The Effect of Water Quality on Rural Nonfarm Residential Property Values

Donald J. Epp and K. S. Al-Ani

The past decade has seen a phenomenal increase in public awareness and concern over environmental quality. The desire to consume larger amounts of environmental quality has been difficult to satisfy because many of the natural resources involved do not lend themselves to market allocation. This failure of markets to solve the major environmental quality problems has been well documented (Bator, Mishan, Samuelson, Turvey), and generally can be attributed to externalities imposed by use of the environment and the public goods nature of many natural resources.

The failure of markets to perform the allocation function to the satisfaction of most people has caused us to turn to other institutions for solutions. Most frequently society has turned to legal processes, both the passage of new legislation and the interpretation or enforcement of existing legislation in the courts. While these activities affect many environmental areas, this paper is focused on water quality, where many state and federal laws have been passed in recent years. Typical of this legislative effort are the 1972 Amendments to the Water Pollution Control Act (P.L. 92-500) and the 1977 Clean Water Act (P.L. 95-217). These acts specify national goals and policies to eliminate the discharge of pollutants into surface waters, encourage policies that maintain a level of water quality sufficient to protect fish and wildlife, require local authorities to establish waste treatment projects, and finance the development of pollution abatement technology.

While there has been political support for these laws, economic analyses of their effects have concentrated largely on determining the costs of achieving the standards set through the political process (e.g., Nagadevara, Heady, Nicol; Pound, Crites, Griffes; Van Note, Hebert, Patel; Young). Very little evidence has been presented that measures the demand (in the economic sense) for environmental quality in general or water quality specifically. This article reports an attempt to determine one aspect of the demand for one kind of environmental quality—clean streams.

The study reported here used real estate prices to determine value of improvements in water quality in small rivers and streams in Pennsylvania. The specific objectives of the study were (*a*) to estimate the relationship between water quality and the value of residential properties adjacent to small rivers and streams; and (*b*) to estimate the effect of various components of water quality, such as acidity, dissolved oxygen, biochemical oxygen demand, and nitrate and phosphate levels, on the value of properties adjacent to small streams.

The second objective was included because various pollutants have different physical and biological effects in the streams, have very different costs for removing marginal increments, and usually are listed separately in quality standards established for specific streams.

The Model

Traditionally, the real estate market consists of at least four parts—residential, commercial, industrial, and agricultural—each of which may be divided into a market for rental of services and a market for purchase of stocks. The model developed in this study concentrates on the market for the purchase of housing stocks, but does not use the conventional supply and demand approach. Due to the wide variety of housing characteristics provided by units on the market at any one time, especially in the rural areas of particular interest to this study, it is inappropriate to represent these markets with a model that assumes homogenous products. Instead, a hedonic model based on property characteristics is developed. Using such a model, the economic analyst can determine the implicit price of various attributes of properties from observed prices of differential products and the specific amount of each attribute associated with them (Rosen, p. 34).

For this study, the characteristics of residential property are divided into four groups and related to market value as

$$V = f(\Sigma R_j, \Sigma S_j, \Sigma T_j, \Sigma U_j),$$

where V is the market value of the property; R_j is the value of physical housing characteristic j, such as number of rooms or age of the house; S_j is the value of neighborhood characteristic j, such as

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community average income, average education level, or employment rate; T_j is the value of accessibility characteristic j, such as distance to major highways, to a metropolitan area, or to a waterway; and U_j is the value of amenity characteristic j, such as water quality or topography (Al-Ani).

Estimating the Model

Small rivers and streams in Pennsylvania (average discharge of 850 cubic feet per second or less) with documented levels of various water quality components were classified as clean if all components were within the normal range established for surface waters by the National Academy of Science and polluted if one or more components had levels outside the normal range. A paired sample, consisting of twelve clean streams which had not undergone recent quality improvement and thirteen polluted streams, was selected. On each stream a site was selected to consist mainly of rural, nonfarm, small communities located away from the suburbanizing influence of large cities. It was required that each site be located along the stream and within two stream miles of a Pennsylvania water quality network stream station (Pennsylvania Department of Environmental Resources).

Data on properties containing one single-family, owner-occupied dwelling, ownership of which was transferred between 1969 and 1976, were collected for these sites from public records and from telephone interviews with present property owners. Only properties occupied by the owner year-round and located within 700 feet of the stream were included in the study.

The sampling procedure was designed to isolate the influence of water quality on property value by minimizing the variability between properties of characteristics other than water quality. Similarly, a comparison across streams rather than a time-series was used to minimize the impact of changes in value that occur over time. An additional advantage of the across-stream comparison is that it gives a greater variation in water quality characteristics. Time-series data on streams that have experienced significant changes in water quality are very limited.

Specification of the Variables

The dependent variable, property value, was measured using actual sale price and excluded invalid transactions, such as sales to relatives and nominal sale prices. Sale prices were deflated to the base year 1972 using the quarterly implicit price deflators of residential nonfarm structures (U.S. Department of Commerce).

The independent variables are of two kinds, those that vary for each property and those that vary between sites but which have identical values for all properties within a site. All of the independent variables used in this study are shown in table 1 along with an indication of whether the variation is by site or individual property, the unit of measurement, and the a priori expectation of direction of effect.

The selection of the components of water quality to be included in the model was based upon their possible effects on nonconsumptive uses of the stream, primarily recreation or aesthetic appreciation. Several specific components of water quality were tried in this study—pH, dissolved oxygen, biochemical oxygen demand, acid from minerals, acid from carbon dioxide, and nitrate and phosphate concentrations. Only the three measures of acidity had consistently significant effects on property values. Acidity from minerals, acidity from carbon dioxide, and pH each had similar effects on property value when entered as the single measure of water quality. Because pH is the more widely used measure of acidity in water, it was used throughout the rest of the analysis. For some purposes, pH was transformed into a dummy variable equal to zero if pH was 5.5 or lower, otherwise equal to one. The pH of 5.5 was chosen for this purpose because water with a pH of less than 5.5 has severe limitations for recreational use.

A general measure of water quality was based on the perceptions of the property owners as determined in the survey. If the owner indicated a belief that the stream had a water quality problem and that this prevented his using the stream for a specific recreational or aesthetic activity, the value of zero was assigned to the variable. In this way, perceptions of water quality, whether factual or not, could be entered into the analysis.

The hazard of flooding was determined from interviews with present homeowners. Responses to the question about frequency of flooding were converted to probabilities ranging from zero if the property never flooded to 0.99 if the property was flooded annually.

Lots in rural communities may vary greatly in size, being as small as one-fifth of an acre to as large as several acres. In this study, lot size was calculated to the hundreth of an acre.

The opportunity to find employment nearby is an important consideration in choosing a residence and is hypothesized to be positively related to sale price. An index of potential employment (*PER*) was constructed using a gravity model to weight actual numbers of employed individuals by distance using the following equation.[1]

$$PER_i = \sum_{j=1}^{n} D_{ij}^2 + 1$$

where PER_i is potential employment by residence

[1] The authors acknowledge the assistance of Frank M. Goode in developing the final form of the equation and in providing access to data for calculating *PER* values.

Table 1. Single Equation Estimates of the Effect of Selected Variables on the Value of Residential Properties

Variable and Level of Observation (*P* = property, *S* = site)	Units	Expected Sign	Mean Values	Coefficient Values Model 1	Coefficient Values Model 2
pH (*S*)	*pH* units	+	5.694	.344* (.130)	
Interaction of pH_D and percentage change in population, 1960–70	%	+		.115* (.023)	
Perceived water quality (*P*)	0,1	+			.246* (.055)
Interaction of perceived water quality and percentage change in population, 1960–70	%	+			.129* (.022)
Flood hazard (*P*)	Probability	−	.063	−.568* (.176)	−.491* (.171)
Lot size (*P*)	acre	+	.917	.349* (.088)	.317* (.086)
Number of rooms (*P*)	number	+	9.085	.604* (.109)	.586* (.106)
Potential employment (*S*)	number of jobs	+	1090.052	.160* (.027)	.133* (.025)
Per pupil expenditure (*S*)	$	+	1007.100	1.861* (.435)	2.180* (.404)
Percentage change in population, 1960–70 (*S*)	%	+	.548	−.001 (.015)	−.002 (.015)
Age of house (10–24) (*P*)	0,1	−	.156	−.274 (.174)	−.273 (.169)
Age of house (25–49) (*P*)	0,1	−	.264	−.516* (.172)	−.526* (.165)
Age of house (50 and over) (*P*)	0,1	+ or −	.557	−.847* (.170)	−.822* (.164)
Income (>$10,000 = 1) (*P*)	0,1	+	.590	−.197* (.053)	−.169* (.052)
Constant				−6.449	−7.841
$\bar{R}^2$				.67	.69
N				212	212

Note: Standard errors in parentheses. Asterisk denotes coefficient was significant at the 1% level.

at site i; E_j is employment at the jth minor civil division (*MCD*) within a 20-mile radius of site i, including the *MCD* containing site i; and D_{ij} is distance (in miles) from the center of site i to the center of MCD_j.

Another important factor in choosing a residence is the level of services provided by local government and schools. School expenditures per pupil (annual operating budget divided by average daily enrollent) was selected as the measure of school services. Expenditure per pupil was chosen over school tax rate because state aid payments to school districts vary greatly. It is believed expenditures more accurately reflect school quality in this case than do local tax revenues. The real estate tax rate for schools and local government combined also was tried as an independent variable but did not improve the model.

The dummy variable for age of the house over fifty years is of uncertain effect on property value. In some localities in Pennsylvania, very old houses have added value as antique or historic properties. Thus, the expected effect is indeterminate.

Income in this study is reported individual family income. To increase response, the income question in the survey was worded to determine which of five income categories contained the family annual income. Thus, income was treated as a dummy variable. Several specifications were tried and a qualitative variable form with $10,000 as the dividing point was chosen. Contrary to previous studies, this study did not use median income as a proxy for housing quality but, rather, measured housing quality directly.

Several variables were considered in addition to the variables used in the final specifications of the model. Characteristics of the house and neighborhood included the age of the house as a continuous variable and the size of the stream measured by average annual flow. Accessibility characteristics considered included the distance to a major highway, the distance from the property to the waterway, and the ease of access to the waterway indicated by a dummy variable which took the value of one if there was a building, hill, or other obstruction between the stream and the property being studied. None of these variables increased the explanatory ability of the models when added to those shown in table 1 or substituted for similar variables.

Empirical Estimates

Estimation of the model was conducted in two ways. First, all 212 property observations were combined into one pooled-data set to estimate the parameters of various forms of the equation. A second estimate of the effect of water quality on property value made use of the fact that the sample was taken in part from streams of good water quality and in part from polluted streams. The second, or paired sample, approach estimated the parameters of the equation twice, once with data from clean stream sites and once with data from polluted stream sites.

The logarithms of the dependent variable (property sale price) and the continuous independent variables were used in estimating the parameters of the equation. Other functional forms were considered. The linear, semilogarithm and inverse semilogrithmic forms were rejected because of greater hetroscedasticity and because coefficients of the selected form are more easily given economic meaning. The analysis also specifically considered the potential problems caused by multicollinearity among independent variables. Initial screening of the variables using the Klein test (Klein, p. 101) did not indicate any potential problem. Preliminary runs of the paired-sample approach seemed to indicate, however, that three variables had an interaction with water quality. These were the number of rooms, the percentage change in population, and the dummy variable representing houses between ten and twenty-four years old. Interaction terms between water quality and the three variables listed were constructed and tested. Only the interaction term between water quality and the percentage change in population was found to be significant and added to the explanatory power of the equation (Al-Ani, chap 5).

Pooled sample results. The results of two different models are presented in table 1. Model 1 uses an actual measure of water quality—pH—and its interaction with the percentage change in population. Model 2, on the other hand, uses perceived water quality and its interaction with population change. All other variables are the same in both models.

The coefficients for most of the independent variables are significantly different from zero. Only two, change in population and the dummy variable denoting houses ten to twenty-four years old, were not statistically significantly different from zero at the 1% level. The lack of significance of the change in population variable probably can be attributed to the presence of the interaction variable with water quality. It is likely that population change effects are picked up by that variable. The age of the house apparently is not significant for houses less than twenty-five years old. Houses more than twenty-five years old are, however, sold at significantly lower prices.

The second observation of importance for this study is that all of the variables reflecting conditions in the natural environment (water quality and flood hazard) are significant. Water quality, whether measured by pH or by the owners' perceptions, has a significant effect on the price of adjacent property. Water quality has an additional impact through its interaction with the percentage change in population. That variable indicates that population growth is significantly related to property value, but only for good quality streams. Flood hazard, too, is significantly related to land price with the expected negative relationship.

The coefficient for the dummy variable income has a negative sign in model one and is statistically significantly different from zero. This is the only instance in either model where a coefficient that is statistically significantly different from zero does not have the expected sign, and the authors are unable to offer any explanation for this phenomenon.

From the analysis of single equation approaches to determining the effects of water quality on housing values, it can be concluded that buyers are aware of the environmental setting of a home and, specifically, that differences in the quality of water in nearby waterways affect the price paid for a residential property. The relationship is shown to be positive, as hypothesized.

The capitalized benefits from higher quality water to a property of average value can be calculated from the results shown in table 1. A one point increase in pH represents a 17.5% increase from the mean value of pH. Using the regression coefficient for pH from table 1, one would expect a 5.95% increase in the mean sales value of residential properties. This is equal to $653.96.

Paired sample results. In addition to measuring the effect of water quality on residential property value directly, as was done with the pooled-sample approach, it is possible to examine the effect water quality has on the magnitude and relative importance of other factors affecting price. For instance, one can hypothesize that the physical characteristics of the house (size, number of rooms, age) take on additional significance to a buyer if the package does not include a high quality stream. Because the data for this study were gathered from sites that had been stratified so as to represent clean streams and polluted streams (one or more components outside the normal range), the hypothesis about interaction between water quality variables and other variables can be tested by separately estimating the model using data from clean streams and polluted streams.[2]

The results of the paired-sample estimation of the coefficients are presented in table 2. In general, the results support the contention that when water quality is poor other characteristics of the housing package assume greater importance. The environmental variables provide a good example. In clean streams, variation in pH level is statistically very significant and positively related to property value. On the other hand, variation in pH in polluted streams has no significant effect on property value. The flood hazard has the opposite effect. On clean streams, where the average of reported flooding probability was nearly 10%, the prospect of flooding had no statistically significant effect on price. On polluted streams, however, the flooding hazard had a significant negative impact on price, even though the average of reported flooding probabilities was one-third that of properties along clean streams. Apparently, if owners do not have the benefits of a clean stream, they are influenced by negative aspects of the stream, such as flooding.

Other characteristics appear with larger coefficients and greater significance in the estimates for polluted streams than for clean streams. The importance of expenditures on schooling is not only significant in the polluted stream estimate and nonsignificant for clean streams, it also is dramatically larger than other coefficients in the equation. The large coefficient indicates a great importance in the minds of buyers.

Characteristics of the house itself also take on added importance when the stream is polluted. The coefficient for number of rooms is nearly twice as large in the polluted stream equation as in the clean stream equation. Likewise, the negative impact of age of the house when more than twenty-five years old is significantly greater in polluted areas. This finding takes on greater practical importance when one realizes that 85% of the houses in the polluted stream sample and 60% in the clean stream sample are over twenty-five years old.

[2] Preliminary analysis showed such interaction to be present. These interactions were tested and one, the interaction of water quality and percentage change in population, was selected to be included in the empirical model. That variable is entered in the paired sample approach in place of percentage change in population.

Table 2. Effect of Selected Variables on the Value of Residential Properties along Clean Streams and Polluted Streams

			Mean Values		Coefficient Values	
	Units	Expected Sign	Clean Streams	Polluted Streams	Clean Streams	Polluted Streams
pH	*pH* units	+	7.190	4.500	3.322*** (1.209)	.532 (.457)
Flood Hazard	probability	−	.099	.035	−.283 (.195)	−.892** (.377)
Interaction of pH_D and change in population	%	+			.062*** (.026)	.164*** (.057)
Lot size	acres	+	.940	.890	.345** (.137)	.306** (.119)
Number of rooms	number	+	8.800	9.260	.389** (.195)	.639*** (.135)
Potential employment	number of jobs	+	1040.000	1128.800	.292*** (.049)	.148*** (.045)
Per pupil expenditure	$	+	1022.500	995.050	.868 (.565)	2.076** (.896)
Age of house (10–24)	0,1	−	0.200	0.110	−.126 (.207)	−.415 (.284)
Age of house (25–49)	0,1	−	0.200	0.300	−.216 (.211)	−.804*** (.272)
Age of house (50 and over)	0,1	+ or −	0.400	0.550	−.394* (.208)	−1.208*** (.270)
Income (>$10,000 = 1)	0,1	+	0.500	0.630	.195*** (.075)	.168*** (.077)
Constant					−6.567	−7.872
$\bar{R}^2$					.74	.65
N					93	119

Note: Standard errors in parentheses. Asterisks denote significance: *** for above 1%; ** for between 1% and 5%; * for between 5% and 10%.

Conclusions

The results of various forms of estimating the model show that water quality significantly affects the value of adjacent residential properties. This is true when either an index of measured water quality characteristics is used or the owners' perceptions of water quality are used. The separate analysis of clean streams and polluted streams revealed that variation in pH has a large and significant effect on property values adjacent to clean streams but no effect on property values adjacent to polluted streams. One explanation of this finding is that increases in pH within the normal range (6.5–8.5) has increased value to property owners because it permits additional recreational activities, such as trout fishing. Increases in pH below the normal range (i.e., 3.7–5.5 in this study), however, permit no additional recreational activities and therefore, have no value.

Other variables found to be statistically significant as determinants of residential property value include the age of the house, lot size, number of rooms, potential employment, income, percentage change in population, per pupil expenditure on schools, and flood hazard.

Of equal importance with the finding of the relationship between stream acidity and property values is the demonstration that analysis of real estate markets can measure at least some of the value of environmental quality. This success can be attributed to two features of this study. First, the study examined a type of environmental quality that has noticeable effect on the buyers of the type of real estate studied. The relationship between water quality and rural nonfarm residences may be much clearer than some other environmental quality-property value relationships. Second, this study used primary data on individual properties and property owners to estimate directly the effect of all variables theoretically linked to property values. This contrasts sharply with some of the previous studies which employed proxy variables and applied them to aggregate units of property, such as a census tract. Direct estimation using the actual units of decision avoids losing the environmental effect through poor specification and certainly makes interpretation of the results more straightforward.

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References

Al-Ani, K. S. "The Relationship of Water Quality to Residential Property Values." Ph.D. thesis, Pennsylvania State University, 1977.

Bator, F. M. "The Anatomy of Market Failure." *Quart. J. Econ.* 72(1958):351–79.

Klein, L. R. *An Introduction to Econometrics.* Englewood Cliffs, N.J.: Prentice-Hall, 1962.

Mishan, E. J. "The Postwar Literature on Externalities: An Interpretive Essay." *J. Econ. Lit.* 9(1971):1–28.

Nagadevara, V. S., E. O. Heady, and K. J. Nicol. *Implications of Application of Soil Conservancy and Environmental Regulations in Iowa within a National Framework.* CARD Rep. 57, Iowa State University, 1975.

National Academy of Science, Committee on Water Quality Criteria, Environmental Studies Board. *Water Quality Criteria,* Washington D.C., 1972.

Pennsylvania Department of Environmental Resources. *Pennsylvania Water Quality Network, Sampling Station Descriptions.* Pub. No. 33, 1975.

Pound, C. E., R. W. Crites, and D. A. Griffes. *Costs of Wastewater Treatment by Land Application.* Environmental Protection Agency. EPA-430/9-75-003, 1975.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Polit. Econ.* 82(1974):34–55.

Samuelson, P. A. "The Pure Theory of Public Expenditures." *Rev. Econ. and Statist.* 36(1954):387–89.

Turvey, R. "Divergencies between Social Cost and Private Cost." *Econometrica* 30(1963):309–13.

U.S. Department of Commerce. *Survey of Current Business,* vol. 56, nos. 1 and 12, 1976.

Van Note, R. H., P. V. Hebert, and R. M. Patel. *A Guide to the Selection of Cost Effective Wastewater Treatment Systems.* Environmental Protection Agency, EPA-430/9-75-002, Washington, D.C., 1975.

Young, C. E. *The Cost of Land Application of Wastewater: A Simulation Analysis.* USDA ERS Tech. Bull. No. 1555, 1976.