Simple is Better? Understanding the impact of Technical and Non-Technical Measures of Water Quality on Hedonic Property Values in South Florida

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Abstract:

As more and more of the population continue to move into coastal areas the health and hence value of coastal waterbody resources is continuously subjected to degradation. One way to ascertain the economic value of a healthy waterbody is through a hedonic property value analysis utilizing water quality as the amenity of interest. Increasingly, volunteer organizations are responsible for collecting and reporting to the community the water quality measures collected. The collected water quality information must be conveyed in a way that maintains the attention and interest of the community and as a result is likely significant in a home purchase decision and therefore relevant as a notion of economic value. As an outcome of our hedonic analysis we investigate whether there is an economic value trade-off in conveying technical or non-technical measures of water quality. We compare hedonic property value model results using technical measures of water quality to the results using a non-technical measure of water quality "location grade" available to homebuyers in an urban coastal housing market of South Florida. Our results indicate that water quality does in fact matter to the waterfront homebuyers, and that this holds for both technical and non-technical measures of water quality. The technical measures of water quality appear to convey sophisticated information to homebuyers in assisting their house purchase decision. The non-technical measure seems also relevant as it provides a weighted average of more technical measures. We further impute implicit prices for both the technical and non-technical measures of water quality where mean willingness-to-pay (WTP) values for significant estimates range from $7,531 to $43,158.

JEL Classifications: Q25, Q51, R21, D60
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I. Introduction

Waterbodies, such as estuaries, are valuable resources. However, as more and more of the population continue to move into coastal areas the health and hence value of these resources is continuously subjected to degradation via pollution, habitat destruction, overfishing, wetland loss, etc. (U.S. Environmental Protection Agency, 2006). Consequently, a good understanding of the economic value of these natural resources in a healthy state is critical to effective management of them such that suitable measures that reduce damage to a waterbody can be implemented at an appropriate cost. Hedonic property value models in general are used to determine whether a relationship exists between an environmental amenity and housing prices, and if so, to often impute implicit prices for the environmental amenity that can then potentially be used for an associated economic analysis. As people frequently choose to live on or near a waterbody to enjoy the amenity values provided by it, one way to ascertain the economic value of a waterbody is through a hedonic property analysis of its water quality levels. .

Various chemical, physical, and biological water quality measures are available to measure the health of a waterbody including, but not limited to, dissolved oxygen, salinity, and submerged aquatic vegetation respectively (U.S. Environmental Protection Agency, 2006). Thus, an overarching issue in ascertaining the amenity value of good water quality via a hedonic property analysis is which available water quality measure will be valid in driving actual homebuyer behavior and consequently relevant in the home purchase decision and any associated economic analysis (Epp and Al-Ani, 1979; Michael et al. 2000; Poor et al., 2001; Lewis et al. 2008; Egan et al., 2009). Water clarity as a technical measure of water quality is most often used in assessing the amenity value of good water quality for waterfront and non-waterfront homes since it is likely to be perceived by homebuyers, as well as more readily understood, compared to other technical but more relatively sophisticated measures of water quality. Steinnes (1992), Boyle et al. (1999), Michael et al. (2000), Poor et al. (2001), Gibbs et al. (2002), Krysel et al. (2003) all investigate the effect of water clarity on lakefront home prices. Walsh et al. (2010) expand the analysis to understand the effect of water clarity on both lakefront and non-lakefront homes in the urban housing market of Orange County, Florida. The drawback to using this measure is that "the benefits of improvements in water clarity have ambiguous ecological merit" (Leggett and Bockstael, pg. 122, 2000). While a number of other studies have used other technical measures of water quality in the hedonic analysis that may have more ecological merit and be more useful to waterbody managers including pH (Epp and Al-Ani, 1979), fecal coliform (Leggett and Bockstael, 2000), total suspended solids and dissolved inorganic nitrogen (Poor et al., 2007), and total suspended solids, total phosphorous, and dissolved oxygen (Phaneuf et al., 2008), variations in these measures tend to be less observable and hence of less value to homebuyers (Leggett and Bockstael, 2000; Micheal et al., 2000).

Furthermore, as government agencies have limited funding for water quality monitoring activities, the role of volunteer water quality monitoring has become increasingly more important to maintaining the health of a particular waterbody (U.S. Environmental Protection Agency, 2006). It becomes the role of these volunteer organizations to make the community aware of what has been found concerning the water quality and health of the waterbody in a way that maintains the attention and interest of the community (U.S. Environmental Protection Agency, 2006) and as a result is likely significant in a home purchase decision. Specifically, the EPA recommends amongst other items that "it is very important to convey information in a non-technical style …" (U.S. Environmental Protection Agency, 2006). The Florida Oceanographic Society is one such volunteer organization that monitors water quality in the St. Lucie, Florida estuary and associated ecosystem. They have developed a non-technical measure of water quality, location grade, which is the percentage score of 96–100%, 86-95%, 76-85%, 70-75%, and < 70% (with an associated letter grade of A, B, C, D, or F respectively) designed precisely such that it "… gives the average reader a simple way to evaluate the river water quality" (Voisinet, 2006). This measure is constructed directly from the other technical measures of water quality they collect, and all are reported together and easily accessible via the local newspapers and internet.

Using weekly water quality data collected by the Florida Oceanographic Society, the purpose of this study is to compare hedonic property value model results using the technical measures of water quality to the results using the non-technical measure of water quality location grade in order to investigate whether there is an economic value trade-off in conveying technical or non-technical measures of water quality. We conduct our hedonic analysis on the urban coastal housing market of Martin County, FL which is predicated upon the waterbodies of the St. Lucie River, St. Lucie Estuary, and Indian River Lagoon. Similar to Poor et al. (2007) we assume that water quality matters to homebuyers in this area given that the health of these waterbodies are an integral part of the local history as well as the environmental and economic well-being of the community (SFWMDa, 2010; FLDEP, 2010; SFWMDb, 2010). Citing the well-being of the St. Lucie River and Estuary to the Florida economy and quality of life, Governor Crist recently pledged continued funding (FLDEP, 2010) of the $1 billion Indian River Lagoon South (IRLS) Everglades restoration effort that is currently being conducted to improve water quality in this area. In fact the IRLS restoration effort is only one of three major efforts currently underway to improve the water quality of the river, estuary, and lagoon (SFWMDb, 2010). Moreover, Martin County residents are "outraged over the systematic destruction of the

St. Lucie River and Estuary" (CFPBMC, 2010) and a 2006 poll conducted for the Community Foundations for Palm Beach and Martin Counties (Princeton Survey Research Associates International, 2006) found that eight out of ten Martin County residents indicate protecting the natural environment as the number one priority of Martin County.

As expected, our results indicate that water quality does in fact matter to Martin County waterfront homebuyers, and that this holds for both technical and non-technical measures of water quality. However, there is some distinction in how the technical and non-technical measures are used in the home purchase decision. As the non-technical measure ostensibly provides homebuyers a simple way to evaluate water quality in their home purchase decision, our results indicate that they likely use it as a warning sign in their house purchase decision when the location grade is within a failing range. In contrast, the technical measures of water quality seem to provide relevant information to homebuyers in assisting their house purchase decision. Higher values of all of the technical measures, excluding dissolved oxygen, increase property values significantly although the effect diminishes as the level of these measures increases. These results indicate that waterfront homebuyers in this market appear to be relatively sophisticated in terms of their understanding and use of the varying technical water quality measures. We hypothesize that the construction of the non-technical grade water quality score may also potentially assist in forming this level of sophistication – i.e., knowledge is gained of the individual parameters in trying to effectively understand the overall score. We further impute implicit prices for both the technical and non-technical measures of water quality where mean willingness-to-pay (WTP) values for significant estimates range from $7,531 to $43,158. These WTP results are potentially notable given the $1 billion Indian River Lagoon South (IRLS)

Everglades restoration effort being conducted to improve water quality in this area, and the lack of any formal economic benefit analysis conducted to-date (USACE/SFWMD, 2002).

This paper is organized as follows: Section II provides an overview of the study area and associated data used; Section III presents the empirical model; Section IV gives the results; and Section V has the concluding comments.

II. Study Area and Data

Martin County is located on the Southeastern Atlantic coast of Florida. The Northeastern portion of the county and its accompanying waterfront housing market located on the St. Lucie River, St. Lucie Estuary, and Indian River Lagoon, are analyzed for this study. Analogous to Leggett and Bockstael (2000), this area is well-suited for a hedonic analysis of water quality due to the substantial and sufficiently varied number of waterfront properties, the lively housing market in the area, as well as the variation in water quality across the St. Lucie River, St. Lucie Estuary, and the Indian River Lagoon.

The specific home sale data used for the analysis are sales of waterfront properties located in the Northeastern portion of Martin County from January 2000 to August 2004 as supplied by the Martin County property appraiser's office. The sales price is adjusted to 2nd quarter 2004 values[1] using the Office of Federal Housing Enterprise Oversight (OFHEO, 2004) housing index for the Fort Pierce-Port St. Lucie Metropolitan Statistical Area.[2] Table 1 provides the summary statistics for housing sales price in 2004 Q2 values as well as for each of the variables included in the empirical analysis. A total of 991waterfront property sales were

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[1] Despite having July and August 2004 sales data, a 2nd-quarter index is chosen (the last complete quarter of home sales) such that April through August 2004 home sale prices were not adjusted.

[2] It should be noted that this index did experience a significant overall increase of 56% between 3rd quarter 2001 and 2nd quarter 2004 as compared to a 15% increase from 4th quarter 1998 to 3rd quarter 2001, a prior but similar length of time. These results do raise some concerns in regard to the equilibrium assumptions of the hedonic model.

collected over this timeframe. After deleting the observations with incomplete information, a total of 510 single family residential home sales are included in our data. All the relevant data are stored in a geographical information system (GIS) for our spatial analysis.

Water quality data for the Martin County waterfront area is tracked on a weekly basis by the Florida Oceanographic Society (FOS, 2004) for nine separate locations as depicted in the upper-right hand corner of Figure 1. Beside the public availability of data on the FOS website, this data is also published weekly in the local newspapers and therefore it is reasonable to consider it a known, important, and readily available source of water quality data. The specific water quality locations tracked and used for this study include 2. North Fork, 3. South Fork, 5. Wide Middle River, 6. Narrow Middle River, 7. Manatee Pocket, and 8. Inlet Area.[3]

Direct effects on a water body due to poor WQ levels are decreased light availability, algal dominance changes, and increased organic matter decomposition. These direct effects can in turn lead to other significant indirect effects such as loss of submerged aquatic vegetation, harmful algae blooms, and low dissolved oxygen levels (Bricker et al., 1999). The direct and indirect effects due to poor WQ can then result in significant adverse impacts to a water body such as loss of habitat, increase of algal toxins, fish kills, and offensive odors which would subsequently impair use and aesthetic values (Bricker et al., 1999)[4]. For example, fish kills would curtail use of the water body for any commercial or recreational fishing, while offensive odors would most likely lower any aesthetic values or tourist related activities. Figure 1 additionally presents an example of the weekly WQ data available by location. A total of five distinct technical water quality variables are collected and published weekly – temperature, pH,

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[3] Location 1. Winding North Fork is a part of St. Lucie County for which home sales were not collected. No home sales from the original data were provided for location 4. Winding South Fork, and location 9. IRL had significant water quality issues consistently throughout the study time period

water visibility, salinity, and dissolved oxygen (DO); as well as one non-technical compiled measure of water quality – location grade. The Florida Oceanographic Society website (FOS, 2004) provides an overview of each of these measures:

> *Temperature* – "dramatically affects the rates of chemical and biological reactions" including "the solubility of chemical compounds in water, distribution and abundance of organisms, rate of growth of biological organisms, water density, mixing of different water densities, and current movements". Inversely related to dissolved oxygen, and interrelated to salinity. Undergoes wide seasonal variations.
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> *pH* – measure of the acidity or excess alkali of a water body where on a scale of 1 to 14, 7 is neutral, < 7 is acidic, and > 7 has excess alkali. "Affects the solubility of minerals in water. The buffering capacity of water, its ability to resist changes in pH, is critical to aquatic life", where aquatic organism survival greatly decreasing with pH < 5 or pH > 9. Most of the extreme situations will be found in low salinity situations.
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> *Water Visibility (Water Clarity)* – "material that becomes mixed or suspended in water will cause the water to become more turbid and reduce the clarity of the water. As the water clarity decreases, light will not be able to penetrate as far below the water's surface. If light levels become too low, photosynthesis of plants below the water may stop, and the plants will die. These plants produce oxygen and habitat for aquatic life." Secchi disks are typically used to measure visibility levels.
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> *Salinity* – "the concentration of dissolved salt in water normally expressed in parts per thousand. While in any given location salinity levels will vary, extreme salinity changes can affect the well-being and distribution of biological populations". Undergoes wide seasonal variations.
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> *Dissolved Oxygen (DO)* – "one of the most important indicators of water quality, as it is essential for the survival of fish and other aquatic life. When levels are too low, aquatic life cannot survive. The colder the water is, the more oxygen it can hold and vice versa. Also, as water becomes more fresh (lower salinity), more oxygen can dissolve into the water. Fish kills occur with DO < 3 mg/L." Exhibits high seasonal as well as daily variations stemming from its inverse relationship to temperature.

All of the distinct technical water quality measures, excluding temperature, are briefly explained in the weekly published data with water visibility and dissolved oxygen given corresponding labels of poor, fair, and good over specified ranges of values; and pH and salinity given corresponding labels of poor (above or below range) or good over specified ranges of values. These labels of poor (above or below range), fair, and good for each of the four measures excluding temperature are then used to calculate an equally weighted location grade percentage value.[5] For example, from Figure 2 WQ area 2. North Fork had pH value of 8.0 = "good", a water visibility value of 36.4% = "fair", a salinity value of 7.4 ppt = "good", and a DO value of 7.9 mg/L = "good". Good, fair, and poor/above or below range values are equal to 100%, 52%, and 0% respectively. Therefore the location grade percentage value for North Fork during this week is determined by the equally weighted average of (100%+52%+100%+100%)/4 = 88%, or a B corresponding letter grade (Voisinet, 2006). In this way, location grade captures the variations in the otherwise less observable yet more ecologically meaningful technical measures of WQ such as DO, salinity, and packages them in less technical, more familiar, and hence more understandable format for residents and homebuyers to use. Consequently, we collect and use the location grade percentage value, in addition to the traditional technical measures of water visibility, pH, salinity, and dissolved oxygen in our hedonic analysis.[6]

Each home sale is assigned to a water quality location by viewing the actual location of the home through the use of both the constructed GIS database and Martin County property appraiser website (MCPA, 2004) overlaid upon the given water quality location map.[7] The associated WQ data for each location is then assigned to each home by the date of the sale. Following the literature, we use the median annual value during the year of the sale for our WQ measures in the empirical analysis. There are 16 homes located directly in the middle of the North and South Forks that are assigned to a created location of 2.5 with associated WQ data

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[5] Temperature is dropped from our analysis because it is highly correlated with dissolved oxygen and it is not included in calculating the location grade measure.

[6] As can be seen in Figure 2, not all locations report WQ data every week. Significant gaps occurred with 6. Narrow Middle River, 7. Manatee Pocket, and 8. Inlet Area in 2004, as well as 8. Inlet Area for 2000, 2001, and 2003. Consequently, corresponding location waterfront home sales during these time periods were excluded from the analysis.

[7] Our visual approach minimizes potential errors from using the Euclidean distance. For example, some houses located on St. Lucie Estuary could be closer to a monitoring site on Indian River Lagoon. It represents a unique feature of the landscape in the study area.

taken to be the average of the two North and South Forks locations. Figure 2 presents the home sales as per their assigned WQ locations from our GIS database. Sufficient variation exists in the WQ data used across locations. For example, Figure 3 illustrates the variation in the median annual values of water visibility by location over time associated with the 510 sales used in our analysis, with similar variation existing for the other five WQ measures. Although one may suspect that water quality would be poorer in the river areas as one moves further from the coast, we see from Figure 3 that area 3. South Fork has the best water visibility during 2000 and 2001.

We also include land square footage, home square footage, and the number of bathrooms in the estimated hedonic price functions. These three structural variables are all squared to allow for non-linearity in them. Being that these are waterfront homes, a series of dummy variables are also included to indicate whether the house has a pool, boat lift, dock, etc[8]. Other dummy variables indicate whether the house has more than one structure[9] and notably the type of exterior wall (1=concrete block) due to the frequency of hurricanes in Florida. Three neighborhood variables are selected in order to capture ethnicity (percent white), age (percent older than 65), and socio-economic demographics (percent of household owners). This neighborhood information is obtained from the 2000 census data (FGDL, 2004), and using the constructed GIS database, each home is spatially joined to its corresponding census tract level. Lastly, we also include the mortgage interest rate[10] which is commonly thought to be one of the main drivers of housing sales and prices. Despite the significance of interest rates in purchasing a home, this is typically not included in the environmental hedonic models reviewed in the literature.

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[8] These data were listed under improvements on the property appraiser website and no date for the improvement was given. Therefore, it was assumed that if an improvement was listed it was there as the time of sale.

[9] If the home did have more than one structure, the square footage and number of baths were summed and the other dummy variables were taken from the largest structure listed.

[10] Monthly national interest rate for a 30 year fixed rate mortgage as provided by HSH Associates (HSH, 2004)

III. Model Estimation

Hedonic price models are based on the intuitive notion that the component values of various attributes of heterogeneous goods are reflected in price differentials (Rosen 1974). Hedonic property price models use observations on property values, typically residential properties, to infer values for non-traded attributes such as environmental quality. We assume that the housing supply is fixed and the prices of existing houses are demand determined.[11] The equilibrium hedonic price function is represented by:

$$P = P(s, n, w), \qquad [1]$$

where P is the property price, which is a function of structural characteristics, s, neighborhood characteristics, n, and water quality, w. The hedonic price function emerges from competitive bidding among housing buyers when housing supply is taken as given. The housing market is in equilibrium when buyers have maximized their utility, $u = U(s, n, w, y, \boldsymbol{\alpha})$, subject to a budget constraint, $m = P(s, n, w) + y$, where U is a strictly concave utility function with the usual properties, y is the non-housing numeraire good, m is consumer income, and $\boldsymbol{\alpha}$ is the vector of variables representing demographic factors, knowledge of water quality, and water quality management expectations. Assuming that $P(\bullet)$ is continuously differentiable, the first derivative of [1] with respect to any continuous attributes produces an estimate of the representative households' marginal willingness to pay for an additional unit of that attribute:

$$\frac{\partial U(s, n, w, y, \boldsymbol{\alpha})}{\partial z} = \mu \frac{\partial P(s, n, w)}{\partial z}, z = s, n, w \qquad [2]$$

where μ is the marginal utility of income.

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[11] The fixed housing supply is a common assumption in the short-run or for situations where the stocks of existing houses dominate the market (Palmquist 2004).

Considerable attention has been given to examining spatial dependence in estimated hedonic price functions (Kim, Phipps, and Anselin 2003; Bin et al. 2008; Carruthers and Clark 2010). Spatial dependence arises because houses in a neighborhood share similar location amenities or because they have similar structural characteristics due to similar timing of construction (Anselin and Bera 1998). The existence of spatial dependence implies that a sample contains less information than an uncorrelated one, and that the loss of information should be acknowledged in estimation to properly carry out statistical inference. Regression diagnostics based on Ordinary Least Squares (OLS) estimation and the Lagrange Multiplier (LM) test statistics suggest the first-order spatial error hedonic model which is given in equation [3].[12]

$$\begin{aligned} ln\, P &= \alpha + \sum_i \beta_i s_i + \sum_j \gamma_j n_j + \sum_k \phi_k w_k + \varepsilon \\ \varepsilon &= \lambda \Pi \varepsilon + u, \end{aligned} \qquad [3]$$

where $ln\ P$ is the log of sales price, α, β, γ, and ϕ are the unknown parameters to be estimated, ε is an independent random error term, λ is the spatial autoregressive coefficient, Π is the spatial weighting matrix, and u is a vector of independent and identically distributed random error terms. This model assumes that one or more omitted variables in the hedonic equation vary spatially, and thus the error terms are spatially autocorrelated. In this specification, the OLS estimator remains unbiased but is no longer efficient due to the nonspherical error covariance. Efficient estimators are obtained by utilizing the particular structure of the error covariance implied by the spatial process. The spatial autoregressive error models are estimated via

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[12] Alternative models to incorporate the spatial dependence include a spatially lagged dependent variable model, which assumes that the spatially weighted sum of neighborhood housing prices enters as an explanatory variable in the hedonic price function. Failing to account for spatial lag dependence leads to biased and inconsistent parameter estimates, whereas failing to account for spatial error dependence leads to inefficiency. The robust Lagrange Multiplier (LM) tests for Table 2 showed no spatial lag dependence ($\chi^2 = 0.002$; p-value = 0.967) but indicated spatial error dependence ($\chi^2 = 3.190$; p-value = 0.074). For all columns in Table 3, the robust LM test also suggested the spatial error models. Neither the spatial lag nor the general model with both spatial lag and error terms were significant in any models considered.

maximum likelihood (ML). The estimation is implemented within the GeoDa v.0.9.5-i (2004) environment in conjunction with ArcView GIS 3.3 extensions.

The elements of the weighting matrix are binary indicators that identify observations within a neighborhood: $\pi_{ij} = 1$ when observations i and j are neighbors and $\pi_{ij} = 0$ otherwise. By convention, the diagonal elements of the weighting matrix are set to zero and row elements are standardized such that they sum to one, facilitating the interpretation of results derived from the weighting matrix as an average of neighborhood values. The neighborhood is usually determined by distance contiguity—the binary indicator is set to '1' if two corresponding houses are within some specified distance of one another. Using methods suggested Anselin and Bera (1998), we experimented with different weights matrices, and in this analysis use a spatial weighting matrix that identifies properties within a 0.1 mile as nonzero elements. This spatial weighting matrix was based on a comparison of the fits for several alternative specifications using a range of distances. The distance cut-off of 0.1 mile resulted in overall the best fit and the regression results reported hereafter are based on this weighting matrix.

IV. Results

Recall that in estimating the first-order spatial error hedonic model of [3], the log of sales price is used as the dependent variable across all of our models. Table 2 provides the ML estimation results of the spatial autoregressive hedonic model for the nontechnical WQ measure using location grade percentage value. We experimented with several alternative specifications and found that the primary results were robust to alternative functional forms. Estimation results exhibit a significant spatial autoregressive coefficient ($\lambda = 0.139$), suggesting that a spatial dependence in our primary sample of housing prices indeed exists. Intuition would suggest that homebuyers interpret any “poor” water quality designation – or location grade percentage value at or below 75% corresponding to a D or F letter grade – as a warning sign in their house purchase decision, but could be less sensitive to the differences between higher percentage grades. This intuition seems to be especially plausible given the varied amount of weighted technical information contained in the score, as well as the relatively tight grading scale employed where only 25 percentage points separate an A from an F.[13] Consequently, we use a quadratic specification for location grade in addition to the other continuous variables such as lot size, total structure square footage, and number of bathrooms in order to capture any non-linear effects. Regression coefficients for the location grade variables have expected signs and are statistically significant. These results indicate that water quality does in fact matter to coastal waterfront homebuyers in Martin County, FL, and that the non-technical version of location grade ostensibly provides homebuyers a simple way to evaluate water quality in their home purchase decision. Moreover, the quadratic specification seems to capture the diminishing marginal effects of the location grade variable where our results indicate that higher location grade percentage values increase property values significantly, but at a decreasing rate.[14]

It is interesting to examine which part of the water quality matters to homebuyers the most. Table 3 provides the ML estimation results of the spatial autoregressive hedonic model including four technical WQ measures - water visibility, pH, salinity, and dissolved oxygen. Again, we experimented with several alternative specifications and found that the primary results were robust to alternative functional forms. The estimation results exhibit significant spatial autoregressive coefficient ($\lambda = 0.173$), suggesting that a spatial dependence in our primary

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[13] Starting in 2006, a new grading methodology was employed including a wider percentage grading scale (Voisinet, 2006)

[14] In runs of our model using only a linear specification of location grade, this non-technical measure of water quality was not statistically significant.

sample of housing prices indeed exists. Regression coefficients for the WQ variables have expected signs and are statistically significant for all coefficients except dissolved oxygen, indicating once more that water quality does in fact matter to coastal waterfront homebuyers in Martin County, FL. Moreover, these results indicate that waterfront homebuyers in this market appear to be relatively sophisticated in term of their understanding and use of the varying technical water quality measures. Outside of the fact that the waterbodies are an integral part of the local history as well as the environmental and economic well-being of the community, we hypothesize that the construction of the non-technical grade water quality score may also potentially assist in forming this level of sophistication.

As seen in the literature, water clarity/visibility is one of the most used technical measures of water quality in a hedonic analysis due to its likely perception and ease of understanding by homebuyers. Further, Voisinet (2006) suggests that water visibility and salinity are the two key water quality measures in indicating the health of the waterbodies in the study area. Thus, we are particularly interested in the water visibility and salinity results. Both higher water visibility and salinity have a positive association with the house sales price and their coefficients are significant. The pH scale may go from 1 to 14, but the pH of natural water ranges between 6.5 and 8.5, where all our observations locate. The pH value in a productive water body will range between 7.5 and 8.5 and in less productive waters between 6.5 and 7.5. Our results indicate that the higher pH is associated with higher water front property values, indicating that the abundant aquatic life may be valued by home buyers. Dissolved oxygen normally exhibits a high seasonal variation. However, it is relatively steady in our study area and within a tolerance range for most fish and aquatic life. Dissolved oxygen concentration is insignificant at any conventional level. Adding credence to this insignificant dissolved oxygen result, Voisinet (2006) found that dissolved oxygen rarely falls into the range of values deemed poor, and if this did occur it was a relatively short-lived phenomenon.

The individual parameter estimates from Table 3 should reflect component values of the water quality to potential homebuyers in the urban coastal housing market. We impute implicit prices for both the technical and non-technical measures of water quality, with Table 4 reporting the estimated marginal willingness to pay (WTP) for the various WQ measures. A bootstrapping procedure is used to generate confidence intervals for the marginal willingness to pay (Krinsky and Robb 1986). The procedure generates 5,000 random variables from the distribution of the estimated parameters and computes 5,000 marginal WTP estimates. The marginal WTP estimates are sorted in ascending order, and the 90% confidence bounds are found by dropping the top and bottom 5% of the estimates. We find that mean WTP to increase location grade by one point is \$43,158, evaluated at the mean value of sales price of \$937,295 and the mean value of location grade. Lower and upper 90% confidence interval estimates are \$474 and \$84,400, respectively. Given the marginal significance of the non-technical measure, one potential interpretation is that the link between water quality and property values is weaker with the non-technical measure because it averages in aspects of water quality that homeowners may not care about such as dissolved oxygen. Increasing water visibility by one percent, evaluated at the mean value, results in \$36,070 increase in average property value, *ceteris paribus*. The 90% lower bound and upper bounds for WTP for visibility are \$13,552 and \$58,749, respectively. Given a small range of pH values, the marginal change is defined as a one-tenth increase. The mean WTP to increase pH level by a one-tenth point is \$7,531. Also, the mean WTP for salinity is \$31,938 with a lower bound of \$1,647 and upper bound of \$61,486.

While we are primarily interested in the results of our water quality variables, we briefly discuss results from the structural and neighborhood variables used. Lot size, total structure square footage, the dummy variables for a pool/patio enclosure and an in-ground pool, and interest rate are consistently significant at the 1% level with the expected signs. Given the prominence of hurricane threats in this area, the non-significance of our concrete block exterior wall dummy variable is surprising. The fact that most our neighborhood variables are insignificant is also unexpected, although the percentage of the population older than 65 is significant at the 1% level. Lastly, the insignificance of the water features of these waterfront homes such as a boat lift or dock is notable. As the semi-log functional form is used for estimation, the estimated coefficient is interpreted as the percentage change in the mean sales price for an additional unit of the variable. For example, the existence of in-ground pool increases a home's value in our study area by approximately 10-15% per structure while a pool/patio enclosure lowers property values.

V. Conclusions

This study utilizes a unique WQ dataset for an urban coastal housing market in Martin County, Florida to find that various WQ measures affect waterfront housing prices in this setting. Using weekly water quality data collected by the Florida Oceanographic Society, we compare hedonic property value model results using technical measures of water visibility (water clarity), pH, salinity, and dissolved oxygen with the results using a less technical measure of water quality, location grade. Our results indicate that water quality does in fact matter to the waterfront homebuyers in South Florida, and that this holds for both technical and non-technical measures of water quality. We impute implicit prices for both the technical and non-technical measures of water quality where mean willingness-to-pay (WTP) values for significant water quality measures range from $7,531 to $43,158. These WTP results are potentially notable given the $1 billion Indian River Lagoon South (IRLS) Everglades restoration effort being conducted to improve water quality in this area, and the lack of any formal economic benefit analysis conducted to-date (USACE/SFWMD, 2002).

There is some distinction in how the technical and non-technical measures are used in the home purchase decision. The use of nontechnical measure seems appropriate as it provides a weighted average of more technical measures. It is an advantage of using a more easily understood measure of water quality over a traditional technical measure of water quality that may not be as easily understood by homebuyers. In contrast, waterfront homebuyers in this market appear to be relatively sophisticated in term of their understanding and use of the varying technical water quality measures. Higher values of all of the technical measures of water quality, excluding dissolved oxygen, increase property values significantly. Our results continue to advance the current notion in the WQ hedonic literature that more efforts need to be aimed at understanding what particular WQ variable to be included in the analysis.

A number of caveats, however, are in order. First, we do not explicitly control for coastal amenities in this market that are possibly correlated with the water quality measures. Earlier studies have documented that distance to ocean, ocean viewshed, and beach access are among important amenities that are highly valued in coastal housing markets (Bin et al, 2008; Hazen and Sawyer, 2008. Although our data include only waterfront properties that might have similar coastal amenities, we have no information about detailed information about individual homes. Second, it is important to note that our estimates provide only a limited measure of total economic benefits of water quality improvement as perceived by waterfront property owners.

Improved water quality would generate many ecological, environmental, and recreational benefits. There could be price effects on second or third row properties as well. The value of these services is likely not to be fully reflected in waterfront property value. In such case, water quality improvement will likely have to be made on grounds other than appeals to increased property value. Evidence that water quality improvement is associated with higher property values, however, may help resource managers and policy makers make informed policy decisions.

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Table 1. Summary Statistics for the Hedonic Data

Variable	Mean	Std Dev	Minimum	Maximum
House sales price in 2004 Q2 values	937,294.72	851,731.89	89,907.39	7,224,467.27
Sold in 2001 (=1)	0.21	0.40	0.00	1.00
Sold in 2002 (=1)	0.22	0.41	0.00	1.00
Sold in 2003 (=1)	0.21	0.41	0.00	1.00
Sold in 2004 (=1)	0.13	0.33	0.00	1.00
Lot square footage (in thousands)	26.22	45.22	2.60	883.69
Total housing square footage (in thousands)	2.69	1.50	0.56	13.39
Number of bathrooms	2.75	1.18	1.00	10.00
Concrete block exterior walls (=1)	0.53	0.50	0.00	1.00
Fireplace (=1)	0.37	0.48	0.00	1.00
Pool/patio enclosure (=1)	0.24	0.42	0.00	1.00
In-ground pool (=1)	0.54	0.50	0.00	1.00
Boat lift (=1)	0.33	0.47	0.00	1.00
Waterfront dock (=1)	0.77	0.42	0.00	1.00
Home special feature (=1)	0.29	0.45	0.00	1.00
Percent of population that is white*	94.98	7.29	41.72	99.08
Percent of population that is age 65 or over*	32.76	7.99	14.81	51.30
Percent of households that are owner occupied*	80.67	8.91	36.59	92.57
National 30 year fixed interest rate	6.93	0.88	5.43	8.71
Location grade (%)	80.82	7.81	63.00	88.00
Water visibility (%)	49.10	13.84	31.20	77.80
pH	8.01	0.12	7.80	8.20
Salinity (ppt)	15.75	7.41	1.00	30.40
Dissolved oxygen (mg/L)	6.42	0.49	5.70	7.70

Notes: The number of observations is 510. Asterisk (*) denotes the 2000 census track level data. The national 30 year fixed interest rate is measured at the month and year of sale.

Table 2. ML Estimation Results for the Spatial Hedonic Model – Nontechnical WQ Measure

Variable	Coefficient	Std. Error	p-value
Constant	10.108^{a}	2.442	0.0000
Sold in 2001 (=1)	-0.168^{c}	0.098	0.0854
Sold in 2002 (=1)	0.011	0.121	0.9291
Sold in 2003 (=1)	-0.207	0.166	0.2140
Sold in 2004 (=1)	-0.117	0.160	0.4657
Lot square footage	0.005^{a}	0.001	0.0000
Lot square footage squared	-5.61e-06^{a}	1.43e-06	0.0001
Total housing square footage	0.486^{a}	0.048	0.0000
Total housing square footage squared	-0.027^{a}	0.005	0.0000
Number of bathrooms	0.099	0.071	0.1617
Number of bathrooms squared	-0.008	0.009	0.3674
Concrete block exterior walls (=1)	-0.001	0.040	0.9715
Fireplace (=1)	-0.005	0.045	0.9042
Pool/patio enclosure (=1)	-0.176^{a}	0.053	0.0009
In-ground pool (=1)	0.122^{a}	0.046	0.0079
Boat lift (=1)	0.039	0.042	0.3547
Waterfront dock (=1)	0.055	0.048	0.2494
Home special feature (=1)	0.024	0.044	0.5947
Percent of population that is white	-0.001	0.004	0.7631
Percent of population that is age 65 or over	-0.003	0.003	0.3295
Percent of households that are owner occupied	0.002	0.003	0.5822
National 30 year fixed interest rate	-0.231^{a}	0.067	0.0006
Location grade	0.103^{c}	0.062	0.0951
Location grade squared	-0.001^{c}	4.01e-04	0.0777
LAMBDA	0.139^{b}	0.054	0.0106
Log likelihood	-288.792		
Akaike info criterion	625.584		
Schwarz criterion	727.209		

Notes: Dependent variable is natural log of sales price. Superscripts a, b, and c denote significance at the 0.01, 0.05, and 0.10 levels, respectively.

Table 3. ML Estimation Results for the Spatial Hedonic Model – Technical WQ Measures

Variable	Coefficient	Std. Error	p-value
Constant	-627.127^a	206.456	0.0024
Sold in 2001 (=1)	0.029	0.112	0.7937
Sold in 2002 (=1)	-0.038	0.126	0.7628
Sold in 2003 (=1)	0.364^c	0.205	0.0761
Sold in 2004 (=1)	0.082	0.165	0.6211
Lot square footage	0.003^b	0.001	0.0108
Lot square footage squared	-3.19e-06^b	1.39e-06	0.0219
Total housing square footage	0.404^a	0.046	0.0000
Total housing square footage squared	-0.021^a	0.004	0.0000
Number of bathrooms	0.114^c	0.067	0.0881
Number of bathrooms squared	-0.010	0.008	0.2492
Concrete block exterior walls (=1)	0.016	0.038	0.6740
Fireplace (=1)	-0.003	0.042	0.9360
Pool/patio enclosure (=1)	-0.135^a	0.050	0.0077
In-ground pool (=1)	0.139^a	0.043	0.0014
Boat lift (=1)	0.046	0.040	0.2501
Waterfront dock (=1)	0.050	0.045	0.2718
Home special feature (=1)	0.003	0.042	0.9496
Percent of population that is white	0.004	0.004	0.2982
Percent of population that is age 65 or over	-0.008^a	0.003	0.0056
Percent of households that are owner occupied	0.005	0.003	0.1310
National 30 year fixed interest rate	-0.239^a	0.064	0.0002
Water visibility	0.067^a	0.025	0.0076
Water visibility squared	-0.001^b	2.27e-04	0.0115
pH	0.016^a	0.005	0.0018
pH squared	-0.001^a	3.26E-04	0.0019
Salinity	0.029^c	0.016	0.0817
Salinity squared	3.42e-04	4.21e-04	0.4166
Dissolved oxygen	-0.015	0.011	0.1528
Dissolved oxygen squared	0.001	0.001	0.1761
LAMBDA	0.173^a	0.054	0.0012
Log likelihood	-260.573		
Akaike info criterion	581.146		
Schwarz criterion	708.179		

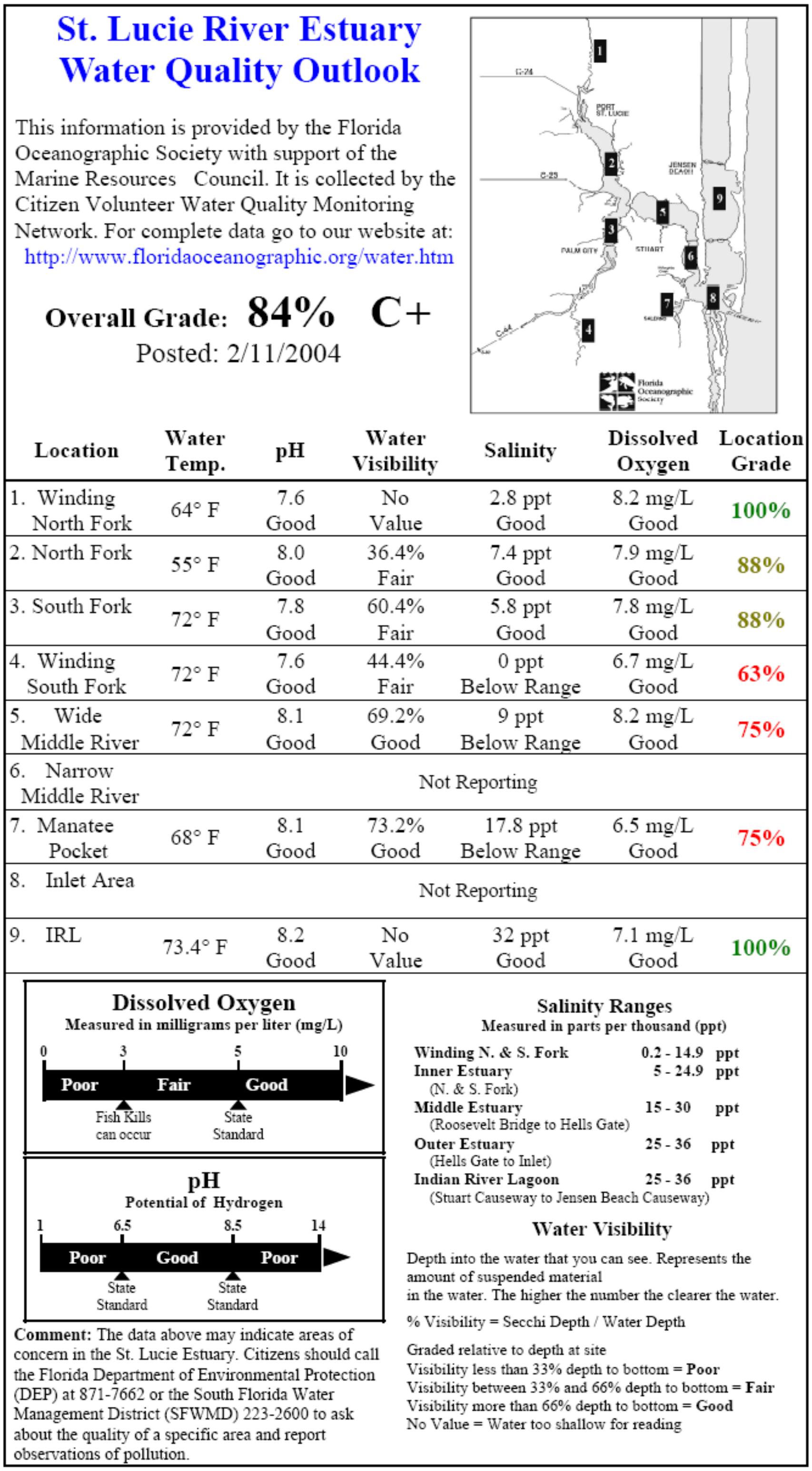
Notes: Dependent variable is natural log of sales price. Superscripts a, b, and c denote significance at the 0.01, 0.05, and 0.10 levels, respectively.

Table 4. Marginal Willingness to Pay for Water Quality Measures

Variable	Marginal Willingness to Pay ($)		
	90% Lower Bound	Mean	90% Upper Bound
Location grade (%)	474.23	43,158.00	84,400.36
Water visibility (%)	13,551.98	36,069.73	58,749.34
pH	3,535.90	7,531.18	11,478.66
Salinity (ppt)	1,647.16	31,937.65	61,485.98
Dissolved oxygen (mg/L)	-30,583.51	-14,052.26	1,628.30

Notes: The marginal willingness to pay is evaluated at the observed mean value of sales price. A marginal change is evaluated at the observed mean level of water quality measures. A marginal change in pH is defined as a one-tenth increase. A bootstrapping procedure is used to generate 90% confidence intervals for the marginal willingness to pay (Krinsky and Robb 1986). The reported confidence intervals are based on 5,000 sets of random parameter vectors from the distribution of the estimated parameters.

Figure 1. Example of Martin County Weekly Water Quality Data & Collection Locations



St. Lucie River Estuary Water Quality Outlook

This information is provided by the Florida Oceanographic Society with support of the Marine Resources Council. It is collected by the Citizen Volunteer Water Quality Monitoring Network. For complete data go to our website at: http://www.floridaoceanographic.org/water.htm

Overall Grade: 84% C+

Posted: 2/11/2004

Location	Water Temp.	pH	Water Visibility	Salinity	Dissolved Oxygen	Location Grade
1. Winding North Fork	64° F	7.6 Good	No Value	2.8 ppt Good	8.2 mg/L Good	100%
2. North Fork	55° F	8.0 Good	36.4% Fair	7.4 ppt Good	7.9 mg/L Good	88%
3. South Fork	72° F	7.8 Good	60.4% Fair	5.8 ppt Good	7.8 mg/L Good	88%
4. Winding South Fork	72° F	7.6 Good	44.4% Fair	0 ppt Below Range	6.7 mg/L Good	63%
5. Wide Middle River	72° F	8.1 Good	69.2% Good	9 ppt Below Range	8.2 mg/L Good	75%
6. Narrow Middle River	Not Reporting					
7. Manatee Pocket	68° F	8.1 Good	73.2% Good	17.8 ppt Below Range	6.5 mg/L Good	75%
8. Inlet Area	Not Reporting					
9. IRL	73.4° F	8.2 Good	No Value	32 ppt Good	7.1 mg/L Good	100%

Dissolved Oxygen

Measured in milligrams per liter (mg/L)

0 3 5 10

Poor Fair Good

Fish Kills can occur

State Standard

pH

Potential of Hydrogen

1 6.5 8.5 14

Poor Good Poor

State Standard

State Standard

Comment: The data above may indicate areas of concern in the St. Lucie Estuary. Citizens should call the Florida Department of Environmental Protection (DEP) at 871-7662 or the South Florida Water Management District (SFWMD) 223-2600 to ask about the quality of a specific area and report observations of pollution.

Salinity Ranges

Measured in parts per thousand (ppt)

Winding N. & S. Fork	0.2 - 14.9 ppt
Inner Estuary (N. & S. Fork)	5 - 24.9 ppt
Middle Estuary (Roosevelt Bridge to Hells Gate)	15 - 30 ppt
Outer Estuary (Hells Gate to Inlet)	25 - 36 ppt
Indian River Lagoon (Stuart Causeway to Jensen Beach Causeway)	25 - 36 ppt

Water Visibility

Depth into the water that you can see. Represents the amount of suspended material in the water. The higher the number the clearer the water.

% Visibility = Secchi Depth / Water Depth

Graded relative to depth at site
Visibility less than 33% depth to bottom = **Poor**
Visibility between 33% and 66% depth to bottom = **Fair**
Visibility more than 66% depth to bottom = **Good**
No Value = Water too shallow for reading

(Source: FOS, 2004)

Figure 2. Waterfront Home Sales by WQ Monitoring Location

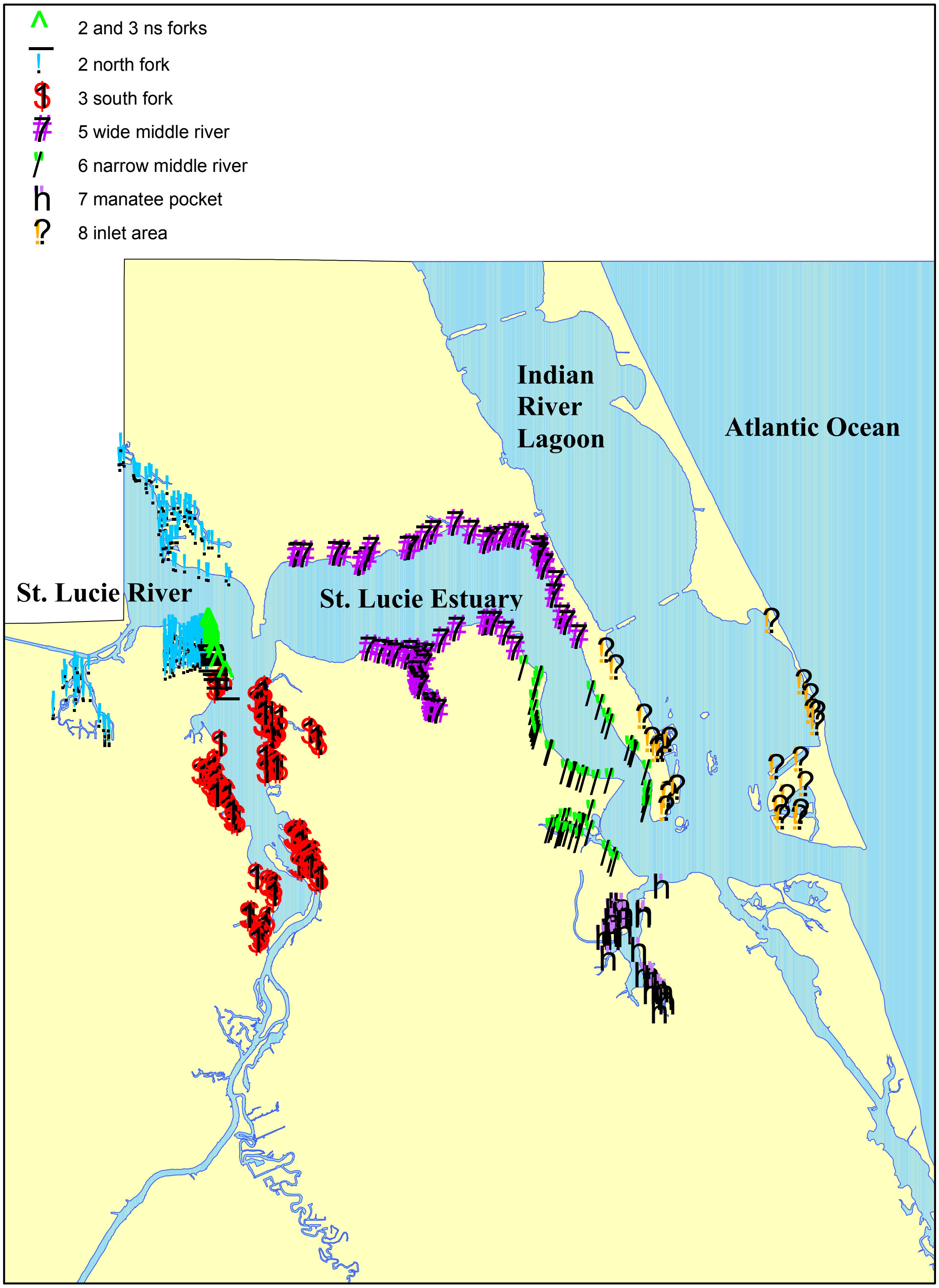
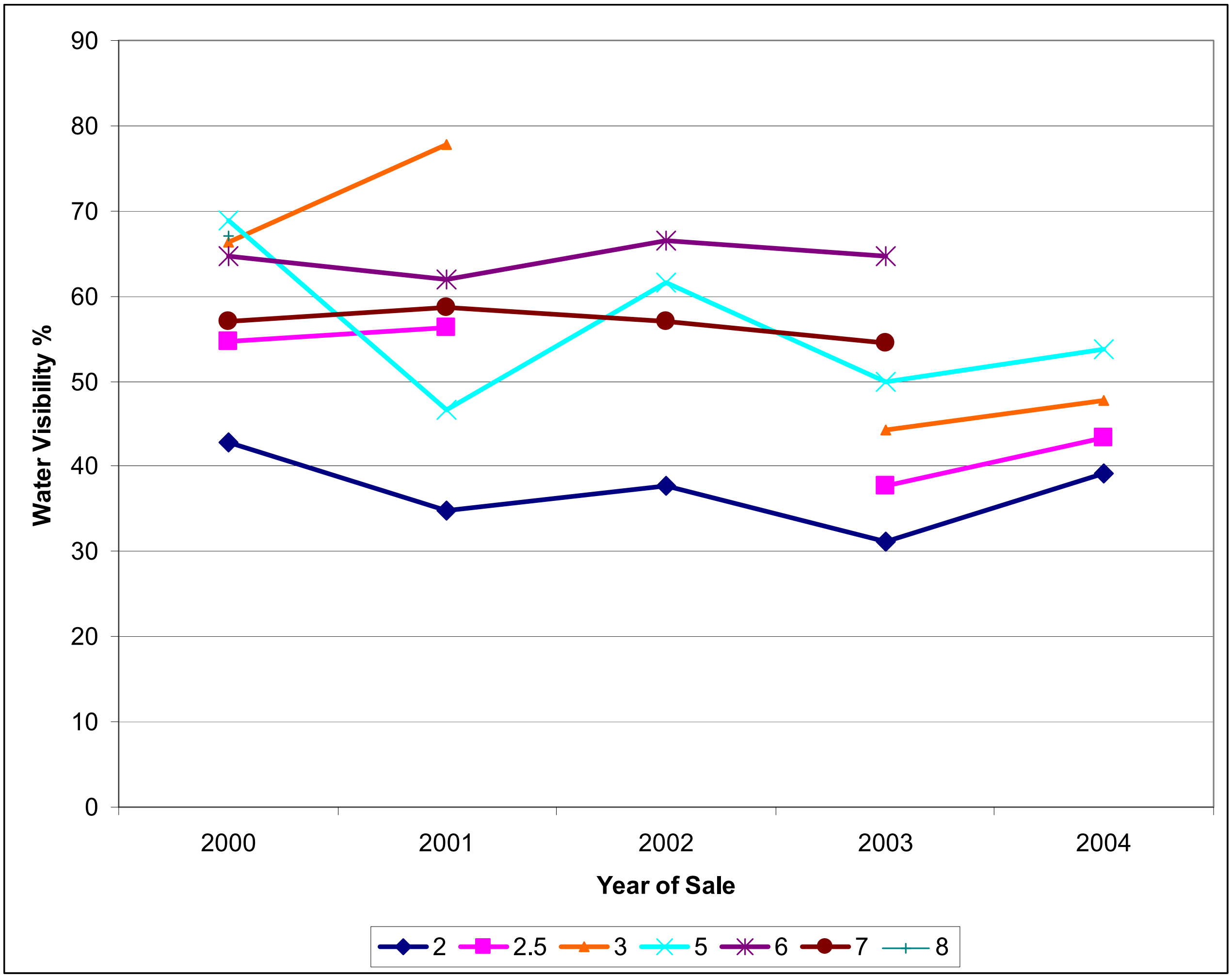


Figure 3: Median Water Visibility by Year & Location for Jan 2000 to Dec 2004



Note: Yearly gaps exist where no sales data for that year in a particular location was included in the analysis, e.g., water quality area #3 in 2002.