Economic Valuation for Coastal Water Infrastructure Planning: Analysis of the Housing Market and Nutrient Pollution in Suffolk County, NY

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ABSTRACT

The waters around Suffolk County, New York, are plagued by water quality concerns from nitrogen inputs, algal blooms, and eutrophication. Meanwhile, waterfront and near-water homes fuel a robust real estate market with many iconic regions, such as the Hamptons. Aging cesspools and septic systems are a paramount concern in the area. With approximately 74% of homes outside sewer systems, several jurisdictions are evaluating approaches to funding retrofits that would improve septic systems and water quality. It is therefore an ideal location to assess the impact that water quality has on home values; this paper investigates property sales near the Long Island Sound, South Shore Bays, and Peconic Estuary System. Results show that water quality has a significant impact on nearby home sales, with the largest effects generally seen nearest to the coastline. These results inform a discussion about potential benefits and costs of widespread septic tank and cesspool retrofitting, which is currently incentivized by grant and loan programs.

Key words: Coastal management, hedonic analysis, home values, Long Island, septic systems, Suffolk County, water clarity.
JEL codes: Q51, Q53.

INTRODUCTION

Long Island, New York, is an area surrounded by waterbodies with a rich coastal history of commerce and recreation. However, in recent years, water quality (WQ) has been getting worse, with algal blooms frequently closing beaches in the summer. Nearby coastal waters face multiple sources of water pollution, including several major rivers with significant agricultural and industrial upstream activity, considerable urban runoff from New York City, and leaking septic tanks across Long Island. Brown tides have led to documented impacts upon the scallop industry (Cosper et al. 1987; Gobler, Lonsdale, and Boyer 2005), and fish kills in the Peconic system have attracted media attention (Semple 2015), but research addressing recreational or amenity impacts across Suffolk County or Long Island is scarce. In particular, there has been limited research into

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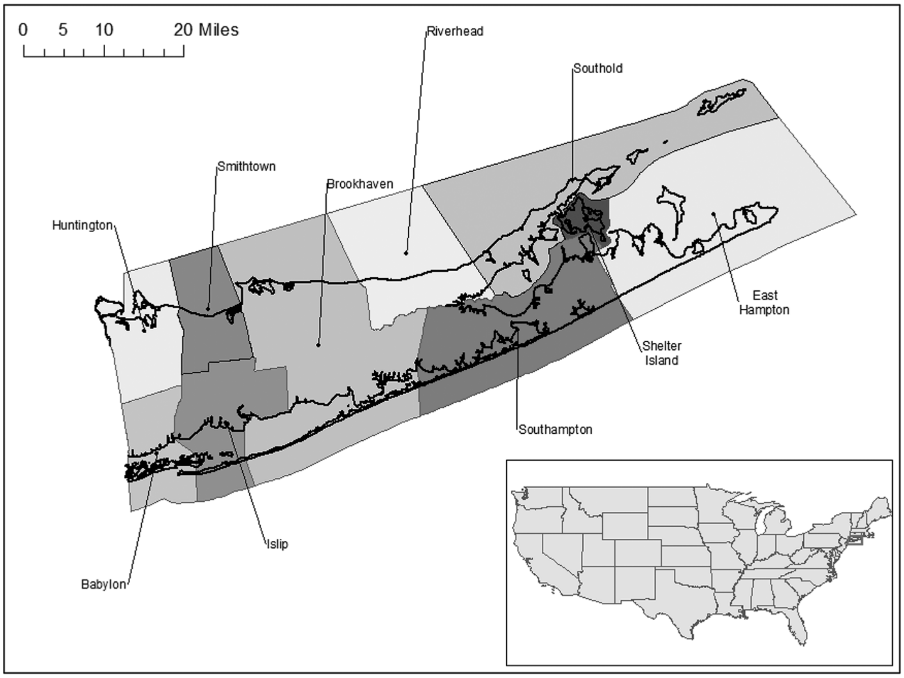

Figure 1. Study Area. A color version of this figure is available online.

potential property price impacts, even though there are billions of dollars of value in Long Island coastal real estate.

Long Island septic systems and cesspools are a major source of nutrients and other pollutants into local waterbodies and groundwater, with an estimated 74% of residents on the island served by septic systems or cesspools.[1] Recent research has found causal links between the nitrogen released by septic systems and the proliferation of algal blooms along the coasts of Suffolk County (Gobler and Sañudo-Wilhelmy 2001; Gobler, Lonsdale, and Boyer 2005).

Recognizing the magnitude of the problem, there are several county and local grant and loan programs for septic system and cesspool upgrades. In Suffolk County, the "Reclaim Our Water" initiative provides grants of $10,000 and low-interest loans of up to $10,000 for retrofits. However, these retrofits are expensive, estimated at $17,850 to $19,200 for average homes, and with some installations exceeding $30,000. So, although septic and cesspool upgrades could provide significant welfare improvements to a broad population in terms of improved water quality, they involve both significant individual costs and widespread participation.

To help inform local policy, this research evaluates the impact of WQ on housing values in Suffolk County, New York. There are several major waterbodies in the area, as well as a varied shoreline of bays and inlets, which provide robust variation in water quality. These waterbodies include the Long Island Sound, the South Shore Bays (Great South Bay, Moriches Bay, and Shinnecock Bay), and the Peconic Estuary System (figure 1). Using spatial econometric hedonic

1. A recent overview of Long Island's septic problems can be found at https://www.wsj.com/articles/suffolk-county-has-4-billion-plan-to-update-how-it-handles-sewage-11564521448. Additional information can be found on the Long Island Sound Study's website: http://longislandsoundstudy.net/2010/03/the-impact-of-septic-systems-on-the-environment/ (accessed February 2020).

models, we find that water clarity has a significant impact on nearby home prices, suggesting that environmental improvements could produce substantial benefits. Using our econometric results, we compare retrofit prices with the potential benefits that might be capitalized into local home prices. This illustrates both the benefits at stake and the magnitude of retrofit and sewerage costs, partially explaining the local political barriers and lack of prior action.

LITERATURE REVIEW

With increasing national trends in development and land use, as well as agricultural pollution, waterways are experiencing nutrient pollution at record rates, resulting in eutrophication and reduced clarity in many once-scenic bodies of water (Bricker et al. 2008). Reduced visibility in waterbodies can weaken nearby property values (Michael, Boyle, and Bouchard 2000; Walsh, Milon, and Scrogin 2011; Walsh et al. 2017), ultimately cutting into the welfare of the surrounding community and reducing tax revenue accrued by the local government (Ramachandran 2015). Research that defines this link between WQ and property value has been beneficial in providing a nonmarket valuation for WQ, offering an economic incentive for communities to preserve and restore these damaged aquatic ecosystems. Such work has been performed in freshwater (Michael, Boyle, and Bouchard 2000; Walsh Milon, and Scrogin 2011), estuarine environments (Bin, Czajkowski, and Villarini 2016; Walsh et al. 2017), and marine environments (Artell 2010).

In the early literature on WQ and home prices, Michael, Boyle, and Bouchard (2000) analyzed waterfront homes surrounding 34 Maine lakes that sold between 1990 and 1994, reviewing the impact that changes in WQ (due to eutrophication and algal blooms) had on property sales prices. The researchers found that WQ had a significant positive impact on the prices of properties bordering a lake (i.e., improved WQ equated to higher housing value; Michael, Boyle, and Bouchard 2000). Depending on which region of Maine the house fell into, the impact from a one-meter improvement in WQ ranged from $11 to $200 per foot frontage (the total number of feet the property had bordering the lake). Importantly, the researchers note that a one-meter increase in water clarity could, when aggregated for an entire lake, translate into millions of dollars through improved property prices (Michael, Boyle, and Bouchard 2000).

As research progressed, studies have gone beyond waterfront homes to test the WQ property price impact on non-waterfront homes. Walsh et al. (2017) assessed over 200,000 home sales in 14 Maryland counties between the years 1996–2008 to determine the impact of Chesapeake Bay WQ (in the form of light attenuation—a proxy for clarity). In seven of these counties there was a statistically significant waterfront property price impact, ranging from 3% to 16%, meaning that an improvement in Chesapeake Bay WQ could substantially improve the value of a waterfront home. Results also indicated that the impact of WQ on the housing market could range 1,000–2,000 m past the waterfront (Walsh et al. 2017).

Similar hedonics work has been performed on lakes in New Hampshire (Gibbs et al. 2002), Wisconsin (Kashian & Kasper 2010), Maine (Boyle et al. 1998), Ohio (Ara, Irwin, and Haab 2006; Wolf and Klaiber 2017), and Minnesota (Krysel et al. 2003); rivers and estuaries in Maryland (Poor et al. 2001) and Florida (Bin, Czajkowski, and Villarini 2016); and marine environments like the Baltic Sea (Artell 2010). Here, too, researchers found positive relationships between improvements in WQ and housing values.

Suffolk County provides an appropriate laboratory for a hedonic analysis, as coastal WQ has been regularly monitored for more than four decades and it regularly experiences dense algal blooms that can reduce water clarity (Carlson 1977; Gobler et al. 2008; Gobler, Lonsdale, and Boyer 2005). These algal blooms have raised public concern, leading several NGOs (Citizens Campaign for the Environment, Group for the East End, Long Island Pine Barrens Society, The Nature Conservancy, and Peconic Baykeeper 2015) to complete an assessment that summarized decades of Long Island watershed research, which concluded in stating the immediate necessity of a protection plan for Suffolk County waters (Suffolk County 2015). The county also has an irregular coastline bordering three types of waterbodies, providing ample variation in clarity.

DATA

WATER QUALITY DATA

Data for WQ, the primary independent variable, was attained through the Suffolk County Department of Health Services (SCDHS), for the years 2001–15. The DHS measures water clarity twice monthly with the use of a Secchi disk, which records the visible depth of a water column in feet. Thus, greater Secchi depth equates to clearer water, which is the proxy for higher WQ in the present study.

While clarity is a commonly used WQ metric in the literature (Michael, Boyle, and Bouchard 2000; Walsh, Milon, and Scrogin 2011; Walsh et al. 2017; and Bin, Czajkowski, and Villarini 2016), other studies have used different measures that merit discussion. Leggett and Bockstael (2000), for example, use fecal coliform counts within the Chesapeake Bay, while Bin and Czajkowski (2013) use an indicator that combines several other variables. Many other alternatives have also been used, including pH, nutrients, and algae (Netusil, Kincaid, and Chang 2014; Wolf and Klaiber 2017).

While these other metrics may in some cases more fully highlight the overall health of an ecosystem and potential health impacts, clarity is a reasonable ecological indicator, as it is visible to homeowners and has a full dataset available. Moreover, given that the specific ecological problem plaguing Suffolk County waters is eutrophication-driven algal blooms, which most readily impact the appearance of water, clarity is an especially relevant metric for this region.

The Suffolk County WQ stations that monitor Secchi disk depth are shown as points in figure 2. Because of the heterogeneity in WQ monitoring across Long Island, an interpolation of the available data was performed to assign an estimated WQ value to areas that were not directly measured. In this way, it was possible to associate housing parcels to their nearest WQ value, rather than the nearest WQ station (which may have been farther away than the nearest shoreline and therefore less accurate). The WQ data were interpolated across the entirety of the three waterbodies (separately for each), resulting in relatively complete WQ data for the whole region. This was done with the interpolation functions offered through ArcMap, similar to past research (Murphy, Curriero, and Ball 2010; Ramachandran 2015). Once complete, homes were matched with the WQ value nearest to their location, which was based on linear distance to the shore.

The Secchi values used in the analysis were averages taken between May and October. These specific months are used for two reasons. First, the majority of water-related recreation takes place during these warmer months, meaning that the impact of a WQ impairment during that time frame, such as an algal bloom, would be most detrimental and therefore most likely to influence one's decision to purchase property near a waterbody (Boyle, Poor, and Taylor 1999; Gibbs et al. 2002). Second, it is during these months that Long Island waterbodies suffer deteriorated WQ, primarily from algal blooms (Gobler et al. 2008; Gobler, Lonsdale, and Boyer 2005; Gobler and Sañudo-Wilhelmy 2001), making them the most relevant months to consider when determining

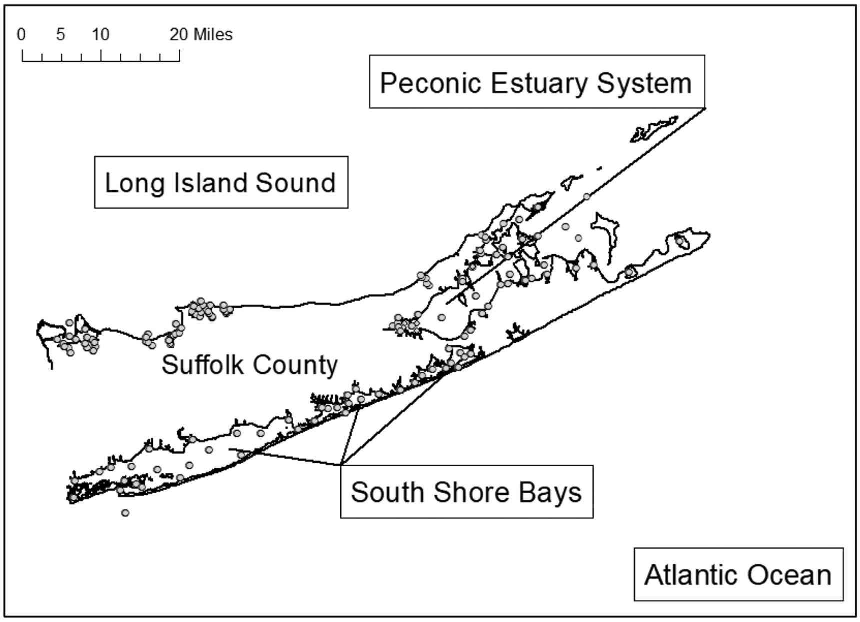

Figure 2. Monitoring Stations. A color version of this figure is available online.

whether WQ is impacting the local real estate market. Online appendix figure A.1 compares Peconic Bay WQ from May to October (summer) and November to April (winter), highlighting the higher degree of WQ impairments during summer months. We also find in the data that WQ impairments are more severe the farther west one goes and improve as you move east. This can be seen in online appendix figure A.2, which displays the west-to-east WQ gradient in the South Shore Bays.

Each sale was associated with the closest WQ value recorded the summer prior to the sale. In other words, the most recent May–October WQ value was used when considering whether a buyer or seller took WQ into account when entering a transaction. For example, if a sale took place in June 2014, then the May–October WQ from 2014 was used. However, if the sale took place in January 2014, the May–October WQ from the year prior (2013) was used.

RESIDENTIAL REAL ESTATE DATA

Residential real estate transaction data from the New York State Department of Taxation and Finance for the years 2002–15 were used to provide the sales price, the dependent variable for the hedonic analysis. These years were selected because they represent the most recent and up-to-date real estate data available. Only arms-length transactions (i.e., one where the buyer and seller have no relationship, other than conducting the transaction) were considered, as these are the most representative of a free market transaction. In this way, we can be certain that the observations for the dependent variable are accurate depictions of the true property values. Home values were adjusted for inflation and put into 2016 dollars using the Housing Price Index (HPI), available through the Federal Housing Finance Agency. Additionally, only parcels categorized as year-round, single-family residences (NYS Property Code 210) were considered. This was done to avoid the inclusion of secondary homes (e.g., summer homes), as there may be differences in the market for homes that were formerly rental homes.

Parcel attribute data—total bathrooms, square footage, acreage, and whether the parcel was waterfront—were obtained through Freedom of Information Law (FOIL) requests sent to each town in Suffolk County (figure 1). These attributes were selected as a result of data availability (i.e., the attributes that all the included towns had collected during property assessments). The present analysis includes data from 7 of the 10 towns across Suffolk County, with East Hampton, Islip, and Huntington excluded due to data limitations.

Of particular interest in WQ hedonic property models is the waterfront variable. In general, waterfront homes are expected to show the greatest impact from a change in WQ, as these homes are often associated with a price premium attributable to the benefits of living so close to the water. Broadly speaking, these benefits include quick and easy access to the water, for use and recreation, as well providing a scenic vista. Given this, homebuyers may be less incentivized to pay such a premium when WQ impairments impact the usability (e.g., swimming, bathing, fishing) and appearance of the water. Approximately 2% of our sample of homes (657 observations) are classified as waterfront. This classification was provided by the various local property offices. Although it appears to be mostly correct, there are some concerns about the accuracy of the variable. For example, there may be some homes on small inland neighborhood lakes or streams that get classified as waterfront. Ideally, waterfront homes would be associated with the waterbodies that are described by the water quality data that we obtain. As such, it is important to include distance measures (table 1) to control for other influences.

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Price ($)	485,218	725,594.80	25,590	23,864,734
WQ (ft)	6.11	2.61	1.60	22.50
WF dummy variable	0.02	0.15	0	1
Total bathrooms	2.10	0.96	1	15
Square feet	1,765	806.28	500	13,816
Acres	0.38	0.34	0.01	2.49
Distance to shore (km)	3.72	3	0.0004	11.44
Distance to public park (km)	2.50	1.68	0	9.28
Distance to train station (km)	3.95	2.93	0.06	16.47
Distance to train tracks (km)	3.10	2.66	0.005	12.45
Distance to public school (km)	1.27	1.13	0.04	8.16
Distance to inlet (km)	3.97	3.40	0.002	14.54
Distance to New York City (km)	81.22	26.91	45.16	151.50
Distance to shopping center (km)	4.76	3.71	0.16	25.88
Distance to hospital (km)	5.87	3.51	0.11	16.17
Distance to lake (km)	3.52	2.56	0	13.63
Distance to highway (km)	1.26	1.20	0.0001	10.37
Distance to airport (km)	12.91	7.66	1.04	37.87
Educational attainment	0.31	0.13	0.04	0.80
School district quality	0.88	0.08	0.70	0.98
Median household income ($)	92,397	22,760.70	33,609	210,559
Percentage impoverished	2.86	4.22	0.002	32.50
Percentage white	0.84	0.20	0.03	1
Percentage Hispanic	0.12	0.08	0	0.61
Percentage black	0.08	0.17	0	0.89
Percentage Asian	0.02	0.03	0	0.51

DEMOGRAPHIC DATA

United States Census Bureau demographic data were collected at the tract level and included median household income (in dollars), educational attainment (percentage of the population 25 years and over with a bachelor's degree or higher), poverty (percentage of the population whose income is below the poverty level), and race (percentage of the population that is Asian, black, Hispanic, or white). Additionally, school district quality (average high school graduation percentage for each school district) was obtained through the New York State Education Department.

Median household income was adjusted for inflation and put into 2016 dollars using the consumer price index (CPI), available from the United States Bureau of Labor Statistics. US Census Bureau data were attached to residential property sales in the following manner: properties sold between 2002 and 2004 received data from the 2000 Decennial Census, properties sold between 2005 and 2010 received data from the 2009 American Community Survey five-year estimates, and properties sold between 2011 and 2016 received data from the 2015 American Community Survey five-year estimates. These data were selected to account for any relative changes in demographics across Suffolk County during the study period.

LOCATIONAL DATA

Lastly, the distances to nearby amenities and disamenities across Suffolk County were calculated for each parcel using ArcMap. Expected amenities included the shoreline, train stations, public parks and schools, hospitals, lakes, inlets, airports, shopping centers, and New York City, while expected disamenities included train tracks and highways. These distances are necessary control variables for the model, as a parcel's location relative to these items potentially plays a role in the home buyer's decision-making process. Summary statistics for model variables are available in table 1.

HEDONIC MODEL

THEORETICAL MODEL

A hedonic property model determines the expected value of a parcel based on that parcel's structural and locational features. In equation 1, parcel characteristics (such as acres and number of bathrooms) are represented by $\boldsymbol{H}_i$, a vector of structural attributes. Community and location characteristics (e.g., distance to a train station or school district quality) are represented by $\boldsymbol{N}_i$, a vector of locational attributes. Because of their importance in the present model, WQ and distance to the shore are given their own vectors, $\boldsymbol{WQ}_i$ and $\boldsymbol{D}_i$, respectively. In the present study, two variations of $\boldsymbol{D}_i$ are used. The first is a continuous variable representing linear distance, and the second is a set of predetermined buffer groups of increasing distance from shore (discussed further in the Empirical Model section). Importantly, the buffer groups include a group solely for waterfront properties, accounting for the relatively stronger expected reaction that waterfront homes will have to a change in WQ.

$$\boldsymbol{P}_i = \mathrm{f}(\boldsymbol{H}_i, \boldsymbol{N}_i, \boldsymbol{D}_i, \boldsymbol{WQ}_i). \tag{1}$$

Here, sales price ($\boldsymbol{P}$) of parcel $\boldsymbol{i}$ is a function of the parcel's structural characteristics ($\boldsymbol{H}_i$), environmental/locational characteristics ($\boldsymbol{N}_i$), distance to the nearest waterbody ($\boldsymbol{D}_i$), and the quality of the water at that waterbody ($\boldsymbol{WQ}_i$).

EMPIRICAL MODEL

For the analysis, the natural log of the dependent variable was taken to account for a nonlinear relationship between home values and the independent variables (Gibbs et al. 2002). Additionally, vectors representing year ($\boldsymbol{T}_t$) and spatial ($\boldsymbol{V}_j$) indicator variables were included to control for trends in the Suffolk County housing market. These fixed effects also reduce bias stemming from uncontrolled variation between years and between towns by ensuring that only parcels sold in the same town and during the same year are compared. Fixed-effects regressions are favorable when working with the property market, as the value of a home could be influenced by the year (e.g., one's perception of the country's economic health in a given year might alter their willingness to pay) or the town (e.g., the pros and cons of living in a certain region that are not necessarily captured by control variables). Finally, an interaction effect between $\boldsymbol{WQ}$ and $\boldsymbol{D}$ was included ($\boldsymbol{D}_i\boldsymbol{WQ}_{ijt}$) in order to model the change in influence that WQ has on a home's value as the distance from shore increases. The empirical model is shown in equation 2.

$$\ln\left(\boldsymbol{P}_{ijt}\right) = \beta_0 + \beta_1\boldsymbol{H}_{ijt} + \beta_2\boldsymbol{N}_{ijt} + \beta_3\boldsymbol{D}_{ij} + \beta_4\boldsymbol{T}_t + \beta_5\boldsymbol{V}_j + \gamma\boldsymbol{D}_i\boldsymbol{WQ}_{ijt} + \boldsymbol{\varepsilon}_{ijt}. \quad (2)$$

The coefficients that will be estimated for the variable vectors are β_0 through β_5, and γ. The change in parcel selling price stemming from a change in structural characteristics is represented by β_1, and the change in selling price due to changes in community/locational characteristics is represented by β_2. Vectors β_4 and β_5 reflect housing market trends over time and between spatial areas (such as towns), respectively. Modeling distance from shore on its own ($\boldsymbol{D}_{ij}\beta_3$) elicits the change in parcel selling price due solely to a change in distance from shore (β_3), all else constant. With the effect that distance has on selling price controlled for, the coefficient reflecting the interaction term, γ, reveals the percentage change in selling price due to a one-unit change in WQ (i.e., a one-foot increase in coastal water clarity).

Distance from shore is modeled in two ways. The first treats distance as a continuous variable, allowing it to increase linearly as one moves farther from shore. The interaction of that distance variable with the WQ variable also allows the implicit price of WQ to vary with distance to the shore. The second treatment of distance from shore uses a vector of four dummy variables that denote each parcel as being located either at the waterfront, within 0–500 m of the shore (excluding waterfront homes), within 500–1,000 m from the shore, within 1,000–1,500 m from the shore, and within 1,500–2,000 m from the shore. This specification allows the marginal effect of WQ to have different effects on home prices at different distances and is used widely across hedonic applications involving distance (Taylor and Smith 2000; Netusil 2005; Landry and Hindsley 2011). A cutoff point of 2,000 m involves an assumption that WQ will have no effect on the value of homes located over 2,000 m from shore. This is in line with previous work that has found the WQ–home value relationship to disappear at distances past 2,000 m (Walsh, Milon, and Scrogin 2011; Walsh et al. 2017; Netusil, Kincaid, and Chang 2014).

We control for spatially correlated unobservable influences using several different levels of fixed effects. We use census tract identifiers, which are the most spatially explicit, as well as town and school district fixed effects. We also use town *x* year fixed effects, resulting in four models for each of the distance specifications (buffer versus linear distance). This variation in spatial fixed effects should allow controls for omitted variable bias while mitigating potential overlap of the fixed effects with the water quality attribute (Kuminoff, Parmeter, and Pope 2010).

RESULTS

SUFFOLK COUNTY

Table 2 shows the results from the first regression specification, where all Suffolk County parcels were included and WQ was interacted with the distance from shore variable. Additionally, waterfront (WF) homes, which were expected to realize the greatest impact from WQ of all homes in the sample, were given their own interaction with WQ. This was done to remove the effect that WQ has on WF homes from the overall effect that WQ has on homes across Suffolk County. R^2 measures indicate that the model explained more than three-quarters of the variation in home values across Suffolk County, indicating a good statistical fit. In general, the control variables have their anticipated signs and are statistically significant (see online appendix table A.1 for the full set of coefficients).

The type of fixed effects used appears at the top of each column. Across the four models, the signs and significance for most of the primary variables of interest were consistent. The WQ variable is positive and significant in all models, and its interaction with distance is negative and significant. This indicates that there is a positive value for water quality that declines with distance. In the first model with tract fixed effects, a one-unit increase in Secchi disk depth (i.e., a one-foot increase in water clarity) equates to a 0.84% rise in home values across Suffolk County. The interaction between WQ and the continuous distance from shore variable (WQ × DistShore) revealed, as expected, that the impact WQ has on a home's selling price is reduced for homes farther from the coast. Specifically, the rate of decay is 0.2% for each one-kilometer increase in the home's distance from shore ($p < 0.01$) in the first model.

Finally, the interaction between WQ and WF homes also returned anticipated coefficients in the census tract model, which predicts a 0.99% increase in a WF home's selling price for each one-foot increase in water clarity. However, this interaction term differs between model specifications, with insignificant values in the other three models. This may potentially be due to issues with the waterfront classification in the underlying data from the county. We also further explore this relationship by estimating regressions with only waterfront observations and then only non-waterfront observations in online appendix table A.2. The waterfront-only results show a significant impact of water quality in all models except the census tract–level models, which are likely

Table 2. Regression Results—Full Sample, Distance Interaction

	Tract FE	Town FE	School FE	Town *x* Year FE
WF	0.3677***	0.4972***	0.4420***	0.4985***
	(0.0300)	(0.0315)	(0.0308)	(0.0314)
DistShore	–0.0246***	0.0105***	–0.0110***	0.0109***
	(0.0041)	(0.0020)	(0.0028)	(0.0020)
WQ	0.0084***	0.0208***	0.0191***	0.0221***
	(0.0015)	(0.0013)	(0.0014)	(0.0013)
WQ × DistShore	–0.0016***	–0.0029***	–0.0022***	–0.0031***
	(0.0004)	(0.0003)	(0.0003)	(0.0003)
WF × WQ	0.0099**	0.0010	0.0040	–0.0003
	(0.0040)	(0.0042)	(0.0041)	(0.0042)
N	30,456	30,456	29,575	30,456
R^2	0.786	0.747	0.773	0.752

Note: Standard errors appear in parentheses. The full set of coefficients appears in the online appendix. *** $p < 0.01$, ** $p < 0.05$.

too spatially explicit for the much smaller sample. The non-waterfront results are also more consistent, in terms of significance and the magnitude of effects.

Next, a buffer approach was applied to the distance variable. Rather than treating WQ as a continuous variable over distance, this analysis modified the treatment of distance, breaking it into discrete segments. Results are shown in table 3 (full results in online appendix table A.3). Buffers included 0–500 m (excluding WF homes), 500–1,000 m, 1,000–1,500 m, and 1,500–2,000 m, with each separately interacted with WQ. As with the previous regression, WQ was interacted with WF separately, ensuring that the effect for WF homes would not bias the overall effect. For the full sample (i.e., "Suffolk County"), the WQ × WF interaction and the first three buffer interactions (out to 1,500 m) were both statistically significant at the $p < 0.05$ level and revealed anticipated direction and magnitudes of coefficients. WF homes realize the greatest benefit from a one-foot improvement in water clarity in the tract and school fixed-effects models, with the effect equal to the 0–500 m buffer in the other two models (using a chi-squared test). The magnitude of the WQ interactions diminish between the 0–500 m and 500–1,000 m buffers in all models, and then become statistically insignificant after 1,500 m. These results indicate that homes located farther from the water realize less benefit from improvements in WQ, as anticipated.

Table 3 also highlights the value of living near the water, as illustrated by the positive and significant WF coefficient and its interaction with WQ, implying that the value of a waterfront home increases with better water quality. The coefficients on the other distance buffers are harder to interpret. For example, the marginal effect of living in the 0–500 m buffer in the tract model is

Table 3. Regression Results—Full Sample, Buffer Distances

	Tract FE	Town FE	School FE	Town *x* Year FE
WF	0.3280***	0.4625***	0.3888***	0.4633***
	(0.0317)	(0.0318)	(0.0316)	(0.0317)
Dist 0–500	–0.0549***	0.0098	–0.0302*	0.0084
	(0.0199)	(0.0168)	(0.0181)	(0.0169)
Dist 500–1,000	–0.0855***	–0.0719***	–0.1240***	–0.0703***
	(0.0201)	(0.0178)	(0.0189)	(0.0177)
Dist 1,000–1,500	–0.1115***	–0.1018***	–0.1502***	–0.1013***
	(0.0208)	(0.0184)	(0.0192)	(0.0184)
Dist 1,500–2,000	–0.0170	–0.0398*	–0.0535***	–0.0440**
	(0.0211)	(0.0204)	(0.0206)	(0.0204)
WQ	–0.0015	0.0088***	0.0051***	0.0090***
	(0.0014)	(0.0013)	(0.0014)	(0.0013)
WF × WQ	0.0190***	0.0108**	0.0155***	0.0103**
	(0.0040)	(0.0042)	(0.0041)	(0.0042)
Dist 0–500 × WQ	0.0138***	0.0110***	0.0139***	0.0118***
	(0.0023)	(0.0022)	(0.0023)	(0.0022)
Dist 500–1,000 × WQ	0.0083***	0.0077***	0.0116***	0.0084***
	(0.0024)	(0.0023)	(0.0024)	(0.0023)
Dist 1,000–1,500 × WQ	0.0095***	0.0088***	0.0132***	0.0094***
	(0.0025)	(0.0024)	(0.0025)	(0.0024)
Dist 1,500–2,000 × WQ	–0.0003	0.0040	0.0046*	0.0051*
	(0.0028)	(0.0027)	(0.0027)	(0.0027)
N	30,456	30,456	29,575	30,456
R^2	0.786	0.749	0.774	0.753

Note: Standard errors appear in parentheses. The full set of coefficients appears in the online appendix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

equal to –0.0549 + 0.0138 × WQ. This is graphed in figure 3, which shows increasing values for higher water quality. At a mean WQ value of approximately 6, an average home in the 0–500 m buffer has a premium of 2.8% over homes beyond 2,000 m. We can also rescale the WQ data as the difference from the annual mean to better assess the impact of the different distance buffers, as shown in online appendix table A.4.

REGIONAL ANALYSES

The analysis was then broken out regionally, with each subregion representing one of the three major Suffolk County waterbodies: Long Island Sound (LIS), South Shore Bays (SSB), and Peconic Estuary System (PES). This allows us to explore differences between waterbody types. Results for SSB are shown in table 4 (full results in online appendix tables A.5 and A.6). Here, the same four models were run, but samples included only the parcels that drew their WQ values from their respective waterbodies. In each of these subsamples, there was only limited statistical significance in the variables of concern, making interpretations difficult (see full results for LIS and PES in online appendix tables A.7 to A.10). The one exception was the SSB, where the coefficient on the WQ × WF interaction revealed a 2.6% to 2.8% premium (depending on the model) for WF homes for each one-foot increase in water clarity ($p < 0.05$). For the LIS, this interaction term was only significant in one of the models.

As with Suffolk County, we then analyzed each region with the buffer specification for distance. Similar to the regional continuous distance models, there are less significant effects than the full county models. Table 5 shows the results of the SSB models. The WQ variable is significant and positive in three of four models, and the WF × WQ and Dist_0_500 × WQ interactions are positive and significant in two of the four models. However, the 500–1,000 m WQ interaction is surprisingly negative and significant across models. Nevertheless, this finding could be the result

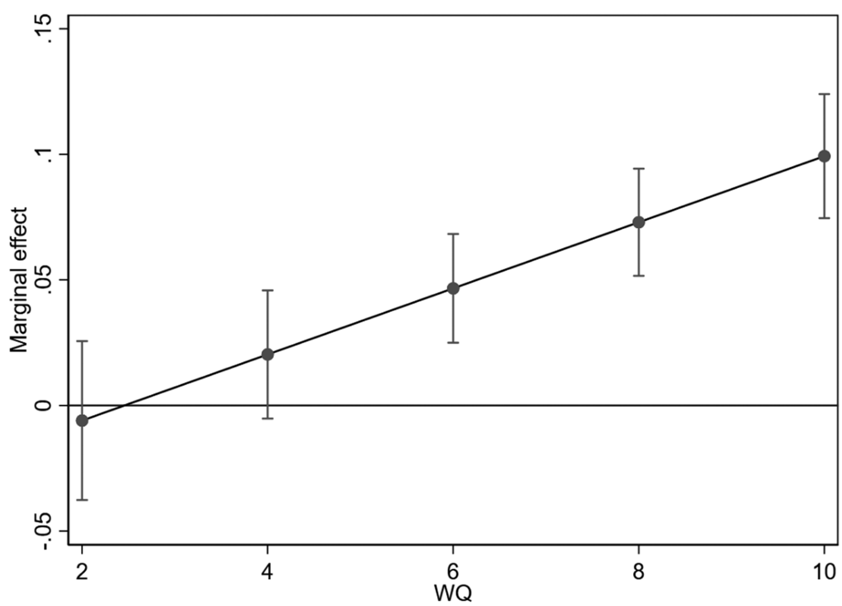

Figure 3. Marginal Effect of the 0–500 m Distance Buffer

Table 4. Regression Results—South Shore Bays (SSB), Distance Interaction

	Tract FE	Town FE	School FE	Town x Year FE
WF	0.2318***	0.3267***	0.3075***	0.3245***
	(0.0555)	(0.0563)	(0.0576)	(0.0564)
DistShore	–0.0060	–0.0235***	–0.0167***	–0.0257***
	(0.0076)	(0.0038)	(0.0054)	(0.0039)
WQ	0.0026	–0.0016	0.0070	–0.0009
	(0.0037)	(0.0032)	(0.0045)	(0.0033)
WF × WQ	0.0277**	0.0262**	0.0263**	0.0266**
	(0.0111)	(0.0114)	(0.0118)	(0.0114)
WQ × DistShore	0.0005	0.0012	0.0004	0.0016**
	(0.0008)	(0.0007)	(0.0008)	(0.0007)
Observations	12,658	12,658	11,777	12,658
R^2	0.667	0.639	0.667	0.642

Note: Standard errors appear in parentheses. The full set of coefficients appears in the online appendix. *** $p < 0.01$, ** $p < 0.05$.

of many factors, such as a missing variable or simply the reduced sample size for each regional regression (as compared with the full sample regression, where no negative coefficients were predicted by the model). The smaller numbers in the PES and LIS regressions also exhibited limited statistical significance across fixed-effects variations for our variables of concern.

Table 5. Regression Results—South Shore Bays (SSB), Buffer Interaction

	Tract FE	Town FE	School FE	Town x Year FE
WF	0.1900***	0.4291***	0.3086***	0.4347***
	(0.0583)	(0.0572)	(0.0595)	(0.0574)
Dist 0–500	–0.1078***	0.1075***	–0.0395	0.1110***
	(0.0346)	(0.0286)	(0.0342)	(0.0290)
Dist 500–1,000	–0.0019	0.1165***	0.0020	0.1219***
	(0.0368)	(0.0315)	(0.0382)	(0.0317)
Dist 1,000–1,500	–0.0436	0.0142	–0.0754*	0.0275
	(0.0397)	(0.0342)	(0.0398)	(0.0344)
Dist 1,500–2,000	0.0250	0.1216***	0.0524	0.1316***
	(0.0444)	(0.0425)	(0.0469)	(0.0425)
WQ	0.0050	0.0072**	0.0098**	0.0095***
	(0.0032)	(0.0030)	(0.0039)	(0.0031)
WF × WQ	0.0260**	0.0170	0.0248**	0.0156
	(0.0113)	(0.0114)	(0.0119)	(0.0115)
Dist 0–500 × WQ	0.0096*	–0.0048	0.0114*	–0.0063
	(0.0055)	(0.0052)	(0.0063)	(0.0053)
Dist 500–1,000 × WQ	–0.0141**	–0.0193***	–0.0144**	–0.0205***
	(0.0060)	(0.0057)	(0.0072)	(0.0058)
Dist 1,000–1,500 × WQ	–0.0056	–0.0007	–0.0011	–0.0027
	(0.0068)	(0.0065)	(0.0078)	(0.0065)
Dist 1,500–2,000 × WQ	–0.0079	–0.0167*	–0.0144	–0.0184**
	(0.0089)	(0.0088)	(0.0100)	(0.0088)
Observations	12,658	12,658	11,777	12,658
R^2	0.668	0.639	0.669	0.642

Note: Standard errors appear in parentheses. The full set of coefficients appears in the online appendix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

MARGINAL IMPLICIT PRICES

To identify the practical implications of the estimated coefficients, marginal implicit prices (MIPs) for WQ were calculated. This also allows us to see the statistical significance of the interaction effects better by illustrating the overall impacts. Tables 6 and 7 present these values for the full sample and the three regional samples, for both the distance and the buffer specifications. To save space, the results of the fourth models that use town *x* year fixed effects are presented. The MIPs can be evaluated at the same distances in both model specifications to facilitate better comparison.

MIPs tell us the anticipated change in a home's value given a one-unit change in a specified characteristic. In the case of this research, the MIP is the change in home value given a one-foot increase in water clarity. Consequently, under certain conditions, this value can be interpreted as the homeowner's marginal willingness to pay for that one-foot improvement in water clarity (Poor, Pessagno, and Paul 2007). Although the strict conditions set out in Kuminoff and Pope (2014) may not be achieved, at the least they represent the potential capitalization of water quality into property prices.

The results from the full county regressions in table 6 show positive and significant implicit prices for all relevant water quality effects out to 2,000 m. The implicit prices are highest for waterfront homes, at approximately $30,000–$31,000, and then decline with distance from the shore. In the farthest (1,500–2,000 m) buffer, the implicit price is still approximately $7,000–$8,000 per foot of clarity. Finally, the magnitude of the implicit prices is also fairly comparable between the linear distance and buffer models.

The regional results presented in table 7 are much less consistent. Although the SSB MIPs are positive and significant for the waterfront SSB models, there is much less significance and consistency across models. This reflects the similar results observed for the coefficients themselves and suggests that there may not be enough variation in the attributes in these smaller samples, or that there may be other unobserved influences at that level.

Our results are in the same range as earlier studies, although on the lower range. For example, Michael, Boyle, and Bouchard (2000) found that WQ improvements in freshwater lakes in Maine

Table 6. Marginal Implicit Prices—Full Sample

	Suffolk County	
	Buffered Distance	Continuous Distance
WF	30,200.94***	31,283.29***
	(6,392.40)	(6405.93)
0–500 m	16,691.69***	16,996.09***
	(1,558.33)	(1004.32)
500–1,000 m	10,856.57***	12,311.74***
	(1,297.59)	(729.97)
1,000–1,500 m	9,217.73***	9,143.41***
	(1,105.02)	(550.97)
1,500–2,000 m	6,859.06***	8,089.79***
	(1,248.19)	(505.32)
Non-WF[a]	NA	4,705.09***
		(474.10)

Note: Standard errors appear in parentheses. [a] Average effect for non-WF homes. *** $p < 0.01$.

Table 7. Marginal Implicit Prices—Regional Samples

	South Shore Bays		Long Island Sound		Peconic Estuary System	
	Buffered Distance	Continuous Distance	Buffered Distance	Continuous Distance	Buffered Distance	Continuous Distance
WF	27,681.90**	28,914.84**	5,455.52	4,846.23	28,484.31	29,368.37
	(12,389.36)	(12,364.74)	(5,884.20)	(5,887.44)	(32,971.11)	(33,122.99)
0–500 m	1,737.77	–255.51	–4,509.09***	–1,244.56	11,151.55*	8,600.01
	(2,435.46)	(1,653.97)	(1,695.56)	(900.99)	(6,514.59)	(5,827.78)
500–1,000 m	–4,603.43**	103.30	–5,795.57***	–1,156.03	–708.05	2,497.76
	(2,211.81)	(1,226.62)	(1,242.87)	(713.80)	(6,954.39)	(4,262.52)
1,000–1,500 m	2,230.86	333.55	–3,262.38***	–1,206.10*	–17,703.75*	–2,284.99
	(2,027.27)	(898.87)	(1,149.64)	(631.72)	(10,406.31)	(4,189.56)
1,500–2,000 m	–2,812.09	574.13	–1,993.73	–1,461.72**	–8,680.20	–6,239.30
	(2,745.14)	(830.99)	(1,367.73)	(654.87)	(12,219.24)	(4,455.07)
Non-WF[a]	NA	1,876.09**	NA	–1,851.66***	NA	619.74
		(894.92)		(521.41)		(4,725.37)

Note: Standard errors appear in parentheses. [a] Average effect for non-WF homes. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

yielded a waterfront price premium of 1%–30%, and Walsh et al. (2017) found that WQ in the estuarine Chesapeake Bay corresponded with a 3%–16% waterfront price premium. All else equal, waterfront homes in Suffolk County command a 1%–2% (table 3) higher premium for water quality. However, because of the higher value of waterfront homes, the water quality implicit price for waterfront homes was $13,000 to $14,000 higher than nearby non-waterfront homes. Given that homeowners are paying such a substantial premium for water proximity (33%–46% in table 3), it is not surprising then that they respond strongly to changes in WQ.

As we move away from the waterfront, we see that the price premium for WQ improvements begins to fall, as hypothesized. The WQ-distance interaction shows that the price premium extends beyond waterfront homes. That effect is confirmed in the buffered distance model.

POLICY APPLICATION

Overall, results indicate that WQ plays a small but statistically significant role in determining the value of a home in Suffolk County. To illustrate the magnitude of these effects, we estimate the total value of a change in water clarity of one foot, assuming widespread septic upgrades could produce an average change of that magnitude. Using Suffolk County data on building locations and residential zoning, there are approximately 9,192 single-family homes within 100 feet of the water. Since it is difficult to identify waterfront homes in these data from New York, we use 100 feet as a reasonable proxy. Using the waterfront implicit prices from both the buffer and continuous results in table 6, this translates to an estimated increase in $277.6 to $287.6 million in capitalized value. Similarly, there are approximately 98,182 homes within 500 m of the water. Applying the corresponding implicit prices from table 6 yields an increase in capitalized value of $1.64 to $1.67 billion. A one-foot increase in water clarity would therefore yield a total increase in capitalized value of close to $2 billion (table 8).

Regarding the cost of septic upgrades, the typical cesspool system (figure 4b) costs between $2,000 and $4,000, whereas the advanced (less polluting) treatment system (figure 4a) costs

Table 8. Benefits of a Hypothetical One-Foot Increase in Clarity

	Buffer Model	Continuous Model
Waterfront	$277,607,040	$287,556,002
Within 500 m	$1,638,823,508	$1,668,710,108
Total	$1,916,430,548	$1,956,266,110

$13,500 to $23,800 (Dooley and Schwartz 2018). Additional information about these systems and costs is posted on the Suffolk County website, as well as at http://www.reclaimourwater.info (also a county site). That site lists average costs for advanced treatment as $19,200, with an upper range of as much as $30,000.

However, it is difficult to estimate the aggregate costs of converting the septic and cesspool residential areas to more sustainable systems. Based on county GIS maps of sewer areas, there are approximately 373,000 homes that are not connected to sewers. While it would be unrealistic to expect all those homes to convert without significant government regulation and/or assistance, the county has instead released a figure of priority areas that would produce the greatest benefit from conversion. The map roughly includes homes within 1,000 feet of waterbodies. Based on existing parcel data, there are approximately 43,900 (non-sewer) homes within 1,000 feet of Suffolk County waterbodies. Using the Suffolk County average price of $19,200, that would correspond to a cost of $842,880,000. The higher price of $30,000 for advanced treatment yields a total cost of $1.317 billion. These are fairly high costs for any local government.

As mentioned earlier, the county has an existing incentive program that provides up to a $10,000 grant for upgrades, as well as low-cost financing for the remaining cost. Using the average cost figure of $19,200, the county would be paying approximately $439,000,000 in grants and financing $403,880,000 in loans. These large amounts (which could be significantly higher in some areas) are one potential explanation for the previous delay in government action. For purposes of

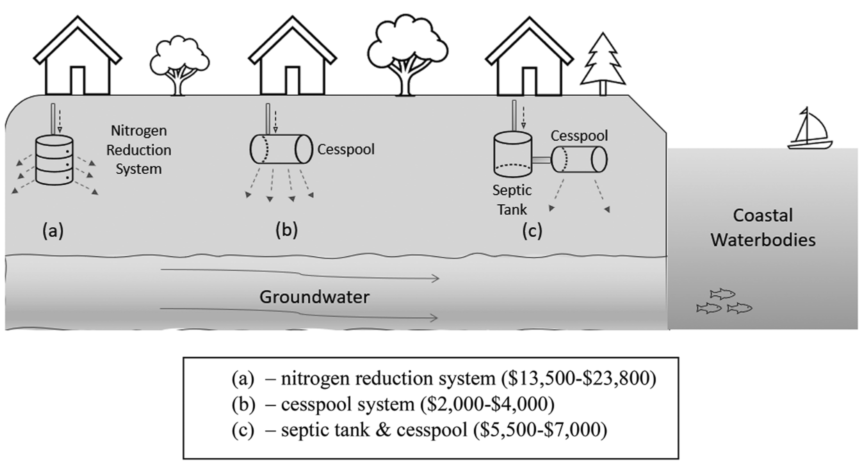

Figure 4. Different Wastewater Treatment Options. A color version of this figure is available online.

comparison, after Hurricane Sandy, voters approved a project that connected 6,400 homes to public sewers at a cost of $360 million.[2]

Although it is not clear how much water quality would improve after converting the priority septic systems, our initial estimates suggest that increases in property prices resulting from a one-foot improvement in clarity represent roughly $600 million more than the costs of converting priority areas to advanced treatment systems. It is also important to note that home values are only one of the many potential benefits of improved water quality. There are a number of other benefits that both county residents and others outside the region would enjoy, such as improved beach tourism, recreation, fisheries, and commerce (US EPA 2015; Moore et al. 2018), whereas the benefits capitalized into property prices only accrue to homeowners near waterbodies.

LIMITATIONS

There are several limitations to this analysis that are worth noting and that serve as avenues for future research. One area of potential concern is the lack of information on access for shoreline recreation and use. While it is assumed in the present work that being closer to the water is favorable because it confers greater usability of the water, this neglects the fact that access to the water may differ between neighborhoods. Moreover, it is very likely that certain spots and amenities, such as public beaches and boat launches, are going to be more sought after. As a result, it is unlikely that being nearer to the coast objectively will always be preferable, as some homes may be closer to the water but farther from a beach. Here the data limitations were problematic, as there was no reliable data on the locations for such water access point amenities. Future research should explore the relationship between water access and the value of water quality.

A second issue we encountered was data availability for home characteristics. We acknowledge that our data are somewhat limited, most notably the absence of bedrooms per parcel. Unfortunately, the data collected across Suffolk County towns is inconsistent, resulting in a reliance on only the subset of characteristics that were commonly reported across all towns. That said, we have included key characteristics such as the number of bathrooms and square footage of the property, which would be expected to be closely correlated with the number of bedrooms.

CONCLUSION

This study estimated the economic value of one stream of ecosystem service benefits coming from improved WQ in Suffolk County. The area has a history of harmful algal blooms, and several studies have linked them to local septic systems and cesspools as a primary source.[3] We find that water quality has a significant impact on nearby home sales. Waterfront homes have the largest amount capitalized into their sales price, although we also find significant impacts extending beyond the waterfront, to at least 2,000 m. We use our results in a policy application regarding upgraded wastewater treatment systems. Although the potential costs of converting priority septic systems is intimidating for any local government, at over $1.3 billion, our estimates indicate that the capitalized increases of nearby property prices could more than offset those costs (assuming the septic upgrades yield at least a one-foot improvement in clarity). Since these benefits are only a fraction of people's likely total willingness to pay, these results suggest significant value to improving local water quality.

2. Additional background can be found at https://www.wsj.com/articles/suffolk-county-has-4-billion-plan-to-update-how-it-handles-sewage-11564521448 (accessed February 2020).

3. See http://www.reclaimourwater.info, a Suffolk County website, for additional sources and explanation.

Due to the local nature of this disamenity and projected costs, it is important to illuminate local benefits. Moving forward, several biophysical models are being developed for nitrogen loading in Suffolk County; these models could be paired with our results for more accurate benefit and cost projections that incorporate a wider range of local benefits.[4]

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