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An Assessment of the Economic Value of Clean Water in Lake Champlain

September 2015

Final Report

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For:
The Lake Champlain Basin Program and
New England Interstate Water Pollution Control Commission

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Executive Summary

The regional economy, quality of life and tourism rely on clean water in Lake Champlain and its surrounding basin. This project explored elements of this relationship between water quality and property valuation, tourism expenditures and regional economic activity at various scales.

At the parcel scale, both single family residential and seasonal home purchasers associated higher water quality with increased selling price. A one meter increase in water clarity is equated with a nearly 3% average increase in single family home value, and a 37% average increase in seasonal home value. Proximity to the Lake also contributes significantly to property valuation. Single family and seasonal residences within 100 m of Lake Champlain are expected to sell for nearly 30% and 49% more than similar residences that are located outside this area. Scenario analysis of changes in total phosphorous in the Lake from both climate change and meeting legal maximum daily load targets found that increased loading associated with climate change is estimated to result in a $7,000 average price decrease for single family dwellings, while reduced loading from TMDL implementation would result in a $15,200 average price increase for single family dwellings.

At the scale of lake-side towns, water clarity during the peak summer months of July and August indicate a significant impact on lodging expenditures, an indicator of tourism spending more broadly. A linear regression model estimated a $2,303 increase per average lodging unit per meter of water clarity increase. Extrapolating to the five-town scale concludes that a one-meter improvement in water clarity is expected to lead to a 10% increase ($110,544) in room expenditures for the month of August alone.

At the regional scale an input-output model was constructed for a six-county lakeshore economy in Vermont and New York. County-level employment, income, industry and household characteristics were used to assess the economic flows among sectors. The input-output model suggests that for each dollar of labor income required within lake-related tourist sectors an additional $0.57 in labor income through indirect industry inputs and induced impacts from additional spending of households will be generated. Similarly, each dollar of value-added (taxes, property income, profits) income generated in tourism-related sectors generates another $0.62. In terms of employment, every new job related to the lake tourism economy creates an additional 0.4 jobs to support indirect and induced activities. The $300 million estimated annual tourist expenditures in Vermont's four main lakeside counties generate an additional $72.75 million in spending and nearly 1,070 jobs. Extrapolating from the town-scale model, a one-meter decrease in water clarity during the months of July and August would lead to the loss of 195 full-time equivalent jobs, a $12.6 million reduction in tourism expenditures and a total economic reduction of nearly $16.8 million.

This analysis represents a snapshot in time. The example of Georgia, VT underscores the importance of understanding how changes over time (i.e.

downward trending water quality) might affect real estate transactions, vacation rentals and tourism expenditures as losses in any of these sectors are further magnified when considering their effect on employment and indirect expenditures. Moving forward, scenarios ranging from individual events (e.g. fishing tournaments) to long-term environmental and economic conditions could be further analysed. Building on this framework could allow for rapid assessment of land use plans, zoning regulations, and environmental restoration, while additional scenario analysis could inform regional, integrated economic development and watershed management planning.

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1 Tasks Completed

1. **Literature review:** (Project Outline Task 3) Identified and documented relevant literature resources in a searchable database. The database includes a list of commonly used attributes for the estimation of hedonic models related to lakes and/or water quality. Each article (entry in the database) contains a brief summary of the publication, keywords that describe it, model parameters (for articles detailing hedonic analysis) and a link to the article so that interested staff are able to read the article in its entirety.

2. **Data collection and gap analysis:** (Project Outline Task 4) Collected existing data from publically available sources, and derived additional data from these existing data layers. Corresponding documentation for all of the derived data is included in Appendix I and stored in an Excel Workbook. Data collection for the econometric models was largely informed by the results of the literature review. Data for the input-output model was purchased from implan.com and includes detailed economic and employment data at the county level for both New York and Vermont. Data gaps for the econometric models were identified, and, when possible, proxy data were developed for inclusion in the model.

3. **Econometric models:** (Project Outline Task 6) Econometric models were developed to understand the relationship between Lake Champlain, its water quality and residential property ownership and tourism expenditures within the region. At the parcel scale, hedonic price models were developed for single family residences and seasonal second homes (i.e. camps) using real estate transaction data and other ancillary data. At the town scale, a model of lodging expenditures was created using water quality and room receipts data. The models were explicitly designed with lake water quality parameters so they could be used for modelling alternative future conditions.

4. **IMPLAN SAM model:** (Project Outline Task 5) Characterized economic flows within the Lake Champlain shoreline economy to understand the economic relationships among employment sectors and the contributions from seasonal property ownership and tourism expenditures related to lake visitation and use. The lake economy was defined to include the four Vermont and two New York counties that make up the majority of the Lake Champlain shoreline. An analysis of lakeside communities in Grand Isle and Franklin counties of Vermont with a predominance of lake-based summer tourism provided the basis of modelling the influence of water quality on tourism expenditures.

5. **Scenario analysis:** (Project Outline Task 7 & Task 8) Scenario analysis was used to explore how changes in current water quality conditions might affect home ownership, tourism expenditures and their relative contributions to the regional economic system. Each of the models described above includes a water quality parameter to enable scenario analysis for estimating changes in economic returns from private property values, tourism expenditures and regional economic flows. Working in cooperation with regional experts (e.g. LCBP Technical Advisory Committee) a set of scenarios was identified and

implemented for each of the models and compared against the baseline conditions.

2 Project Introduction

Water quality in Lake Champlain is a strong determinant of regional economic activity. From private property ownership along the lake shore, to the number of tourist visits and their expenditures, to broad patterns of economic development, the livelihoods of a broad range of actors are dependent on access to clean water. The quality of the water also has implications regarding the need for infrastructure development, most prominently the need for water filtration capacity to provide a reliable supply of potable water. Land use and land cover throughout the basin plays an important role in regulating the quality of water in the lake, filtering pollutants, limiting erosion and sediment transport, sequestering and storing carbon and offering diverse recreational opportunities, among other things. The interconnected nature of the landscape and the actors that shape it mean that changes in land use or land management may serve to enhance ecosystem services locally while at the same time limiting overall service delivery throughout the region.

Ecosystem services – the benefits provided by nature to humans – are increasingly used to frame the interdependency between environmental conservation and economic development. The growing interest in using ecosystem services in decision making has prompted a range of analytic methods and software tools to quantify their provision, delivery and economic valuation. Research approaches have included using geographic information systems (GIS) to map and value ecosystem services using spatial data (Eade and Moran 1996, Chan et al. 2006, Raudsepp-Hearne et al. 2010), deriving economic value by applying a transfer function to specific land use / land cover types (Costanza et al. 1997), and more recently developed software tools such as Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) (Kareiva et al. 2011) and the Artificial Intelligence for Ecosystem Services (ARIES) modeling platform (Villa et al. 2009).

A central tenet of the conceptual model of the region is the acknowledgement that sustaining a high quality of life within the basin requires healthy, functioning ecosystems capable of producing and delivering ecosystem services. Generally speaking, the challenges for developing effective, sustainable watershed management plans are two-fold: 1) Connect the biophysical, ecological, and socio-economic characteristics of the basin to the supply of freshwater ecosystem services generated by water quality and the demand for those services by various constituencies; and 2) Quantify the benefits delivered and values ascribed to ecosystem services across multiple spatial scales by those constituencies. These challenges define the complexity of the coupled natural-human system that is the Lake Champlain basin, within which multiple, interconnected ecosystem services influence and are influenced by water quality. This project focused on the latter of the two challenges by developing econometric models to relate indicators of water quality to local to regional economic expenditures..

The project approach is designed to quantify the value of clean water in Lake Champlain at multiple spatial scales for two primary classes of beneficiaries, residential property owners and tourists. Each of these beneficiary groups has their own expectations for the condition of the Lake and in the case of residential property owners, a financial stake in an increase (or decrease) in local to regional water quality. For tourists, poor water quality conditions within the Lake and its surrounding basin may lead to the selection of alternative destinations, taking with them the direct, indirect and induced expenditures that are a critical component to a thriving regional economy.

This multi-scale approach follows the conceptual framework of the Millennium Ecosystem Assessment (MEA) (2005) by allowing us to consider exogenous drivers of change as well as the differential outcomes that policy actions may have throughout the basin, depending on the level of demand for a given service and the presence of specific types of beneficiaries. It also offers an opportunity to evaluate whether and how these benefits accrue across spatial scales and the role they play in contributing to the regional economy. Understanding how and why benefits accrue differently across alternative spatial scales could yield potential solutions for maximizing the total benefit flow across all spatial scales.

This project quantifies the economic value of clean water in Lake Champlain using household-scale real estate transactions, tourist lodging expenditures and a regional economic impact analysis. The development of these models was influenced by prior studies, with added emphasis placed on related research that was conducted within the region. Further, the availability of data to support the modelling effort was also a significant consideration in the model estimation phase. Data resources were compiled from a variety of sources. Missing data were imputed from existing data when possible and strategies for addressing data shortcomings and future data collection efforts and priorities were developed. Together with the model outputs, these data and analyses should prove useful for facilitating a shared understanding, between stakeholders and other interested parties, of biophysical processes and socio-economic values which could inform decisions supporting sustainable economic development and both recreation and employment opportunities.

3 Methodology

1. **Literature review**
   The search for valuation literature identified research methods that were successfully applied in locations with similar physical and socio-economic characteristics, as well as generalized approaches and model parameters that have been used for other valuation efforts. To that end, a literature search was conducted using multiple alternative search engines, including: Web of Science, JSTOR, Elsevier and Google Scholar. More than 40 peer-reviewed

publications were identified through this search. A database of relevant documents was assembled, including an annotated bibliography, to document and justify the modelling approach taken. The database allows for rapid search and retrieval of the reviewed literature and data.

Table 1 lists model parameters used in previous hedonic estimations. These parameters can be roughly grouped into the following classes: water resources (e.g. proximity to, area of and views towards), historic and present-day nutrient and sediment loads, presence of invasive species and categorical variables describing the quality of the lake. An additional table describing parcel and structural characteristics, proximity to cultural features and central business districts, neighborhood and demographic characteristics and non-water natural amenities is included in Appendix II.

Table 1: Water-related hedonic parameters documented in the literature database.

Attribute	Studies Using
Surface area of lake acres	Gibbs et al. 2002, Michael et al. 2000, Yoo et al. 2014, Boyle et al. 1999, Poor et al. 2007, Zhang and Boyle 2010, Michael et al. 1996
Deviation from average water level at time of sale	Lansford and Jones 1995
Categorical variable describing lake or beach	Orr and Pickens 2003
Distance to public access	Orr and Pickens 2003
Tons of sediment loads/lake acre in the nearest lake	Yoo et al. 2014
Travel time/ travel time squared to nearest lake	Yoo et al. 2014
Lake Area * Water Quality	Gibbs et al. 2002, Boyle et al. 1999, Poor et al. 2007, Zhang and Boyle 2010
Feet of exposed shoreline	Loomis and Feldman 2003
Average depth of lake	Bejranonda et al. 1999
Annual agricultural sedimentation accumulated / dredged	Bejranonda et al. 1999
Water clarity	Gibbs et al. 2002, Boyle et al. 1999, Kashian et al. 2006, Poor et al. 2007, Zhang and Boyle 2010
Min water clarity for year property sold	Michael et al. 2000, Michael et al. 1996
Min water clarity for year previous to sale	Michael et al. 2000
Ten year average of min water clarity	Michael et al. 2000
Current year clarity * ten year average	Michael et al. 2000

Attribute	Studies Using
Current year clarity * ten year average adjusted for degrading/improving condition	Michael et al. 2000
Difference between current min and historical min	Michael et al. 2000, Michael et al. 1996
Percent change in clarity over summer months	Michael et al. 2000
Total Nitrogen	Dodds et al. 2008
Total phosphorus	Dodds et al. 2008
Eurasian watermilfoil percent cover rating/Total Aquatic macrophyte percent cover rating	Zhang and Boyle 2010
Other lake / stream on property	Orr and Pickens 2003
Lakefront	Loomis and Feldman 2003, Lansford and Jones 1995, Orr and Pickens 2003, Gibbs et al. 2002, Michael et al. 2000, Boyle et al. 1999, Kashian et al. 2006, Poor et al. 2001, Zhang and Boyle 2010
Lake view	Loomis and Feldman 2003
Water source is the lake	Boyle et al. 1999, Poor et al. 2001, Zhang and Boyle 2010
Improving / degrading water quality trend	Michael et al. 2000

* Parameters presented in *italics* are used as dummy variables, while those presented in **bold** are categorical variables.

2. **Data collection and gap analysis**

The data collection effort to support the hedonic price model was largely guided by the results of the literature view (see Table 1 and Appendix II). These data, focused exclusively on Vermont, were downloaded from a variety of public sources, including the Vermont Center for Geographic Information, US Census Bureau, US Geological Survey, Vermont Department of Taxes and the Vermont Department of Environmental Conservation. Derived data were also created from the primary source data using a combination of geoprocessing (in ArcGIS) and data conflation and aggregation (using Microsoft Access). A complete description of the data processing methods for the econometric models is included in Appendix I.

The estimation of the hedonic price model suffered from three primary types of data gaps. The first is a result of parcel attribution (e.g. parcel boundaries, zoning), structural attribution (e.g. bedrooms, bathrooms, square footage) and real estate transactions (e.g. selling price) being managed by different data authorities and stored in separate databases with a variety of data structures and different reference naming schema (e.g. parcel number, SPAN number, physical address) that make conflating the data both challenging and time consuming. Data processing was prioritized according to the level of importance in model estimation. Real estate transaction data were geocoded. Data detailing structural information was not included due to the amount of time required to acquire it from individual town authorities and then join the information to existing spatial data and the real estate transaction data. The only exception to this was the presence of a garage which was observed through a visual inspection of transacted properties using recent aerial photography. The second issue is incomplete data. For example, there is not complete parcel data for all of the towns in the study area. So, for example, instead of a simple spatial query to identify lakefront property, alternative (and potentially less accurate) methods were required (i.e. selecting all parcels within a specified buffer distance from the Lake boundary). The third type of gap is unavailable data. For example, there are no survey data to characterize the decision-making process for selecting one property over another, including location and accessibility preferences or the influence of socio-economic, biophysical or natural and cultural resource information.

The tourism expenditure model, also focused on Vermont, was limited by the availability of detailed tourism expenditure data. Time series data from the Vermont Department of Taxes that quantifies room, meal and alcohol expenditures by town were used in place of more detailed information that disaggregates total expenditures. From a modelling perspective, understanding the motivations (recreational and economic) that guide destination and expenditure decisions should lead to a more robust model that is better able to inform scenario analysis by relating personal motivations, environmental quality and visitation and expenditure decisions.

Data for the input-output model was purchased from a data vendor and includes detailed economic and employment data at the county level for both New York and Vermont. Additionally, expenditure data was gleaned from a report issued by the Agency of Commerce and Community Development (Jones, 2015). Both of these datasets represent the best available information for the region for developing this type of model. The primary data gap related to this model is the availability of survey data with fine resolution expenditure information, duration of stay, destination choices and level of influence of the Lake on the selection process (versus other natural and cultural amenities that bring visitors to the region) that could better inform the development of scenarios that support economic development planning.

3. Econometric models

Hedonic Model

The hedonic price model was used to identify statistically significant determinants of the selling price of a property for towns in close proximity to the Lake in the Vermont portion of the basin. A stepwise multiple linear regression approach, informed by a thorough review of the literature (see Table 1 and Appendix IV for more detail) was used to identify significant covariates. Data for the time period between January 2013 and April 2014 were downloaded from the VT Department of Taxes Property Transfer database. The data used in the analysis includes approximately 800 property transactions (for single-family residential) and 70 property transactions (for seasonal homes). The data includes the physical address of the property, the size of the property and the use type, among other attribution. The physical address attribute was used to assign the transaction location on a map through the process of geocoding. Once completed, the mapped location of transacted properties was used to select relevant data and derive a suite of potential model parameters that were hypothesized to influence the selling price of a property. The data used in model estimation are separated into thematic groupings and are described below. Their summary statistics are included in Table 2 (for single-family residential) and Table 4 (for seasonal homes).

Single-family residential

Property parameters

The parcel area and the assessed property value were included in the VT Department of Taxes Property Transfer database. The assessed property value was included as an independent variable to account for the lack of readily accessible structural data (e.g. number of bedrooms, bathrooms, square footage) that are typically included in this type of analysis (Kashian et al. 2006, Orr and Pickens 2003, Yoo et al. 2014). Data indicating the presence of an attached or detached garage (Loomis and Feldman 2003, Bejranonda et al. 1999, Michael et al. 2000, Kashian et al. 2006, Lansford and Jones 1995, Michael et al. 1996) was generated using Google Earth. The determination regarding the presence and type of garage was made through a visual inspection of the property (via the most recently collected aerial photography for the region) and assigned a code for one of three classes: no garage (0), attached garage (1) or detached garage (2).

Location parameters

A variety of locational parameters were derived using the Network Analyst extension to ArcGIS. Network Analyst allows a user to compute travel cost (e.g. measured as time or distance) across a road network. Using a dataset that describes employment in the region by sector (i.e. the North American Industry Classification System (NAICS)), the location and number of employees were used to characterize the accessibility of each transacted property in terms of its network distance to clusters of employment types, including industrial, service, agricultural and retail establishments. A polygon delineating the extent of the road network within 1-, 2.5- and 5-km of each transaction point was defined. These bounding polygons were then used to tabulate the number of establishments and employees of a specified type (e.g. services) that are located within their bounds. Given the relative scarcity of large central business districts in Vermont, accessibility to employment and commercial activity are used as proxy measures for centers of economic activity (Lansford and Jones 1995, Michael et al. 1996, Bejranonda et al. 1999, Boyle et al. 1999, Michael et al. 2000, Gibbs et al. 2002, Orr and Pickens 2003, Poor et al. 2007, Zhang and Boyle 2010). We hypothesize that increased proximity to services and retail will have a positive effect on selling price while the opposite holds true when considering industrial sites.

A 100-m buffer around the lakeshore was computed and then used to identify all transacted properties located within this bounding region (Loomis and Feldman 2003, Bejranonda et al. 1999, Lansford and Jones 1995). This information helped distinguish between properties that are adjacent to the Lake (assigned a Lake proximity value of 1) versus those that are more distant (assigned a Lake proximity value of 0) (Loomis and Feldman 2003, Lansford and Jones 1995, Orr and Pickens 2003, Gibbs et al. 2002, Michael et al. 2000, Boyle et al. 1999, Kashian et al. 2006, Poor et al. 2001, Zhang and Boyle 2010). Additionally, the county of each location was assigned to each transaction point to test for potential county-level effects (Yoo et al. 2014). Based on this information, a dummy variable was created to indicate whether a property was located inside (assigned a value of 1) or outside (assigned a value of 0) Chittenden County.

<u>Demographic parameters</u>
Data from the 2013 American Community Survey was downloaded at the Block Group scale from AmericanFactfinder (http://factfinder.census.gov). Median household income (Boatwright et al. 2013, Yoo et al. 2014) and percent vacant housing units were expected to have positive and negative effects, respectively. Each transacted property is coded according to the Block Group within which it resides and the census data values are assigned accordingly.

In addition, the E911 (emergency services) data was used to compute the residential density (Michael et al. 1996, Bejranonda et al. 1999, Michael et al. 2000, Poor et al. 2001, Gibbs et al. 2002, Boatwright et al. 2013, Yoo et al. 2014) within 1-km of a transacted property. The E911 data were accessed via the Vermont Center for Geographic Information (VCGI) online data portal (http://vcgi.vermont.gov/). This data is coded according to use type (e.g. residential, commercial), enabling the selection of residential properties for use in the development density computations. The ArcGIS Spatial Analyst Point Density Tool was used the E911 residential property locations to derive a dataset that represents the housing density (Boatwright et al. 2013) over a continuous surface for the entire study area. A 1-km buffer was delineated for each real estate transaction point and the ArcGIS Spatial Analyst Zonal Statistics Tool computed the average housing density within each buffered region. Given the relatively low-density development patterns observed throughout the state, it was expected that a higher development density would translate to a lower transaction price.

<u>Landscape and environmental parameters</u>
In addition to Lake proximity (described above), a parameter defining the visibility of the Lake (Lansford and Jones 1995, Orr and Pickens 2003) from each transaction point was computed using the ArcGIS Spatial Analyst Viewshed tool. This tool requires a viewpoint location (i.e. the transaction point) and an elevation surface (i.e. a Digital Elevation Model (DEM)) over which the views are to be computed. The USGS SRTM 10-m DEM was

downloaded from The National Map (http://nationalmap.gov/) and used as the elevation surface in the analysis.

Ideally the view from the entire parcel would be considered. However, parcel data is not available for all of the jurisdictions within the study area. As a result, we computed the viewshed from the location of the E911 points that are coincident with the real estate transactions. These points represent the approximate location of the building footprint within the parcel. The viewshed was computed from the surface elevation at each transaction point over a 30-km radius. Because the Lake surface was the landscape feature of interest, no vertical offset was assigned to the Lake level. Finally, the default value for the earth curvature correction factor was applied to limit the visibility of more distant locations.

A viewshed analysis yields a data layer with two values 0 (location is not visible) and 1 (location is visible). Once the viewshed of a property was computed the result was intersected with the Lake boundary to determine the proportion of a property's viewshed that is comprised of the Lake. The expectation here is that, all things being equal, properties with greater Lake visibility are expected to have a higher selling price.

Finally, because the primary concern of this portion of the study is the effect of Lake water quality on property valuation, a number of alternative representations of water quality were explored, including Secchi depth (m) (Boyle et al. 1999, Gibbs et al. 2002, Kashian et al. 2006, Poor et al. 2007, Zhang and Boyle 2010), net phytoplankton density (cells/L), net zooplankton density (cells/L), Total Nitrogen (µg/L), Total Phosphorous (µg/L), water temperature (°C) and chlorophyll-A (mg/L). Data were downloaded from the Lake Champlain Long-term Water Quality and Biological Monitoring Project (http://www.watershedmanagement.vt.gov/lakes/htm/lp_longterm.htm). The monitoring program includes 15 stations scattered throughout the Lake, as well as 22 stations located at tributary mouths around the Lake. Data collection under this program began in 1992, and data has consistently been collected at each station through the present day (with the exception of stations that have been added since the monitoring program began).

Data from May through September for the years 2010 – 2014 were acquired. Data were grouped according to the month in which they were collected and a monthly average value across all years for each of the potential parameters was computed. Ultimately the August average Secchi disk depth value was selected for inclusion in the model. This Secchi disk depth factor was selected because of its connection to not only Lake water quality, but also to the easily understood nature of the parameter by a non-technical audience, as well as its impacts on recreation (Egan *et al*, 2009) and quality of life. While nitrogen or phosphorous loads have a more direct relationship with water quality, changes in these values typically require scientific instrumentation to quantify as they are not discernible to the naked eye, and therefore less apparent to a current or prospective property owner in the absence of an extreme event (e.g. algal bloom) (Leggett and Bockstael, 2000). The month of August was selected because it had the second most real estate transactions of any month in the year and because it corresponds with the typical timing of summer algal blooms and other water clarity problems. Each of the transacted properties was assigned the value of the nearest long-term monitoring station and data values were ascribed accordingly to reflect differences in water clarity throughout the Lake.

Summary statistics for the selected model parameters are presented in Table 2. Mean selling price for all houses in the study area is approximately $300,000. Most properties are located outside the 100-m Lake buffer. Slightly more than half of the properties are located inside Chittenden County and feature an attached garage. The mean Secchi disk depth reading for the previous five years is nearly 4.4-m, and the mean percent of Lake visibility within the viewshed of a transacted location is more than 10%.

<u>Results</u>
The result of the OLS regression for single-family residential properties is listed in Table 3 below. The model explains approximately 59% of the variation in the dependent variable. A log-level model approach (Bin, O. and J. Czajkowski, 2013; Cropper, M. L., L. B. Deck, and K. E. McConnell, 1988) was applied, meaning that the dependent variable (Selling Price) is log-transformed (to deal with the right-skewed makeup of the transaction data) (see Equation 1 below). All of the independent variables maintain their original form. The result of this estimation is interpreted as a one-unit change in x results in a 100*β_1 percent change in y.

Equation 1: $$\ln(y) = \beta_0 + \beta_1(x) + \varepsilon$$

While the primary concern here relates to the effect of the Lake on selling price, the coefficients of structural, locational and demographic covariates behaved as expected. The assessed property value, parcel size, number of service and retail establishments in close proximity, locations within Chittenden County and the inclusion of a garage (attached or detached) are all positive determinants of price, while the number of industrial facilities within 5-km of a property, residential density within 1-km of a property and the percentage of vacant housing units in the block group are all negative determinants of price. Of these model parameters, a location within Chittenden County has the greatest positive effect on overall property value (0.269), followed by the presence of an attached garage (0.143) and a detached garage (0.101).

These results also highlight the role of the Lake in accentuating the value of properties within the region. First, given two properties one located within 100-m of the Lake and the other outside the 100-m buffer, the former is expected to bring a selling price nearly 30% more than the latter, all else being equal. A one-unit increase in lake visibility would be expected to bring almost a 44% premium on the selling price. Finally, and of particular relevance to this investigation, water clarity is also important to homebuyers. A one-meter increase in average August Secchi depth (over a 5-year period) would be expected to result in a nearly 3% increase in the selling price of a single family residence, all else being equal.

Table 2: Summary statistics for single-family residential homes in Vermont towns near Lake Champlain.

Parameter*	Mean	Std. Dev.	Min	Max
Selling Price ($)	303,954.1	161222.1	100,000	959,500
Parcel Size (acres)	101.1053	119.6864	1	441
Industrial facilities w/in 5-km	62.50771	83.46671	0	284
Services w/in 1-km	41.92408	118.6462	0	756
Retail outlets w/in 5-km	121.1103	184.2672	0	532
Is w/in 100-m of Lake Champlain	0.098225	0.297795	0	1
Lake Visibility	0.10238	0.125665	0	0.575038
Average August Secchi Depth (m)	4.373148	1.30664	1.540217	5.18942
Garage Code				
1 - Attached Garage	0.536095	0.498991	0	1
2 - Detached Garage	0.263905	0.44101	0	1
Is in Chittenden County	0.570749	0.495264	0	1
Assessed Property Value	933.5337	543.8839	1	1957
Housing density w/in 1-km	201.7777	232.9954	1.183507	862.0738

* Parameters presented in *italics* are used as dummy variables, while those presented in ***bold italics*** are categorical variables.

Seasonal Home

Property parameters

Unlike the model for single-family residential, the assessed value of a property was not found to be a statistically significant explanatory variable for seasonal dwellings. Because the assessed value parameter was used to account for the structural characteristics of the property, and structural parameters are frequently featured in hedonic models, an alternative was developed by digitizing building footprints for transacted properties using Google Earth. The City of Burlington was the only jurisdiction within the study area that had this data available in digital format (ArcGIS shapefile). Footprints digitized in Google Earth were merged with those from the City of Burlington to create a unified data set. It is assumed that camps are single-story structures and that the footprint data is an accurate predictor of the size of the structure. The remaining property parameters used in the estimation were derived from the same data sources described in the single-family dwelling section above.

Location parameters

Two additional locational parameters (not used in the single-family model) were developed for use in the camp model estimation. The first used the ArcGIS Network Analyst Extension to compute the driving distance to the nearest highway interchange. The network distance uses a shortest path algorithm to compute the least cost path (measured as a distance in m) from a property to the closest highway interchange. Additionally, the linear distance between individual properties and the nearest conserved land was computed. It was assumed that people spending time at their camp require reasonable accessibility to the highway (to minimize travel time between their primary and secondary residences) and conserved land while expressing a desire to be outside more developed areas (e.g. housing density factor).

Table 3: Model coefficients for single family residential dwellings.

Parameter	Coefficient	Std. Err.	t-value
Constant	11.6257***	0.0529	219.9
Parcel Size (acres)	0.0006143***	0.0001	5.28
Industrial facilities w/in 5-km	-0.001568*	0.0009	-1.79
Services w/in 1-km	0.0003828***	0.0001	2.89
Retail outlets w/in 5-km	0.0010464***	0.0004	2.86
Is w/in 100-m of Lake Champlain	0.2975233***	0.0414	7.18
Lake Visibility	0.4361667***	0.105	4.15
Average August Secchi Depth	0.0298202**	0.0121	2.47
Garage Code			
1 – Attached garage	0.1425714***	0.0303	4.71
2 – Detached garage	0.1005899***	0.0329	3.06
Is in Chittenden County	0.2691349***	0.0378	7.13
Assessed Property Value	0.0003978***	2E-05	16.15
Housing density w/in 1-km	-0.000276***	9E-05	-3.09
Observations	806		
F(14, 791)	93.62		
Prob > F	0		
R-squared	0.5862		

* Denotes significance at the 0.10 confidence level.
** Denotes significance at the 0.05 confidence level.
*** Denotes significance at the 0.01 confidence level.
Parameters presented in *italics* are used as dummy variables, while those presented in ***bold italics*** are categorical variables.

Results

Table 4 details the summary statistics for the parameters selected for inclusion in the hedonic model specification. The mean selling price of a seasonal home is lower than a full-time single family residence, even though the majority of the transactions used in this stage of the analysis are located within 100-m of Lake Champlain. The low mean housing density within 1-km reveals a preference for lower-density development than one might consider when purchasing a full-time residence.

The result of the OLS regression for camp properties is listed in Table 5. The model explains nearly 70% of the variation in the selling price of camps on or near Lake Champlain. Although the coefficient of variation is higher in this model compared to the single-family residential properties, there is a greater degree of variability in the level of significance of the model parameters (which may be attributed to the smaller sample size used in model estimation). Once again a log-level approach was applied for model

Table 4: Summary statistics for camps in Vermont towns near Lake Champlain.

Parameter	Mean	Std. Dev.	Min	Max
Selling Price	264741.5	235077.6	12936	1051000
Parcel Size (acres)	91.30882	123.6028	1	415
Building Footprint (m)	154.9033	124.8854	34.16978	587.8153
Is w/in 100-m of Lake Champlain	0.823529	0.384054	0	1
Average August Secchi Depth	4.017165	1.261142	1.540217	5.18942
Housing density w/in 1-km	28.59574	15.34159	4.457757	85.98135
Lake Visibility	0.061474	0.057693	0	0.279914
Driving Distance to Highway Interchange (m)	33.78455	17.91894	8.739854	88.82067
Driving Distance to Conserved Land (m)	1337.311	886.1205	49.45374	3575.006

* Parameters presented in *italics* are used as dummy variables, while those presented in ***bold italics*** are categorical variables.

Table 5: Model coefficients for a camp on or near Lake Champlain.

Parameter	Coefficient	Std. Err.	t-value
Constant	10.46129***	0.4087625	25.59
Parcel Size	-0.0017204**	0.0007373	-2.33
Building footprint size (sq m)	0.0036444***	0.0007116	5.12
Is w/in 100-m of Lake Champlain	0.4927785**	0.2383224	2.07
Average August Secchi Depth (m)	0.3670227***	0.0631481	5.81
Housing density w/in 1-km	-0.01277**	0.0058238	-2.19
Lake Visibility	5.703466***	1.465948	3.89
Driving Distance To Highway Interchange (m)	-0.0105241*	0.0062328	-1.69
Distance to Conserved Land (m)	-0.0001974**	0.0000978	-2.02
Observations	64		
F(8, 55)	17.02		
Prob > F	0		
R-squared	0.6909		

[*] Denotes significance at the 0.10 confidence level.
[**] Denotes significance at the 0.05 confidence level.
[***] Denotes significance at the 0.01 confidence level.
Parameters presented in *italics* are used as dummy variables, while those presented in ***bold italics*** are categorical variables.

estimation, meaning that the dependent variable (Selling Price) is log-transformed. All of the independent variables maintain their original form. Unlike the single family residential model results, the parameters with the greatest effect on the selling price of a seasonal property are all lake-related, including: views of the Lake, the proximity to the Lake and the 5-year average August Secchi disk depth measurement (in order of decreasing importance). Further, purchasers of seasonal homes positively value building size, while considering larger parcels, longer distances to a highway interchange or conserved land and higher household density as features that detract from the overall selling price.

Sub-Regional Expenditure Model

While the link between water quality and lake-based tourism and second home expenditures is obvious to many, in the absence of targeted surveys it's difficult to directly measure. This is particularly true in more diversified economies like Chittenden or Clinton Counties, or economies like Essex County with a predominance of non-Lake related summer tourism. Therefore, a more detailed case study of lakeside communities was pursued. This analysis used meals and rooms receipts data for six towns between May and September. The communities chosen included the five main lakeside towns in Grand Isle County (Alburgh, Grand Isle, Isle La Motte, North Hero, and South Hero), and one lakeside town in Franklin County (Swanton). Each of these towns had complete data for monthly room receipts for 2010 through 2014, as well as water quality data at nearby lake sampling points. St. Albans Town and City were considered, but lacked complete room receipt data because there were fewer reporting entities than required to meet thresholds for public dissemination of the data. Summer tourism in these communities is particularly dependent on Lake Champlain, whereas more diverse tourism economies in Chittenden and Addison Counties makes any water quality impact difficult to distinguish from other tourism draws (e.g. hiking and cycling in the Green Mountains).

The general hypothesis regressed monthly room receipts data (adjusted for inflation) as the dependent variable against Secchi disk depth data (the independent variable). Models were estimated for each summer month by pooling data from 2010 through 2014 across the six lakeside towns. Table 6 summarizes regression results for each month. There is insignificant correlation between Secchi values and room receipts for the May, June, and September models. However, the July and August models show evidence that room receipts depend on water quality at the height of the summer tourism season during the months when algal blooms and other water clarity problems have been most present. For example, between 2012 and 2014, St. Albans Bay Park and Red Rocks Beach were closed more than ten times and nine times, respectively, due to either an excess of e coli or the presence of toxic blue-green algae (Lake Champlain Basin Program, 2015).

Figure 1 highlights the August model results, the strongest evidence of a water quality impact on tourism with an estimated $71,721 impact on room receipts per meter of water clarity decline across the six lakeside communities (in 2014 dollars). This represents 6.7% of the five-year average of August room receipts for the five towns with complete yearly data (i.e. not including Grand Isle). A two-meter loss – well within the change from Alburgh or Isle La Motte conditions to Swanton conditions – would result in a 13.4% decrease in lodging revenues. If this percent loss is extended to other tourism sectors, the estimated impact grows from tens of thousands to hundreds of thousands, just for the month of August, and just for these six lakeside towns. If even a portion of this percentage loss were translatable to the broader, $300 million lake-based tourism economy summarized in Table 10, the water quality impact on tourism revenues would likely be in the millions.

Table 6: Regression results for monthly rooms expenditures and average August Secchi depth.

Model	Intercept	Coefficient	t-statistic	p-value	R-squared
May	14,012	8,541	1.68	0.144	0.320
June	137,681	-8,308	-0.84	0.412	0.040
July	25,849	42,179	2.27	0.031	0.156
August	-36,733	71,721	3.39	0.002	0.324
September	4,466	23,707	1.50	0.163	0.169

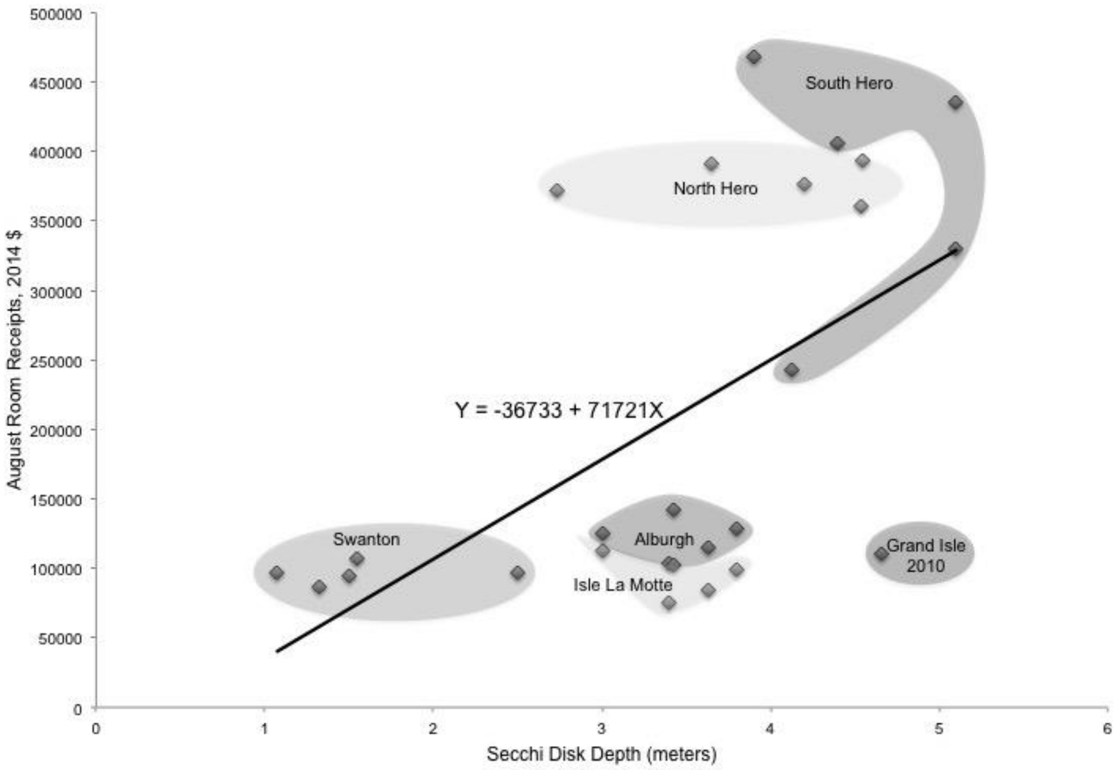

Figure 1: August room receipts plotted against Secchi disk depth, 2010-2014.

One problematic aspect of the data used in the regression analysis presented in Table 6 is that it is not normalized by the relative size of the lodging sector within each of the six towns. Data in Figure 1 represents two clusters of room receipts: 1) North and South Hero feature relatively high total room receipts for August, while 2) Swanton, Alburgh, Isle La Motte and Grand Isle are grouped along a lower room receipt axis. In order to normalize the room receipts data, the total number of lodging units in each of the six towns was estimated by browsing Chambers of Commerce, Google Maps and general lodging inquiries. This information was supplemented by referencing individual business web pages for room totals. Estimates for number of units for each town (as of August 2015) was then divided into monthly room receipts. Figure 2 plots August room receipts per unit against Secchi depth data, with each of the six town clusters highlighted again.

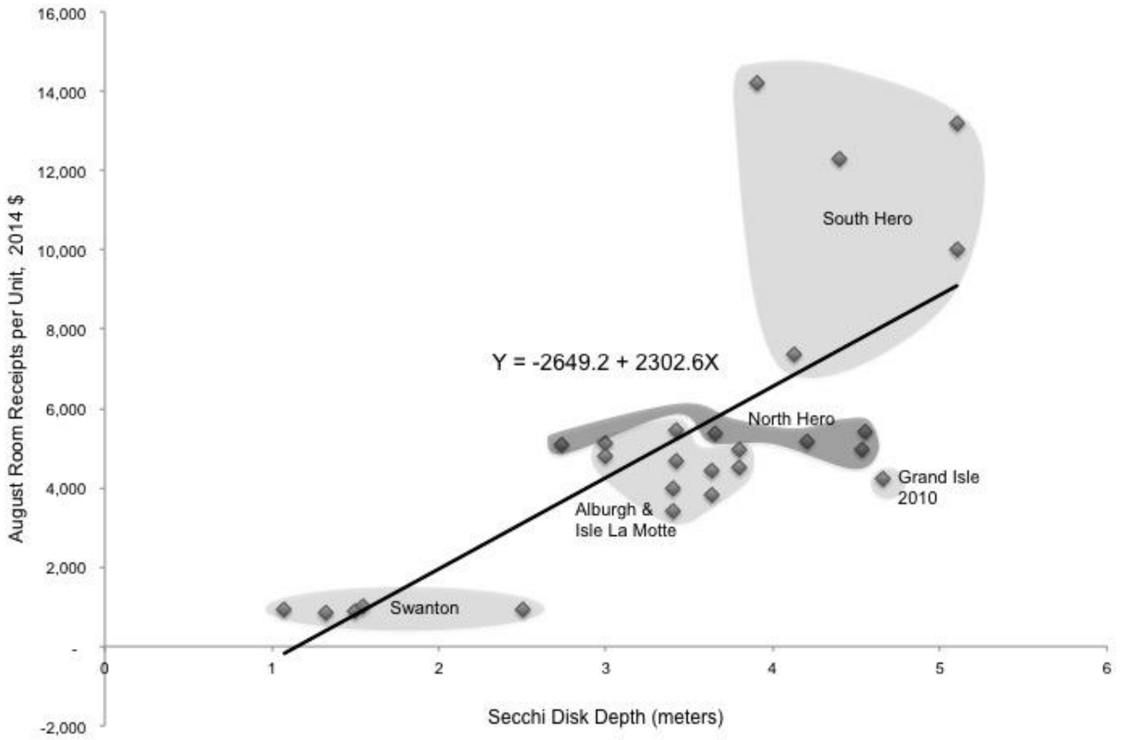

Figure 2: August room receipts per unit plotted against Secchi disk depth, 2010-2014.

South Hero still stands out with relatively high room receipts per lodging unit and high water clarity; however, the other five towns now lie along a water quality impact gradient within a more narrow range of lodging expenditures. This August model has an R-squared goodness-of-fit statistic of 0.510, and a strongly significant ($p<0.0000$) Secchi coefficient of $2,303 loss per average lodging unit per meter of water clarity decline in each town. A July model also demonstrates high correlation, with an R-squared statistic of 0.303 and a significant ($p<0.002$) Secchi coefficient of $1,545. Extrapolating the August model coefficient to an estimated average of 48 lodging units per town (including bed and breakfast, motel/hotel rooms, cottages, and cabins), the impact of a one-meter decline in water quality translates into a loss of $110,544 for the month of August. This amounts to approximately 10.3% of average August room receipts for the five towns with complete yearly data for a one-meter loss of lake clarity, or 28% for a two-meter loss.

4. **IMPLAN SAM model**

The regional economic model was built using the 2013 IMPLAN database for Vermont and New York, a system of economic accounts based on national input-output tables produced by the Bureau of Economic Analysis and tailored for county-level employment, income, household characteristics and industry make-up (see www.implan.com). To focus on tourism and second-home expenditures most directly impacted by water quality, the regional economy was defined as the four Vermont and two New York counties that make up the majority of the Lake Champlain shoreline (see Figure 3). Econometric analysis of tourism expenditures and water quality data in six lakeside communities with a predominance of summer, lake-based tourism activities enabled a sub-regional impact analysis.

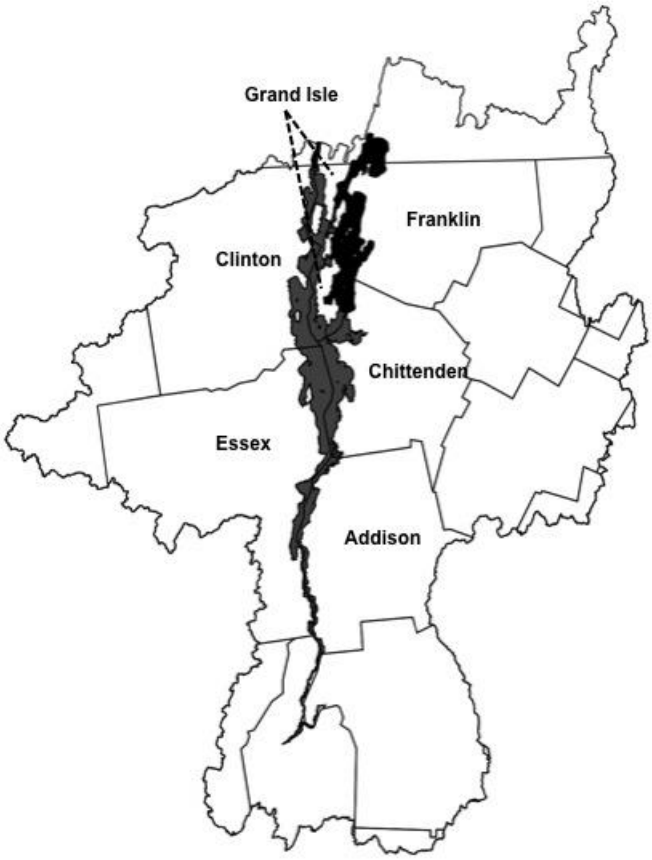

Figure 3: Shoreline counties within the larger basin included in Lake Champlain economy model.

In Vermont, the main shoreline counties include Addison, Chittenden, Franklin and Grand Isle, together accounting for 45% of 2013 Gross State Product (GSP), 43% of employment and 40% of the state's population (Table 7). Chittenden is the largest and most populated county economy in Vermont, centered around the City of Burlington on the shores of the main lake. Grand Isle County, VT is at the opposite end of the spectrum with one of the smallest employment bases (more closely representing Essex County in northeastern Vermont). These four counties account for more than 24% of the land area of Vermont, but make up approximately 48% of the Vermont portion of the Lake Champlain Basin (with all but a small section of Addison County entirely within the Basin).

On the New York side, the main shoreline counties include Clinton and Essex, together accounting for a very small portion of the state's 2013 gross state product (0.41%), employment (0.54%) and population (0.61%). The largest city is Plattsburgh, northwest of Burlington and connected by ferry to Grand Isle, Vermont. The low average household incomes are more characteristic of rural Vermont counties (e.g. Addison), than the New York state average. Aside from the city of Plattsburgh, both are very rural counties. Essex County has one of the lowest population densities in the state, second only to Hamilton County to the west, and is located entirely within the Adirondack Park.

Table 7: Lake Champlain Shoreline Economy Model, 2013

Geography	GSP (billion $)	Employment (Employment Diversity*)	Average HH Income ($)	Population	Land Area (sq. miles)
Vermont	29.760	425,161 (0.76)	106,305	626,630	9,249
Addison	1.501	24,090 (0.70)	99,577	36,791	770
Chittenden	10.006	131,509 (0.74)	117,477	159,515	539
Franklin	1.754	24,492 (0.70)	112,533	48,294	637
Grand Isle	0.146	2,424 (0.66)	115,790	6,987	83
New York	1,303.874	11,641,545 (0.74)	141,763	19,651,130	47,224
Clinton	3.587	41,570 (0.70)	92,485	81,591	1,039
Essex	1.749	21,298 (0.68)	88,524	38,762	1,797
Total	18.743	245,383 (---)	---	371,940	4,865

* Shannon-Weaver diversity index

The six-county region is predominately a service sector economy, with significant employment in professional services, retail trade and the health care sector. Table 8 highlights the top ten sectors by employment (for each county) by aggregating 3-digit North American Industry Classification System (NAICS) codes into region-specific industry groupings. The groupings are similar to a standard 2-digit NAICS aggregation, which includes 20 sectors in IMPLAN. The custom aggregation provides more detail in the agricultural, service, and government sectors, resulting in 53 total sectors for the model (see Appendix II for more information). The left-hand column of Table 8 lists the top ten sectors for the region as a whole, with full-time equivalent employees and sector ranking listed for each of the six counties. Analysis of the ten sectors by employment accounts for 70-74% of the total employment for each county. The county economies are more similar than different, with the top seven sectors for the region all represented in the top ten for each county. Locations with evident differences include employment in state and local government outside of education in the New York counties due to prison and state agency jobs. Franklin, Grand Isle and Clinton Counties each border Quebec, and thus include transportation and warehousing in their top ten. Both Chittenden and Essex counties have the aggregated arts and recreation sector in their top ten, while the influence of the dairy industry stands out in both Addison and Grand Isle counties in Vermont. The county economy with the most tourism-related sectors is Essex with retail trade (1), restaurants (5), hotels & accommodations (9) and arts & recreation (10) all in the top ten. However, much of this is concentrated away from Lake Champlain in the interior of the Adirondack Park near Lake Placid.

Table 8: Top 10 Economic Sectors by Employment, Six-County and Individual County Models, Custom Aggregation, 2013.

Economic Sector	Vermont				New York	
	Addison	Chittenden	Franklin	Grand Isle	Clinton	Essex
(Rank by County)	Sector Employment (County Model Rank)					
(1) Professional Services	2,413 (2)	20,872 (1)	2,400 (2)	342 (1)	3,382 (3)	1,450 (7)
(2) Retail Trade	2,453 (1)	13,902 (3)	2,778 (1)	283 (3)	5,831 (1)	2,217 (1)
(3) Health Care	2,122 (4)	14,022 (2)	2,337 (3)		4,855 (2)	1,873 (3)
(4) State & local gov't payroll, education	1,324 (7)	9,227 (5)	2,130 (4)	76 (10)	2,774 (6)	1,091 (8)
(5) Finance, insurance & real estate	1,562 (6)	9,254 (4)	1,211 (7)	112 (7)	2,380 (7)	1,649 (4)
(6) Restaurants & drinking est.	1,055 (9)	8,609 (6)	1,213 (6)	118 (6)	3,052 (5)	1,522 (5)
(7) Construction, mainten. & repair	1,745 (5)	6,492 (7)	1,518 (5)	289 (2)	1,821 (9)	1,507 (6)
(8) State & local gov't payroll, non-educ.					3,310 (4)	2,181 (2)
(9) Family & community services	1,181 (8)	4,877 (8)				
(10) Wholesale trade		4,034 (9)			2,026 (8)	
(11) Education	2,208 (3)			96 (8)		
(12) Arts & recreation		3,883 (10)				940 (10)
(13) Transportation & warehousing			1,113 (10)	158 (5)	1,298 (10)	
(14) Federal gov't payroll			1,201 (9)			
(18) Food & drink manufacturing			1,201 (8)			
(21) Hotels & accommodations						1,075 (9)
(22) Animal production	818 (10)			91 (9)		
(23) State & local gov't enterprises				190 (4)		
% of Total County Employment	**70.1%**	**72.4%**	**69.8%**	**72.4%**	**73.9%**	**72.8%**

Table 9 lists Vermont estimates of 2013 and 2003 visitor spending in sectors considered a major part of the tourism economy in the "Benchmark Study of the Impact of Visitor Spending on the Vermont Economy" for 2013 (Jones, 2015). Expenditures include day visitors and drive through traffic (7.3 million visitors); overnight visitors staying with friends and family (1.9 million) or using campgrounds (300,000) and commercial lodging (1.6 million); and overnight visitors using second homes (1.7 million visitors). The Benchmark Study provides these estimates in nominal dollars, showing a 42.3% increase in tourism spending over the 10-year period. However, when adjusted for inflation, spending has increased from $2.25 to $2.49 billion in 2013 dollars, or just 10.7%.

Table 9: Estimates of Vermont Tourist Expenditures, 2013 and 2003

Expenditure	2013 (million $)	2003 (million $)
Day and Overnight Tourism		
Lodging	430	320
Restaurants & bars	400	275
Gasoline sales	150	65
Groceries & convenience stores	150	100
Other retail sales	220	150
Recreation & entertainment	300	200
Travel expenses	140	100
Automotive rentals	30	25
Second Home Expenses		
Construction & renovation	200	150
Property taxes	240	140
Utilities & fuel	125	80
Maintenance, insurance & management	105	70
TOTAL	**2,490**	**1,750**

Of the nearly $2.5 billion estimated spending by Vermont tourists in 2013, the Agency of Commerce and Community Development estimates that approximately $300 million was spent "in and around Lake Champlain" (Moulton and Markowitz, 2015).Assuming Vermont-wide sectoral shares of tourism expenditures (based on Jones, 2015), Table 10 summarizes a modelling scenario for $300 million of tourism-related expenditures in the four Vermont counties for a disaggregated version of the shoreline economy model.

Taken together, these Vermont tourism-related expenditures attributed to Lake Champlain account for about 2.2% of the four-county gross regional product. However, this spending has an important multiplier effect in the region. IMPLAN derives regionalized multipliers by adjusting sector-to-sector relationships based on state level data to estimate both the indirect and induced effects from each dollar spent. In the Lake Champlain model, each dollar of labor income required within lake-related tourist sectors will generate an additional $0.57 in labor income through indirect industry inputs and induced impacts from additional spending of households. Similarly, each dollar of value-added (taxes, property income, profits) income generated in tourism-related sectors generates another $0.62. In terms of employment, every new job related to the lake tourism economy creates an additional 0.4

jobs to support indirect and induced activities. Table 11 summarizes this total economic impact across the four Vermont counties. The direct effect includes the initial round of spending highlighted in Table 10, less the property tax expenditures (calculated separately in IMPLAN as a value-added output). The indirect effect comes from all the necessary inputs from across the economy needed to support the tourism expenditures. The induced effect arises from regional spending from labor income.

Table 10: Inferred Tourism Spending in Vermont Lake Champlain Counties, 2013.

Expenditure	IMPLAN Sector #	% of VT Tourism Spending	Inferred 4-County Spending (million $)
Day and Overnight Tourism			
Lodging	499	17.3%	51.807
Restaurants & bars	501	16.1%	48.193
Gasoline sales	402	6.0%	18.072
Groceries & convenience stores	400	6.0%	18.072
Other retail sales	405	8.8%	26.506
Recreation & entertainment	496	12.0%	36.145
Travel expenses	412	5.6%	16.867
Automotive rentals	442	1.2%	3.614
Second home expenses			
Construction & renovation	59	8.0%	24.096
Property taxes		9.6%	28.916
Utilities & fuel	49	5.0%	15.060
Maintenance, insurance & management	440	4.2%	12.651
TOTAL		**100.0%**	**300.000**

Table 11: Economic Impact Analysis of Vermont Lake Tourism Spending in Four-County Model, 2013.

Effect Type	Employment	Labor Income	Value Added	Output
Direct	2,818.8	$78,060,759	$124,907,998	$222,397,943
Indirect	468.3	$19,934,026	$34,747,850	$62,605,641
Induced	602.8	$24,830,150	$42,071,180	$71,343,980
Total Effect	**3,889.9**	**$122,824,935**	**$201,727,027**	**$356,347,563**

Table 12 highlights the top ten sectors by employment impacted by tourism spending in the four-county region. Non-tourism sectors such as hospitals that were not part of the direct spending make the top ten because of the induced spending from labor income. Also, sectors such as real estate appear due to the indirect effects from second home expenditures.

Table 12: Top Ten Employment Impacts of Vermont Lake Tourism Spending, 2013.

Description	IMPLAN Sector	Employment	Labor Income	Value Added	Output
Restaurants	501	1,044.5	$23,108,900	$26,118,392	$50,318,104
Hotels and motels	499	552.4	$16,643,463	$32,808,759	$51,944,431
Amusement & recreation	496	549.8	$11,738,862	$22,033,182	$36,449,977
Passenger transportation	412	257.7	$7,960,451	$9,751,883	$17,232,167
Residential Construction	59	167.3	$9,280,381	$10,696,033	$24,096,000
Real estate	440	133.4	$3,420,671	$21,363,392	$26,012,401
Retail - General merchandise	405	118.8	$3,384,789	$4,989,671	$8,158,037
Retail - Food & beverage	400	105.6	$2,990,761	$4,068,955	$6,532,853
Hospitals	482	39.0	$2,769,695	$3,142,183	$5,454,535
Retail - Gasoline stores	402	37.4	$1,417,161	$1,781,058	$2,790,054

5. **Scenario analysis:** The IMPLAN model was used to analyse scenarios examining the relationship between visitation rates, visitor expenditures and regional economic effects. The hedonic model, on the other hand, was used to analyse the relationship between Total Phosphorous and Secchi Depth measurements to estimate changes in water clarity resulting from hypothesized changes in nutrient loading. This information was used to estimate changes in property values in relation to changes in water quality

   IMPLAN SAM Model
   Regression results from the tourism expenditure model provided the basis for a broader assessment of the vulnerability of regional tourism activity to water quality conditions within the Lake. Referring to the estimated $300 million in 2013 tourism expenditures tied to Lake Champlain, Vermont's Secretary of Commerce and Economic Development together with the Secretary of Natural Resources commented earlier this year state that, "Nutrient pollution and the resulting cyano-bacteria outbreaks (or blue-green algae blooms) present a serious threat to all of this lake-based economic activity".[1] Scenario analysis using the 4-county IMPLAN model, together with coefficient estimates from the 6-town room receipts model, was conducted to assess the degree of this threat to the Lake Champlain tourism economy.

   For example, the regression of Secchi disk depth against room receipt data normalized by the number of units per town (Figure 2) showed an estimated impact of lodging revenue ranging between 6.5% in July to 10.3% in August from a one-meter loss of water clarity. Assuming the bulk of the $300 million

[1] April 15, 2015 *Rutland Herald* editorial. See footnote 1.

in lake-related tourist expenditures occurs in the summer, peaking in July and August, suppose that 25%, or $75 million per month, is spent in the four Vermont lake counties in each of the two most impacted months. The total impact for July and August would be $12.6 million. This represents approximately 4.6% of the direct impact used to simulate the IMPLAN tourism scenario summarized in Table 10 and Table 11. Propagated across the regional economy, this translates into a total employment loss in the four Vermont counties of 195 full-time equivalent jobs. In addition, the loss of labor and other value-added income is estimated at $16.8 million.

IMPLAN models can also be used to simulate the estimated impacts of specific events, especially when survey data is available. In the case of tourism directly related to Lake Champlain, these might include lakeside festivals (e.g. Jazz Fest, Burlington Beer Festival), regattas and fishing tournaments. For example, a recent IMPLAN study commissioned by the North Country Chamber of Commerce (Read, 2012) investigated the economic impact of the 2012 summer series of Lake Champlain Pro Bass Fishing Tournaments. The model was built for Clinton County using the 2009 IMPLAN database. Data from a participant survey was used to estimate direct expenditures on lodging, food, fuel, and entertainment related to anglers' direct trips totalling $1.14 million during the five tournaments, with an additional $1.4 million spent on scouting trips to the region. Combined with spending by tour organizers, the bass tournaments generate 27.2 direct jobs and an additional 7.3 indirect and induced jobs (Read, 2012). An estimated $74,285 in labor income is generated, and a total of $2,742,581 in gross regional product (Read, 2012).

Hedonic Model

Regression analysis was used to test the relationship between the natural log of both Secchi disk depth data (m) and Total Phosphorous (µg/L). More than 630 observations from 1992 – 2014 were used in the analysis. The mean value of all Total Phosphorous observations is 24.167 µg/L. Results indicate a strong relationship between the two factors (Table 13, Figure 4) with a one-percent (µg/L) increase in Total Phosphorous yielding a corresponding Secchi disk decrease of 0.88%. These results were used as the basis of scenario analysis for the hedonic models.

Table 13: Regression results for analysis of Total Phosphorous and Secchi disk depth data.

Intercept	Coefficient	t-statistic	p-value	R-squared
3.967	-0.88378	-43.248	0.000	0.748

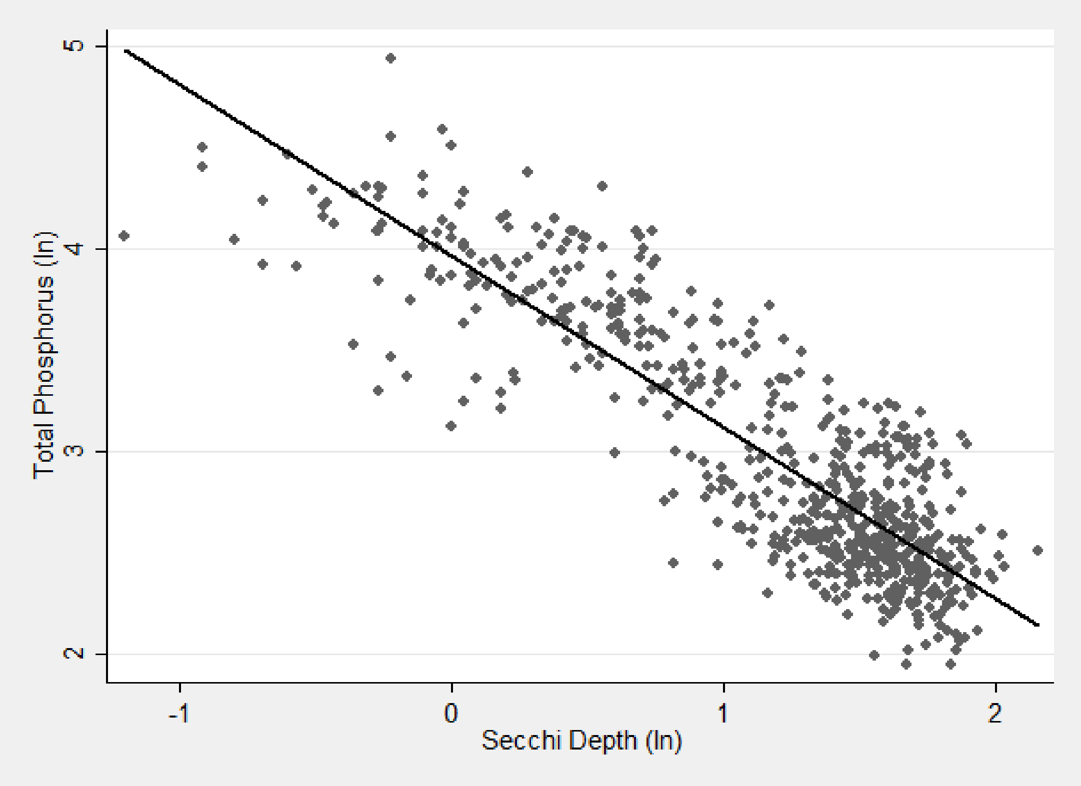

Figure 4: Scatterplot with fitted line for the natural log of Total Phosphorous (µg/L) and the natural log of the Secchi disk depth (m) data.

Required change in Phosphorous load under revised TMDL

In a November 2014 meeting, the US Environmental Protection Agency (EPA) estimated that a 34% reduction in phosphorous loading would be required to meet the target load for the State of Vermont (EPA, 2014). A 34% reduction to the mean Total Phosphorous observations would yield a revised mean Total Phosphorous value of 15.950 µg/L (for an absolute decrease of 8.22 µg/L). Using the regression results described above (Table 13), this translates to 1.67-m increase in Secchi disk depth, and approximately $15,200 price increase for the selling price of the average single family residential dwelling within the study area (see Table 2).

Estimated impacts of climate change on Phosphorous loading within the basin

TetraTech used the Soil and Water Assessment Tool (SWAT) to estimate potential change in phosphorous loading throughout the basin as a result of climate change (TetraTech, 2013). They examined six different climate scenarios extending through 2040 – 2070 as part of their analysis. Taking the average of the six scenarios, the annual phosphorous load for the entire Lake Champlain basin is expected to increase by 29.6%, indicating further impairment of lake water. This increase translates to an increased mean Total Phosphorous load of 31.321 µg/L (for an absolute increase of 7.153 µg/L). Using the regression results described above (Table 13), this translates to 0.773-m decrease in Secchi depth, and an approximate $7,000 decrease in the selling price of the average single family residential dwelling within the study area (see Table 2).

4 Deliverables Completed

1. **Project report:** The project final report presented here describes all data, methods and results produced by this study.

2. **Presentation of Results:** The Principal Investigator is currently scheduled to present the data, methods, findings and conclusions of this investigation at the September 2015 TAC meeting. Additional public presentations are currently being scheduled by LCBP project partners.

3. **Database transfer:** This project produced three databases:
    a. The first is a compilation of the literature search which includes a table of literature that was reviewed and a user interface that facilitates guided author or keyword searches that direct the user to annotated descriptions of the literature resources.
    b. The second is a compilation of the derived data that was used to estimate the econometric models. This database is comprised primarily of spatial data that can be used for additional spatial analysis and map production.
    c. The third is a compilation of all of the source data in its original format as acquired by the Prinicipal Investigator. This meets the requirements established in the Project QAPP (Section 5.2).

5 Conclusions

Project Summary

The regional economy, quality of life and tourism rely on clean water in Lake Champlain and its surrounding basin. This project explored the relationship(s) between water quality and property valuation, tourism expenditures and economic activity to quantify the contribution of the natural amenities offered by the Lake to the regional economy. The project was designed to explore the value of clean water in Lake Champlain for two primary classes of beneficiaries, residential property owners and tourists. At the regional scale, economic flows among sectors were modelled in relation to water quality impacts on tourist expenditures for overnight accommodations. Scenario analysis was conducted to estimate changes in housing value, tourism expenditures and economic impact as a result of changes in water quality, water clarity and recreational activities.

A hedonic modelling approach was used to estimate the market value of water quality, proximity and views to residential real estate in Vermont towns near Lake Champlain. The results highlight the importance of a clean, healthy lake to the regional property market. For example, in Georgia, VT, the assessment of 37 properties adjacent to St. Albans Bay was reduced by $50,000 each representing a net loss of more than $1.8 million from the town's tax rolls (Vermont Public Radio, 2015). In this study, for both single family residential and seasonal home purchasers, higher water quality was associated with increased property selling price. A one-unit increase in Secchi disk depth is equated with nearly 3% and 37% increases in selling prices for single family residential and seasonal homes, respectively.

A strong correlation between Total Phosphorous and Secchi disk measurements was found. This finding was used to translate phosphorous loading recommendations and predictions for the Lake Champlain basin TMDL and water quality impacts from climate change. The increased phosphorous load associated with climate change is estimated to result in a $4,900 and $53,000 price decrease per average single family dwelling and seasonal residence, respectively. Lake clean up and load reductions associated with meeting mandated TMDL targets are estimated to result in a $5,700 or $61,000 price increase per average single family dwelling and seasonal residence, respectively. These two scenarios represent plausible ends of the price spectrum. It is likely that the price signal is non-linear (Boyle, Poor and Taylor, 1999) and that at some level of water quality improvement the marginal return would trend towards zero.

At the sub-regional scale, the relationship between tourism expenditures on overnight accommodations and Secchi disk depth was explored. Findings for the peak summer months of July and August indicate a significant impact on tourism spending related to changes in water clarity. After normalizing town-level expenditures by the estimated number of rooms per town a linear regression model estimated a $2,303 decrease per average lodging unit per meter of water clarity decline in each town. Extrapolating to the five-town scale concludes that a one-meter decline in water quality is expected to lead to a 10% decrease ($110,544) in room expenditures for the month of August.

Finally, at the regional scale an input-output model was constructed for the lakeshore economy surrounding Lake Champlain. Four counties in Vermont and two counties in New York were included in the analysis. The IMPLAN SAM software and county-level employment, income, household characteristics and industry make-up tables were used to assess the economic connections among sectors. The six-county region is predominately a service sector economy, with significant employment in professional services, retail trade and the health care sector. The county economies are more similar than different, with the top seven sectors for the region all represented in the top ten for each county. Additionally, the top ten sectors by employment account for 70-74% of the total employment for each county.

A four-county Vermont model found that tourism expenditures feature a corresponding multiplier effect that ripples through the regional economy as every dollar of lake-related tourism activity generates an additional $0.57 in labor income alone, $0.62 in other value added (taxes, property income, profits), and all together an additional $0.60 in total output in the region. Similarly, the lake tourism economy creates an additional 0.4 jobs in supporting and induced activities for every new job. The $300 million in annual tourist spending in the four lakeside counties of Vermont generates an additional $72.75 million in spending and nearly 1,070 jobs.

Secchi disk depth data regressed against room receipt data revealed an estimated impact on lodging revenue ranging between 6.5% in July to 10.3% in August from a one-meter loss of water clarity. Assuming that 50% of all lake-based tourism spending within the basin occurs during the months of July and August, a one-meter decrease in water clarity would lead to the loss of 195 full-time equivalent jobs, a $12.6 million reduction in tourism expenditures and a total economic reduction of nearly $16.8 million.

Lessons Learned and Future Opportunities

This project reaffirms the importance of a healthy Lake Champlain to the condition of the regional economy as reflected in property valuation, tourism expenditures and economic activity between various sectors. The project evaluated the influence of water quality influence on different aspects of valuation across all three spatial scales. A mechanism was established to use the findings from the sub-regional model to inform scenario development at the regional scale.

Data acquisition and processing, particularly for the real estate transaction data, presented a number of challenges, not the least of which is the storage of different parcel-level information in multiple formats with varying reference IDs. The process of data conflation is both technically challenging (with respect to process automation) and time consuming (since most of this effort was conducted manually). While these types of data limitations were overcome through the use of proxies (e.g. assessed value in the place of detailed, household-level structural information), they effectively limit the scope of the analysis due to the data assembly effort involved for broadening the spatial and temporal scales of analysis.

The development of the regional-scale input-output model was relatively straightforward (compared to the parcel-scale hedonic model). Customized economic activity clusters were designed to focus on impacts to (and from) household and tourism-related expenditures and their magnitude relative to the regional economy. Limited scenarios analysis was conducted; however, possible scenario types ranging from individual events (e.g. fishing tournaments) to long-term environmental and economic conditions could be further analysed given a set of input conditions. This type of approach could allow for a rapid assessment of the economic impacts of anything from land use plans and zoning regulations, to environmental restoration and mitigation efforts, to regional economic development strategies. Outputs from these types of analyses could support decision-making for effective policy formulation and implementation.

This analysis represents a snapshot in time, and although the Secchi disk measurement parameter was averaged over time, the analysis in general lacks temporal specifications that could better reveal lagged effects (i.e. across multiple seasons or years) between changes in water quality and human perception of Lake suitability and its influence on economic decision making (e.g. where to buy a house, go on vacation). The example of Georgia, VT reveals that a continued downward water quality trend has real (and lasting) impacts on the local housing market, affecting town-level appraisal, real estate transactions, vacation rentals and tourism expenditures. Losses in one or more of these sectors are further magnified when considering their effect on employment and indirect expenditures.

The importance of targeted survey data capturing consumer perspectives on topics ranging from real estate preferences to factors influencing vacation decisions and economic development should not be underestimated. In the absence of this information, proxy data were used. However, the roots of the economic analysis presented here are a series of individual (and oftentimes personal) financial decisions that scale to the regional economy. A set of well-crafted survey instruments designed for specific target audiences (e.g. homebuyers, business owners) could help understand spending and investment differentials throughout the Lake. Survey findings could be used to improve or enhance existing model specifications whose results in turn could inform the development of a long-term economic development plan that addresses potential climate change impacts, includes measures to improve environmental quality and expand the lake-based tourism market throughout the basin.

This effort represents a step towards understanding the relationship(s) and interdependencies of economic actors, current and future economic development and local- to regional environmental conditions. Generally speaking, this project and potential future extensions of the work presented here could be used to address several of the tasks included in the LCBP's Opportunities for Action. Project findings could inform the public about the economic implications of lake water quality. Actions 3.1 and 4.5 could include the development of educational materials that connect individual decisions to water quality metrics. This connection in turn establishes a context for understanding the sectors of the economy that are strongly influenced by the overall health of the Lake. The modelling framework developed for this project could also be used to address Actions 10.1.2, 10.2 and 10.3.1. The scenario analysis capabilities could easily be extended to encompass additional policy and management questions related to restoration and mitigation activities and prioritizing spending on such efforts to maximize return on investment. Finally, economic indicators (e.g. real estate valuation, visitation rates and expenditures, employment opportunities and economic development) estimated by modelling a range of potential policy and climate alternatives could lead to more informed watershed management plans and economic development strategies.

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7 Appendices

Appendix I: Quality Assurance Tasks Completed

Primary data resources

All data for the econometric models were obtained from one of five sources:

1. Vermont Center for Geographic Information (VCGI), a division of the Agency of Commerce and Community Development. VCGI is the lead agency in charge of geospatial data storage and dissemination in the State of Vermont.
2. Vermont Department of Taxes, a division of the Agency of Administration. The Department of Taxes maintains state-wide records

pertaining to real estate transactions and meals and rooms expenditures. This department is the only source for these data in the State of Vermont. The real estate transaction data underwent a thorough review by the Principal Investigator to ensure the deletion of duplicate records and elimination of records with incomplete attribution. These data were geocoded using the address field in both the real estate transaction data and the state-wide E911 data. Transaction data without a corresponding address record in the E911 dataset were eliminated from the database.

3. Vermont Department of Environmental Control / Lake Champlain Basin Program Lake Champlain Long-term Water Quality and Biological Monitoring Project. These data are collected by the New York State Department of Environmental Conservation and the Vermont Department of Environmental Conservation in collaboration with the Lake Champlain Basin Program. The program includes data collection to monitor water quality and biological conditions within the Lake. The Quality Assurance Project Plan for this program can be found online at www.watershedmanagement.vt.gov/lakes/docs/lp_2015ltmpqapp.pdf.
4. US Geological Survey - The National Map. The National Map is the primary outlet for national scale elevation and land cover data. As such, data from The National Map were the best available because of the spatial extent of their coverages and their temporal proximity (in particular the 2011 National Land Cover Dataset (2011 NLCD)) to many of the other primary datasets, including the real estate transaction data, the meals and rooms expenditures and the water quality monitoring data. Data served by The National Map have undergone extensive review, meet all federally established data standards and are internationally recognized as being of high quality.
5. Claritas, Inc. 2103 employment data for the State of Vermont was purchased from this commercial data vendor. This data was purchased for another project that the Principal Investigator worked on, and no funds from this project were spent on its acquisition. The data are of the highest quality available and are routinely used for complex economic analysis and land use planning applications. Although there are certainly other vendors distributing this data, they all originate from the same source, and no funding was requested to support additional data acquisition.

The 2013 IMPLAN database for Vermont and New York counties was purchased from the IMPLAN Group, LLC who also developed the IMPLAN System (data and software) used in the analysis. The data represent a system of economic accounts based on national input-output tables produced by the Bureau of Economic Analysis and tailored for county-level employment, income, household characteristics and industry make-up (see www.implan.com). Scenario data for the IO model was developed using data from the Vermont Department of Taxes and the Lake Champlain Long-term Water Quality Monitoring Program, both of which are described above.

Table 14: List of primary data sources included in one or more models described in the project report.

Dataset Name	Source	Description of Use
Real estate transaction data	Vermont Department of Taxes	Selling price information used as the dependent variable in the hedonic model. Parcel size and assessed value used as independent variables in the hedonic model.
Lake Champlain Boundary	VCGI	Used to delineate 100-m buffer zone and compute the amount of lake visibility from real estate transaction locations.
Recreation Sites	VCGI	Combined fishing access locations with other recreational sites on the lakeshore and then derived proximity measures between them and the transaction locations.
Roads	VCGI	The E911 roads dataset was used to build the transportation network that served as the primary input for computing proximity measures and service areas around transaction locations.
Employment	Claritas, Inc.	The employment data was split according to generalized NAICS classifications (e.g. Service, Industrial, Finance) and then used to compute the proximity of transaction locations to different types of commercial establishments.
E911 Sites	VCGI	The E911 data were used to geocode the real estate transaction data and the employment data. This data represents the most complete database of georeferenced residential and non-residential addresses in the State of Vermont.
Town and County Boundaries	VCGI	The town and county boundaries data were used to define the spatial extents of the various models in the project.
Demographics	VCGI – US Census Bureau	Data from the 2010 Decennial Census of the Population were used as independent variables in the hedonic model.
Water Quality Monitoring Data	VT DEC	The water quality monitoring data was used as an independent variable in the hedonic model and the tourism expenditure model, and was used as an input to the scenario development process for the IO model.
2011 National Land Cover Dataset	USGS – The National Map	The 2011 NLCD was used to identify specific land cover classes (e.g.

Dataset Name	Source	Description of Use
		forested) for inclusion as an independent variable in the hedonic model. However, none of the derived land cover parameters were found significant.
Digital Elevation Model (DEM)	USGS – The National Map	The DEM was one of two primary inputs for the viewshed analysis that determined the amount of Lake visibility from each of the transaction locations.

Data Storage

Secondary data collected for this project is currently stored on the UVM central network. Data is backed up on a regular basis according to UVM network protocols. All of the data includes documentation of the data source, date collected, and provider contact information. A guide to the primary data is provided in Table 14, and a complete list of derived data is included in Appendix I: Data Documentation and as a standalone spreadsheet. Techniques used to derive, interpret and display data in the report has been documented, is stored on the UVM central network and is available to the public upon inquiry. The data will remain on the UVM central network for a period of at least 2 years and can be accessed via a request to the Principal Investigator.

Appendix II: Quality Assurance Tasks Completed

IMPLAN Sector	Description	3-digit NAICS Sector
1	Crop Farming	1-10
11	Animal Production	11-14
15	Forestry & logging	15-16
17	Fishing, hunting & trapping	17-18
19	Support for agriculture & forestry	19
20	Mining & energy extraction	20-40
41	Utilities	41-51
52	Construction, maintenance, & repair	52-64
65	Food & drink manufacturing	65-110
111	Tobacco, fiber, and apparel	111-133
134	Wood products manufacturing	134-153
154	Printing	154-155
156	Petrochemicals & chemicals	156-168
169	Fertilizer, pesticide & agrochemical	169-172
173	Medicinal & pharmaceutical	173-176
177	Other chemical manufacturing	177-187
188	Plastic products	188-195
196	Rubber products	196-198
199	Cement, glass & other nonmetallic products	199-216
217	Metals	217-233
234	Fabricated metal manufacturing	235-261
262	Industrial machinery manufacturing	262-271
272	Instrument & equipment manufacturing	272-300
301	Computers & electronics	301-313
314	Control & measurement devices	314-324
325	Lights & appliances	325-331
332	Electrical equipment manufacturing	332-342
343	Transportation manufacturing	343-367
368	Other manufacturing	368-394
395	Wholesale trade	395
396	Retail trade	396-407
408	Transportation & warehousing	408-416
417	Publishing, entertainment & telecommunications	417-432
433	Finance, insurance & real estate	433-440
441	Owner occupied dwellings	441
442	Rentals & leasing	442-446
447	Professional services	447-471

IMPLAN Sector	Description	3-digit NAICS Sector
472	Education	472-474
475	Health care	475-484
485	Family & community services	485-487
488	Arts & recreation	488-498
499	Hotels & accommodations	499-500
501	Restaurants & drinking places	501-503
504	Auto & equipment repair	504-508
509	Personal services	509-512
513	Non-governmental organizations	513-516
517	Private households	517
518	Federal government enterprises	518-520
521	State & local government enterprises	512-526
527	Not an industry	527-530
531	State & local gov't payroll, non-education	531, 533
532	State & local gov't payroll, education	532, 534
535	Federal gov't payroll	535-536

Appendix III: Data Documentation

Lake Champlain Recreation Access Points

1. Download TourismRecreation_FISHACCESS.zip from vcgi.vermont.gov >>> \LCBP\Hedonic\zips\TourismRecreation_FISHACCESS.zip
2. Unzip TourismRecreation_FISHACCESS.zip >>> \LCBP\Hedonic\incoming\FishAccess\
3. Download TourismRecreation_RECSITES.zip from vcgi.vermont.gov >>> \research\LCBP\Hedonic\zips\TourismRecreation_RECSITES
4. Unizip TourismRecreation_RECSITES.zip >>> \LCBP\Hedonic\incoming\RecreationSites\
5. Select By Location from TourismRecreation_FISHACCESS, TourismRecreation_RECSITES ALL RECORDS WITHIN 100m of LakeChamplain_step1 (FISHACCESS = 29 records selected, RECSITES = 113 records selected)
6. Export selected FISHACCESS records >>> \LCBP\Hedonic\hedonic_scratch.mdb\FishAccess_step1
7. Export selected RECSITES records >>> \LCBP\Hedonic\hedonic_scratch.mdb\RecreationSites_step1
8. Select By Attributes from RecreationSites_step1 WHERE [PUBLIC_PRI] = 1 (69 records selected)
9. Export selected records >>> \LCBP\Hedonic\hedonic_scratch.mdb\RecreationSites_step2
10. Select By Attributes from RecreationSites_step2 WHERE [BOATING_MA] = 'Y' OR [SWIMMING] = 'Y' (42 records selected)
11. Export selected records >>> \LCBP\Hedonic\hedonic_scratch.mdb\RecreationSites_step3
12. Export RecreationSites_step3>>> \LCBP\Hedonic\hedonic_scratch.mdb\RecreationSites_step4
13. Analysis Tools > Proximity > Near WHERE INPUT = RecreationSites_step4, NEAR FEATURE = RecreationSites_step3
14. Turn off extraneous fields in RecreationSites_step4
15. Export RecreationSites_step4 >>> \LCBP\Hedonic\hedonic.mdb**DistanceToRecreationSites**

Proximity to Lake Champlain

1. Download NHDH_VT_931v220.zip from vcgi.vermont.gov >>> NHDH_VT_931v220.zip
2. Unzip geodatabase >>> NHDH_VT.gdb
3. Select By Attributes from NHDWaterbody WHERE GNIS_Name = 'Lake Champlain' (1 record selected)
4. Export selected record >>> \LCBP\Hedonic\hedonic_scratch.mdb\LakeChamplain_step1
5. Export PT_step8_ALL >>>\LCBP\Hedonic\hedonic_scratch.mdb\DistanceToLakeChamplain_step1
6. Analysis Tools > Proximity > Near WHERE INPUT = DistanceToLakeChamplain_step1, NEAR FEATURE = LakeChamplain_step1

7. Export DistanceToLakeChamplain_step1 >>> \LCBP\Hedonic\hedonic.mdb**DistanceToLakeChamplain**

Employment

(This data was purchased from a proprietary data supplier and is not available to be shared in its original format. Derived data products are described here and included in the project database.)

1. ArcMap > right click StatewideEmployment_step1 > Display XY Data using NewX and NewY as the coordinates
2. Data Management Tools > Features > Copy Features WHERE INPUT = StatewideEmployment_step1 >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb\StatewideEmployment_step2
3. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '7221%' (1133 records selected)
4. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_FullServiceRestaurants**
5. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '7221%' or NAICS_string LIKE '7222%' (1413 records selected)
6. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_AllRestaurants**
7. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE ('111%') OR NAICS_string LIKE ('112%') OR NAICS_string LIKE ('114*') OR NAICS_string LIKE ('115*') (451 records selected)
8. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Agriculture**
9. Select By Attributes from StatewideEmployment_step WHERE NAICS_string LIKE '113%' OR NAICS_string LIKE '321%' OR NAICS_string LIKE '311%' OR NAICS_string LIKE '313%' OR NAICS_string LIKE '236%' OR NAICS_string LIKE '211%' OR NAICS_string LIKE '221%' OR NAICS_string LIKE '322%' OR NAICS_string Like '312%' OR NAICS_string Like '314%' OR NAICS_string Like '237%' OR NAICS_string Like '212%' OR NAICS_string Like '323%' OR NAICS_string Like '315%' OR NAICS_string Like '238%' OR NAICS_string Like '213%' OR NAICS_string Like '324%' OR NAICS_string Like '316%' OR NAICS_string Like '325%' OR NAICS_string Like '326%' OR NAICS_string Like '327%' OR NAICS_string Like '331%' OR NAICS_string Like '332%' OR NAICS_string Like '333%' OR NAICS_string Like '334%' OR NAICS_string Like '335%' OR NAICS_string Like '336%' OR NAICS_string Like '337%' OR NAICS_string Like '339%' (4619 records selected)

10. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Industrial**
11. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '44%' OR NAICS_string LIKE '45%' (5412 records selected)
12. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Retail**
13. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '52%' OR NAICS_string LIKE '531%' OR NAICS_string LIKE ''533%' (2364 records selected)
14. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Finances**
15. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '511%' OR NAICS_string LIKE '512%' OR NAICS_string LIKE '515%' OR NAICS_string LIKE '517%' OR NAICS_string LIKE '518%' OR NAICS_string LIKE '532%' OR NAICS_string LIKE '54%' OR NAICS_string LIKE '55%' OR NAICS_string LIKE '56%' OR NAICS_string LIKE '62%' OR NAICS_string LIKE '721%' OR NAICS_string LIKE '722%' OR NAICS_string LIKE '81' (13246 records selected)
16. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Service**
17. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '221%' (87 records selected)
18. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Utilities**
19. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '711%' OR NAICS_string LIKE '712%' (414 records selected)
20. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_CulturalAttractions**
21. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string LIKE '61%' (XXX records selected)
22. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Education**
23. Select By Attributes from StatewideEmployment_step2 WHERE NAICS_string = '445110' OR NAICS_string LIKE '4452%' (483 records selected)
24. Export selected records >>> \LCBP\Hedonic\EmploymentAnalysis_scratch.gdb**StatewideEmployment_Grocery**

E911

1. Download EmergencyE911_ESITE .zip from vcgi.vermont.gov >>> EmergencyE911_ESITE.zip
2. Unzip archive >>> \Hedonic\incoming\E911\Emergency_ESITE_point
3. Select By Location from Emergency_ESITE_point ALL RECORDS THAT INTERSECT PrimarySecondaryTowns (92,755 records selected)
4. Export selected records >>> \E911_scratch.mdb\E911_ESITE_step1
5. Select By Attribute from E911_ESITE_step1 WHERE [SITETYPE] In ('CAMP', 'MOBILE HOME', 'MULTI-FAMILY DWELLING', 'OTHER RESIDENTIAL', 'RESIDENTIAL FARM', 'SEASONAL HOME', 'SINGLE FAMILY DWELLING') (79,250 records selected)
6. Export selected records >>> \Hedonic\incoming\E911\E911_scratch.mdb\E911_ESITE_step2 (residential)
7. Select By Attribute from E911_ESITE_step1 WHERE [SITETYPE] In ('ACCESSORY BUILDING', 'AIR SUPPORT / MAINTENANCE FACILITY', 'AIRPORT TERMINAL', 'AMBULANCE SERVICE', 'BANK', 'BOAT RAMP / DOCK', 'BORDER PATROL', 'CAMP', 'CAMPGROUND', 'CITY / TOWN HALL', 'COAST GUARD', 'COLLEGE / UNIVERSITY', 'COMMERCIAL', 'COMMERCIAL FARM', 'COMMERCIAL GARAGE', 'COMMERCIAL W/RESIDENCE', 'COMMUNICATION BOX', 'COMMUNICATION TOWER', 'COMMUNITY / RECREATION CENTER', 'COMMUNITY / RECREATION FACILITY', 'DAY CARE FACILITY', 'DEVELOPMENT SITE', 'EDUCATIONAL', 'FIRE STATION', 'GAS STATION', 'GATED W/BUILDING', 'GOLF COURSE', 'GOVERNMENT', 'GREENHOUSE / NURSERY', 'GROCERY STORE', 'HAZARDOUS MATERIALS FACILITY', 'HEALTH CLINIC', 'HELIPAD / HELIPORT / HELISPOT', 'HISTORIC SITE / POINT OF INTEREST', 'HOUSE OF WORSHIP', 'HYDROELECTRIC FACILITY', 'INDUSTRIAL', 'INSTITUTIONAL RESIDENCE / DORM / BARRACKS', 'LANDFILL', 'LAW ENFORCEMENT', 'LIBRARY', 'LODGING', 'MINE', 'MOBILE HOME', 'MULTI-FAMILY DWELLING', 'NURSING HOME / LONG TERM CARE', 'OFFICE BUILDING', 'OIL / GAS FACILITY', 'OTHER', 'OTHER COMMERCIAL', 'OTHER RESIDENTIAL', 'PARK AND RIDE / COMMUTER LOT', 'POST OFFICE', 'PRISON / CORRECTIONAL FACILITY', 'PUBLIC GATHERING', 'PUBLIC TELEPHONE', 'PUBLIC WATER SUPPLY WELL', 'PUMP STATION', 'RACE TRACK / DRAGSTRIP', 'RADIO / TV BROADCAST FACILITY', 'RAILROAD STATION', 'RESIDENTIAL FARM', 'RESTAURANT', 'RETAIL FACILITY', 'RV HOOKUP', 'SCHOOL', 'SEASONAL HOME', 'SINGLE FAMILY DWELLING', 'SOLAR FACILITY', 'STATE GOVERNMENT FACILITY', 'STORAGE UNITS', 'SUBSTATION', 'TEMPORARY STRUCTURE', 'TOWN GARAGE', 'TOWN OFFICE', 'US GOVERNMENT FACILITY', 'UTILITY', 'UTILITY POLE W/PHONE', 'VETERINARY HOSPITAL / CLINIC', 'VISITOR / INFORMATION CENTER', 'WAREHOUSE', 'WASTE / BIOMASS FACILITY', 'WASTEWATER TREATMENT PLANT', 'WATER TANK', 'WATER TOWER', 'WIND FACILITY / WIND TOWER') (185,279 records selected)

8. Export selected records >>> \Hedonic\incoming\E911\E911_scratch.mdb\E911_ESITE_step3 (general development density)
9. Spatial Analyst Tools > Density > Point Density WHERE INPUT = E911_ESITE_step2, POPULATION FIELD = NONE, CELL SIZE = 10, NEIGHBORHOOD = CIRCLE, RADIUS = 500m >>> \LCBP\Hedonic\incoming\E911\E911_scratch.mdb**ResidentialDevelopmentDensity**
10. Run model ResidentialDensityAnalyzer to calculate zonal statistics on ResidentialDevelopmentDensity within 1- and 5-km boundaries surrounding each real estate transaction point
    a. This step uses ArcGIS ModelBuilder to iterate over all of the transaction point data to compute residential density values for 1- and 5-km boundaries

Town Boundaries
1. Select By Location from Boundary_BNDHASH_region_towns ALL RECORDS THAT INTERSECT PT_step8_ALL (23 records selected)
2. Export selected records >>> \Hedonic\hedonic.mdb**PrimaryTowns**
3. Select By Location from Boundary_BNDHASH_region_towns ALL RECORDS THAT SHARE A LINE SEGMENT WITH PrimaryTowns (45 records selected)
4. Export selected records >>> \Hedonic\hedonic.mdb**PrimarySecondaryTowns**

US Census
1. Download DemoCensus_BLCKGR2010.zip from vcgi.vermont.gov >>> DemoCensus_BLCKGR2010.zip
2. Unzip archive >>> \Hedonic\incoming\Census\DEMO_BLCKGR2010_POLY
3. Select By Location from DEMO_BLCKGR2010_POLY ALL RECORDS THAT INTERSECT PropertyTransfer_ALL (98 records selected)
4. Export selected records >>> \Hedonic\incoming\Census\Census_scratch.mdb\BlockGroup2010_step1
5. Join BlockGroup2010_step1 to PropertyTransfer_ALL based on SPATIAL LOCATION >>> \Hedonic\incoming\Census\Census_scratch.mdb\BlockGroup2010_step2
6. Turn off extraneous fields from Layer Properties
7. Export _step2 >>> \Hedonic\incoming\Census\Census_scratch.mdb\BlockGroup2010_step3
8. Export _step3 >>> \Hedonic\hedonic.mdb**BlockGroup2010**

Water Quality Monitoring Stations
1. Used Table 1 in the report found at http://www.watershedmanagement.vt.gov/lakes/docs/lcmonitoring/lp_lclongtermprogdesc.pdf to identify the coordinates for the 15 long-term lake monitoring stations >>> \Hedonic\incoming\WaterQuality\LCBPMonitoringStations.xlsx
2. Display X,Y data >>> creates a temporary file

3. Export temporary file >>> \Hedonic\incoming\WaterQuality\WaterQuality_scratch.mdb\WaterQualityStations_step1
4. Data Management Tools > Projections and Transformations > Features > Project WHERE INPUT = WaterQualityStations_step1, COORDINATE SYSTEM = NAD83, VT State Plane, m >>> \Hedonic\incoming\WaterQuality\WaterQuality_scratch.mdb\WaterQualityStations_step2
5. Export PropertyTransfer_ALL >>> \Hedonic\incoming\WaterQuality\WaterQuality_scratch.mdb\WaterQualityStations_step3
6. Analysis Tools > Proximity > Near WHERE INPUT FEATURES = WaterQualityStations_step3, NEAR FEATURES = WaterQualityStations_step2
7. Add field StationID to WaterQualityStations_step3 AS INTEGER
8. Join WaterQualityStations_step2 to WaterQualityStations_step3 on OBJECTID and NEAR_FID, respectively
9. Calculate WaterQualityStations_step3.StationID = WaterQualityStations_step2.StationID
10. Download the data tables for each of the sensors from http://www.watershedmanagement.vt.gov/lakes/htm/lp_longterm.htm

National Land Cover Dataset

1. Download 2011 NLCD for Vermont and New York from The National Map >>> \LCBP\Hedonic\zips\NLCD2011_LC_New_York & NLCD2011_LC_Vermont
2. Unzip archives >>> \LCBP\Hedonic\incoming\LandCover\NLCD2011_LC_New_York & NLCD2011_LC_Vermont
3. Data Management Tools > Projections and Transformations > Raster > Project Raster WHERE INPUT = NLCD2011_LC_Vermont, OUTPUT COORDINATE SYSTEM = NAD_1983_2011_StatePlane_Vermont_FIPS_4400 \LCBP\Hedonic\LandCoverAnalysis_scratch.mdb\NLCD2011_VT_step1
4. Data Management Tools > Projections and Transformations > Raster > Project Raster WHERE INPUT = NLCD2011_LC_New_York, OUTPUT COORDINATE SYSTEM = NAD_1983_2011_StatePlane_Vermont_FIPS_4400 >>> \LCBP\Hedonic\LandCoverAnalysis_scratch.mdb\NLCD2011_NY_step1
5. Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster > WHERE INPUT = NLCD2011_NY_step1 & NLCD2011_VT_step1 >>> \LCBP\Hedonic\LandCoverAnalysis_scratch.mdb\NLCD2011_step1
6. Spatial Analyst Tools > Extraction > Extract by Mask WHERE INPUT = NLCD2011_step1, MASK = HUC8_step1 >>> \LCBP\Hedonic\LandCoverAnalysis_scratch.mdb\NLCD2011_step2
7. Run model TabulateArea to tabulate the area of different land cover types (from NLCD2011_step2) within the 5-km buffer regions surrounding real

estate transaction points >>>
\LCBP\Hedonic\LandCoverAnalysis_scratch.gdb\TabulateLandCover5km_%Iterator%

a. This step uses ArcGIS ModelBuilder to iterate over all of the transaction point data to land cover characteristics for 1- and 5-km boundaries

Appendix IV: Literature review of hedonic pricing model parameters

Property	Studies Using
Lot Size	Loomis and Feldman 2003, Bejranonda et al. 1999, Michael et al. 2000, Orr and Pickens 2003, Boatwright et al. 2013, Zhang and Boyle 2010
Number of bathrooms	Loomis and Feldman 2003, Bejranonda et al. 1999, Kashian et al. 2006, Boatwright et al. 2013, Boyle et al. 1999, Poor et al. 2007, Zhang and Boyle 2010
Building size / living area	Loomis and Feldman 2003, Bejranonda et al. 1999, Gibbs et al. 2002, Michael et al. 2000, Boyle et al. 1999, Kashian et al. 2006, Lansford and Jones 1995, Poor et al. 2001, Boatwright et al. 2013, Zhang and Boyle 2010, Michael et al. 1996
Garage	Loomis and Feldman 2003, Bejranonda et al. 1999, Michael et al. 2000, Kashian et al. 2006, Lansford and Jones 1995, Michael et al. 1996
Adjacent to golf course	Loomis and Feldman 2003
Mortgage interest rate	Loomis and Feldman 2003
Number of rooms	Bejranonda et al. 1999
Building age yrs, yrs sqrd,	Bejranonda et al. 1999, Gibbs et al. 2002, Boatwright et al. 2013, Yoo et al. 2014
Air conditioning	Bejranonda et al. 1999, Kashian et al. 2006
Heat	Bejranonda et al. 1999, Michael et al. 2000, Boyle et al. 1999, Poor et al. 2007, Zhang and Boyle 2010, Michael et al. 1996
Basement	Bejranonda et al. 1999, Michael et al. 2000, Kashian et al. 2006, Michael et al. 1996
Fireplace	Bejranonda et al. 1999, Kashian et al. 2006
Patio / deck / porch	Bejranonda et al. 1999, Michael et al. 2000, Michael et al. 1996
Full plumbing	Gibbs et al. 2002, Michael et al. 2000, Michael et al. 1996
Tax rate in yr of purchase	Gibbs et al. 2002, Michael et al. 2000, Michael et al. 1996
More than one story	Michael et al. 2000, Poor et al. 2007, Michael et al. 1996
Number of fireplaces	Michael et al. 2000, Michael et al. 1996
Septic system or town septic	Michael et al. 2000, Michael et al. 1996
Public road	Michael et al. 2000, Michael et al. 1996

Property	Studies Using
Assessed land and / or property value	Kashian et al. 2006, Orr and Pickens 2003, Yoo et al. 2014
Number of bedrooms	Kashian et al. 2006
Month / Year of sale	Lansford and Jones 1995, Orr and Pickens 2003, Boatwright et al. 2013
Carport spaces	Lansford and Jones 1995
Street frontage	Lansford and Jones 1995
Construction quality	Lansford and Jones 1995
House condition	Lansford and Jones 1995
Stumpage value	Orr and Pickens 2003
Road access	Orr and Pickens 2003
Current utilities	Orr and Pickens 2003
Potential utilities	Orr and Pickens 2003
Area of ground floor	Yoo et al. 2014
Ratio of patio area to floor area	Yoo et al. 2014
Ratio of total land full cash value to sale rice	Yoo et al. 2014
Specific subdivisions	Boatwright et al. 2013
Recreational areas in subdivision	Boatwright et al. 2013
Commercial Forest Land Adjacent	Orr and Pickens 2003
Subdivision allowed	Orr and Pickens 2003
Presence of curb / gutter	Boatwright et al. 2013
House is locate on a street with a cul-de-sac	Boatwright et al. 2013
House is located on a narrow street	Boatwright et al. 2013
On a bluff	Lansford and Jones 1995
Building present, unimproved land	Orr and Pickens 2003, Zhang and Boyle 2010
Natural Amenities Parameters	
Scenic view	Lansford and Jones 1995, Orr and Pickens 2003
Length of border with public land	Orr and Pickens 2003
Adjacent to public land	Orr and Pickens 2003
Open space within a 0.19 km radius of the house	Boatwright et al. 2013
Open space has trees	Boatwright et al. 2013

Property	Studies Using
Proximity Parameters	
Distance to lake / distance to lake squared	Loomis and Feldman 2003, Bejranonda et al. 1999, Lansford and Jones 1995
Distance to nearest central business district/ town with pop > 9,000	Bejranonda et al. 1999, Gibbs et al. 2002, Michael et al. 2000, Boyle et al. 1999, Lansford and Jones 1995, Poor et al. 2007, Zhang and Boyle 2010, Michael et al. 1996
Distance to small town	Orr and Pickens 2003
Distance to large town	Orr and Pickens 2003
Neighborhood Parameters	
Housing density lots/ 1,000 feet of lake frontage,	Gibbs et al. 2002, Michael et al. 2000, Poor et al. 2001, Michael et al. 1996
Location by school system	Lansford and Jones 1995
Number of buildings in a 0.19km radius of house	Boatwright et al. 2013
Number of population/mile^2 in 2000	Yoo et al. 2014
Number of people with at least a college degree 2000	Yoo et al. 2014
Which city	Yoo et al. 2014
Demographic Parameters	
County population	Bejranonda et al. 1999
County unemployment	Bejranonda et al. 1999
Median income	Boatwright et al. 2013, Yoo et al. 2014
Percent of population that is white	Boatwright et al. 2013

* Parameters presented in *italics* were used as dummy variables. Parameters presented in ***bold italics*** were used as categorical variables.