studies on which the meta-analysis transfer function is based rarely tackle such large and heterogeneous areas. Thus, we judged these AOCs "out of sample" and excluded them. Three of the included AOCs, Buffalo River, NY, Sheboygan River,WI, and Waukegan Harbor, IL have been studied in detail and are included in the meta-analysis data sets. Thus, they provide a means of checking the transfer calibration.

We focus on the market value of owner-occupied residences. While other types of property could also be affected (Ihlanfeldt and Taylor 2003), it is difficult to obtain good aggregate data about their numbers and values. We rely on year 2000 census data for owner-occupied residences near the policy sites. Census reporting areas do not conform geographically to the impact zones as defined above. To achieve rough correspondence, we begin with geo-referenced maps of the AOCs (http://www.epa.gov/glnpo/aoc). We use GIS software to delineate two-mile "impact zones" surrounding each AOC perimeter, then overlay these zones on 2000 census tract maps (U.S. Census Bureau 2005). Census tracts for which at least 50% of the tract lies within two radial miles of the AOCs are included in the analysis. This procedure excludes residential properties that are within two miles of an AOC but within a census tract that lies mostly outside that boundary. It includes properties located more than two miles away that happen to fall within census tracts that lie mostly within the impact zone. We assume that these effects approximately offset one another. This assumption is more plausible for the entire data set than for an individual AOC. Table 2 lists the number of census tracts included at each AOC and the median market value of those homes. The market value is calculated as an average of the census tract median values weighted by the relative numbers of homes in the included census tracts.

With regard to counting affected properties, Torch Lake, MI is a special case. There are three census tracts near Torch Lake, all with very low residential density. None of the three has at least half of its geographic area within the assumed two-mile impact zone. The approximation procedure described above therefore would exclude

Torch Lake as a policy site. To avoid this exclusion, instead of assuming no homes in the impact area, we estimated the fraction of each of the three census tracts falling within the two mile boundary and assumed that the equivalent fraction of homes in each census tract reside within that sphere. In any case, the number of residents is small enough that the inclusion of Torch Lake will have little effect on the overall benefit estimates.

It is important to note that the method of estimating price impacts almost certainly understates the average impacts. The meta-analysis function estimates a proportional price impact defined by *mean* property values while census data offer only median values of homes. It is not clear whether the estimates of PPE over- or under-estimate the equivalent impacts on median values. However, it is clear that median values are systematically less than mean values. Mean values are generally greater because the distribution of housing values is skewed upward. As a result, their use in computing dollar impacts causes our estimates to be systematically biased downward relative to mean values.

The meta-analysis revealed that *PPE* varies from region to region. The AOCs occur in three different census regions: the New York and Pennsylvania sites are in the Mid-Atlantic region; the most westerly AOC, St. Louis River, straddles the West North Central and East North Central regions; and all other policy sites are in the East North Central region. In applying the transfer function, we vary the regional calibrations accordingly. Since St. Louis River straddles two regions, for this AOC, we set EN_Cent = WN_Cent = 0.5.

All of the New York and Pennsylvania sites are in areas that have experienced substantial economic difficulties in recent decades. In this respect, their property markets much more closely resemble those of the low-growth East North Central states than of the Mid-Atlantic region, where rapid growth in coastal areas and big cities skews the average growth rates. Nevertheless, the transfer exercise remains true to the regional designations of the meta-function.

RESULTS

To compute the nominal dollar impacts on property values within two miles of the AOCs, the estimated proportional price effect (*PPE*) is multiplied by the number of owner-occupied houses and the weighted median property value. Table 3 lists the number of homes and the estimated weighted average median dollar reduction in home prices. To illustrate the calculation, for Ashtabula, PPE = 7.785%. Multiplying this percentage by the year 2000 weighted median housing value of that area, $84,235 shown in Table 2, we obtain a median projection of the property price impacts within two miles of the AOC – $6,557/home. Multiplying by the estimated 9,747 owner-occupied homes within two miles of the AOC produces the total property value effect – $63.9 million.

To compute the overall property value effect in the 23 policy sites, this procedure is replicated for each AOC in our sample, and the results are summed together. Table 3 reports the calculations. The total estimated impact for all of the included AOCs sums to $1.7 billion in year 2000 dollar values. If adjusted to year 2005 housing values using state-level indices provided by the Office of Federal Housing Enterprise Oversight (OFHEO) (2005), the total increases to $2.7 billion.

DISCUSSION AND CONCLUSIONS

One measure of the reliability of the transfer procedure is to compare the estimates it produces to those of detailed, site-specific hedonic studies. Because of differences in the methods and assumptions, however, such comparisons are not easily made.

We limit the comparisons to studies that used hedonic property value methods, on which our meta-transfer function is based. One such study, by McMillen (2003), addressed properties within just a few blocks of the Grand Calumet, IN AOC. It's small geographic scope makes it difficult to compare to our analysis. Another, by Zegarac and Muir (1998), is based on Canadian data and therefore cannot be compared.

Braden and colleagues used hedonic property value methods in studies of Buffalo River, NY (Braden *et al*. 2008a), Sheboygan River, WI (Braden *et al*., 2008b, and Waukegan Harbor, IL (Braden *et al.*, 2004; Chattopadhyay *et al*., 2005). All of these studies focused on properties within five miles of the AOCs. The Buffalo study is most easily compared. They found that 4,721 properties within 1.5 miles of the Buffalo River AOC sustained approximately $61.5 million in price discounts due to the AOC. This estimate was in year 2004 housing values. Using an

OFHEO (2005) price index for the Buffalo, NY SMSA, the year 2000 equivalent value is $52.8 million. A proportional adjustment to the number of homes in our analysis, 5,264, produces a value impact of $58.6 million. The correspondence to our estimate is nearly exact. However, this may be fortuitous since the meta-functional transfer estimate reflects median values while Braden *et al.* base their estimate on the mean value of actual sale prices.

For Sheboygan River, Braden *et al.* (2008b) estimated an average percentage impact of 7% and a total value reduction of $157 million for 16,724 homes. Our method produces a very similar percentage impact – 7.8%. Adjusting proportionally for fewer homes in the smaller impact area used here and for price changes between 2000 and 2004 produces a year 2000 estimated impact of $51.1 million. This is more than double the estimated impact estimated here. The differences in the percentage impacts and between mean and median values account for some of the discrepancy.

For Waukegan Harbor, Braden *et al.* (2004) and Chattopadhyay *et al.* (2005) found a price discount on the order of 15% equivalent to approximately $450 million in 2001 dollars for 15,697 homes. Here, we apply the regional impact percentage, 7.8%, to 5,220 homes near the harbor and estimate the impact at $50 million in year 2000 dollar. Adjusting proportionally for the number of homes and price increases from 2000 to 2001 in the Chicago SMSA reduces the larger estimate to approximately $127 million. The difference between the site-specific estimate of percentage impact and the regionally estimated impact, together with the mean/median difference, probably accounts for most of the remaining discrepancy.

Overall, it is at least reassuring that the estimates produced here are either similar to those produced by the site-specific studies or reasons for differences are reasonably apparent.

Several caveats are in order. First, by relying on a statistical representation of the relationship between AOCs and property values, our methodology relies on estimates of percentage effects for regional clusters of sites. This aggregation to the regional level results in averaging away some of the differences between AOCs within regions. Thus, some of the AOCs undoubtedly have affected values less than suggested by our results while others may have been affected more than our estimates suggest. Second, a more fine-grained use of census data – for example, using census block groups rather than tracts to identify affected properties and their median values – could improve the precision of our estimates.

Finally, based on these forecasts of property value discounts, it would be irresponsible to predict specific percentage or dollar value gains that AOC communities might anticipate from remediation. The scientific scaffolding is simply not yet available to carve such monuments. The fact that property values are reduced for properties close to AOCs does not necessarily mean that remediation and delisting will lead to recovery of those values. Nevertheless, near-water real estate, such as that found near AOCs, is often priced at a premium and would seem to be ideally positioned to gain in value with remediation.

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Table 1. Illustrative Application of Transfer Methodology, Ashtabula River, OH, AOC

Dependent Variable=PPE (Proportional Price Effect, %) **Variable**	**Coefficient**	**Transfer Calibration**	***Policy Site MPPE Estimate (%)***
Constant	-42.949	1	*-42.949*
Nonhaz (0,1=Non-hazardous site)	Default	0	*0.000*
Terr (0,1=Terri site)	14.049	0	*0.000*
Aquatic (0,1=Aquatic site)	21.219	1	*21.219*
Nuclear (0,1=Nuclear site)	2.230	0	*0.000*
M_Site (0,1=Multiple site)	-3.127	1	*-3.127*
Pacific (0,1=Pacific)	6.386	0	*-6.386*
Mountain (0,1=Mountain)	12.495	0	*-12.495*
WN_Cent (0,1=W. N.Central)	-6.327	0	*6.327*
EN_Cent (0,1=E.N.Central)	Default	1	*58.561*
Mid_Atl (0,1=Mid-Atlantic)	9.837	0	*-9.837*
New_Eng (0,1=New England)	1.268	0	*-1.268*
WS_Cent (0,1=W.S.Central)	-2.272	0	*2.272*
ES_Cent (0,1=E.S.Central)	11.514	0	*-11.514*
S_Atlant (0,1=South Atlantic)	8.831	0	*-8.831*
Canada (0,1=Canada)	16.828	0	*-16.828*
NPL (0,1=On NPL List)	-5.452	1	*-5.452*
Residen (0,1=Data is residential property)	16.141	1	*16.141*
Mean_dt (Mean distance from property to the site)	-0.916	1.41	*-1.292*
Sample (Sample size)	-3.110E-05	4,582	*-0.143*
Ind_Sale (0,1=Data is individual and sales)	12.815	0.891	*11.419*
Demoecon (0,1=Demographic and economics data included)	-6.259	0.488	*-3.057*
Access (0,1=Other accessibility included)	6.305	0.566	*3.568*
Publish (0,1=Published)	9.820	0.907	*8.906*
Linear (0,1=Linear model)	-1.091	0.217	*-0.237*
Sig (0,1=Estimate of environmental variable is significant)	3.585	0.705	*2.529*
Sar (0,1=Spatial autocorrelation controlled)	3.723	0.070	*0.260*
Estimated PPE(%) for a single house in a policy site			***7.785***
Median price impact ($2000) per owner-occupied residence			***6,557***
Total median price impact ($2000), tracts within 2-mile zone			***63,914,493***

Table 2. Selected AOCs and Data for Census Tracts within 2 Miles[a]

U.S. Area of Concern	Area (km^2)	Census Tracts (No.)	Weighted Median Price (2000$)
Ashtabula River, OH	35	11	84,235
Buffalo River, NY	14	15	58,996
Deer Lake,MI	191	10	75,739
Eighteenmile Creek, NY	4	1	84,100
Fox River & Green Bay, WI	621	15	115,168
Grand Calumet River, IN	336	29	74,313
Kalamazoo River, MI	57	9	168,900
Manistique River, MI	6	1	49,700
Menominee River, WI	26	6	59,808
Milwaukee Estuary, WI	258	48	101,809
Muskegon Lake, MI	171	9	80,658
Niagara River, NY	470	36	84,664
Osewego, NY	13	5	70,036
Presque Isle Bay, PA	135	5	85,722
River Raisin, MI	302	4	110,574
Rochester Embayment, NY	987	29	98,110
Sheboygan River, WI	12	6	81,518
St. Lawrence River, NY	335	4	73,523
St. Louis River/Bay, MN/WI	547	21	72,319
St. Mary's River, MI	4,327	5	74,670
Torch Lake, MI	97	3[b]	57,900
Waukegan Harbor, IL	10	8	131,300
White Lake, MI	191	2	99,337

[a] *Lists of included census tracts are available from the authors*

[b] *See text for explanation of exception to method of identifying tracts.*

Table 3. Estimated Residential Property Value Effects by AOC & Total, Year 2000

AOC Sites	PPE (%)	Weighted Median Price Impact (2000$)	No. Owner-Occupied Homes (2000)	Total Median Price Effect (2000$)
Ashtabula River, OH	7.785	6,557	9,747	63,914,493
Buffalo River, NY	17.622	10,396	5,264	54,726,033
Deer Lake,MI	7.785	5,896	6,146	36,236,640
Eighteenmile Creek, NY	17.622	14,820	690	10,225,878
Fox River & Green Bay, WI	7.785	8,965	10,308	92,414,908
Grand Calumet River, IN	7.785	5,785	18,110	104,765,682
Kalamazoo River, MI	7.785	10,005	13,914	139,209,570
Manistique River, MI	7.785	3,869	980	3,791,563
Menominee River, WI	7.785	4,656	5,637	26,244,791
Milwaukee Estuary, WI	7.785	7,925	8,314	65,891,894
Muskegon Lake, MI	7.785	6,279	5,446	34,194,864
Niagara River, NY	17.622	14,920	26,045	388,578,405
Oswego River/Harbor, NY	17.624	12,343	3,536	43,646,206
Presque Isle Bay, PA	17.622	15,106	3,523	53,218,234
River Raisin, MI	7.785	8,608	2,414	20,779,069
Rochester Embayment, NY	17.622	17,289	23,225	401,536,025
Sheboygan River, WI	7.785	6,346	3,767	23,904,790
St. Lawrence River, NY	17.622	12,956	3,533	45,774,370
St. Louis River/Bay, MN/WI	4.621	3,342	11,681	39,038,960
St. Mary's River, MI	7.785	5,813	3,396	19,740,113
Torch Lake, MI	7.785	4,507	376	1,694,737
Waukegan Harbor, IL	7.785	8,619	5,220	49,991,180
White Lake, MI	7.785	6,376	2,305	17,824,517
TOTAL			**173,577**	**1,696,193,852**
Mean	10.641	8,709		73,747,559
Std.Dev	4.766	4,034		105,215,660
Std.Err	0.994	841		21,938,982
95% Upper Conf..Limit	12.589	10,358		116,747,963
95% Lower Conf..Limit	8.693	7,060		30,747,154

Table. A-1. Economic Studies of AOC Remediation Benefits

City	Method[a]	Payment Mechanism	Period Studied	Est. Average % Δ Real Estate Price	Geographic Coverage	Source
Hamilton Harbor, ONT	Relative real estate price changes	Residential real estate sales price trend comparison between Harbour area and elsewhere	1983 - 1996	~ 12%	2/3 mi. radius	Zegarac & Muir (1998)
Ashtabula Harbor, OH	Referendum survey	Tax increase to pay for cleanup	1997	Avg. $32.50~ 1%[a]	Ashtabula County, OH	Lichtkoppler & Blaine (1999)
Green Bay, Fox & Wolf Rivers, WI	SP, both 1) referendum & 2) open-ended	1)Tax increase to pay for cleanup; 2) contribution to a fund to pay for cleanup	1997	Avg. $222/house/yr. (*est. ~ 2%*)[b]	State of Wisconsin[c]	Stoll *et al.*, 2002
Grand Calumet River, IN	RP – property values	Assessed residential real estate values as indicator of damage	2002	17 - 27%	W/in 6 blocks; Low income; assessed values	McMillen (2003)
Waukegan Harbor, IL	1)RP – property values; 2) SP – Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	1999 – 2001[d]	Each method: 15 - 20%	W/in 5 miles; CC estimates large value further away	Braden *et al*. (2004); Chattopadhyay *et al.* (2005)
Buffalo River, NY	1)RP – property values; 2) SP – Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	2003 – 2005	Hedonic method: 5% of market value; Survey method: 14% of market value	W/in 5 miles; CC estimates insensitive to distance	Braden *et al* .(2008a)
Sheboygan River, WI	1)RP – property values; 2) SP – Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	2003 – 2005	Hedonic method: 7% of market value; Survey method: 10% of market value	W/in 5 miles; CC estimates insensitive to distance	Braden *et al.* (2008b)

[a] SP = stated-preference methods, usually surveys. RP= revealed preference methods, usually market transactions data.
[b] Percentage estimates not computed in original report; estimated here by computing present value of 30 years of annual payments at prevailing mortgage rates of interest in the year of the study, then dividing by median prices of owner-occupied homes as inferred from census data.
[c] County and watershed-level results were not reported in the study.
[d] Some observations predated 1999.