Gerald E. Smolen

Gerald E. Smolen, Ph.D., is a professor of finance at The University of Toledo, having just completed a 5-year term as chairman of the department. He is a frequent contributor to scholarly and trade journals on topics related to real estate, banking, and economic development.

Gary Moore

Gary S. Moore, J.D., Ph.D., is assistant professor of finance at the College of Business of The University of Toledo. As a solo legal practitioner in 1981 he litigated the largest antitrust case in the history of the state of Iowa. Dr. Moore specializes in corporate finance and the management of financial institutions.

Lawrence V. Conway

Lawrence V. Conway, Ph.D., FASA, is Dean of the College of Business at The University of Teledo. A Fellow of the American Statistical Association, he is a past president of its Chicago Chapter, the largest in the nation. His teaching areas of specialization are money and capital markets, investments, and portfolio management.

Hazardous Waste Landfill Impacts on Local Property Values

The research conducted for this article was made possible through a grant from the Center for Real Estate Education and Research at The Ohio State University.

Considerable prior work has been published showing the value-impact on surrounding housing values in the vicinity of a sanitary landfill. As older landfills eventually became surrounded by residential and commercial buildings, and as communities grew, the impacts of existing and proposed landfills have become important questions. There is no question that the highest and best use options on properties adjacent to the landfill are narrowed, particularly where noxious odors, blowing dust, pesky vermin, and possibly polluted water runoff are potential hazards. Consequently, the comparability principle can become violated as one moves directly toward or away from the hazardous waste landfill site in an otherwise homogeneous area. In contrast, the comparability principle is sustained when considering properties approximately the same radial distance from the site. The critical question becomes, how far from the landfill will the highest and best use opportunity profile in a residential neighborhood be diminished, i.e., how far from the site will property values be adversely affected, and what, if any, will be the economic magnitude of the impact?

"As older landfills eventually became surrounded by residential and commercial buildings. . . the impacts of existing and proposed landfills have become important questions."

Prior Studies

Cartee (1989) reviewed four prior studies in which the results generally indicated that a negative impact on residential property values only occurred within a short distance from the landfills, i.e., within approximately one-half mile.

Public consensus has long held that landfills containing hazardous wastes are not a favorable use of land (see Mitchell, 1980; and Smith and Desvousges, 1986). Interestingly, past hedonic studies have not strongly supported a variety of different proxy variables that would explain this hypothesis, or statistically capture the disamenity effects of these sites (see Adler, *et al.*, 1982; Schulze *et al.*, 1986; and Kohlhase 1988).

Both the Adler and Schulze studies used distance from the landfills in their studies as the focal variable. However, the Kohlhase study examined the Houston market from 1976-1985 to determine the impacts

both from an awareness and a distance perspective[1] of announcements of 10 sites in Houston on the EPA's National Priority List on local property values. This empirical study analyzes a unique landfill occurrence situated in Toledo, Ohio.

Why Study Toledo?

The Toledo case offers an interesting opportunity to study the effects of proximity of two hazardous waste landfills on residential housing prices. On the east side of the Toledo metropolitan area is located an established landfill operated by Envirosafe, Inc. The landfill is unique since it is dedicated to accepting a low level category of hazardous (toxic) wastes from throughout the Eastern United States. Applicable state and federal agencies confirm its proper design and continued safety. Nevertheless, among some citizen groups an ebb and flow debate clouds the perception of the facility's long term safety.

". . . among some citizen groups an ebb and flow debate clouds the perception of the facility's long term safety."

In late 1989, a second hazardous waste disposal facility was announced by the State of Michigan in Riga Township, located adjacent to the northwest Toledo metropolitan area. Although the site was far from major population centers in Michigan, it was near Toledo's suburbs. Vocal protest from local residential groups ultimately defeated the proposal. The intense citizen challenge and extensive media coverage offered a unique opportunity to measure the impact of a proposed hazardous waste facility on the local residential real estate market.

Methodology

Two landfill locations were studied, one a potential new site (radioactive) and the other (chemical), an existing site. Actual real estate sale prices in the greater Toledo area from courthouse property transactions and tax report data were used to establish relative benchmarks of housing prices before and after the announced location of the nuclear dump. Adjacent southeast Michigan housing prices were excluded because the area was largely undeveloped rural farm land without a significant real estate sales data base for residential housing facilities during this period. In addition to analyzing descriptive statistics regarding housing trends, a series of regression models were developed.

A number of other macro-economic variables including local unemployment rates and local housing interest rates, number of homes on the market, number and severity of safety-related incidents at the site, and local population trends ordinarily might be relevant during periods of wide economic variability. However, the time period selected in the study was marked by extreme economic stability. For example, FHA mortgage rates trended from 9.91 percent in 1986, to 10.28 percent in August, 1990, peaking at 10.49 percent in 1988[2]. Similarly, unemployment rates remained relatively stable during the period, as did demographic trends. Research showed no safety-related occurences at the landfill during the five year study period. Presumably, a series of such incidents might precipitate fear among homeowners or buyers in proximity to the landfill, and transmit abnormal price variations to the local housing markets.

Using a neighborhood centroid scheme, linear distances between each house sold and the nearest landfill were recorded and entered

1. It should be noted that most prior studies didn't segregate toxic waste landfills from "ordinary" sanitary landfills in their data bases. This may not have been possible because some sites assumed to contain benign wastes are only now being identified as containing varying amounts of hazardous wastes, which require clean-up efforts.

2. *Federal Reserve Bulletin*, Real Estate Mortgage Markets Tables. Years 1986 through 1989, Board of Governors, Washington, D.C.

in the data bases for Envirosafe, Inc., and the proposed Riga site[3].

Multiple regression models were specified using the dependent variable, "house sale prices" for individual housing units from 1986 through mid-1990, and various independent variables, including: "distance from the site," "living space," "number of rooms," "lot size," "bath room configuration," and "porches." The set of independent variables, all common property appraisal attributes, reflected increasing utility to potential homeowners, i.e., normally a full basement is more desirable than a partial basement, which is in turn more desirable than a slab or a crawl space. A regression model was specified for each year in order to capture transitional changes in variable relationships more accurately than using a single regression model with an independent variable for time. A total of 1,312 and 1,237 transactions were used for the Riga Township site and the Envirosafe site, respectively.

The Results

A series of regression models were developed and regression equations computed using the housing sales data. The dependent variable was the actual sales price. A variety of independent variables were examined for their potential impacts on the robustness of the model. The various regression models were modified to best identify the effects of proximity to the landfill on sales prices, recognizing the existence of multi-collinearity. Data were available for the following independent variables: house-level descriptor (e.g., single level, bi-level); house-use (e.g., single family, condominium); construction type (e.g., brick, frame); living space in square feet; number of rooms; number of bedrooms; number of full baths; number of half baths; age of house; central air; type of finished basement; type of enclosed porch, patio or deck; garage size and type; number of outbuildings; lot size; swimming pool; and fireplace.

A priori, each of the independent variables would be expected to exhibit a positive sign, with one questionable variable. The variable for construction type did not lend itself to a meaningful coding convention, because anticipating buyer preference for brick over wood, or wood over aluminum was difficult to obtain. Hence, this variable was excluded from the data base.

The number of independent variables was reduced by using a stepwise regression to identify variables explaining the greatest amount of variation in the dependent variable. The variable "amount of living space in square feet" (livspc) entered first, followed by "lot size" (lotsz), "half baths" (hbaths), "number of porches" (porches), and "garage." "Garage" and "porches" showed negative parameter signs, and "distance in miles from the landfill" (dist) did not enter the model. The R^2 for the model was 0.602.

Models were computed using the data for annual and the entire five year period for three distance or centroid ranges from the landfill, 0 - 2.6 miles, 2.61 - 5.75 miles, and greater than 5.75 miles. Rationale for the three distance ranges hinged on obtaining approximately equal sample sizes within each range. Increasing the number of distance centroids to span uniformally shorter distances, produced unequal transactions per centroid largely because home sales are not uniformly dispersed throughout the Toledo metropolitan area per unit of time.

In research methodology, it is recognized that a control sample is an essential element in the scientific approach. Thus, a control sample can strengthen the interpretation given to the statistical findings to test research hypotheses[4]. A control sample of 49 home sales occurring in 1989 and 1990 was used. The sample included those located seven or more miles south of the landfills, away from other known polluting sources. The Distance variable was statistically non-significant in the

3. The sites are approximately 20 miles apart in linear distance.

4. Discussion of the tests of the research hypotheses is presented in the Conclusions section.

control sample. This finding increases the credibility of results computed from the landfill samples, assuming the coefficients are statistically significant and have expected positive signs.

Envirosafe Landfill

The Distance variable had a regression coefficient value of 12.061, in the regression model for all five years of the Envirosafe site. This means that within the 0 - 2.6 mile range, for each mile the house was removed from the actual landfill location, the sale price of the sample houses increased $12,061, *ceteris paribus*. In other words, a house located two miles away from the landfill, compared to a house located next door to the landfill, would be expected to sell for $24,122 more (i.e., two miles × $12,061). Extending this method of coefficient interpretation to the Living Space variable shows incremental square footage of living space adding $41 to the sale price of the house. A $41 per square foot value on a house is reasonable for the Toledo real estate market. The variable Half Bath with its coefficient of 16.306, indicates each half bath adds $16,306[5] to the sale price of a house located in the 0 - 2.6 mile range of the landfill during 1986 1990, other variables held constant[6].

Another regression model was run on the Envirosafe data in the intermediate distance (2.60 - 5.75 miles) range for all five years of data. The Distance from the landfill variable was significant at the one percent level. The signs on the coefficients, as well as their significance, were similar to those in the previous model, and coefficient interpretation would similarly follow. Interpreting the coefficients in terms of dollar impact showed a $12,106 increase in value per mile more distant from the landfill, a $35 per square foot value of living space in the house, and $11,337 premium per half bath constructed in the house.

A third model provided the regression results for the final distance range from the landfill, 5.75 miles or more. Houses located at distances greater than 5.75 miles from the Envirosafe Landfill show no downward pressure on the sales prices. The coefficient signs appeared plausible, suggesting the model was properly specified. The data showed a strong statistical relationship between proximity to a landfill and sales prices of residential real estate, extending out to between 0 and 5.75 miles from the landfill site.

Other regression models were computed, including one for each of the five years of data for the Envirosafe site using the same distance centroids. The findings indicated that the housing values within the closest range varied from year-to-year over the five year sample period. Table 1 presents the year-by-year findings.

The Distance (Dist) variable, in thousands of dollars, indicates an increased value of $9,344 per mile in 1986, $9,301 per mile in 1987, etc. moving away from the site, within the 0 - 2.6 mile range. The t-scores indicate statistical significance.

A table similar to Table 1 is omitted, but the results show for the Distance 2.6 - 5.75 miles, the incremental changes in values ranged from a $7,416 per mile, in 1986 to as high as $22,793 per mile, in 1988. As a possible explanation, in 1988, the initial news release of the proposed Riga low level radioactive site was made. It is important to note the instability of price changes within centroids from year-to-year

5. The reader will note in the following tables the coefficients will change from the values found in Tables 1 and 2. The differing coefficients are caused by two elements. First, of course, is the causal relationship being measured statistically in the actual data. The second cause for changing values is attributable to errors in specification of the model, or "lack of fit" of the regression model.
6. The statistical means for the respective variables used in the analysis can be useful to provide perspective on the interpretation of the data. The following means are for 1989, and most recent year with 12 months of data, in the 0 - 2.6 mile range.

	Riga Landfill	Envirosafe Landfill
Saleamt ($000)	124.191	57.138
Distance	2.103	1.663
Half baths	0.900	0.276
Living space	1,997.034	1,309.704
Full baths	1.761	1.174

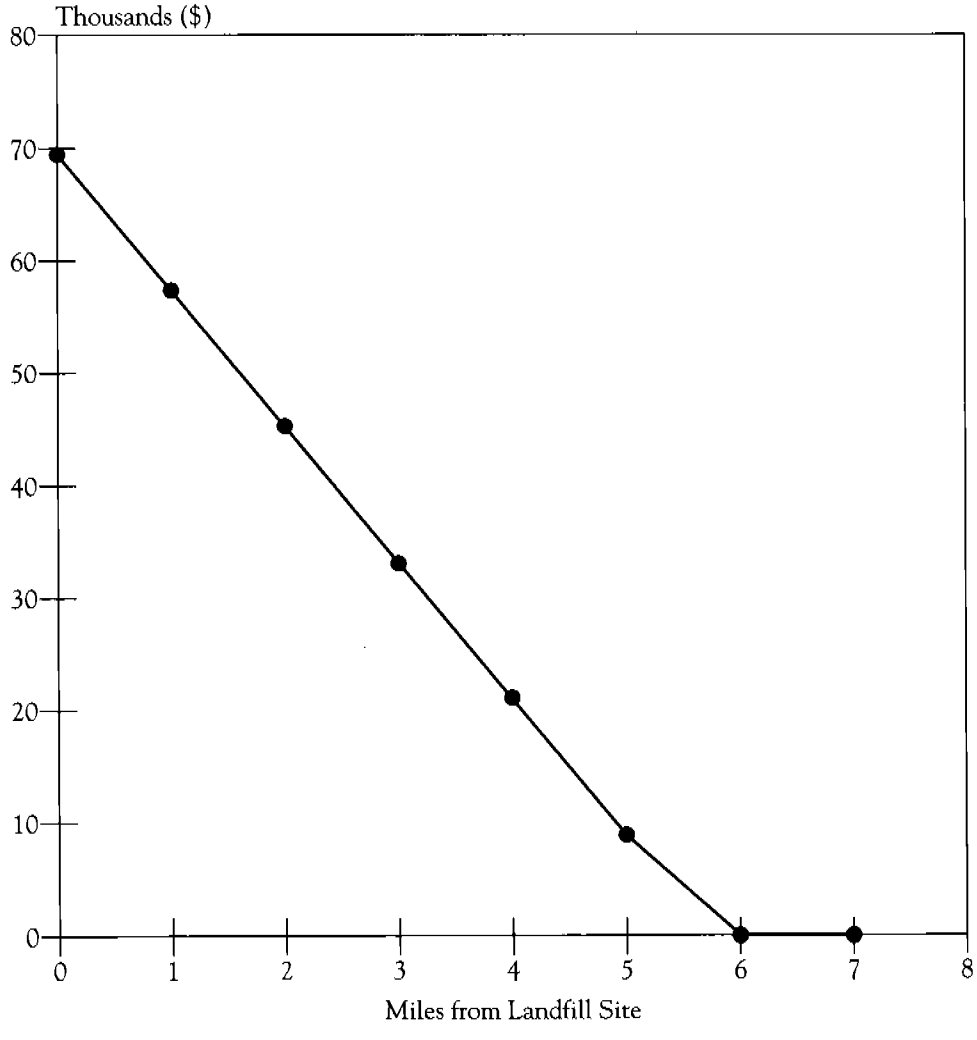
Table 1

MULTIPLE REGRESSION MODELS FOR HOUSES LOCATED LESS THAN 2.6 MILES FROM ENVIROSAFE LANDFILL SITE, 1986, 1987, 1988, 1989, JANUARY-AUGUST 1990, USING THREE INDEPENDENT VARIABLES[a].

Year	Intcpt	Dist	Livspc	Hbath	R^2	F-Ratio	Std. Error
1986	-18.002	9.344	0.035	13.685	0.490	114.4	19.6
	(3.79)	(4.51)	(12.72)	(5.74)			
1987	-26.184	9.301	0.041	12.953	0.551	85.2	18.7
	(4.21)	(3.58)	(11.04)	(4.43)			
1988	-34.410	13.365	0.047	16.154	0.561	87.9	21.3
	(4.73)	(4.18)	(11.71)	(4.98)			
1989	-29.297	14.205	0.059	23.034	0.505	66.4	25.0
	(3.41)	(3.75)	(9.21)	(5.51)			
1990	-45.457	13.030	0.059	11.460	0.619	29.3	20.5
	(2.98)	(2.48)	(6.17)	(1.72)			

[a] T-scores are in parenthesis in absolute values.

CUMULATIVE VALUE LOSS VS. DISTANCE
ENVIROSAFE LANDFILL, CITY OF OREGON, OH
1986-1990 AVERAGE DATA



Vertical grid lines are analogous to centroids. Area under curve is loss due to proximity to landfill.

in the site location of this data.

To illustrate the overall incremental price impact graphically, the following figure presents the findings for the 1986-1990 period in cumulative form. That is, at the zero mile point (at the landfill site), the cumulative loss in value is $69,518, relative to a subject located more than six miles distant. At three miles away from the sight, the cumulative loss is $33,290, relative to a subject more than six miles away, as shown by the area under the curve. Finally, at 5.75 miles, the value loss is zero.

Riga Landfill

The findings for the Riga Landfill are given in Table 2, for 1988, 1989, and 1990, for the 2.60 - 5.75 mile centroid only. The 0 - 2.60 mile centroid findings are similar to the results in Table 2, but are omitted for the sake of brevity. The distance variable (dist) for 1988 shows no significant finding because the public was not aware of the State of Michigan's plans to identify Riga Township as the proposed landfill site. In early 1989, the public began to assimilate the announcement and react to the news. The (dist) variable in 1989 showed a housing value increase of $4,160 per mile for the distance range of 2.60 - 5.75 mile. This centroid is represented by considerably more properties than contained in the 0. 2.6 mile range[7]. The coefficient was statistically significant at the one percent level. The price effect for 0 - 2.6 miles for 1989 was $5,780 per mile.

The 1990 results showed continued depressed values in both centroids, however, the dist coefficients for were not statistically significant in either sector. By mid-1990, it was evident the Riga Landfill proposal would be rescinded by the State of Michigan. Subsequently, housing sales activity in the sample locale began to resume a normal price change pattern.

As with the Envirosafe area, the Riga Township site showed a price decline outward from the proposed site to a much greater distance than found in other studies. The justification of this finding necessarily hinges on the nature of industrial waste disposal and containment. It is interesting to recognize the extent of the negative effect on area prop-

Table 2

MULTIPLE REGRESSION MODELS FOR HOUSES SALES LOCATED BETWEEN 2.60 TO 5.75 MILES FROM RIGA TOWNSHIP LANDFILL SITE PROPOSAL, NEAR THE CITY OF SYLVANIA, OHIO, 1988 AND 1989, JANUARY THROUGH AUGUST, 1990, USING THREE INDEPENDENT VARIABLES[a].

Year	Intcpt	Dist	Livspc	Hbath	R^2	F-Ratio	Std. Error
1988	-21.036	0.664	0.624	3.573	0.701	239.3	24.8
	(2.61)	(0.40)	(23.36)	(1.25)			
1989	-49.684	4.160	0.077	0.004	0.717	431.0	32.0
	(6.11)	(2.53)	(31.53)	(0.001)			
1990	-49.586	4.640	0.070	15.345	0.647	81.8	39.6
	(2.47)	(1.19)	(12.93)	(2.16)			

[a] T-scores are in parenthesis in absolute values.

"It is interesting to recognize the extent of the negative effect on a suburban community at the mere proposal stage of a low level radioactive landfill."

7. Riga Township, Michigan, is largely rural. Immediately across the state line in Ohio, Toledo's suburban growth westward has not yet entirely overlapped the boundry with Riga Township.

erty prices in a suburban community at the mere proposal stage of a low level radioactive landfill. Hence, appraisers must carefully weigh the impact of toxic landfill location factors on subject property valuation.

Conclusions

The findings offer strong evidence that hazardous waste landfills adversely affect residential values to greater distances from the site than implied in previous studies. The residential real estate markets convincingly measure public apprehension associated with the location of landfill sites containing hazardous waste.

Earlier studies didn't identify whether the landfill sample data contained any amounts of hazardous waste. However, current EPA findings are indicating that in the past, uncontrolled dumping in "ordinary" sanitary landfills has resulted in the revelation of varying amounts of hazardous waste containment. As the public becomes more aware of the hazards discovered in their local landfills, this knowledge may affect the values of surrounding land sites and residences. The results of this study show that public awareness and concern, as it impacts housing valuations, extend well beyond the immediate area indicated in previous studies.

Appraisers and expert witnesses must consider the effects of known and suspected hazardous waste containment sites on valuation estimates. The findings show these sites can negatively impact property valuations outward to as much as 5.75 miles from the landfill. The Toledo data showed a negative impact averaging nearly $12,100 per mile from the site.

Selecting comparables in those communities in which hazardous waste landfills are located raises an important challenge in the quest for valid appraisals. To minimize inherent errors in these valuations, the appraiser should select comparable homes within the same centroid or distance radius from the site. That is, comparables should be located a constant distance from the landfill site. Choosing comparables located either more closely to the site, or farther from the site will likely bias the estimated value of the subject, based on the insights gained from this study.

Particularly bothersome are appraisals made during a period of time when an existing "safe" landfill is hit by public disclosure of unexpected landfill toxicity. The appraisal client may be faced with a serious problem because the subject valuation quickly becomes obsolete. The bad news emanating from the authorities which is associated with a particular landfill can precipitate a rapid, sizable downward adjustment in property values. The adjustment is felt well beyond the short distances commonly held as true, as shown in the Riga case. Acknowledgment of the toxic landfill's effects on the appraisal property should be included in the appraisal report.

Clearly, further research is needed on this important topic to build upon the results of this study. More insight is needed to enable real estate appraisers to refine subject valuations which are located in proximity to landfill sites and industrial sites suffering from varying degrees of actual or suspected hazardous waste containment or pollution.

Selected Background Literaure

Adler, K.J., Anderson, R.C., Cook, Z., Dower, R.C., Ferguson, A.R., and M.J. Vickers, "The Benefits of Regulating Hazardous Waste Disposal: Land Values as an Estimator," Tech. Rep., Public Interest Economics Center, Washington, D.C. 1982.

Baker, Don, "Environmental and Cleanup Solutions Preceding Real Estate Transfer," *Industrial Development*, 156:12–14, September–October 1987.

Blackley, Dixie M., James R. Follain and Haduck Lee. "An Evaluation Of Hedonic Price Indexes For 34 Large SMSAs," *AREUEA*, 1986, v14(2), pp. 179–205.

Cartee, Charles P., "A Review of Sanitary Landfill Impacts on Prop-

erty Values," *The Real Estate Appraiser & Analyst*, Spring 1989, pp 43–47.

Edmonds, Radcliffe G., Jr. "A Theoretical Basis For Hedonic Regression: A Research Primer," *AREUEA*, 1984. v12(1), pp. 72–85.

Fama, Eugene F., "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance*, May 1970, pp. 383–417.

Federal Reserve Bulletin, Real Estate Mortgage Markets Tables. Years 1986 through 1990, Board of Governors, Washington, D.C.

Ferri, Michael J. "An Application Of Hedonic Indexing Methods To Monthly Changes In Housing Prices: 1965–1975," *AREUEA*, 1977, v5(4), pp. 455–462.

Kohlhase, J.E., "The Impact of Toxic Waste Sites on Housing Values," unpublished research paper, University of Houston, February 1988.

Lando, Albert M., "Environmental Minefield: Potential Liabilities for Secured Creditors," *Canadian Banker*, 96:28–34, September–October 1989.

Lang, James R. and Wesley H. Jones. "Hedonic Property Valuation Models: Are Subjective Measures Of Neighborhood Amenities Needed?," *AREUEA*, 1979, v7(4), pp. 451–465.

Lorie, J. and R. Brealey, *Modern Developments in Investment Management*, (New York: Praeger, 1972), p. 101.

Michaels, R. Gregory and V. Kerry Smith, "Market Segmentation and Valuing Amenities with Hedonic Models: The Case of Hazardous Waste Sites," *Journal of Urban Economics*, 28:223–242, 1990.

Mitchell, Robert C., "Patterns and Determinants of Aversion to the Local Siting of Industrial, Energy and Hazardous Waste Dump Facilities by the General Public," unpublished paper, Resources for the Future, 1980.

Noland, Charles W. "Assessing Hedonic Indexes For Housing," *Journal of Financial and Quantitative Economics*, 1979, v14(4), pp. 783–800.

Ohio EPA, *1990 Unregulated Sites, Master List*, State of Ohio Environmental Protection Agency, Division of Emergency and Remedial Response, Columbus, Ohio 1990, Preface.

Palmquist, R., "Measuring Environmental Effects on Property Values without Hedonic Regressions," *Journal of Urban Economics, 11:333–347, 1982.*

Pilko , G. and Fred Geer, "Avoiding Hazardous Waste Pitfalls in Real Estate Transactions," *Industrial Develoment*, 156:7–9, November/December 1987.

Reichert, Alan K., *The Impact of Landfills on Residential Property Values*, Monograph, Center for Real Estate Education and Research, The Ohio State University, March 10, 1991.

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economics*, 1974, 82, pp. 34–55.

Rubin, D.K., "Toxics Disclosure Rules Gaining in Real Estate Deals," *ENR*, 222:8–9, Apr 13, 1989.

Ryan, Daniel F., "A Lender's View of Hazardous Substances. . .and Appraiser Responsibility," *The Real Estate Appraiser and Analyst*, Fall 1989, pp. 10–12.

Schulze, W., McClelland, G., Hurd, B., and J. Smith, "Improving Accuracy and Reducing Costs of Environmental Benefit Assessments," Vol. IV, "A Case Study of a Hazardous Waste Site: Perspectives from Economics and Psychology," draft report, U.S. Environmental Protection Agency, Contract CR812054-01-1, 1986.

Shumate, Jack D., *Environmental Concerns of Financial Institutions*, Butzel, Long, Gust, Klein & Man Zile Attorneys, Detroit, 1990, p.5.

Smith, V. Kerry, and William H. Desvousges, "The Value of Avoiding a LULU: Hazardous Waste Disposal Sites", *Review of Economic Statistics*, 1986, 68, 293–299.