The Impact of Water Clarity on Home Value in Northern Wisconsin

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Abstract

This study estimates the property value gains associated with improvements in water clarity on twenty Northern Wisconsin lakes. The analysis uses a two-stage hedonic model applied to Wisconsin Department of Natural Resources water studies data and sales data for over 300 homes. The results estimate that a 3-foot improvement in water clarity would produce a 9%–16% improvement in the value of an average property on lakes with the lowest clarity.

Introduction

A number of lakes in Northern Wisconsin exhibit low levels of water clarity. It is well-established that perceptions of water quality have a significant bearing on property values.[1] As such, this study investigates the possible economic effects of improvement in water clarity of lakes that currently exhibit low clarity. The study shows that improved water clarity could result in a significant improvement in property values as well as economic benefits to surrounding areas, such as increased tourism. Rising property values means increased property taxes and potentially increased government revenue. Improving water clarity is not without costs however. Therefore, communities need to investigate whether the economic benefits exceed the costs associated with water clarity improvement and if there is a clear case to be made for said improvements.[2]

This study seeks to better understand the value increase increments likely to be associated with improvements in water clarity. From this, it will be possible to estimate the likely economic benefits to both the private and public sector. The goal is to produce better informed and economically sound environmental remediation, and an improvement in the already impressive natural resources.

Outline of the Study

The discussion of the case study research will proceed as follows. First, an overview and brief history of the twenty lakes chosen for the study area is given. Then, the method of analysis used for the study and a brief primer on hedonic modeling are presented. An overview of the relevant literature and a discussion of the sources of the data used are also included. Next, the specific model used to conduct the analysis is described in detail. A two-stage hedonic model is used, which is similar to the models in other studies of this type. Some of the problems encountered during the construction of the model and the steps taken to remedy these issues are discussed.

The study analysis section reviews the model output. This section covers the expected economic gains associated with improved water clarity in the private sector (property prices) and the public sector (valuations for property taxes). Specific numbers are given for Lake Chetac (the

1. For example, see Charles Krysel, Elizabeth Marsh Boyer, Charles Parson, and Patrick Welle, *Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Region* (Legislative Commission on Minnesota Resources, May 14, 2003).

2. While there are certainly other measures of water quality (color, odor, bacteria, etc.) this study focuses solely upon water clarity and its economic impacts. This is not to suggest that other measures of quality are not important, but they are merely beyond the scope of this study.

primary focus of this study) and for a sampling of lakes at either end of the clarity spectrum. For all other lakes within the study area, the data and formulae needed to calculate the direct economic effects are given.

Finally, the conclusion section reviews the two basic factors driving the marginal economic benefits associated with improved water clarity. These are, in order of importance, the existing level of clarity and the current level of economic development. The results show that property values improve with any improvement in water clarity on any of the lakes in the study area. That said, the improvement in values (marginal change) is greatest on those lakes that currently have low levels of clarity and where the current level of economic development is the least. In this way, the research results provide a clear and straightforward method for understanding the areas in which the economic benefits can be expected to be the greatest.

Case Study Area

Study Area

Initially, 24 lakes in Northern Wisconsin were chosen for the study. A large number of lakes were chosen to ensure that a statistically significant number of properties could be obtained. Lakes were selected for the study based on the following attributes: distance from a major city (i.e., lakes not located in or adjacent to a metropolitan area), lakes with a significant number of recently sold properties, lakes that have at least 15 separate water clarity readings conducted by the Wisconsin Department of Natural Resources (DNR), and lakes that are not part of a reservation or state/national park.[3] Four of the initial 24 lakes in the study—Castle Rock Lake, Sand Lake, Grindstone Lake, and Metonga Lake—had to be dropped from the study due to unavailability or the lack of water quality readings. Two lakes, Lake Chetac and Birch Lake, are a lake chain and are treated as one lake in the study. The final study data set includes twenty lakes with 324 residential properties (228 homes and 96 empty lots) sold during the most recent year data was available (2014). Each lake is described below, and Exhibit 1 shows the location of each lake.

Description of Lakes

1. Lake Chetac/Birch Lakes.

- *Mean Annual Secchi Disk Reading:* 4 feet
- *Remediation Initiatives:* The Big Chetac Chain Lakes Association sponsored Curly Leaf Pond Weed Reduction Project on Lake Chetac, a three-year project beginning in 2013. This project focused on (1) control curly-leaf pondweed chemical, (2) pre/post treatment monitoring, (3) turion monitoring, (4) planting native aquatic plants, and (5) aquatic invasive species (AIS) education.

  Big Chetac Chain Lake Association sponsored a multiphase comprehensive lake management-planning project ("Getting Rid of the Green") in 2007 on Birch Lake. Phase One included (1) installing and recording of lake-level staff gauge, (2) monitoring water quality or sediment of the lake during the growing season, and (3) collecting data on stream flow measurements and water quality sampling. Phase Two included (1) estimating curly-leaf pondweed beds for comparison to previous mapping or survey, (2) collecting internal load calculations under various conditions for cores, and (3) installing fourteen mini piezometers.

2. Balsam Lake.

- *Mean Annual Secchi Disk Reading*: 7.63 feet
- *Remediation Initiatives*: Several projects were completed in 1994–2014. These projects were to (1) monitor the water quality of the lake, (2) develop aquatic plan management plan, (3) update and reprint an existing guidebook for controlling runoff and erosion on waterfront property, and (4) control aquatic invasive species. An ongoing project, originally proposed by the Balsam Lake Parks and Recreation District in 2015, has the goals of control of giant knotweed, and use of pre/post treatment of aquatic plants, herbicide, turion, and AIS monitoring.

3. Water quality readings refer to Secchi disk readings described in detail below. A Secchi disk is a painted round circular disk measuring 8 to 12 inches in diameter attached to rope or wire. The disk is lowered into the water when the disk is no longer visible from the surface the depth is recorded. Disks used by the Wisconsin DNR are a uniform size and are painted in a uniform black/white pattern. This is a standard measure by which the Wisconsin DNR determines water clarity. See dnr.wi.gov/lakes/waterquality/.

3. Red Cedar Lake.

- *Mean Annual Secchi Disk Reading:* 10.35 feet
- *Remediation Initiatives:* Projects include (1) control of curly leaf and purple loosestrife, (2) diagnostic and feasibility study of the lake, (3) observation of water quality and creation of a watershed map, and (4) education, prevention, and planning of the lake.

4. Long Lake.

- *Mean Annual Secchi Disk Reading:* 8.05 feet
- *Remediation Initiatives:* Past projects include (1) development and modification of lake management plan, (2) control or eradicate invasive species, (3) watercraft inspections, (4) aquatic plant chemical treatment, and (5) conduct social survey of residents or users.

  The FDL Long Lake Association plans to continue to monitor and control AIS on a lake-wide basis through 2018.

5. Sissabagama Lake.

- *Mean Annual Secchi Disk Reading:* 9.55 feet
- *Remediation Initiatives:* Projects in 1991–1997 were proposed to monitor water quality and build a quantitative database to determine changes that may occur. Big Sissabagama Lake Association sponsored a Clean Boats, Clean Water project in 2015 and 2016.

6. Whitefish Lake.

- *Mean Annual Secchi Disk Reading:* 13.45 feet
- *Remediation Initiatives:* Projects in 1997–2012 mainly focused on (1) monitoring water quality, (2) control aquatic invasion, and (3) AIS education. The Whitefish Lake Conservation Organization began sponsoring a Clean Boats, Clean Water project in 2013 and this project continued in 2016.

7. Petenwell Lake.

- *Mean Annual Secchi Disk Reading:* 2.42 feet
- *Remediation Initiatives:* Projects in 1996–1997 were proposed to conduct water quality modeling and monitor water quality. A restoration project in 2006 involved removal of sea walls, minor bank reshaping, placement of rip-rap, establishment of vegetative buffers and implementation if individual storm water management plans. Projects in 2006–2015 involved establishment of a Clean Boats, Clean Water program, AIS education, and habitat restoration.

8. Lake Lucerne.

- *Mean Annual Secchi Disk Reading:* 22.18 feet
- *Remediation Initiatives:* The Lake Lucerne Advancement Association, since 2008, sponsors an AEPP grant that focuses on increasing awareness of AIS issue near the lake. The Clean Boats, Clean Waters Project is ongoing since 2014.

9. Metonga Lake.

- *Mean Annual Secchi Disk Reading:* 22.94 feet
- *Remediation Initiatives:* Conducted a zebra mussel study in 2002–2003 to research the impacts of zebra mussels on Lake Metonga. Projects in 2005–2011 involved (1) AIS education, (2) control AIS, (3) comprehensive planning studies, and (4) Eurasian Water Milfoil (EWM) treatment. Lake Metonga Association Inc. has sponsored the Clean Boats, Clean Water project since 2013.

10. Shell Lake.

- *Mean Annual Secchi Disk Reading:* 14.45 feet
- *Remediation Initiatives:* A hydrologic budget and computer modeling project was initiated the Shell Lake Inland Lake Protection and Rehabilitation District in 1997 to collect data to determine hydraulic parameters and budget component. The City of Shell Lake conducted studies to determine the feasibility of a boat washing station for the effective removal of aquatic invasive species. The projects in 2003–2011 mainly focused on controlling invasive species.

11. Yellow Lake.

- *Mean Annual Secchi Disk Reading:* 5.88 feet
- *Remediation Initiatives:* The Burnett County Lakes and Rivers Association sponsored a two-year boat launch surveillance watercraft inspection, and public education project on five lakes beginning in 2006. An aquatic plant management plan was began in 2009 to monitor aquatic plant and educate lake residents.

12. Upper Eau Claire Lake.

- *Mean Annual Secchi Disk Reading:* 15.64 Feet
- *Remediation Initiatives:* An AIS project was conducted for 2005 to address concerns about EWM and its potential to spread to other lakes in the area. A small-scale planning grant to educate seventh graders about the lake in 2010 and 2013 respectively. A project in 2012–2016 involved: (1) monitor pre/post treatment, (2) information and education, (3) develop aquatic plan management plan, and (4) harvest aquatic plant mechanical.

13. Middle Eau Claire Lake.

- *Mean Annual Secchi Disk Reading:* 18.80 feet
- *Remediation Initiatives:* An AIS project was conducted for 2005 to address concerns about EWM and its potential to spread to other lakes in the area. A small-scale planning grant to educate seventh graders about the lake occurred in 2010 and 2013. Projects in 2012–2016 involved (1) monitoring pre/post treatment, (2) information and education, (3) developing aquatic plan management plan, and (4) harvesting aquatic plants.

14. Lower Eau Claire Lake.

- *Mean Annual Secchi Disk Reading:* 16.43 feet
- *Remediation Initiatives:* A project in 2004 was conducted to develop and modify lake management plan for the lake system that integrates with the town comprehensive land use plan. A small-scale planning grant to educate seventh graders about the lake in 2010.

15. Butternut Lake.

- *Mean Annual Secchi Disk Reading:* 3.47 feet
- *Remediation Initiatives:* The Internal Loading Assessment Project examined the internal phosphorus flux from sediments in Butternut Lake. A project sponsored by the Price County Land Conservation Department focused on modeling and monitoring water quality or sediment.

16. Devil's Lake.

- *Mean Annual Secchi Disk Reading:* 15.91 feet
- *Remediation Initiatives:* The Devil's Lake Property Owners Association sponsored an AIS prevention and education project in 2006 and 2008. A Clean Boats, Clean Water project was conducted in 2006–2015.

17. Round Lake.

- *Mean Annual Secchi Disk Reading:* 20.05 feet
- *Remediation Initiatives:* An EWM inspection project was conducted on shoreline areas near boat landings on Round Lake. Projects in 2007–2015 involved: (1) monitor and control aquatic invasive species, and (2) permit fee reimbursement for the maintenance and containment of AIS on Round Lake.

18. Lake Nebagamon.

- *Mean Annual Secchi Disk Reading:* 6.03 feet
- *Remediation Initiatives:* A survey was conducted to determine each septic system's compliance with state codes. Lake Planning Grant project was done to collect and disseminate local shoreline zoning regulation information to all shoreline property owners around Lake Nebagamon.

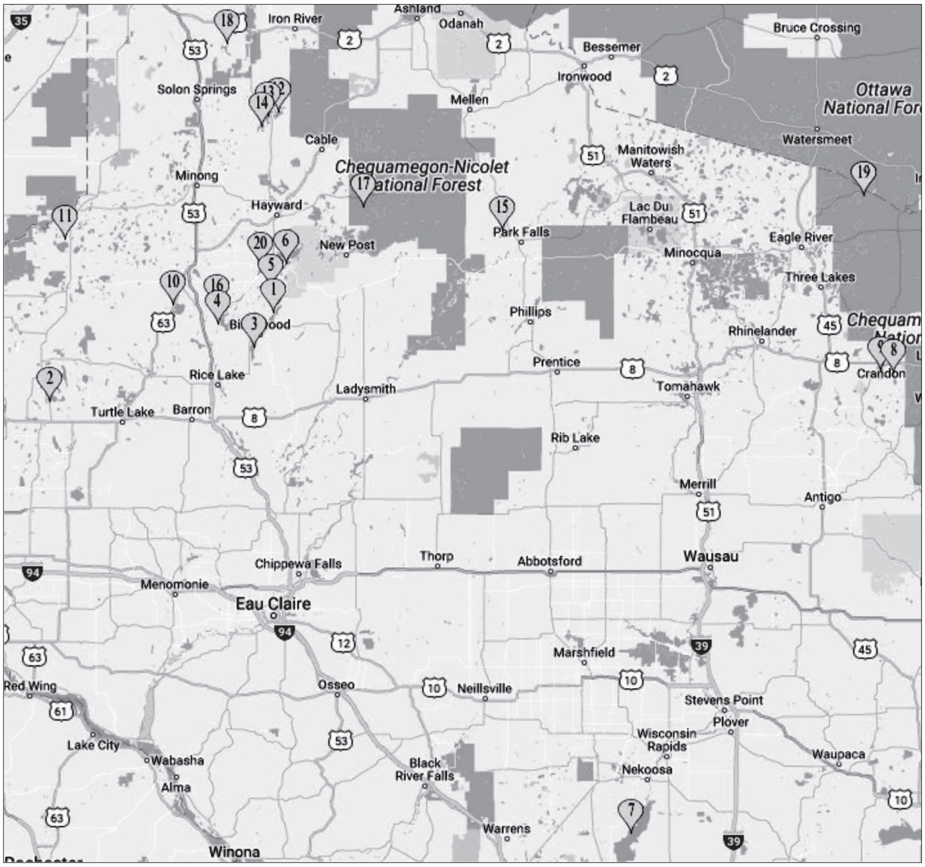
19. Big Sand Lake.

- *Mean Annual Secchi Disk Reading:* 10.09 feet
- *Remediation Initiatives:* Property owners were surveyed to estimate the demand for a project that would have purchased lab equipment for phytoplankton analysis to support expanding food-web monitoring.

20. Stone Lake.

- *Mean Annual Secchi Disk Reading:* 23.94 feet
- *Remediation Initiatives:* None

Exhibit 1 Locations of Case Study Lakes



Case Study Methodology

The case study uses hedonic modeling as its method of analysis. Hedonic modeling is a commonly used technique used to estimate the value of a specific attribute within a larger set of attributes associated with a specific commodity.[4] This technique uses home sales data to estimate the marginal contribution to value from specific property attributes; for example, how much would adding another bedroom to a given property add to its value? The most common usages include estimating the value of property improvements, the impact of public space on private property value, and the value impact of environmental attributes. The models do this by creating a statistical picture of each attribute of a given property. These attributes can then be isolated to determine the specific value added. If desired, the additional step can be taken to create a hypothetical situation to determine the economic benefit of making a change to that attribute. This can then be weighed against the costs associated with making the change to test the economic feasibility of the project.

Regression analysis is used to create a statistical picture of the attributes of a sample set of properties and serves as the foundation for hedonic

4. See Matt Monson, "Valuation Using Hedonic Pricing Models," *Cornell Real Estate Review* (2009) and Stephen Malpezzi, "Hedonic Pricing Models: A Selective and Applied Review" (working paper no. 5, University of Wisconsin Center for Urban Land Economic Research, 2002): 68–89, for a recent, more complete overview of the uses of hedonic modeling.

modeling. For studies that seek to determine the value of a specific environmental attribute the basic form of the regression generally is as follows:

$$P = f\,(S, L, E) \qquad (1)$$

where,

P = Sale price of the property
S = A vector of structural attributes
L = A vector of locational attributes
E = A vector of environmental attributes

From the estimated coefficients on each of the attributes within of the vectors, an estimate of the marginal value of each of those attributes can be developed.[5] This regression output is commonly referred to as the fundamental hedonic equation, and in more complicated studies (such as the one presented here) this is referred to as the "first stage equation." Attributes with estimated negative coefficients have a negative impact on property prices, while attributes with positive estimated coefficients have a positive effect on property prices. Here, it is expected that the estimated coefficient for water quality will have a positive coefficient. Conversely, the estimated coefficient on the local tax rate is expected to be negative. The research confirmed these expectations.

In the analysis, the "second stage equation" is derived from the first. This second stage creates a hypothetical demand curve or willingness to pay for the attribute in question. By summing the estimated constant as well as the mean value of all variables, and multiplying their estimated coefficients (excluding the variable of interest) it is possible to create a statistical picture of the average property—as if the attribute of interest did not exist. To create a statistical picture of the average property with the observed focus attribute, the mean value of that attribute can be added in and multiplied by its estimated coefficient. To test the impact of an alteration to the attribute, the altered value, multiplied by the previously estimated coefficient of the average property, can be added in.

To understand how this works, consider the decision to remodel a bathroom. The costs of doing so are not insignificant, and it is reasonable to investigate if the improvements would be worth the cost and effort in terms of the change to the expected value of the property. Using hedonic modeling, information would be gathered about the sale prices of a large number of houses. Some of the homes are large, some small, some of them have newly remodeled bathrooms, some have old bathrooms and some have in-between—the larger the sample the better, all things being equal. From this data, a regression analysis can be run.[6] The regression output will show how each of the attributes of the houses within the data set have impacted the sale prices of houses. This is the first stage equation discussed above.

From this, it is possible to create an "average house" in terms of both attributes and sale price. If the bathroom values are removed from this calculation, then it is possible to create the sale price of an average house—without a bathroom. Then, a bathroom can be added back in with the attributes being considered. From this, it is possible to determine the expected value of the property post renovation. Taking the value generated, the estimated value with the current attribute value is then subtracted to get an idea about how much value a change in the attribute (e.g., bathroom) is likely to generate.

Literature Review

There is a long but narrow set of literature on the economic value of water clarity stretching back to the 1960s. The issue that appears repeatedly in the early literature is the question of the best measure of water quality. That is, is quality or clarity a better determinant of property values? If it is clarity that matters, are subjective or objective measures better?

5. Each vector of attributes simply refers to the set of attributes of a given property. For example: Structural attributes would include items such as the number of bedrooms or whether there is an attached garage or not. The set of locational attributes might include things such as the proximity to shopping or schools. Incorporating a larger number of attributes into the model is not always desirable. In general, attributes should be tailored to the specific research question.

6. The presentation here is simplified for the purposes of explanation. In the development of the specific form of the regression careful consideration must be given to a variety of factors.

Early papers by David, and Epp and Al-Ani[7] use subjective valuations of water clarity to measure the impacts on property prices. The 1968 study by David uses a simple rating of good, moderate, and poor convey water quality. These were then added to other property attributes in a simple hedonic model to determine the impact of water clarity upon property prices. The David study finds that perceptions regarding water clarity have a significant impact upon property prices. The 1979 study completed by Epp and Al-Ani focuses on the impact of river water clarity on property prices. They find that water clarity has bearing upon property prices—but only in terms of a decrease in quality. That is, a perceived decline in quality caused prices to fall but a perceived improvement in quality did not cause prices to rise. However, Epp and Al-Ani find a consistent correlation between water acidity (as measured by pH) and property prices. This raises an interesting distinction between the perception of water quality and water quality itself.

This trend in the literature continues with a 1985 study by Brashares.[8] Using a hedonic model, this study focuses on many lakes in Southern Michigan and uses eight different measures of water quality. Brashares finds that only turbidity (an objective measure of clarity—similar to that used in this study) and fecal coliform have a significant impact on property prices. Brashares concludes that although perception of water clarity does impact property prices, water quality is most effectively captured with objective—rather than subjective—measures.

Some studies have focused specifically on the question of using objective versus subjective measures of value, and perception of quality (clarity) versus actual water quality as measured. A study by Steinnes[9] finds that it is the perception of water quality (clarity) rather than actual water quality that has the most significant bearing on property values, suggesting that subjectivity is an important factor. A later study by Poor et al.[10] finds significant differences between the economic values produced using subjective measures of water clarity and those produced using objective measures. Poor et al. find that subjective measures tend to underreport water clarity compared to objective measures (such as Secchi disk readings).[11] In the current case study, some preliminary tests on the subjective water clarity data were run, but no significant correlation was found between perceptions of water clarity and home prices. Indeed, there was little correlation between subjective measures and the objective measures. Also, it seems that the "Lake Woebegone" effect was in full play in the subjective measures, with clarity almost always being perceived as "better than average."

A 1996 study by Michael, Boyle, and Bouchard uses a hedonic model and data from a set of lakes in Maine to demonstrated the effect of water clarity on lakefront property prices.[12] In addition to the customary locational and structural variables, they use Secchi disk readings as an objective measure of water clarity. In developing the model, clarity data was converted into log form to better represent willingness to pay for improved water. That is, to convey that individuals are likely to pay more for an improvement of 1 foot to 4 feet of water clarity than for an improvement of 21 feet to 24 feet of clarity. (Both being an improvement of 3 feet.) The authors conclude that about 15% of the property value on the lakes in the study area was the result of water quality. They further conclude that an improvement of an additional 1 meter of clarity would roughly double the value associated with

7. Elizabeth L. David, "Lakeshore Property Values: A Guide to Public Investment in Recreation," *Water Resources Research* 4 no. 4 (1968): 697–707; Donald J. Epp and K. S. Al-Ani, "The Effect of Water Quality on Rural Nonfarm Residential Property Values," *American Journal of Agricultural Economics* 61, no. 3 (1979): 529–534.

8. E. Brashares, "Estimating the Instream Value of Lake Water Quality in Southeast Michigan." PhD dissertation, University of Michigan, 1985.

9. Donald Steinnes, "Measuring the Economic Value of Water Quality: The Case of Lakeshore Land," *Annals of Regional Science* 26, no. 2 (1992): 171–176.

10. Joan Poor, Kevin J. Boyle, Laura O. Taylor, and Roy Bouchard, "Objective versus Subjective Measures of Water Clarity in Hedonic Property Value Models," *Land Economics* 77, no. 4 (2001): 482–493.

11. Poor et al. suggest that property owners underreport clarity because of the reflective effects when the water is viewed from an angle.

12. Holly J. Michael, Kevin J. Boyle, and Roy Bouchard, *Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes* (Maine Agricultural and Forest Experimentation Station, University of Maine, Miscellaneous Report 398, 1996).

water quality on property prices. In terms of total property prices, the study results suggest about a 15% improvement in the sale price of property adjacent to the lake.

Subsequent studies by Boyle et al. and Krysel et al.[13] use models very similar to the one described above. These studies produce similar results, with a rough doubling of the value attributable to water clarity being associated with an improvement of an additional 1 meter of clarity for lakes with low initial water clarity.

Based on the studies in literature, it appears that the use of hedonic models combined with objective measures of water clarity (rather than quality) have become the industry standard when attempting to uncover the implicit value of water clarity on property prices.

Data Sources

For the current study, water quality data was obtained using Wisconsin DNR reports for twenty Northern Wisconsin lakes.[14] The Wisconsin DNR reports are published several times a year at irregular intervals for most lakes and include data on water clarity. Average reported data over the prior three years was used.[15] The water clarity data is collected and reported in two ways—one objective and one subjective. First, Secchi disks are used to measure the maximum water depth at which an object may be observed from the surface. Second, the water clarity is rated on a scale of 1 to 5 (1 being the highest rating) on the perception of clarity.[16] For the study, statistical tests were run on both measures, which will be discussed in the next section.

The housing prices and attributes were taken from the website Zillow.com. To verify the accuracy of the data, a sampling was checked against records with the respective county assessors offices. The prices and attributes of all houses and vacant properties sold in the last year over the study area were used. Following the attributes used by Michael, Boyle, and Bouchard, data was gathered on the following structural attributes:

- Square footage of living area (zero for empty lots)
- Number of stories
- Fireplace
- Heat
- Electric heat
- Basement
- Deck
- Plumbing
- Septic system
- Garage
- Lot size (acres)

Information was also collected for the following locational attributes:

- Public road
- Local tax rate
- Distance from an incorporated city
- Lake area

While it certainly is possible to develop a longer list of attributes for the given set of properties, this list has been shown in previous studies to be sufficient to generate statistically significant results. Also, these variables are nearly always mentioned in the original property listing. To include variables that exist for only a portion of the listings would be akin to comparing apples and oranges. In the rare cases where the specific attributes of a listing were unknown, the site was assumed to not have said attribute. For example, if no fireplace was mentioned in the listing, a value of zero was assigned for that attribute in that listing (binary variable). For properties that were simply a vacant lot, all structural variables were assigned a value of zero. Finally, the water quality attributes were added. Properties were removed that were on lakes with

13. Kevin J. Boyle, Steven R. Lawson, Holly J. Michael, and Roy Bouchard, *Lakefront Property Owners' Economic Demand for Water Clarity in Maine Lakes* (Maine Agriculture and Forest Experiment Station, University of Maine, Miscellaneous Report 410, 1998); Krysel et al. *Lakeshore Property Values and Water Quality*.
14. Reports available at http://dnr.wi.gov/lakes/waterquality/. These reports are available free to the public and, in many cases, date back several years.
15. Averages were used as water clarity can change over the course of the season. The numbers used here represent the average value over three years of readings prior to home sales.
16. Results outlined in this study use only the objective measurements of water clarity. Reports on water clarity are filed by trained volunteers and Wisconsin DNR staff using material provided by Wisconsin DNR. Further details on who, how, and when water clarity studies are done can be found at the Wisconsin DNR website, http://dnr.wi.gov/lakes/clmn/.

fewer than 10 houses or parcels of land sold over the prior three years. This produced a sample size of 324 listings.

The Model

The model used in the current study is based on the one developed by Michael, Boyle, and Bouchard. Specifically, Secchi disk readings are used as an objective measure of water clarity and applied to a standard two-stage hedonic model. This model formed the basis of several subsequent studies of the impact of water clarity on housing prices, and it has been shown to generate reliable results.[17] The model used here includes a few notable changes to take account of data availability and to test for anomalies noted in the literature.

This study uses the sale price of the property as the dependent variable rather than the sale price per linear footage of lake frontage, which was used in the Michael, Boyle, and Bouchard model. The reason for this modification is that data was not available for most of properties within the study area. Given the rarity of irregular shaped lots within the study area, however, the included variables for lot size and square feet of living area (both of which were significant in all regressions) capture much the same information.

Three separate linear regressions are run in the analysis.[18] (These regression outputs are the first stage equations discussed earlier.) The first regression used all the variables listed in the previous section as well as one of the following: the log of mean annual water clarity in feet (Secchi disk reading), or water perception (on a scale of 1 to 5).[19] The second regression again used all the above-mentioned variables but removed the observations associated with the sale of vacant lots. The final regression removed several of the above variables and was run to test some potential unusual outcomes associated with the first two; this will be discussed further in the next section.

In each case, the regression output was first used to construct a statistically average valuation for each lake—excluding the value attributable to water quality. This allows for variation between lakes in terms of the types of properties that exist on the lake.[20] One way of thinking about this would be as the average value of the set of houses on a given lake within the study if the lake were not there. This was accomplished by taking the sum of the mean value for each lake of each of the variables multiplied by the estimated coefficient for that variable. To this, the estimated constant term of the regression was added to complete the picture (equation 2).

$$\begin{aligned} &a = \textit{Estimated value of } c \\ &+ (\textit{mean value of } a * \textit{est. coefficient of } a) \\ &+ (\textit{mean value of } b * \textit{est. coefficient of } b) + \ldots \\ &+ (\textit{mean value of } x * \textit{est. coefficient of } x) \qquad (2) \end{aligned}$$

Next, the observed water quality is added; for example, on Lake Chetac the mean annual Secchi disk reading of 4 feet. This provides an estimate of what the average house, on a given lake, would sell for given all its attributes. Equation 3 shows the formula used in this computation.

$$\begin{aligned} &\textit{Est. Price} = a + (\textit{Log of Water Quality on Lake } x \\ &* \textit{estimated coefficient for water quality}) \qquad (3) \end{aligned}$$

The table in Exhibit 2 gives the values used for each lake to complete the analysis. In Exhibit 2, the "A" columns represent the mean value of all attributes on a lake, excluding water quality for each of tested hypothesis. In other words, column A represents the average value of a property on that lake as though the lake did not exist. The "B" columns are the estimated coefficients for water quality. The table shows the estimated values using all the properties within the data set, the estimated values when the vacant lots are removed from the set of data, and the estimated values with the reduced attribute set. The table also shows the mean values for water clarity for each lake.

The values in Exhibit 2 show that the average property on Lake Chetac would sell for an estimated $179,000 without the value added by the

17. For example, see Krysel et al. *Lakeshore Property Values and Water Quality*.

18. Regression outputs can be found in the appendices.

19. All other studies that estimate the economic value of water quality use the log function form. This is done to reflect the fact that willingness to pay for water quality is not linear. That is, people are generally willing to pay more to improve water clarity from 1 foot to 3 feet than they are willing to pay to improve water clarity from 22 feet to 24 feet. (Both being an improvement of two additional feet.)

20. For example, some of the lakes in the study area are highly developed with large high-value properties on them. Other lakes are not nearly as developed in all aspects. Creating different statistical pictures for each lake allows us to account for these differences.

Exhibit 2 Results, Three Linear Regressions

Lake	All Properties		Properties with Houses		Limited Variable		Mean WATERQ (m)
	A	B	A	B	A	B	
Lake Chetac	$179,071	46459.33	$196,072	45292.89	$145,906	66046.22	1.22
Birch Lake	$181,471	46459.33	$187,721	45292.89	$158,523	66046.22	1.22
Balsam Lake	$485,299	46459.33	$492,952	45292.89	$403,674	66046.22	2.32
Red Cedar Lake	$230,689	46459.33	$262,320	45292.89	$164,657	66046.22	3.15
Long Lake	$306,743	46459.33	$293,973	45292.89	$262,086	66046.22	2.44
Sissabagama Lake	$157,429	46459.33	$191,547	45292.89	$76,723	66046.22	2.90
Whitefish Lake	$411,802	46459.33	$416,948	45292.89	$354,273	66046.22	4.10
Petenwell Lake	$241,060	46459.33	$306,942	45292.89	$220,935	66046.22	0.74
Lake Lucerne	$262,544	46459.33	$266,131	45292.89	$199,427	66046.22	6.76
Metonga Lake	$184,561	46459.33	$202,936	45292.89	$143,617	66046.22	7.00
Shell Lake	$160,496	46459.33	$168,527	45292.89	$136,473	66046.22	4.43
Yellow Lake	$237,198	46459.33	$250,313	45292.89	$206,103	66046.22	1.78
Eau Claire (Upper)	$266,770	46459.33	$266,641	45292.89	$187,206	66046.22	4.77
Eau Claire (Middle)	$113,368	46459.33	$139,951	45292.89	$42,407	66046.22	5.73
Eau Claire (Lower)	$81,424	46459.33	$115,462	45292.89	$23,283	66046.22	5.01
Butternut Lake	$116,013	46459.33	$132,159	45292.89	$78,750	66046.22	1.06
Devil's Lake	$257,164	46459.33	$251,201	45292.89	$247,673	66046.22	4.86
Round Lake	$254,495	46459.33	$282,801	45292.89	$194,519	66046.22	6.11
Lake Nebagamon	$204,001	46459.33	$200,816	45292.89	$161,428	66046.22	1.84
Big Sand Lake	$236,274	46459.33	$246,586	45292.89	$201,429	66046.22	3.06
Stone Lake	$182,472	46459.33	$163,917	45292.89	$216,294	66046.22	7.29
Combined	**$218,562**	**46459.33**	**$238,142**	**45292.89**	**$175,331**	**66046.22**	**3.75**

Notes: The "A" columns represent the estimated average property value without the attribute of being located on the lake and the estimated average value associated with being on the lake (at existing clarity levels) for each of the three regressions run. The "B" columns represent the estimated coefficient for water quality. The first regression includes all properties in the sample, the second excludes all properties without houses, and the third includes all properties but with a much more limited set of attributes. The final column gives the existing water clarity in meters.

lake. Later, when the lake with existing water quality is added, the estimate increases to $243,400. When the vacant properties are removed from the data set, the estimated value of the average lake property increases to $196,000. Finally, when several property attributes are removed from the whole data set the estimated average Lake Chetac property value falls to about $146,000. Each of these changes in value are each as would be expected.

Using the values in Exhibit 2, it is possible change the water quality to a hypothetical level to estimate the value of the average property on a given lake with that alternative water quality. For example, a later section of this article will show estimates for a 1-foot and 3-foot increase in water clarity on several of the lakes in the study. This is the "second stage" analysis mentioned above.

Extensions and Concerns

Exhibit 2 shows the results of the three separate regressions run to estimate the impact of water quality upon property prices. The second and third regression were applied to address issues discussed in the literature. Also, the additional analysis was warranted based on some unexpected outputs in the regression to ensure that these results were not biasing the estimated values.

The first regression included all the variables mentioned, and it is the basis of the study conclusions.[21] Several of variables had estimated coefficients that had signs opposite of what would be expected. For example, the coefficient for the variable *DECK* was estimated to be negative and was statistically significant. Since it is unreasonable to suggest that the presence of an outdoor deck reduces the value of a property some concerns were raised. An investigation of the source data revealed that in several instances a deck was visible in the pictures but was not mentioned in the listing. Since all variables were defaulted to zero, this meant that any structural attribute not mentioned in the listing was assumed to not be present. This led to two hypotheses: first, listings for larger properties may not be including all the attributes of the property; and second, large vacant properties in the study might be biasing the sample. To test these two hypotheses, two additional regressions were run.

The second regression removed all the vacant properties from the sample[22] to ensure that the presence of large—and expensive—vacant lakefront properties were not having a significant impact on the value of the amenities within the developed properties. The second regression output shows, however, that this was not the case. Indeed, removing undeveloped properties had little impact on the estimated impact of water clarity on property prices (about a 1% change in most cases). The estimated values of this second sample can be seen in Exhibit 2.

The third regression removed several of the structural attributes to attempt to test the significance of the non-reporting problem noted in the data. The estimated values of this new sample can be seen in Exhibit 2's "Limited Variable" column. All locational attributes were retained. Removing several attributes had the effect of putting more weight on the remaining attributes in the sense that they are being asked to provide additional explanatory power.[23] As would be expected, this had a larger effect on the estimated impact of water quality on property prices. (As it did for all other remaining attributes.) However, the associated *r*-squared fell significantly (from 0.519 to 0.48), suggesting that the explanatory power of this final model was inferior to the original one.[24] This indicates that the nonreporting of certain property attributes did not reduce the effectiveness of the model.

Multicollinearity is a common problem with models of this type. Briefly stated multicollinearity is the idea that two or more of the independent variables are correlated. For example, it might be expected that larger, more expensive houses are built on lakes with clearer water. Or, it

21. This first regression produced an *r*-squared of 0.519 and an *F*-statistic of 23.23.

22. Regression outputs can be found in Appendix 2.

23. To understand consider the case where all explanatory variables are removed excepting one. Our regression output would give the relationship between only those two variables. The relationship between the two might be strong but the explanatory power of one upon the other would very likely be poor.

24. *R*-squared is a statistical measure of the explanatory power of the regression output. That is, the correlation between the independent and dependent variables. All things being equal a higher *r*-squared indicates greater explanatory power. (*R*-squared values for all regressions can be found in Appendix 2.)

Exhibit 3 Variable Correlation Matrix

	Price	STORY	LVAREA (sqft)	FIRE	HEAT	ELHEAT	BSMNT	DECK	PLUMB	SEPTIC	GARAGE	LOTSZ (acres)	TAXRT	DIST	LKAREA (acres)	WQ Min (ft)	WQ Min (m)	WQ Mean (ft)	WQ Mean (m)	WQ Max (ft)	WQ Max (m)	lnWQ (ft)
Price	1.00	0.36	0.67	0.32	0.14	0.06	-0.01	0.14	0.30	0.11	0.25	0.07	-0.09	0.06	-0.05	0.15	0.14	0.12	0.12	0.03	0.03	0.14
STORY	0.36	1.00	0.52	0.35	0.22	0.01	0.15	0.35	0.36	0.22	0.35	0.01	0.06	0.02	-0.09	0.06	0.06	0.05	0.05	0.03	0.03	0.07
LVAREA (sqft)	0.67	0.52	1.00	0.53	0.27	0.01	0.15	0.37	0.65	0.34	0.53	-0.01	0.00	-0.07	-0.09	0.03	0.03	0.01	0.01	-0.02	-0.02	0.03
FIRE	0.32	0.35	0.53	1.00	0.24	0.03	0.20	0.41	0.58	0.36	0.47	-0.02	-0.03	0.01	-0.13	0.08	0.08	0.06	0.06	0.03	0.03	0.07
HEAT	0.14	0.22	0.27	0.24	1.00	0.05	0.20	0.29	0.38	0.44	0.38	-0.04	0.07	0.08	-0.20	0.15	0.15	0.11	0.11	0.06	0.06	0.10
ELHEAT	0.06	0.01	0.01	0.03	0.05	1.00	0.09	0.06	0.15	0.08	0.04	0.01	-0.09	0.05	-0.08	0.06	0.06	0.06	0.06	0.06	0.06	0.10
BSMNT	-0.01	0.15	0.15	0.20	0.20	0.09	1.00	0.36	0.36	0.35	0.36	0.00	0.04	0.10	-0.10	0.07	0.07	0.05	0.05	0.04	0.04	0.01
DECK	0.14	0.35	0.37	0.41	0.29	0.06	0.36	1.00	0.48	0.42	0.48	-0.02	0.05	0.04	-0.09	0.11	0.11	0.07	0.07	0.02	0.02	0.01
PLUMB	0.30	0.36	0.65	0.58	0.38	0.15	0.36	0.48	1.00	0.61	0.63	-0.02	-0.04	0.02	-0.27	0.10	0.10	0.08	0.08	0.08	0.08	0.08
SEPTIC	0.11	0.22	0.34	0.36	0.44	0.08	0.35	0.42	0.61	1.00	0.56	-0.08	-0.09	0.08	-0.30	0.19	0.19	0.17	0.17	0.15	0.15	0.15
GARAGE	0.25	0.35	0.53	0.47	0.38	0.04	0.36	0.48	0.63	0.56	1.00	-0.05	0.03	0.06	-0.13	0.14	0.14	0.10	0.10	0.07	0.07	0.03
LOTSZ (acres)	0.07	0.01	-0.01	-0.02	-0.04	0.01	0.00	-0.02	-0.02	-0.08	-0.05	1.00	0.01	0.07	-0.02	0.12	0.12	0.08	0.08	0.04	0.04	0.01
TAXRT	-0.09	0.06	0.00	-0.03	0.07	-0.09	0.04	0.05	-0.04	-0.09	0.03	0.01	1.00	0.02	0.36	-0.21	-0.20	-0.25	-0.25	-0.25	-0.25	-0.27
DIST	0.06	0.02	-0.07	0.01	0.08	0.05	0.10	0.04	0.02	0.08	0.06	0.07	0.02	1.00	-0.25	0.62	0.62	0.59	0.59	0.48	0.48	0.49
LKAREA (acres)	-0.05	-0.09	-0.09	-0.13	-0.20	-0.08	-0.10	-0.09	-0.27	-0.30	-0.13	-0.02	0.36	-0.25	1.00	-0.44	-0.43	-0.43	-0.43	-0.43	-0.44	-0.54
WQ Min (ft)	0.15	0.06	0.03	0.08	0.15	0.06	0.07	0.11	0.10	0.19	0.14	0.12	-0.21	0.62	-0.44	1.0 0	1.00	0.94	0.94	0.78	0.78	0.70
WQ Min (m)	0.14	0.06	0.03	0.08	0.15	0.06	0.07	0.11	0.10	0.19	0.14	0.12	-0.20	0.62	-0.43	1.00	1.00	0.94	0.94	0.78	0.78	0.70
WQ Mean (ft)	0.12	0.05	0.01	0.06	0.11	0.06	0.05	0.07	0.08	0.17	0.10	0.08	-0.25	0.59	-0.43	0.94	0.94	1.00	1.00	0.93	0.93	0.83
WQ Mean (m)	0.12	0.05	0.01	0.06	0.11	0.06	0.05	0.07	0.08	0.17	0.10	0.08	-0.25	0.59	-0.43	0.94	0.94	1.00	1.00	0.93	0.93	0.83
WQ Max (ft)	0.03	0.03	-0.02	0.03	0.06	0.06	0.04	0.02	0.08	0.15	0.07	0.04	-0.25	0.48	-0.43	0.78	0.78	0.93	0.93	1.00	1.00	0.84
WQ Max (m)	0.03	0.03	-0.02	0.03	0.06	0.06	0.04	0.02	0.08	0.15	0.07	0.04	-0.25	0.48	-0.44	0.78	0.78	0.93	0.93	1.00	1.00	0.84
lnWQ (ft)	0.14	0.07	0.03	0.07	0.10	0.10	0.01	0.01	0.08	0.15	0.03	0.01	-0.27	0.49	-0.54	0.70	0.70	0.83	0.83	0.84	0.84	1.00

might be expected that larger houses are built on larger lots. A significant amount of correlation can bias estimates of the impact of any one variable on the dependent variable—home prices in this case.[25] Indeed, a certain degree of multicollinearity is almost unavoidable when trying to understand the impact of various factors on housing prices.[26] In order to better understand the degree of multicollinearity in the results, a correlation matrix was generated, as shown in Exhibit 3. This table gives the correlation of each variable with every other variable. Higher absolute values imply stronger correlations.

Several items are of note in the correlation matrix. First, water clarity (ln*WQ*) is virtually uncorrelated with square feet of living space (*LVAREA*) or lot size (*LOTSZ*). It is therefore not the case that people are building larger, more expensive houses on larger properties on clearer lakes. It is also apparent that water clarity is not strongly correlated with any of the housing attributes. Thus, the possibility that housing attribute impacts are significantly mixed up in the estimates of water clarity impacts is limited.

It is also interesting that both the presence of a septic system (*SEPTIC*) and distance (*DIST*) from a metro area are correlated with clearer water. These would seem to support the notion that lack of water clarity is often the result of increased runoff from agriculture and other human-based activities.[27] Proof of this inference, however, is beyond the scope of this study and should be the focus of future studies.

Finally, following up on the work of Steinnes' and others regarding subjective versus objective measures of water clarity, several regressions were run using the subjective measures of water clarity from the Wisconsin DNR reports. Using this data, it was not possible to derive statistical significance with any of the above-mentioned models. As such, there did not appear to be any clear connection between water perception and property prices. This inconsistency with some prior studies may be due to the way this data is collected. Using a simple scale of 1 to 5, subjectively determined, perhaps makes it difficult for individuals collecting the data to make an evaluation that corresponds to the valuations being made by other data reporters in different locations. Consistent with some studies in the literature, the subjective measures of water clarity were found to be unreliable in their ability to predict property prices. Surprisingly, there seemed to be a fairly low correlation between Secchi disk readings and water perceptions.

Results Analysis

Property Value Impacts

Using the output from the first regression, the estimated value impacts associated with changes to water clarity were derived.[28] Using Lake Chetac as an example, it was estimated that the economic value of the lake to the average property, at existing clarity, was approximately $64,400 ($243,400 – $179,000). If clarity is increased by 1 foot, then it is estimated that this would increase the property value associated with the lake to $74,700, resulting in an average property value of about $253,700. If clarity is increased by 3 feet, it is estimated that the value associated with the lake will increase to about $90,400, resulting in a total average property value of about $269,400—a little more than a 10% increase over the original estimated value. A summary of the estimated changes for all lakes within the study area can be seen in Exhibits 4 and 5.

In Exhibit 4, the column shows the estimated average property value with current water clarity. The second column gives the amount of value attributable to the current water quality. For example, the estimated value of the average property (with all attributes) on Lake Chetac is $243,477, and of that, $64,406 is attributable to the house's location on that lake with its existing water clarity. The third and fourth columns give the value attributed to the lake with

25. See Damodar N. Gujarati, *Basic Econometrics*, 3rd ed. (New York, NY: McGraw-Hill, 1995), 344–345.

26. See B. Kristom, "Applying Hedonics in Environmental Economics," in *Hedonic Methods in Housing Markets*, ed. A. Baranzini, J. Ramirez, C. Schaerer, and P. Thalmann (New York, NY: Springer, 2008), 247–269.

27. See Carolyn Betz and Patricia Howard, *Wisconsin Citizen Lake Monitoring Training Manual*, 3rd ed., Wisconsin Department of Natural Resources. Chapter 3 gives a lay explanation of the impact of runoff on water clarity. Available for download at http://bit.ly/CitizenMonitor.

28. The numbers presented in this paragraph are derived from the output associated with the first regression output. (Full attribute list and all properties included.)

improved water clarity in increments of 1 foot and 3 feet. The next column shows the property value with an additional 3 feet of clarity; mathematically, this is the first column minus the second column plus the fourth column. The last column on the right gives the percentage change in property values associated with an additional 3 feet of water clarity.

Using the numbers presented in Exhibit 2, similar calculations can be made for any amount of additional clarity for any other lake. For example, on Shell Lake the estimated average house value is $284,574, of which $124,079 is attributable to the property being located on the lake at its existing clarity level. If water clarity were to improve by 3 feet, the average property value would increase to an estimated $299,338, i.e., (284,574 –124,079) + $132,843. Completing the same calculation for Butternut Lake suggests that the expected property value would increase by $28,946. The same improvement in water clarity for Round Lake would increase the estimated average property value from $393,790 to $400,268—a 1.65% increase.

The changes in estimated values are similar when vacant properties are excluded from the sample data (Exhibit 5). Focusing again on Lake Chetac, Exhibit 5 shows that the estimated impact of improved water clarity on property values is only slightly different when vacant properties are excluded (only about a $2,000 difference in value compared with the Exhibit 4 estimate).

The results show that the size of the change in value is highly dependent on the current status of the lake. Lakes with very poor water quality will find that improvements have a very large effect, while lakes that already exhibit high levels of water clarity will see little benefit from increased clarity. For example, Butternut Lake (3.47 feet clarity) would be expected to experience a nearly $30,000 increase in the value per property if its water clarity improved by 3 feet. On the other hand, Round Lake (20.05 feet clarity) would expect to see only about $6,400 in increased valuation with an additional 3 feet of clarity. Note that Lake Chetac, used in the discussion examples, is near the bottom of the study group in terms of existing water clarity (4 feet). As such, it is expected that value gains for properties on this lake would be greater than average if water clarity improved.

Using the information in Exhibits 4 and 5, the aggregate impact to property values associated with improved lake water clarity can be determined for any of the lakes in the study area. This computation is as follows:

$$\textit{Change in valuation} = N * \textit{estimated change in average property valuation} \tag{4}$$

where,

N = number of properties adjacent to the lake

For example, Lake Chetac, with approximately 400 properties, potentially could see a total expected change in value of around $10.4 million dollars.[29] Using the 2015 average property tax rate (1.085%) for Sawyer County, where Lake Chetac is located, the value increase translates to an annual increase of $112,800 in potential county property taxes collected. The property value increase provides an approximation of the direct private sector benefits of an additional 3 feet of water clarity, while the tax figure estimates the public sector benefit. These same methods could be applied to any of the lakes in the study area to arrive at the direct benefits associated with improvements in water clarity.

These figures give only the direct benefits associated with the change in water clarity. It is very likely that other indirect benefits would result from the improvements. For example, several studies have pointed to the correlations between water clarity and tourism.[30] For some areas with lakes in the case study, it is highly likely that if lake water quality improved there would be increased tourism and the associated economic benefits to commercial establishments on and near the lake.

29. This figure is computed as follows: (400 properties) * ($26,000) – (expected average change in property valuation). This estimate does not take into account of rising property values near but not adjacent to the lake. If the estimated values from the third regression output are used, the results suggest an increased value $7.4 million, and consequently, an $80,200 annual increase in property taxes.

30. For recent examples, see Lee-Hsueh Lee and Yan-De Lee, "The Impact of Water Quality on the Visual and Olfactory Satisfaction of Tourists," *Ocean and Costal Management* 105 (March 2015): 92–99; Marina Farr, Natalie Stoeckl, Michelle Esparon, Silva Larson, and Diane Jarvis, "The Importance of Water Clarity to Great Barrier Reef Tourists and Their Willingness to Pay to Improve It," *Tourism Economics* 22, no. 2 (2016): 331–352.

Exhibit 4 Lake Property Values Related to Clarity, All Properties

Lake	Est. Average Property Value ($)	Water Attribute Value ($) Current Clarity	+1 ft. Clarity	+3 ft. Clarity	Value Increase ($), +3 ft. Clarity	Value Increase (%), +3 ft. Clarity
Lake Chetac	243,477	64,406	74,773	90,406	25,999.37	10.68
Birch Lake	245,878	64,406	74,773	90,406	25,999.37	10.57
Balsam Lake	579,709	94,409	100,131	109,815	15,405.56	2.66
Red Cedar Lake	339,264	108,575	112,860	120,400	11,825.29	3.49
Long Lake	403,642	96,899	102,339	111,615	14,716.38	3.65
Sissabagama Lake	262,266	104,837	109,464	117,529	12,691.74	4.84
Whitefish Lake	532,549	120,747	124,079	130,101	9,354.42	1.76
Petenwell Lake	282,119	41,059	57,128	78,521	37,461.47	13.28
Lake Lucerne	406,530	143,986	146,035	149,880	5,893.79	1.45
Metonga Lake	330,113	145,552	147,534	151,262	5,710.04	1.73
Shell Lake	284,574	124,079	127,187	132,843	8,764.33	3.08
Yellow Lake	319,503	82,305	89,602	101,458	19,152.62	5.99
Eau Claire (Upper)	394,526	127,755	130,635	135,908	8,152.59	2.07
Eau Claire (Middle)	249,673	136,305	138,713	143,183	6,878.45	2.75
Eau Claire (Lower)	211,469	130,045	132,790	137,836	7,791.66	3.68
Butternut Lake	173,815	57,803	69,568	86,748	28,945.16	16.65
Devil's Lake	385,714	128,551	131,383	136,576	8,025.53	2.08
Round Lake	393,790	139,045	141,557	145,774	6,478.13	1.65
Lake Nebagamon	287,477	83,476	90,604	102,236	18,760.53	6.53
Big Sand Lake	343,667	107,393	111,783	119,486	12,093.54	3.52
Stone Lake	330,006	147,534	149,435	153,019	5,485.06	1.66
Combined	**335,126**	**116,564**	**120,198**	**126,710**	**10,145.91**	**3.03**

Notes: The table gives (1) the estimated property value at existing water clarity, (2) the estimated value of the waterfront attribute at the existing level of clarity, (3) the estimated value of the waterfront attribute at an additional 1 foot of clarity, (4) the estimated value of the waterfront attribute at an additional 3 feet of clarity, (5) the estimated added value with an additional 3 feet of clarity, and (6) the estimated change in property value with an additional 3 feet of water clarity. All values were derived using the full regression results.

Exhibit 5 Lake Property Values Related to Clarity, Only Properties with Houses

Lake	Est. Average Property Value ($)	Water Attribute Value ($) Current Clarity	+1 ft. Clarity	+3 ft. Clarity	Value Increase ($), +3 ft. Clarity	Value Increase (%), +3 ft. Clarity
Lake Chetac	258,861	62,789	72,896	88,136	25,346.62	9.79
Birch Lake	250,510	62,789	72,896	88,136	25,346.62	10.12
Balsam Lake	584,991	92,039	97,617	107,058	15,018.78	2.57
Red Cedar Lake	368,168	105,849	110,026	117,377	11,528.39	3.13
Long Lake	388,439	94,466	99,770	108,813	14,346.90	3.69
Sissabagama Lake	293,753	102,205	106,716	114,578	12,373.09	4.21
Whitefish Lake	534,663	117,715	120,963	126,835	9,119.56	1.71
Petenwell Lake	346,971	40,028	55,694	76,549	36,520.94	10.53
Lake Lucerne	406,502	140,371	142,369	146,117	5,745.81	1.41
Metonga Lake	344,833	141,897	143,830	147,464	5,566.68	1.61
Shell Lake	289,491	120,963	123,994	129,508	8,544.29	2.95
Yellow Lake	330,552	80,239	87,353	98,911	18,671.76	5.65
Eau Claire (Upper)	391,189	124,548	127,355	132,496	7,947.91	2.03
Eau Claire (Middle)	272,834	132,883	135,230	139,589	6,705.75	2.46
Eau Claire (Lower)	242,242	126,780	129,456	134,376	7,596.04	3.14
Butternut Lake	188,510	56,351	67,821	84,570	28,218.44	14.97
Devil's Lake	376,524	125,323	128,084	133,147	7,824.03	2.08
Round Lake	418,600	135,798	138,003	142,114	6,315.49	1.51
Lake Nebagamon	282,196	81,380	88,330	99,669	18,289.51	6.48
Big Sand Lake	351,283	104,697	108,977	116,486	11,789.91	3.36
Stone Lake	307,747	143,830	145,683	149,177	5,347.35	1.74
Combined	**351,779**	**113,637**	**117,180**	**123,528**	**9,891.18**	**2.81**

Note: This table is the same as in Exhibit 4, but the results were derived using the limited sample regression output. This regression eliminated all properties that did not have houses on them.

Conclusions

This study demonstrates a clear economic rationale for the improvement of water clarity. Using a two-stage hedonic model, the case study analysis estimates that a 3-foot improvement in water clarity would increase property values by 1%–16%. The variation is largely dependent on existing water clarity and the degree to which the lake is already economically developed. Lakes with lowest water clarity—such as Lake Chetac, Petenwell Lake, and Butternut Lake—would see an improvement of 9%–16%. The figures for these lakes are much higher than for others within the study area because the willingness to pay for given improvements is likely higher on lakes where clarity is poor. That is, people are likely to pay more for a 3-foot improvement in clarity when the current level is just a few feet than they would if the current clarity were 20 feet.

The differences in value increases also are related to the existing level of development on the lake. For example, properties on Butternut Lake would be expected to experience a greater gain in property values than properties on Petenwell Lake—even though Butternut Lake's clarity is worse. The reason for this is the properties adjacent to Lake Petenwell are larger and have more amenities when compared to Butternut Lake properties.[31] Therefore, any changes to the overall property picture can be expected to have a smaller marginal component.

From this research, it can be concluded that the marginal economic benefits of improvements in water clarity are most significant when applied to lakes with low existing clarity and even more so when the surrounding areas have low levels of economic development (smaller houses with fewer amenities).

Of course, improvement efforts must be paid for, and generally the improvements have been undertaken by the public sector. For this reason, the local tax implications of water quality improvement have been estimated. Taken over just a few years, the potential property valuation differences are not insubstantial and conservatively can result in several hundred thousand dollars in additional tax revenue. If probable increases in tourism are taken into account, the potential additional revenues (state and local) rise substantially.

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31. The estimated average property value on Petenwell Lake is just under $347,000, while on Butternut Lake estimated average property value is only $188,000.

Appendix 1 Mean Values for Variables by Lake

Variable	Lake Chetac	Birch Lake	Balsam Lake	Red Cedar Lake	Long Lake	Sissabagama Lake	Stone Lake	Whitefish Lake	Petenwell Lake
STORY	0.13	0.07	0.67	0.25	0.40	0.17	0.33	0.38	0.16
LVAREA	1382.47	1583.86	2908.67	1575.63	2823.20	911.33	1840.11	2768.20	1265.19
FIRE	0.67	0.50	1.00	0.46	0.80	0.33	0.56	0.75	0.30
HEAT	0.27	0.21	0.00	0.04	0.20	0.33	0.44	0.63	0.03
ELHEAT	0.07	0.00	0.33	0.00	0.00	0.17	0.00	0.19	0.00
BSMNT	0.13	0.36	0.33	0.17	0.40	0.33	0.44	0.31	0.14
DECK	0.27	0.29	0.33	0.29	0.40	0.00	0.78	0.69	0.27
PLUMB	0.80	0.79	1.00	0.50	1.00	0.50	1.00	0.94	0.38
SEPTIC	0.40	0.57	0.33	0.46	0.40	0.50	0.89	0.75	0.05
GARAGE	0.53	0.57	0.67	0.50	0.80	0.33	1.00	0.75	0.38
LOTSZ	1.70	5.70	1.65	1.57	1.96	2.23	10.48	1.27	3.11
RDPUB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TAXRT	6.03	6.03	6.03	6.03	12.18	6.51	6.51	6.51	10.98
DIST	26.00	20.00	41.00	20.00	17.00	38.00	36.00	43.00	26.00
LKAREA	2400.00	364.00	1901.00	1897.00	423.00	805.00	87.00	848.00	23173.00
WATERQ (ft)	4.00	4.00	7.63	10.35	8.05	9.55	23.94	13.45	2.42
WATERQ (m)	1.22	1.22	2.32	3.15	2.44	2.90	7.29	4.10	0.74
WP	3.00	3.00	2.00	2.00	2.00	2.00	1.00	1.00	3.00

Note: Table includes mean values of all variables included in all regressions. The variables, *FIRE* (fireplace), *HEAT* (central heating), *ELHEAT* (electric central heating), *BSMNT* (basement), *DECK* (deck), *PLUMB* (indoor plumbing), *SEPTIC* (septic system), and *GARAGE* (garage) were treated as dummy variables. Other variables units are *STORY* (number of stories), *LVAREA* (square feet of living area), *LOTSZ* (size of lot in acres), *TAXRT* (combined local and state tax rate), *DIST* (distance to nearest city), and *LKAREA* (lake area in acres).

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Appendix 1 (*continued*)

Variable	Lake Lucerne	Metonga Lake	Shell Lake	Yellow Lake	Eau Claire (Upper)	Eau Claire (Middle)	Eau Claire (Lower)
STORY	0.24	0.27	0.38	0.27	0.38	0.08	0.13
LVAREA	1617.57	1309.80	1572.54	1594.67	1767.50	939.17	481.00
FIRE	0.52	0.53	0.46	0.40	0.75	0.25	0.25
HEAT	0.33	0.27	0.31	0.20	0.38	0.42	0.13
ELHEAT	0.10	0.07	0.12	0.20	0.00	0.08	0.00
BSMNT	0.33	0.40	0.27	0.27	0.25	0.08	0.13
DECK	0.38	0.47	0.35	0.27	0.25	0.33	0.13
PLUMB	0.76	0.73	0.85	0.93	0.75	0.50	0.50
SEPTIC	0.52	0.67	0.50	0.53	0.25	0.42	0.25
GARAGE	0.67	0.67	0.54	0.47	0.38	0.42	0.25
LOTSZ	9.70	1.23	1.48	1.52	11.95	1.85	3.10
RDPUB	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TAXRT	9.43	9.43	9.75	6.42	9.78	9.78	5.93
DIST	94.00	94.00	24.10	59.00	50.00	50.00	53.00
LKAREA	1039.00	2038.00	2513.00	2283.00	1024.00	880.00	784.00
WATERQ (ft)	22.18	22.94	14.45	5.88	15.64	18.80	16.43
WATERQ (m)	6.76	7.00	4.43	1.78	4.77	5.73	5.01
WP	1.00	1.00	1.00	3.00	2.00	2.00	2.00

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Appendix 1 (*continued*)

Variable	Butternut Lake	Devil's Lake	Round Lake	Lake Nebagamon	Big Sand Lake	Combined
STORY	0.28	0.60	0.30	0.43	0.50	0.28
LVAREA	1091.11	1828.80	1444.79	2065.87	1654.00	1550.73
FIRE	0.33	0.80	0.47	0.65	0.50	0.49
HEAT	0.33	0.60	0.30	0.57	0.25	0.29
ELHEAT	0.00	0.40	0.04	0.00	0.00	0.06
BSMNT	0.44	0.40	0.21	0.17	0.25	0.25
DECK	0.50	0.80	0.38	0.52	0.50	0.39
PLUMB	0.67	1.00	0.64	0.87	0.75	0.70
SEPTIC	0.50	0.80	0.51	0.65	0.50	0.48
GARAGE	0.56	0.80	0.51	0.61	0.50	0.55
LOTSZ	2.16	6.70	3.14	1.98	6.84	3.42
RDPUB	1.00	1.00	1.00	1.00	1.00	1.00
TAXRT	10.72	6.42	6.51	12.58	6.42	8.43
DIST	83.00	40.00	71.00	29.00	42.00	47.58
LKAREA	983.00	975.00	3294.00	986.00	1427.00	4004.53
WATERQ (ft)	3.47	15.91	20.05	6.03	10.09	12.29
WATERQ (m)	1.06	4.86	6.11	1.84	3.06	3.75
WP	3.00	1.00	2.00	2.00	2.00	2.03

Appendix 2 Regression Output, Estimated Hedonic Coefficients

Variable	All Properties	No Empty Properties	Short Regression
INTERCEPT	72459.3	145876.7	-28437.48
	(77004.02)	-227794.6	-76891.69
STORY	31606.74	34496.84	26108.07
	(-35969.34)	(-33465.08)	(-36271.27)
FIRE	29240.85	29789.45	-
	(-32120.69)	(-29771.28)	
HEAT	27438.92	30174.3	-
	(-33092.41)	(-30801.14)	
ELHEAT	115701.3**	120614.2**	58451.3
	(-57031.36)	(-52684.37)	(-57939.02)
BSMNT	-29018.8	-28806.02	-
	(-33286.17)	(-30878.47)	
DECK	-59158.01*	-66089.74**	-
	(-32854.93)	(-30758.46)	
PLUMB	-147572.6	-203013.6	-
	(-51714.76)	(-215674.7)	
SEPTIC	-22372.15	-24586.61	-
	(-37767.73)	(-36229.02)	
GARAGE	-30330.72	-38023.3	-
	(-39797.96)	(-37994.19)	
LOTSZ_ACRES	1802.686	313.4863	2083.186*
	(-1131.806)	(-1112.975)	(-1164.586)
TAXRT	-11415.32*	-13283.65**	-12186.67*
	(-6198.084)	(-6561.469)	(-6350.258)
DIST	1170.126*	1266.913**	733.0093
	(-595.738)	(-627.9005)	(-609.0434)
LKAREA_ACRES	4.209942*	5.944177**	7.343657***
	(-2.474707)	(-3.426787)	(-2.423283)
LVAREA_SQFT	185.1292***	185.1749***	144.8257***
	(-14.40669)	(-13.4661)	(-11.21874)
LNWQ_FT	46459.33**	45292.89*	66046.22***
	(-22129.11)	(-24704.45)	(-22669.91)
R^2	0.529158	0.600311	0.480499
N	0.506153	0.572032	0.467263

*Significant at the 90th percentile, **Significant at the 95th percentile, ***Significant at the 99th percentile.
Standard errors are shown in parentheses.

Additional Resources

Suggested by the Y. T. and Louise Lee Lum Library

Appraisal Institute, Lum Library

- **External Resources, Information Files [Login required]**
  Special-purpose properties/Sports, recreation and entertainment/Recreational properties
- **Reports**
  Lake Management Case Study: Westlake Village, California

Natural Resources Agencies, Government Agencies (federal and state)

http://www4.ncsu.edu/~leung/agusa.html

US Environmental Protection Agency, Standards for Water Body Health

https://www.epa.gov/standards-water-body-health/what-are-water-quality-standards

US Geological Survey, Water Science School

https://water.usgs.gov/edu/waterquality.html