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ANALYSIS

Exploring the hedonic value of ambient water quality: A local watershed-based study

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ARTICLE INFO

ABSTRACT

Non-point source water pollution of local watersheds can result from various sources but is tied most closely to runoff from impervious surfaces associated with development activities such as roadways, parking lots and large commercial structures. This research investigates the value of ambient water quality as measured by data from twenty-two monitoring stations located throughout a local watershed in Maryland; the St. Mary's River watershed. A hedonic property value model is used to investigate the marginal implicit values of the following water quality variables: total suspended solids and dissolved inorganic nitrogen. The econometric results indicate the marginal implicit prices associated with a one milligram per liter change in total suspended solids and dissolved inorganic nitrogen, are $–1086 and $–17,642, respectively.

1. Introduction

Development activities can be disruptive to the natural environment. Impervious surfaces such as roadways and parking lots, can accelerate runoff into local watersheds. Limnologists and ecologists monitor water quality in an effort to better understand these relationships between human activities and aquatic eco-systems. It has been well established by natural scientists that development or conversion of natural land uses results in the loss of watershed services (Schueler and Holland, 2000). However, if local policy to preserve water quality is to be influenced by watershed scientific monitoring, welfare economic studies linking local residents' willingness to pay for maintaining watershed services and water quality should be considered. Schueler and Holland (2000) explain that local watersheds consist of both small streams and their associated riparian areas, which

provide not only ecological services or habitat, but also numerous other services and amenities to people who reside within the watershed boundaries. Healthy or unimpaired small watersheds serve as a natural flood control and also provide residents with small stream recreational activities, encounters with wildlife and places of solitude. In many locations, small watersheds provide a sense of historical or cultural heritage related to settlement patterns which give rise to the layout of present day roads. Watershed quality monitoring and preservation policies are therefore of particular importance at the local level, and their deterioration can have negative consequences on local residents. It is therefore not unreasonable to assume that declining quality of local natural environments such as watersheds can have negative consequences on local housing prices.

One economic method of studying the value people place on local environmental quality is through the analysis of

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real estate transactions via hedonic property valuation models. For water quality valuation studies to be applicable for policy purposes, we must assume a corresponding relationship between residential homeowner utility functions and ambient water quality within their local watersheds. In certain localities where the health of the watershed and its associated tributaries are an integral part of the local culture and heritage such an assumption is realistic. One such area in the United States where there is a lengthy history of local fish harvests and water based recreation is the Chesapeake Bay estuary and its associated tributaries and sub-watersheds. Residents living within jurisdictions adjacent to the Bay tend to be knowledgeable about water quality issues and associated development activities; often to a point where water quality deterioration can become an important local political issue.

The Chesapeake Bay watershed is one such area where people are concerned with the water quality of its numerous tributaries and sub-watersheds; even at very local levels. A recent poll of Virginia voters conducted by the Chesapeake Bay Foundation (2004) found that two-thirds of those polled felt the Bay was in fair condition or worse and 63% said their nearest river was in a similar state with respect to water quality. This poll also found that 63% of those polled would support an annual $50 dedicated user fee on their water bills to fund programs to improve local rivers and the Bay. Similarly, in Maryland, a public opinion poll (Marx, 2004) found that there is widespread support for an annual sewer fee of about $30 (72% support) as well as support for a similar annual septic fee (68% support) where these monies are to go directly toward Chesapeake Bay restoration efforts. Public polls such as these, indicate individuals throughout the Chesapeake Bay watershed value water quality improvement of both the Bay and its tributaries.

This research uses water quality data from the St. Mary's River Watershed; a small localized watershed entirely located within a southern Maryland county which forms a peninsula surrounded by the Potomac and Patuxent Rivers, and the Chesapeake Bay. This region's history dates back to the colonial times and the impact of recent deterioration in water quality on local blue crab and oyster harvests are well publicized and important local issues. We investigate the relationship between water quality variables associated with run-off or impervious surfaces which scientists directly attribute to increase development, and residential housing prices within the St. Mary's River watershed using water quality data from monitors located throughout the watershed. We apply the hedonic property valuation model and estimate the marginal values of ambient water quality as measured by dissolved inorganic nitrogen and total suspended solids.

Hedonic property valuation studies have been used to estimate the marginal implicit prices of numerous environmental amenities including ambient air quality (Graves et al., 1988; Smith and Huang, 1993, 1995), water quality of streams (Epp and Al-Ani, 1979; Streiner and Loomis, 1995), lakes (Boyle et al., 1998, 1999; Gibbs et al., 2002; Michael et al., 1996; Hsu, 2000; Poor et al., 2001; Steinnes, 1992), and coastal/tidal waters (Parsons, 1992; Leggett and Bockstael, 2000), as well as proximity studies of environmental disamenities such as

hazardous waste sites (Lewis and Acharya, 2003; Hite et al., 2001; Ihlanfeldt and Taylor, 2001; Faber, 1998; Palmquist et al., 1997; Kiel, 1995; Kiel and McClain, 1995; Zeiss and Atwater, 1990; Michaels and Smith, 1990).

As noted above, land use development activities are associated with increased impervious surfaces, which consequently impede local water quality through increase runoff. Numerous land use studies have looked specifically at the external benefits from farmland preservation and associated open-space environmental amenities which include wildlife habitat and wetland and riparian or forest buffers which are directly associated with local water quality; as farmlands are converting for development purposes (Halstead, 1984; Bergstrom et al., 1985; Beasley et al., 1986; Ready et al., 1997; Nickerson and Lynch, 2001). These land-use spatial studies help explain the indirect impacts that various land uses can have on local water quality when open space is not preserved. However, these spatial land use studies do not directly estimate the implicit marginal values of water quality; rather they indirectly assume the potential impairment of local water quality which can result from various types of land use. Correspondingly, waterfront property studies that incorporate water quality measures have limited spatial analyses. While numerous hedonic property valuation studies exist that estimate the marginal prices of ambient or 'air-shed' quality (Smith and Huang, 1993, 1995), we find none that consider the ambient water quality within a local watershed that includes both waterfront and non-waterfront property sales. This paper presents a hedonic analysis of ambient water quality throughout a watershed that uses residential property sales throughout a watershed and considers the water quality measures of total suspended solids (TSS) and dissolved inorganic nitrogen (DIN). Through the use of local watershed environmental quality monitoring data as a direct measure of non-point source pollution, we are able to estimate the associated marginal values. In addition, by using ambient water quality data, we are able to construct a data set which is not limited to waterfront properties. Investigations which link local scientific water quality monitoring data and residential properties located with these watersheds will become increasingly important in a policy context, as more public funds are spent on water quality monitoring activities. In other words, the need to quantify the value of the benefits associated with preserving local watershed quality will become increasing apparent, in order to justify the scientific monitoring costs.

Essentially this research utilizes the hedonic property value model to investigate the marginal value that residents place on water quality within a small localized watershed through the use scientific data from twenty-two monitoring stations located throughout the watershed. Ambient water quality within this watershed is determined almost exclusively from non-point sources associated with impervious surfaces which are directly related to development or land use activities and to a lesser extent agricultural runoff. The following sections include a review of related literature; a review of the hedonic theory; a description of the data; a discussion of the econometric model; the empirical results and conclusions.

2. Related literature

There have been several hedonic property value studies that have concluded that water quality does influence waterfront-housing prices. Many of these studies find that the most significant water quality variables are those that can be perceived by the property purchaser and/or those that prohibit the use of water for recreational purposes. None of these studies consider the overall ambient water quality within a watershed including both waterfront and non-waterfront properties.

Epp and Al-Ani (1979) studied waterfront residential properties located along small rivers and streams in Pennsylvania and found that pH levels low enough to limit recreational use do affect housing prices. They found that acidity from minerals and carbon dioxide, which affects pH levels, significantly influenced housing prices. In addition to testing individual water quality measures, Epp and Al-Ani performed regressions with a dummy variable that classified streams as clean or polluted based on standards set by the United States Environmental Protection Agency.

A series of studies throughout Maine, New Hampshire and Vermont found water clarity to significantly influence lakefront-housing prices (Boyle et al., 1998; Michael et al., 1996; Gibbs et al., 2002; Hsu, 2000). The primary phenomenon affecting water clarity in the lakes studied was eutrophication. Eutrophication attributed to non-point source pollution results in increased algal growth and eventually leads to reduced water clarity and, correspondingly reduced dissolved oxygen. In the Maine lakes study, owners' perceptions of water clarity as well as Secchi disk readings were found to be significant throughout the 36 lakes examined in the study (Poor et al., 2001). A similar study done in New Hampshire found that homeowners are concerned with water quality and that a one meter decrease in visibility led to a decrease in property value by up to 6% (Gibbs et al., 2002). A third study using Vermont lakes found that homeowners are willing to pay to prevent a decrease in water clarity and willing to pay to prevent an increase in weed density (Hsu, 2000). Boyle et al. (1999) completed both stages of the hedonic model for lake regions in Maine thereby estimating an inverse demand curve for quantity of water quality associated with lakefront property owners.

Steinnes (1992) studied lakes in Northern Minnesota using continuous water clarity measures as opposed to dummy variables for clean and polluted, as was the case in the Epp and Al-Ani study. Using the value of unimproved residential lots, Steinnes found that water clarity, as measured by Secchi disk readings, was positive and significantly related to the sale price.

Leggett and Bockstael (2000) used water quality data from monitoring stations; however their data set was limited to Chesapeake Bay coastal monitors and waterfront property sales. They also included in their model as explanatory variables, distance to nearest relevant major pollution point source and nearest sewage treatment plant. They found fecal coliform counts, a non-visual measure of water quality, to have a significant, negative effect on waterfront property values.

Land use has a direct impact on local watershed ecosystem services (Schueler and Holland, 2000). When development activities remove forest and wetland buffers replacing them with impervious surfaces, the result is a deterioration of surface water quality associated with increased run-off. Many economic studies indirectly investigate this impact on aquatic eco-systems by investigating the preservation of open-spaces or non-developed (often agricultural) acreages that include critical aquatic habitats (Nickerson and Lynch, 2001). However, these land use studies omit actual measures of water quality that are more direct measures of the impact of development activities on water resources. Residential development associated with the conversion of open-spaces is a major source of increased impervious surfaces and thus the deterioration of ambient water quality from increased run-off, making the hedonic property valuation model a logical choice for analyzing water quality within a watershed. This is of particular concern in local watersheds where development pressures are of greater concern than in areas where water quality is more directly related to intensively cropped agricultural lands or feedlots.

As previously noted, we found no hedonic property valuation studies that have directly investigated ambient water quality across a watershed including non-waterfront properties. There are, however, numerous hedonic property valuation studies regarding ambient air quality within airsheds (Chattopadhyay, 1999; Palmquist and Israngkura, 1999; Zabel and Kiel, 2000). Each of these studies concluded that there is a significant relationship between the air quality measures such as total suspended particulates and sulfur dioxide, and housing prices. These air quality hedonic studies utilize air quality measures from monitoring stations located throughout the air-shed. Our investigation uses a hedonic property valuation model to estimate the marginal implicit prices of water quality from data recorded at twenty-two monitoring stations located throughout a small watershed in southern Maryland. This watershed-based approach allows our study to include approximately 1400 residential property sales, where only about 2% are actual waterfront properties.

3. Hedonic property value model

There are two stages to the hedonic property valuation model. The first stage involves estimating the hedonic price function where the price of a residential property is regressed on its characteristics to determine the value consumers place on the characteristics that comprise the differentiated good (Feenberg and Mills, 1980).[1] Thus for an environmental hedonic model the first stage of the model estimates the marginal implicit

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[1] For environmental quality studies, the typical hedonic price function includes housing (S), neighborhood (N) and environmental quality characteristics (E), denoted as HP=$f(S, N, E)$. The coefficient estimates or the partial derivative of the hedonic price function with respect to any of the characteristics Q_i, represent the implicit prices of the characteristics of the differentiated good. For the linear functional form, the marginal implicit price from characteristic 'i' is calculated as $\partial P/\partial Q_i = \beta_i$ and for the semilogarithmic functional form, the marginal implicit price from characteristic 'i' is calculated as $\partial P/\partial Q_i = \beta_i P$; where 'P' is typically equal to the average housing price of the sample used to estimate the coefficient and Q is the quantity of any specific characteristic (Taylor, 2003).
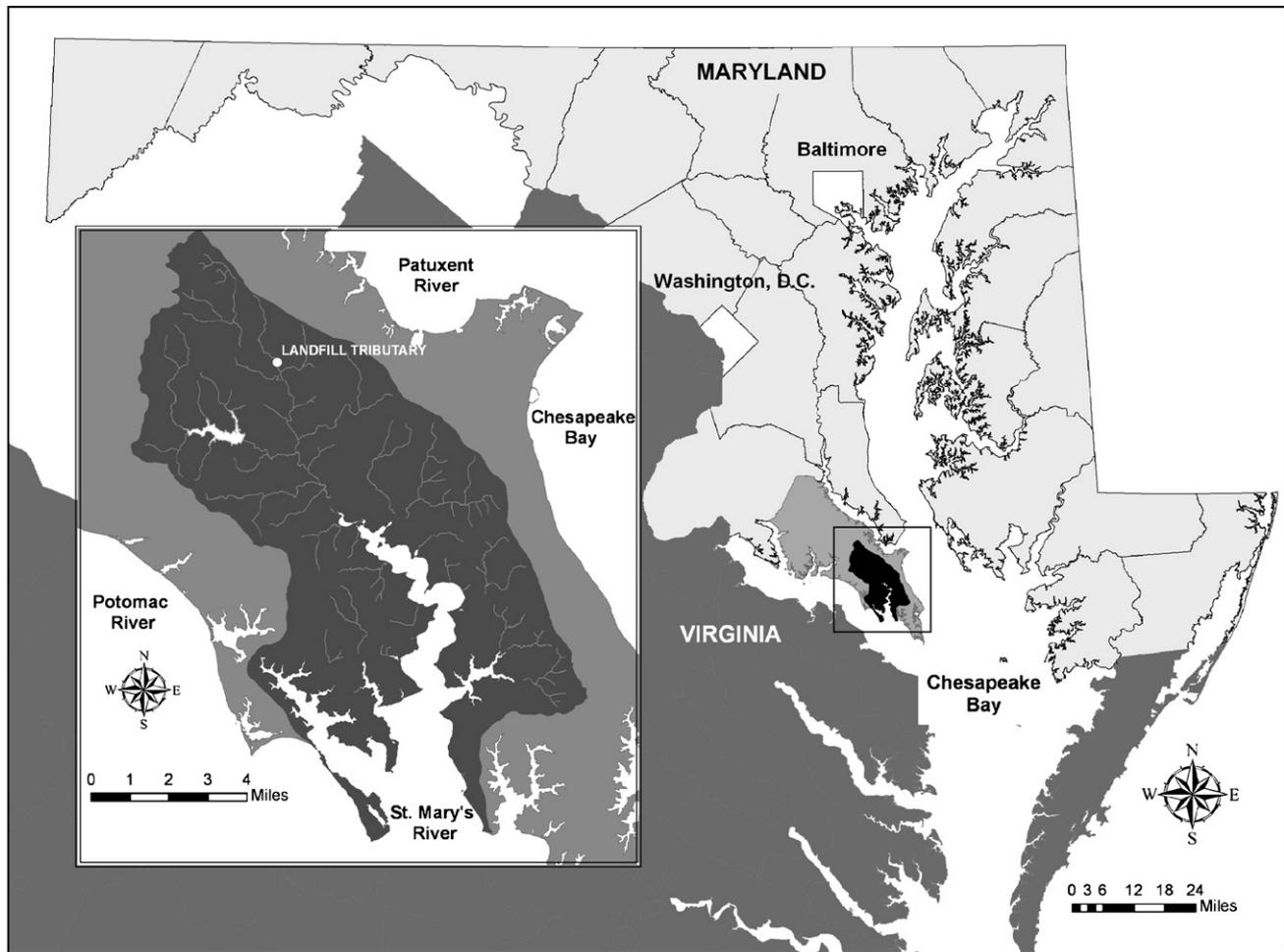
Fig. 1 – Reference map.

prices of the specific environmental characteristic, which can then be used as the price variable in the second stage to estimate the demand equation for the characteristic. See Freeman (2003) for details of the hedonic property valuation model for environmental goods. This research includes a stage one analysis whereby measures of ambient water quality along with other structural and neighborhood characteristics are used to estimate marginal implicit prices (MIPs).

Within this watershed analysis, the MIPs associated with the water quality variables are equivalent to the consumer's marginal willingness to pay for the associated marginal or per milligram per liter changes in TSS and DIN. For this localized watershed this value represents the amount a property owner would be willing to pay to avoid a one unit or milligram per liter change or decline in water quality as measured by TSS or DIN. Based on this value, total willingness to pay for a marginal change in water quality within the watershed would be equal to the sum of implicit prices across all property owners within the watershed who are impacted. For marginal changes of water quality within the watershed, a homeowner's willingness to pay would be equal to the change in the sale price of their property resulting from a change in water quality. A negative MIP would indicate a decline in property value associated with an increase in the TSS or DIN, which is

indicative of a deterioration in water quality. Therefore if local policy decisions regarding develop activities, adversely impact water quality within the watershed, the result would be a decline in welfare or net benefits associated with watershed amenities to the property owners within the watershed, as estimated by changes in total willingness to pay or property values.[2]

4.   The study area and data

The St. Mary's River watershed is located in St. Mary's County in Southern Maryland (see Fig. 1). No point sources pollute its waters and historically its only threat has been run off from local farms and occasional storm runoff. However, over the last few years with the expansion of the county's largest employer, the Patuxent River Naval Air Station, development and associated impervious surfaces and runoff have become an increasing threat to water quality. Beginning in the late 1990s, the Naval Air Station began to dramatically increase the number of people it employs (Maryland Dept. of Natural

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[2] Such estimates of willingness to pay assume no transaction costs are associated with property sales.

Resources, 2002). The rise in employment has led to the transformation of southern St. Mary's County. Residential and commercial development along with other associated infrastructure such as roadways and parking lots, have been constructed to accommodate the nine percent population increase from 1998 to 2003 (Maryland State Data Center, 2004). This development has led to an increase in the amount of impervious surfaces, which in turn, restricts the amount of rainwater percolating into the earth. Restricted absorption results in excess runoff that endangers small streams by overloading them with sediment during storm events.

The Patuxent River Naval Air Station is located in Lexington Park at the headwaters of the St. Mary's River watershed where the majority of the streams that feed the St. Mary's River are located (see Fig. 2). This combination of increased development and numerous ravines and small streams increases the potential for sediment to migrate through these streams and into the river. Biologists monitoring the St. Mary's River watershed warn of the dangers of development and have stated, "In a high discharge year, the water quality will deteriorate, degrading habitat and stressing estuarine organisms of both the watershed and estuary" (Paul and Tanner, 2002). However, the value of these negative external costs has never been quantified.

County planners are aware of the effects of development and have taken measures to reduce its impact. They have established rural preservation areas, set a minimum for tidal and non-tidal wetland buffers and confined development to the major business district along State Route 235 within the town of Lexington Park, where the Patuxent River Naval Air Station is located (Maryland Dept. of Natural Resources, 2002; Fig. 2). However, with increasing population pressures, the need for additional residential development appears inevitable.

As previously noted, the St. Mary's River watershed is located in the southern part of St. Mary's County along the western shore of the Chesapeake Bay, within a sub-watershed of the Potomac River (Fig. 1). It is the largest watershed in St. Mary's County covering approximately 47,000 acres or about 73 square miles (about 15 miles in length by 5 miles wide). The watershed encompasses approximately one hundred miles of freshwater streams and approximately eight miles of tidally influenced river. The water quality throughout the watershed varies, with greater amounts of non-point pollution entering from the northern end in proximity of the largest town, Lexington Park. The southern portion of the watershed consists of primarily rural, farmlands and forests (Fig. 1).

4.1. Housing and neighborhood characteristics

The data set for this study includes 1377 residential property sales occurring within the St. Mary's River watershed over a period of 4 years between June 1, 1999 and May 31, 2003.[3] The

variable definitions and summary data are included in Table 1. The property sale prices and characteristics were obtained from SpecPrint Inc., a real estate information collection company that compiles information for the Maryland State Department of Assessments and Taxation. Only arms-length sales of single-family residential properties were included in the data set. Thus we excluded sales that were noticeably below market value; typically listed as being sold for $1 such as sales between family members. Monthly price indices were calculated from June 1999 to May 2003 using county housing price data from Metropolitan Regional Information Systems, Inc (Real Estate Trend Indicator, 2004). Using the monthly price indices the property sale prices were converted to January 2003 constant or real dollars.

In addition to the housing sale price and characteristics, each sale property was geo-coded allowing a GIS data set to be compiled. Census Block Group median income data were included as a spatial layer.[4] The GIS software ArcView was used to calculate each property's proximity to Gate One of the Patuxent Naval Air Station and to the county landfill located within the watershed. The location of property sales within the watershed, along with the location of the county landfill and Gate One of the Naval Air Station are illustrated on Fig. 2.

4.2. Environmental data

The water quality data were acquired from twenty-two (8 tidal and 14 non-tidal) water-monitoring stations located throughout the watershed. The water quality monitoring activities are part of the St. Mary's River Project conducted by the Biology Department at St. Mary's College of Maryland. The hedonic property value model uses annual averages for dissolved inorganic nitrogen (DIN) and total suspended solids (TSS) measured at each of the monitoring stations. Using Arc View, each property was assigned to the closest monitoring station (using a straight-line distance), and linked by the sale year to the corresponding yearly average of the closest monitor's water quality data. This procedure for assigning the water quality measures to each sale property from the closest monitoring station is consistent with hedonic property valuation studies within air-sheds (Zabel and Kiel, 2000; Chattopadhyay, 1999; Palmquist and Israngkura, 1999).[5]

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[3] We estimated the hedonic price function including a set of categorical year dummy variables. The associated coefficient estimates were not significantly different from zero, so these variables were not included in the model. As such we found no indication of significant changes in real sales prices over the years included within our data set.

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[4] We initially included education and ethnic variables in our models; however concerns regarding multicolinearity arose. The distance to the Gate variable does however capture some of the quality of life characteristics associated with the amenities and disamenities provide by Lexington Park, the major town located within the study area.

[5] We also ran regressions including annual dummy variables, whose coefficient estimates were not significantly different from 0. Both of the coefficient estimates for the water quality variables (TSS and DIN) remained negative and significantly different from zero in the regressions which included the year dummy variables. A model lagging the water quality data by 1 year was also estimated, and the results were remarkably similar to those reported in this paper. We thus assume given our data set that the water quality patterns across monitoring stations and over the years included in the model are relatively stable.
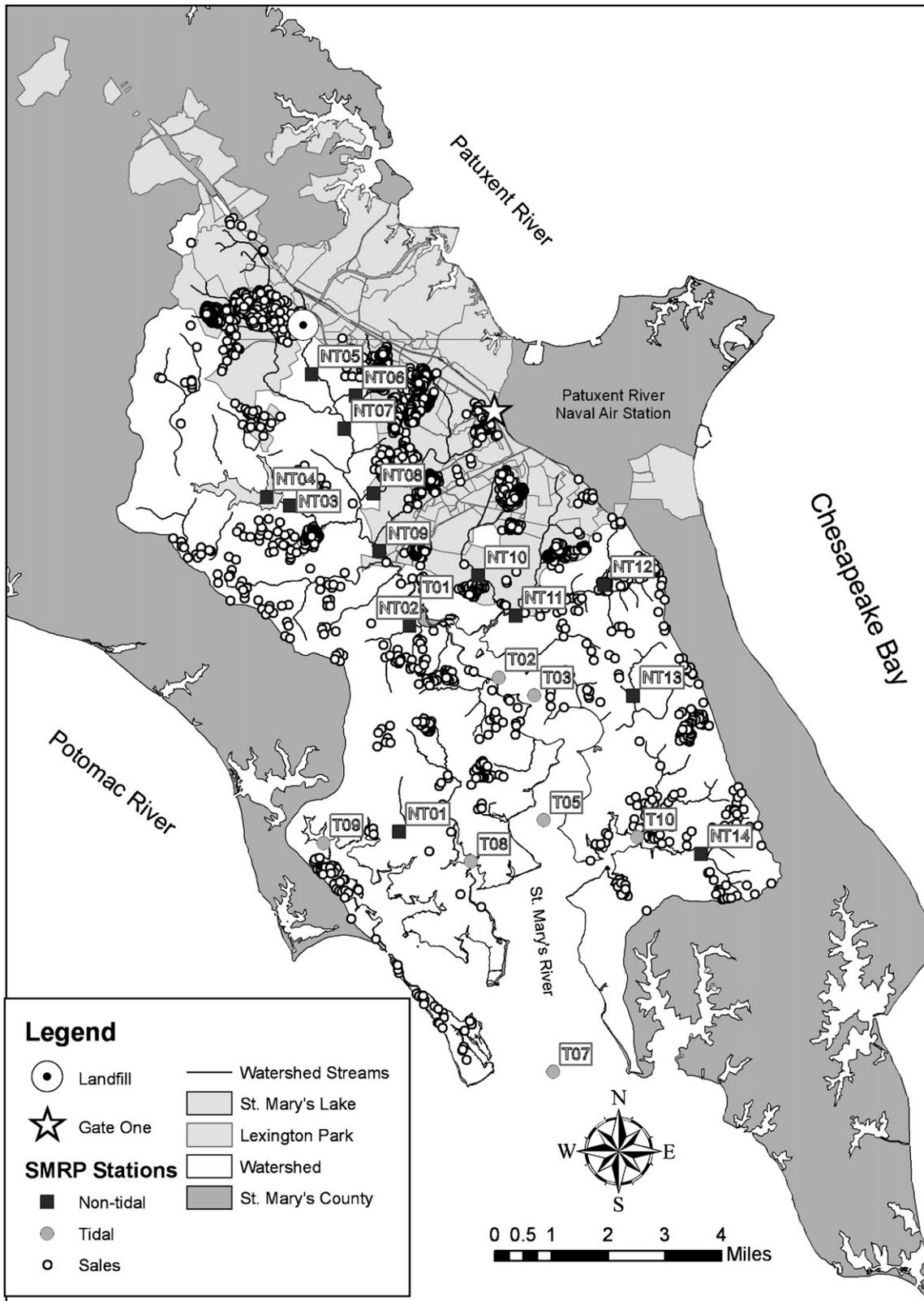
Fig. 2 – The St. Mary's River watershed: property sales and monitoring station locations.

The average TSS and DIN data across the years used in this study are reported for each of the twenty-two monitoring stations (illustrated in Fig. 2) in Table 2. Using the average TSS and DIN measures across the entire watershed, those monitoring stations where water quality is worse than these averages are also indicated in Table 2. These data indicate that there is variation throughout the watershed with respect to water quality and that there are

Table 1 – variable descriptions and expectations			
Name	Description	Mean	S.D.
LNREALPR	Log of real price (January 2003 constant dollars)	12.122	0.452
GARAGE	Garage dummy (=1 if present, else =0)	0.179	0.383
STORIES	Number of stories	1.662	0.460
FIN_BASMT	Finished basement dummy (=1 if present, else =0)	0.127	0.333
PORCH	Square footage of all porches and decks	192.38	195.70
FIREPL	Number of fireplaces	0.289	0.466
BLDAREA	Building area in ft^2	1991.33	756.90
SQ_BLDAR	Building area squared		
ACRES	Land area in acres (calculated to one hundredth of an acre)	0.989	2.498
WTRFRT	Waterfront property dummy (=1 if waterfront property)	0.023	0.148
ADJ_WTFT	Adjacent to waterfront dummy (=1 if adjacent to a waterfront property)	0.060	0.238
LN_LDFL_DIS	Natural logarithm of the distance to landfill (m)	8.569	0.785
GATE_DIS	Distance to gate one of Patuxent Naval Air Station (m)	5711.7	3404.5
MED_INC	Median income of census block group	52761	9748
DINYEAR	Dissolved inorganic nitrogen (mg/L) for all 26 water-quality monitoring stations.	0.626	0.405
TSSYEAR	Total suspended solids (mg/L) for all 26 water quality monitoring stations.	13.314	4.733

no apparent monitoring stations with a high prominence of poorer water quality.[6]

5. Econometric model

Recall the goal of this research is to utilize the hedonic property value model to estimate the implicit values of ambient water quality within a watershed. We used the semi-logarithmic functional form to estimate the hedonic price function where the natural logarithm of the real sale price for each property 'i', is the dependent variable which is regressed on a set of structural characteristics (S), neighborhood characteristics (N), and environmental water quality characteristics (E). The natural logarithm of the real property sale price or the semi-log functional form, has been found to provide a better fit for hedonic data, which was also the case for our data set (Palmquist, 1984; Taylor, 2003).[7] The regression model estimated is as follows:

$$LNREALPR_i = \alpha + \beta_{1i}S + \beta_{2i}N + \beta_{3i}E + \varepsilon_i \qquad (4)$$

where $\alpha, \beta_1, \beta_2, \beta_3$, are the coefficients to be estimated and ε_i is a random error term. Summary statistics for the explanatory variables are given in Table 1. The structural characteristics that describe the physical characteristics of the house include: a garage dummy variable (GARAGE), number of stories (STORIES), a finished basement dummy variable (FIN_BASMT), a porch/deck area variable (PORCH), number of fireplaces (FIREPL), the square footage of the building area (BLDAREA), and the squared building area (SQ_BLDAR). Explanatory variables describing the land or lot characteristics include

the property acreage (ACRES), a waterfront dummy variable (WTRFRT) which indicates whether the sale property is a waterfront lot, and a dummy variable indicating if the lot is adjacent to a water-front property (ADJ_WTFT). It is expected that the coefficient estimates for the following variables will be positively related to sales price: presence of a garage, number of stories, a finished basement, porch/deck area, number of fireplaces, and building area. We expect the square of the building area to be negative, indicating that the sales price increases with building area, at a decreasing rate.

Table 2 – Average water quality data by monitor throughout the watershed		
Monitoring station ID number[a]	Average TSS	Average DIN
NT01	14.075[b]	0.325[b]
NT02	14.1658	0.760[b]
NT03	11.652	0.151
NT04	12.294	0.100
NT05	11.272	0.956[b]
NT06	16.979[b]	0.941[b]
NT07	10.772	0.465[b]
NT08	13.141[b]	0.339[b]
NT09	11.950	0.286
NT10	8.918	0.158
NT11	8.922	0.306
NT12	14.597[b]	0.723[b]
NT13	9.788	0.175
NT14	16.106[b]	0.326[b]
T01	14.401[b]	0.270
T02	13.803[b]	0.082
T03	13.022[b]	0.103
T05	11.885	0.108
T07	13.077[b]	0.196
T08	13.589[b]	0.111
T09	14.774	0.102
T10	13.534	0.124
Watershed minimum	8.918	0.082
Watershed maximum	16.979	0.956
Watershed average	12.851	0.323

a See Fig. 2 for monitor locations throughout the watershed.
b Indicates average water quality is below the overall watershed average levels (note: higher numbers indicate lower water quality).

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[6] Annual water quality data is used because monitoring activities at each station across the watershed did not occur at each station at the same times throughout each year. As discussed by Taylor (2003), sample mean values are one method for dealing with independent variables with missing observations, as is the case in our data regarding month water quality data.

[7] A Box–Cox test was undertaken to test the hypothesis of linear versus the semi-log functional forms. The test statistic LAMBDA was equal to 0 indicating the semi-log functional form was a better fit for our data than the linear (Maddala, 1992).

Table 3 – Regression results

Variable	Total suspended solids model		Dissolved inorganic nitrogen model	
	Coefficient (S.E.) [a]	P-value	Coefficient (S.E.)	P-value
Constant	12.0715[*] (0.1735)	0.0000	11.2034[*] (0.2149)	0.0000
GARAGE	0.0598[**] (0.0311)	0.0548	0.0658[**] (0.0287)	0.0216
STORIES	0.1046[*] (0.0355)	0.0032	0.1063[*] (0.0324)	0.0010
FIN_BASMT	0.1096[*] (0.0326)	0.0008	0.1171[*] (0.0297)	0.0001
PORCH	0.0004[*] (0.00007)	0.0000	0.0004[*] (0.00006)	0.0000
FIREPL	0.0523[***] (0.0238)	0.0284	0.0472[**] (0.0217)	0.0297
BLDAREA	0.0008[*] (0.0001)	0.0000	0.0008[*] (0.0001)	0.0000
SQ_BLDAR	−0.0000001[*] (0.00000002)	0.0000	−0.0000001[*] (0.00000002)	0.0000
ACRES	0.0171[*] (0.0051)	0.0007	0.0176[*] (0.0052)	0.0008
WTRFRT	0.6453[*] (0.0947)	0.0000	0.6358[*] (0.0936)	0.0000
ADJ_WTRFRT	0.0511 (0.0336)	0.1282	0.0621[***] (0.0332)	0.0619
LN_LDFL_DIST	−0.1121[*] (0.0137)	0.0000	−0.1398[*] (0.0187)	0.0000
GATE_DIST	−0.000006 (0.000005)	0.2060	−.000003 (0.000004)	0.4374
MED_INC	−0.000003[*] (0.000001)	0.0057	−0.000003[*] (0.000001)	0.0074
TSS	−0.0053[**] (0.0024)	0.0257	−	−
DIN	−		−0.0879[*] (0.0339)	0.0096
n	1231		1376	
F-statistics	43.66	0.0000	53.23	0.0000
R^2	0.34		0.35	

a White's consistent standard errors are reported.
[*] $P < 0.001$.
[**] $P < 0.01$.
[***] $P < 0.05$.

A number of neighborhood characteristics were included in the model. They include census tract median income (MED_INC), the distance to Gate One of the Patuxent River Naval Air Station (GATE_DIS), and the natural log of the distance to the county landfill located within the northern part of the watershed (LN_LDFL_DIS). Distance to Gate One is included to control for distance to both the primary employer in the watershed and Lexington Park, the largest town within the watershed. It is expected that a closer distance would be desirable. However at the same time, proximity to the Air Station and the more commercial areas may be seen as a disamenity due to aircraft noise and increased traffic. In addition, it is expected that proximity of the residential properties to the landfill will have a negative influence on property values which would decline with distance from the landfill. We also expect median income to be positively related to housing prices.

The water quality measures included in the model are yearly averages of dissolved inorganic nitrogen (DIN) and total suspended solids (TSS). It is expected that high levels of total suspended solids and dissolved inorganic nitrogen will have a negative impact on sales prices, indicating compromised water quality associated with non-point source pollution, which is directly related to impervious surfaces associated with local land development patterns.

6.   Regression results

Given the cross sectional nature of our data set, we tested for heteroskedasticity and rejected the null hypothesis of homoskedasticity. As such we report White's consistent standard errors in our regression results (Table 3). Separate linear regression equations were estimated for each of the water

quality variables. The regression results are presented in Table 3.[8] The coefficient estimates associated with the variables used to describe property characteristics (GARAGE, STORIES, FIN_BASMT, PORCH, FIREPL, BLDAREA, ACRES, WTRFRT, and ADJ_WTFT) all had the expected positive sign. The squared building area variable coefficient estimate was negative as expected, indicating that the relationship between sales price and building area is increasing at a decreasing rate. All of these coefficient estimates for the property characteristics were significantly different from zero.

The sign on the coefficient estimates for the distance to the primary employer or Gate One of the Naval Air Station is negative and not significantly different from zero. The signs on the coefficient estimates for the distance to the county landfill variables in both equations, were opposite of our initial expectations. The county landfill, which is found in the northeastern part of the watershed, is located along the same road as one of the largest and most desirable planned communities in this part of the county. Typically, living near a landfill is deemed undesirable because of potential environmental quality issues as well as truck traffic. However, this study's regression results indicate that proximity to the

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[8] Approximately 2% of the property sales included in our analysis are waterfront properties. In an effort to confirm that these small numbers of sales were not driving the significant results with respect to the water quality variables, we estimated models including only non-waterfront property sales. The coefficient signs and levels of significance were very similar to the results when the waterfront sales were included; the coefficient estimates for the TSS and DIN variables were −0.0052 and −0.083, respectively, when the waterfront sales were excluded versus −0.0053 and −0.087 when the waterfront sales were included.

Table 4 – Marginal implicit prices				
Water quality attribute	Sample mean	Coefficient estimate	Average sample house Price	Marginal implicit price
TSSYEAR	13.310	−0.0053	$204,823	($1086)[a]
DINYEAR	0.625	−0.0878	$200,936	($17,642)
a Parentheses '()' indicate negative dollar values.				

landfill has an overall desirable effect. Median income was significant in each model; however, the negative sign of its coefficient was the opposite our expectations.

As previously noted, separate regression equations were estimated for each water quality variable. The coefficients for total suspended solids and dissolved inorganic nitrogen were of the expected negative sign and were significantly different from zero (see Table 3). Recall that levels of TSS and DIN are associated with non-point source pollution or run-off resulting in part from development activities and associated impervious surfaces. Therefore, as TSS and DIN accumulate within the watershed, water clarity will be reduced.

Marginal implicit prices are calculated using mean residential sales prices for each specific model for TSS and DIN (see Table 4). The estimated models indicate that a one unit (mg/L) increase in total suspended solids (TSS) has a negative impact on average housing prices within the watershed of $1086. Correspondingly, a one-unit change (mg/L) in the dissolved inorganic nitrogen, a water quality attribute that manifests itself as a contributor to eutrophication, also has a negative impact on average housing prices in the watershed of $17,642. It is important to note that both the TSS and DIN units of measure are milligrams per liter. The ranges for the average water quality indicators across the monitoring stations within our sample are 8.918 mg/L to 12.851 mg/L for TSS and 0.082 mg/L to 0.956 mg/L for DIN (see Table 2). As such a one unit change in DIN would be indicative of a relatively large change in this water quality measure, thus the significantly larger marginal implicit price compared to TSS is to be expected.

The welfare policy implications of these results corroborate public opinion polls within Maryland that indicate residents are concerned with local water quality within tributaries and sub-watersheds of the Chesapeake Bay, as indicated by their willingness to pay annual fees to improve water quality. Local policy decisions that adversely impact water quality within the St. Mary's River watershed may result in a decline in welfare or net benefits to the local property owners within the watershed, in terms of changes in their total willingness-to-pay or property values. Given this study's significant results, it is important that the value of the benefits of maintaining local watershed environmental services, be included in land use planning decisions within the watershed.

7. Conclusions

To our knowledge, this is the first hedonic property valuation model to estimate marginal implicit prices of ambient water quality for an entire local watershed using both waterfront and non-waterfront properties. It is important to note that the localized study area/watershed is located in a county adjacent to the Chesapeake Bay where the cultural heritage has depended on water and water quality as it relates to commercial fish harvests as well as recreation. Public opinion polls have shown that homeowners in sub-watersheds of the Chesapeake Bay are both knowledgeable about water quality issues, and willing to pay for improvements. As such, the value of water quality changes should be incorporated into local land use planning and policy issues. The ambient water quality within this watershed depends largely on non-point source pollution sources, which is turn, are dependent directly on development or land use and associated impervious surfaces. This study provides estimates of the marginal values of ecosystem indicators that can be directly linked to development activities within a small local watershed, and thus, could potentially help regional planners who are responsible for weighing the costs (including environmental costs) with the benefits of additional development that will increase impervious surfaces within a watershed thereby impacting water quality. The significant ambient water quality variables included within this study are total suspended solids and dissolved inorganic nitrogen.

We have shown that ambient water quality within a small local watershed can significantly influence residential property values regardless of whether they are waterfront properties. As residential and commercial development continues to intensify in many areas, local land use planning as it relates to the monitoring of ambient water quality should be considered and incorporated into policy decision making. With regards to the St. Mary's River Watershed, which is currently considered one of the least environmentally compromised sub-watersheds of the Chesapeake Bay watershed, this research helps to quantify potential future environmental costs associated with additional development pressures and the associated increases in impervious surfaces, leading to increases in non-point source pollution.

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