ESTIMATING THE EFFECTS OF SHORELINE CHANGE ON PROPERTY VALUES IN SANDWICH, MA USING A HEDONIC REGRESSION MODEL

by

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ABSTRACT

Shoreline erosion poses a destructive threat to many densely developed coastal areas. This project uses a hedonic regression model to estimate whether or not the risks posed by shoreline change significantly influence property values in Sandwich, MA. Sandwich, MA is a historic town located on the inner reaches of Cape Cod with approximately 7.9 miles of Cape Cod Bay shoreline. Two sets of independent variables were used: 1) structural characteristics describing the physical qualities of a home, and 2) environmental characteristics measuring the risk posed to coastal properties by shoreline erosion. Results show that six of seven environmental variables are significant, including the primary variable of interest, Geotime. These results are compared to Atlantic region results published by The Heinz Center in 2000. Recommendations are made on opportunities to extend and improve the model for use in the future.
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INTRODUCTION

Coastal erosion is a physical natural process in which sediment outflow exceeds sediment inflow at a particular location. These sediments are typically transported from one location to another by wind, waves, or moving water currents. Sediment accretion is just the opposite. If conditions are right, sediment inflows exceed sediment outflows at a given location, thus resulting in a build-up or build-out of sediment. Depending on the location, these processes can take place very slowly, whereby the shoreline shifts only inches to a foot per year; or more rapidly, whereby changes can exceed ten feet per year. In addition, intense storms can cause avulsion, resulting in large portions of a beach or dune to being washed away by strong currents and large waves.

Regardless of the time-scale or magnitude of shoreline changes, there is the possibility that such changes to the physical environment influence decisions made by the people who own properties on or near a shoreline; particularly waterfront property owners. This project seeks to measure this relationship. More specifically, how is the value of coastal properties influenced by increasing or decreasing risk of property loss from coastal erosion?

A study carried out by the H. John Heinz III Center for Science, Economics, and the Environment, and published in the report *Evaluation of Erosion Hazards* (2000), made predictions on the number of properties expected to be damaged, and the corresponding property-value expected to be lost, as a result of coastal erosion over the next sixty years. Recommendations were made to Congress in an effort to minimize these losses by re-structuring the National Flood Insurance Program (H. John Heinz Center, 2000). Aside from these overall results, Warren Kriesel, Craig Landry, and Andy Keeler (2000) developed a hedonic price model to determine how erosion hazards influence the value of coastal properties. They specifically investigated how properties depreciate as a result of increasing risk. In their model, the risk preferences of coastal property owners were revealed by measuring the marginal implicit price for which home-owners valued various
environmental characteristics pertaining to their home. These prices were viewed as acceptable tradeoffs for the risks posed by coastal erosion hazards. Kriesel et al. (2000) determined the marginal implicit price for individual risk characteristics in four different U.S. regions: the Atlantic, Pacific, Great Lakes, and Gulf of Mexico.

For reasons unknown, The Heinz Center did not include any coastal communities in New England or the Cape Cod region in their study. This project seeks to extend the model proposed by Kriesel, Landry, and Keeler, with some alteration, to study the influence of shoreline change on property values in Sandwich, Massachusetts.

FIGURE 1: Map showing the political boundary of Sandwich on Cape Cod, MA.

Sandwich, Massachusetts is a historic town located on the inner reaches of Cape Cod (see Figure 1). It was incorporated in 1639, making it the oldest town on the Cape. The population of
Sandwich, MA varies seasonally since it is a vacation destination for thousands of New Englanders, particularly those traveling from nearby Boston, MA and Providence, RI. As a result, dense shoreline development has taken place in this small coastal town. Today, 232 waterfront structures have been built on the town’s 7.9 miles of Cape Cod Bay shoreline. Net alongshore sediment transport moves in an easterly direction.

**PROJECT OBJECTIVES**

This project seeks the following objectives: 1) Determine whether there is a significant relationship between the value of coastal properties and shoreline change characteristics in Sandwich, MA. A significant relationship between a given environmental characteristic and property values implies that not only are property-owners aware of the risks associated with a given environment attribute, but this awareness carries over to how a property is valued. 2) In cases where a relationship exists, identify the implicit price property-owners place on the various components of risk associated with owning coastal properties. 3) Compare results from this study to those from Kriesel et al. (2000). 4) Develop a model that can be adapted and applied to other towns on Cape Cod. Maximizing the model’s functionality will allow its application to towns such as Falmouth, Wellfleet, and Provincetown, thus providing an overall assessment of the effect of coastal erosion risk on property values throughout Cape Cod.

**DESCRIPTION OF HEDONIC MODEL & VARIABLES USED**

*Hedonic Price Models*

In order to accomplish these objectives, a hedonic regression model was constructed similar to that developed by Kriesel et al. (2000). A hedonic model provides a means of determining how individual characteristics of a given property influence property values. Each characteristic is
represented as an independent variable in the hedonic equation, with assessed property values serving as the dependent variable. The estimated regression coefficient for a given variable was used to interpret the marginal implicit price for its associated characteristic (Kriesel et al., 2000). In the case of the environmental variables, marginal implicit prices indicate the buyer’s marginal willingness to pay for risk-reducing characteristics (Smith, 1985).

Three categories of independent variables were used by Kriesel, Landry, and Keeler to construct the hedonic equation. The following equation implies that the value of a property is a function of three main groups of property characteristics: structural, neighborhood, and environmental.

\[
\text{Property Value} = f(S, N, Q) \quad \text{(Freeman, 1993)}
\]

Where independent variables,
\begin{align*}
S &= \text{structural characteristics} \\
N &= \text{neighborhood characteristics} \\
Q &= \text{measure of environmental quality}
\end{align*}

Sandwich is relatively homogeneous with respect to neighborhood and demographic characteristics. Therefore, only structural and environmental characteristics were used in this study.

**Structural Variables**

Structural characteristics describe the physical qualities of a home. The structural characteristics used in this study are commonly used in property assessments. Both the size of a house (\textit{House Size}) and the size of a property (\textit{Parcel Size}) were expected to positively influence the value of a property. In addition, the variables, Number of Bedrooms and Number of Bathrooms were expected to have a similar influence. Thus, larger homes or larger properties with more bedrooms or bathrooms are typically more expensive.

Conversely, the age of the home (\textit{Age of House}) and the number of years since a property was most recently sold (\textit{Age of Transaction}) were expected to negatively influence property value. The age
of a home can be interpreted as an annual depreciation rate (Kriesel et al., 2000). All else being constant, an older home is typically worth less than a newer one. In addition, the waterfront real estate market is more competitive than it once was. Therefore, a more recently sold property was expected to be worth more. Kriesel et al. (2000) note that the Age of Transaction variable can be used to yield an estimate of the average annual price index for coastal property as well.

*Environmental Variables*

Seven environmental characteristics were intentionally chosen to describe and measure the risk associated with capital loss from coastal erosion. The aim of the set of environmental variables used was to fully capture the risks associated with shoreline change, as reflected in property values. Explaining how the above structural characteristics influence the price of a property was relatively straightforward. However, the influence of environmental characteristics used in this study is slightly more complicated. Each environmental variable was deemed appropriate for the model since it served as a critical indicator of shoreline change and was of a form that could be accurately measured or assessed.

The first of seven environmental variables used in the study was a distance to the “erosion reference feature” (*Distance to ERF*). This is the distance measured from the seaward most portion of a given home to the nearest mean high water line of Cape Cod Bay (see Figure 2). It was expected that properties closer to the water will be worth more. This may seem counter-intuitive since a property further from the beach will be considered “safer” from erosion risk. However, the *Distance to ERF* variable is assumed to be a measure of amenity value only. Amenity value is the added benefit of easier recreation or shorter travel distance to the beach. Residents of properties closer to the water have a shorter distance to travel to the beach; therefore, greater value is placed on
those homes. The risk component of the distance to the mean high-water line is contained within the variable \textit{Geotime}.

\textbf{FIGURE 2:} Image illustrating how the \textit{Distance to ERF} variable was calculated.

\begin{center}
\includegraphics[width=\textwidth]{fig2.png}
\end{center}

\textit{\textit{Geotime}} is defined as the expected number years until the setback distance is zero, given the property’s historical erosion rate” (Kriesel et al., 2000). This variable provides the number of years expected for the mean high water line to move from its current location to a given structure. It incorporates the current setback distance of a building, and also the historical shoreline change rate for that area. For example, if a home is 100 feet from the mean high water line and the erosion rate is 1 foot/yr, then \textit{Geotime} is equal to 100 years. Historical shoreline change rates calculated using shoreline position data from the 1950s to 1994 were used for this variable. Figure 3 shows the
distribution of these rates throughout Sandwich. Erosion hotspots, mainly east of the Cape Cod Canal, are colored in red.

**FIGURE 3: Historical shoreline change rates in Sandwich, MA.**

*Geotime* was expected to have a positive influence on property value. Properties with longer *Geotime* will be worth more. The costs of risk faced by a property-owner diminish the further a property is located from the shoreline. Lower risks may be the result of a larger initial setback, lower erosion rate, or the presence of protective structures such as groins, jetties, or seawalls. However, as the cost of risk diminishes with longer *Geotime*, it is expected that a property's value will continue to increase, but at a decreasing rate, thereby asymptotically approaching a no (shoreline change) risk value. In other words, the costs of risk decline at a decreasing rate. This decreasing rate was expected to have a negative influence on property values, and is reflected in the use of the square of
Geotime as a third explanatory variable. The sign of this Geotime\(^2\) variable was expected to be negative, which is equivalent to saying that property value increases at a decreasing rate.

Additionally, using Geotime alone, Kriesel et al. (1993) found that property prices along Ohio’s Lake Erie shoreline decreased dramatically when Geotime was equal to or less than approximately twenty years. In their study, this was equivalent to a setback distance of approximately fifteen feet. This does not seem to reflect real-world decisions made by property-owners. In reality, market participants would not wait until the “last minute” before discounting property. To resolve this issue, Geotime\(^2\) was incorporated into the model. Geotime\(^2\) provides greater flexibility and allows “predicted prices to decrease along a longer range of Geotime values” (Kriesel et al., 1993). Using this variable resulted in “discounting increases at about 50 years of Geotime,” or a setback distance of approximately 40 feet, a much more plausible result (Kriesel et al., 1993).

The fourth environmental characteristic is Beach Width. It is defined as the distance from the mean high water line landward to the first line of stable vegetation (see Figure 4). A wider local beach was expected to increase the value of area homes for two reasons. First, it serves as a protective buffer between the waterline and development. Secondly, it is a measure of beach quality. A wider beach has greater utility and is more appealing than a narrow beach with little room to recreate; therefore, it has greater amenity value as well.
Kriesel et al. (2000) used two variables, *Sand Nourishment* and *Armor*, to identify beaches where erosion mitigation practices have been employed. Beach nourishment projects or the presence of hardened structures on adjacent beaches were expected to influence property values, since both are erosion protection measures that reduce risk to nearby property-owners. Very little beach nourishment has taken place in Sandwich over the past fifteen to twenty years. In fact, there is only one project worth mentioning which involved a dune re-construction in Springhill Beach (part of Sandwich, MA) following an October, 1991 Nor’easter. Built in 1992, the artificial dune is no longer considered to be offering “significant protection” to adjacent properties; “the dune is now in equilibrium with normal natural coastal processes – as if it were never constructed” (O’Connell, 3/8/2007). However, it was included in the model as the fifth environmental variable (*Dune Reconstruction*) in order to explore the influence of erosion mitigation practices on property values (see...
Figure 5). The protection offered by this dune was expected to positively influence the value of adjacent properties; properties adjacent to it are expected to be worth more.

FIGURE 5: Extent of 1992 dune re-construction in Springhill Beach, MA.

This study did not include a variable measuring the influence of hardened structures such as groins, jetties, or seawalls. There are several areas throughout Sandwich where these structures are present, but many “are only marginally functioning at trapping minimal sand volume” (O’Connell, 3/8/2007).

The sixth environmental variable used in the model identified houses located on the Beachfront. In the original sample, 232 properties were identified as being beachfront. Properties closer to the water, especially those that are beachfront, are certainly more vulnerable to shoreline changes. However, this vulnerability is accounted for in the Geotime variable. Therefore, the
expected influence of this variable on property values was positive; beachfront properties were expected to be worth more. There is greater amenity value associated with beachfront properties since residents have a better view of the water and are closer to the beach compared to other properties in Sandwich, MA.

The final environmental variable, V-Zone, indicates whether or not a property is located within a “velocity” flood-zone (see Figure 6). A V-Zone, or velocity flood zone, is an area where wave action from waves greater than three feet can potentially cause structural damage during a 100-year flood. The zones are delineated on the Federal Emergency Management Agency’s Flood Insurance Rate Maps (FIRMs), the most recent of which was published for Sandwich on July 2, 1992 (O’Connell, 3/6/2007). While high-hazard V-zones, as identified on FIRMs, measure flood risk, their relationship with the water serves as an indirect indicator of a property’s proximity to Cape Cod Bay and therefore, increased erosion risk. Thus, it was expected that properties within these zones will be worth less.
Table 1 contains a comprehensive list of the independent variables included in the hedonic regression model, with an indication of the hypothesized influence of that variable on property values. Note that eight of the structural and environmental attributes were continuous in form. As such, they were transformed into a natural-log functional form so that extreme values do not bias model results (see Table 1). This form has been frequently used in numerous other hedonic price studies (Kriesel et al., 2000; Kriesel et al., 1993; Pardew et al., 1986; Anderson & Edwards, 1986; Palmquist, 1984).
Table 1: Independent variables with expected influence on property value.

<table>
<thead>
<tr>
<th>Category</th>
<th>Independent Variable</th>
<th>Form</th>
<th>Expected Influence on Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural</td>
<td>House Size (square footage of house living area)</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Parcel Size (square footage of the property parcel)</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Age of Transaction</td>
<td>CONTINUOUS (LOG)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Age of House</td>
<td>CONTINUOUS (LOG)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Number of Bedrooms</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Number of Bathrooms</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td>Environmental</td>
<td>Distance to Erosion Reference Feature (ERF)</td>
<td>CONTINUOUS (LOG)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Geotime</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Geotime Squared</td>
<td>CONTINUOUS (LOG)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Beach Width</td>
<td>CONTINUOUS (LOG)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Dune Re-construction</td>
<td>1 = IN, 0 = OUT</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Beachfront</td>
<td>1 = IN, 0 = OUT</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>V-Zone</td>
<td>1 = IN, 0 = OUT</td>
<td>Negative</td>
</tr>
</tbody>
</table>

MODEL RESULTS

A non-linear least-squares regression was run on the data for the described variables using LIMDEP, an econometrics software program used to estimate linear and non-linear regression models. Many properties were removed from the initial sample, mainly due to inconsistent or incomplete structural data. The following results were produced using a final sample of 959 properties.

Variable Significance

In running the regression, it was found that the number of bedrooms and number of bathrooms were closely correlated with house size. This makes sense, since homes with bedrooms or bathrooms typically have more square footage. As a result of this correlation, the variables measuring the number of bedrooms and bathrooms were removed from the final model output.
All of the variables were determined to be significant with the exception of two, the *Age of Transaction* and *V-zone* variables. P-values for these variables were 0.8855 and 0.7343 respectively, both greater than an alpha-value of 0.05 (see Table 2). R² was equal to 89.9%, so approximately 90% of the variation in assessed property values is accounted for by this model.

**TABLE 2: List of p-values indicating the significance of independent variables for the Atlantic (Kriesel et al., 2000) and Sandwich, MA models.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Independent Variable</th>
<th>Significance <em>Atlantic</em></th>
<th>Significance <em>Sandwich, MA</em> (alpha = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural</td>
<td>House Size (square footage of house living area)</td>
<td>Y (p&lt;0.001)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td></td>
<td>Parcel Size (acreage of property parcel)</td>
<td>Y (p&lt;0.001)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td></td>
<td>Age of Transaction</td>
<td>Y (p&lt;0.05)</td>
<td>N (p=0.8855)</td>
</tr>
<tr>
<td></td>
<td>Age of House</td>
<td>Y (p&lt;0.05)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td>Environmental</td>
<td>Distance to Erosion Reference Feature (ERF)</td>
<td>N (unexpected positive effect)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td></td>
<td>Geotime</td>
<td>Y (p&lt;0.05)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td></td>
<td>Geotime Squared</td>
<td>Y (p&lt;0.05)</td>
<td>Y (p=0.0007)</td>
</tr>
<tr>
<td></td>
<td>Beach Width</td>
<td>Y (p&lt;0.05)</td>
<td>Y (p=0.0302)</td>
</tr>
<tr>
<td></td>
<td>Dune Re-construction</td>
<td>n/a</td>
<td>Y (p=0.0001)</td>
</tr>
<tr>
<td></td>
<td>Beachfront</td>
<td>Y (p&lt;0.001)</td>
<td>Y (p=0.0000)</td>
</tr>
<tr>
<td></td>
<td><em>V-Zone</em></td>
<td>n/a</td>
<td>N (p=0.7343)</td>
</tr>
</tbody>
</table>

**Regression Coefficients**

Table 3 lists the regression (beta) coefficients for the each independent variable included in the model. The variables, *Age of Transaction* and *V-Zone* are not included in Table 3 since their effect on property values was insignificant. Positive coefficients indicate a positive or increasing influence on property values. Negative coefficients indicate a negative or decreasing influence on property values. With the exception of the variable, *Dune Re-construction*, each explanatory variable had a regression coefficient whose sign matched the expected influence on property value. *Dune Re-construction* was expected to increase the value of properties which are located adjacent to the 1992 re-constructed dune in Springhill Beach, MA. However, the regression model indicates that property
values are negatively influenced by this variable (beta = -0.1098). A property in the dune reconstruction area is worth approximately 11% less than a property outside of this area.

**TABLE 3: List of regression coefficients for significant independent variables in Sandwich, MA model.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Independent Variable</th>
<th>Beta Coefficient Sandwich, MA</th>
<th>Expected Influence on Property Value Sandwich, MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural</td>
<td>House Size (square footage of house living area)</td>
<td>0.3863</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Parcel Size (acreage of property parcel)</td>
<td>0.7081</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Age of House</td>
<td>-0.0556</td>
<td>Negative</td>
</tr>
<tr>
<td>Environmental</td>
<td>Distance to Erosion Reference Feature (ERF)</td>
<td>-0.1767</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Geotime</td>
<td>0.1416</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Geotime Squared</td>
<td>-0.0058</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Beach Width</td>
<td>0.0223</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td><strong>Dune Re-construction</strong></td>
<td><strong>-0.1098</strong></td>
<td><strong>Positive</strong></td>
</tr>
<tr>
<td></td>
<td>Beachfront</td>
<td>0.4674</td>
<td>Positive</td>
</tr>
</tbody>
</table>

**Influence of Geotime on Property Values**

As expected, results show that average property values decrease with decreasing Geotime. Figure 7 illustrates how property value decreases as Geotime decreases from 80 to 0 years. All other characteristics remaining constant, a property with 80 years of Geotime, currently worth $350,525, will depreciate along the Sandwich curve to a value of $97,054 when Geotime is reduced to zero. Conversely, it illustrates how average property values increase as Geotime increases from 0 to 80 years. Trend curves for both the Sandwich, MA model and the Atlantic model (Kriesel et al., 2000) are shown. Atlantic values were adjusted from 1995 to 2005 dollars using an average annual consumer price index of 2.7% (USDL BLS, 2005). While the Sandwich curve is lower than the Atlantic curve, both follow a similar trend.
In addition, Figure 8 shows how property values are influenced by ten year changes in Geotime. All other characteristics the same, a property with ten years of Geotime is worth approximately $22,000 less than a property with twenty years of Geotime. While the intervals of Geotime are the same for each bar (twenty to thirty years, thirty to forty years, etc...), differences in property value decrease as Geotime increases.
Marginal Implicit Price Results

Using the regression coefficients from Table 3, several other significant results were found. Based on a Beachfront beta coefficient of 0.4674, a beachfront property is worth approximately 47% more than an inland lot. This is greater than the Atlantic model results which found a beachfront lot to be worth 30% more than an inland lot (Kriesel et al., 2000).

Marginal implicit prices were calculated using the formula:

\[
\text{MIP} = \beta \times \left( \frac{\text{VALUE}}{X} \right) \quad \text{(Kriesel et al., 2000)}
\]

Where variables,

\( \beta \) = regression coefficient of characteristic
\( \text{VALUE} \) = average property value
\( X \) = mean quantity of characteristic

The average assessed property value in Sandwich, MA is $460,563. With an average land size of 0.49 acres, the MIP, or average value of land in Sandwich, MA is $661,387 per acre. This result is much larger than the average price of land determined using the Atlantic model, which produced a value of $206,486 (in 2005 dollars) per acre (Kriesel et al., 2000). The MIP for house size in Sandwich, MA is
$113 per square foot. Again, this result is much larger than the average of $45 (in 2005 dollars) per square foot calculated using the Atlantic model (Kriesel et al., 2000).

CONCLUSION

The hedonic regression model used in this project provided a means of analyzing the influence of shoreline change on assessed property values in Sandwich, MA. Indeed, it appears that erosion hazards are a significant determinant of property values in this Cape Cod town. As expected, property values rise with increasing Geotime. However, as Geotime increases, changes in property value decrease with diminishing cost of risk. With respect to Geotime, diminishing risk is either a result of a larger setback distance or lower historical shoreline change rate.

While results for Sandwich were not the same as those for the Atlantic, they did follow similar trends. All other characteristics the same, a property with ten years of Geotime is worth approximately $35,855 less than a property with thirty years of Geotime in Sandwich, MA. For the Atlantic model, a property with ten years of Geotime is worth approximately $48,740 less than a property with thirty years of Geotime. Similar comparisons reveal that changes in Geotime have a greater influence on the magnitude of property value differences for the Atlantic than in Sandwich, MA. This indicates that shoreline changes have a greater influence on property values for the broader Atlantic region than in Sandwich, MA specifically. Diminished perceived concern, a greater ability to absorb the costs of coastal erosion by property-owners, or simply the presence of less physical risk in Sandwich, MA are possible explanations for this result.

As mentioned before, results show that property values are negatively influenced by the Dune Re-construction variable. This was an unexpected finding. Values for properties adjacent to the reconstructed dune were expected to be positively influenced by the protective benefits offered by the presence of the dune. Instead, adjacent properties are worth approximately 11% less than properties
outside of the dune re-construction area. A likely explanation for this result is that the Dune Re-construction variable is capturing the increased risk associated with the area that made it necessary to build the dune in the first place. It appears that property-owners no longer realize the protection provided by the dune, but rather understand the erosion hazards that are characteristic of this section of Sandwich, MA.

Results from this study help to establish an estimate of incremental property value losses in Sandwich, MA as a result of physical shoreline changes. This is needed to help in making policy decisions on how to respond to coastal erosion and rising sea levels in the future. It provides a bottom-line for loss or depreciation in property values as shoreline shifts occur. When combined with total property losses (i.e. complete destruction of a structure during periodic storm events), this information allows Sandwich and the state of Massachusetts to make more effective decisions on appropriate mitigation strategies.

This model can be easily applied to other towns on Cape Cod. The environmental data used in this study was primarily built from freely available Massachusetts 2005 digital orthophoto imagery (see Appendix I), and structural data can be collected from most town assessment offices. Developing similar results for other Cape Cod towns would provide decision-makers with information on areas where real estate losses are most likely to occur as a result of coastal erosion risks throughout the region.

On a final note, an important stipulation regarding quantitative models must be made. Quantitative models such as the hedonic regression model used in this study attempt to reflect the real world. Specifically, this model aims to measure the influence of changing shoreline characteristics on how property-owners value the structures built adjacent to them. In an ideal world, results from this study could be directly applied to the decisions made by market participants in Sandwich, MA. However, all models are based on simplifications or assumptions and there is
potential for the influence of unmeasured variables, unpredictable natural disasters, or external forcing on model results. In addition, long-term shoreline change rates may not be direct indicators of short-term shoreline changes. The presence of these uncertainties prevents exclusive reliance on study results. Some recommendations discussed below aim to minimize important uncertainties.

RECOMMENDATIONS FOR FUTURE WORK

1) Some of the properties included in the model sample are a significant distance from the shoreline (i.e. up to 1 km), and therefore have very large Geotime values. Large Geotime values are likely biasing results and in these instances, assuming that market participants are considering Geotime is unrealistic. In the future, an erosion hazard area similar to that developed by The Heinz Center should be constructed and only properties located within it should be included. In order to make comparisons to The Heinz Center’s results, a sixty year erosion hazard area should be used. Based on historical changes, this represents the area expected to erode over the next sixty years.

2) As mentioned before, shoreline change rates used to calculate Geotime were developed using shoreline position data up until 1994. In this project a new 2005 shoreline was constructed to calculate the variables Beach Width and Distance to ERF. In the future, changes in shoreline position from 1994 to 2005 should be measured to update historical rates. However, changes in shoreline position are not expected to be dramatic. Therefore, results presented here are not expected to be significantly different.

3) The dependent variable used in the hedonic was 2005 assessed property values (not the actual price that a property sold for) because price data is missing for approximately half of the sample (627 properties). Using sale price data as the dependent variable would have greatly reduced the
original sample size (from 1157 to 530). While the assessment data is a good proxy for sales price, it appears that there is a trend for sales price to be slightly higher than assessed value. Further investigation into the correlation between sales price and assessed value should be made. Developing a relationship between these two valuations will provide a means of getting around incomplete sale price data.

4) An implicit assumption is made when calculating Geotime that the shoreline is moving toward a given structure (landward). If a shoreline were accreting (moving seaward) Geotime would be infinite. Therefore, as the model stands now, due to the design of the Geotime variable, only properties with eroding shorelines are included in the sample. Adapting the model so that the influence of risk-reducing accreting shorelines on property values can be explored would add meaning to the study.

5) Finally, GIS analysis was used as a primary tool to build data for the environmental variables used in this project. In particular, its use was critical for calculating values for the Distance to ERF, Geotime, and Beach Width variables. These variables were determined through extensive field work in The Heinz Center study; work which was not feasible given limited resources for this project. Ultimately, the use of GIS may prove more efficient in measuring distances and making calculations, but field surveys designed to confirm some of this data would improve spatial accuracy and precision.

OVERVIEW

These medium resolution true color images are considered the new "base-map" for the Commonwealth by MassGIS and the Executive Office of Environmental Affairs (EOEA). The photography for the entire commonwealth was captured in April 2005 when deciduous trees were mostly bare and the ground was generally free of snow.

Image type is 4-band (RGBN) natural color (Red, Green, Blue) and Near infrared in 8 bits (values ranging 0-255) per band format. Image horizontal accuracy is +/-3 meters at the 95% confidence level at the nominal scale of 1:5,000.

This digital orthoimagery can serve a variety of purposes, from general planning, to field reference for spatial analysis, to a tool for development and revision of vector maps. It can also serve as a reference layer or basemap for myriad applications inside geographic information system (GIS) software.

The project was funded by the Executive Office of Environmental Affairs, the Department of Environmental Protection, the Massachusetts Highway Department, and the Department of Public Health.

PRODUCTION

Sanborn LLC of Colorado Springs, CO, performed all work for this project. The source imagery was acquired with a Vexcel Ultracam digital camera at a flying height of 5,070 meters above mean terrain and an approximate pixel resolution of 45 cm.

Forward overlap was approximately 60%, except 80% in areas with tall structures (downtown Boston, Worcester, and Springfield), in order to reduce building lean, with sidelap of 33%. The entire state was covered by about 5500 image frames, captured over seven days from April 9 through April 17, 2005.

The ground control used to support the mapping was collected by photographic identification of strategic points. The ground control coordinates were collected via GPS ground survey techniques. Aerial Triangulation was performed on softcopy workstations using Intergraph ISAT software for photo measurement and matching. The final bundle adjustment was performed using BINGO 5.2 software.

A new digital elevation model was stereo compiled for the entire State from the newly acquired 2005 imagery. The DTM includes mass points, soft break-lines and hard break-lines. The images were ortho-rectified using METRO, Sanborn's proprietary software. Bridges were modeled in 3-D using standard photo-grammetric stereo-compilation techniques on softcopy workstations. Sanborn's Metro process rectifies the bridges using the 3-Dimensional model using similar methodologies for correcting the positional accuracy of other ground features. The bridges were uniquely coded and later removed from the final deliverable DTM file.
Imagery is georeferenced to Massachusetts State Plane Mainland (Lambert Conformal Conic Projection) NAD83 coordinate system, denominated in meters.

Color balancing was performed using METRO_NICE software. The resulting images were mosaicked into one seamless database of imagery and extracted to match the existing MassGIS Orthophoto Index Grid tile layout (each image tile covers 4,000 × 4,000 meters on the ground.). Images were quality-controlled by Sanborn using Adobe PhotoShop software. Final deliverables included 1/2-meter pixel resolution GeoTiff images with supplementary tfw files and metadata.

MassGIS quality assurance included rigorous independent checks of the spatial accuracy using other datasets of significantly higher accuracy, and field work that included the capture of highly accurate GPS points that were compared to the same locations appearing on the deliverables. MassGIS also assessed the visual quality and appearance of the images.
APPENDIX II: Constructing the Sandwich, MA properties database

A majority of the work for this project involved the collection of data to populate the hedonic variables with information for each property. Prior to running the model, significant data collection and adaptation had to be performed. Due to data availability, the study focuses on the year 2005. This is the most recent year for which data exists to study both structural and environmental characteristics. A database was built using Microsoft Access and ArcGIS 9.2. A GIS point feature-layer indicating the location of homes in Sandwich was created. Information needed to run the hedonic model was created as attributes for these points. Various GIS tools and analyses were used to build a database describing homes and their respective properties through each of these attributes for the year 2005.

The first step in building the database required visually locating homes in Sandwich. Massachusetts Geographic Information Systems (MassGIS) made 2005 digital orthophotos freely available to the public for download during the spring of 2006 (MassGIS, 2006). These aerial images were captured between April 7, 2005 and April 17, 2005 (see Appendix A for a more detailed description of the imagery). Nine images were obtained from MassGIS to cover coastal areas throughout Sandwich. With a resolution of 1:5000, buildings are clearly visible in these images.

Homes located throughout Sandwich were manually digitized in ArcGIS 9.2 using this satellite imagery. Before conducting the digitization process, a polygon feature layer containing year 2000 parcel boundaries was laid over the orthophotos (Smith, 2006). The parcel feature layer served two purposes. First, it provided a visual reference that made it easier to distinguish between properties. Second, it was used to join year 2005 assessment data to the digitized points. The parcel layer is five years older than the digital orthophotos and the assessment data. However, this did not cause any error since it was only used to assign an ID-tag to each structure point.
In digitizing the structure points, a selective approach was used to exclude structures that did not appear to be residential homes (i.e. public access points, township facilities, etc…), homes whose outline could not be identified, and homes that did not lie within their respective parcel boundaries. In addition, the following rules were applied when digitizing each structure as a point: 1) the point was placed on the seaward-most side or corner of each building, 2) the point was positioned at the center of a façade, 3) if there were two structures on a given parcel, the larger structure was assumed to be the home, 4) properties with three or more structures were excluded. Figures 9 and 10 provide examples of correct and incorrect placement of the digitized points. These points had to be consistently placed in order to make accurate measurements for the Distance to ERF variable.

**FIGURE 9:** Diagram illustrating how points that represent the location of buildings facing the water were digitized.
FIGURE 10: Diagram illustrating how points that represent the location of buildings were digitized when structures are not laterally facing the water.

Data needed for the six structural variables was obtained from a 2005 Sandwich, MA property assessment (Childs, 2006). To make use of this assessment data, it needed to be joined to the newly created feature layer containing digitized points representing homes in Sandwich. In order to do this, two join processes were performed in *ArcGIS 9.2*. The first join attached the 2005 assessment data to the parcel boundary feature layer based on the common “parcel ID” attribute. This attribute-based join was exported to create a feature layer showing property boundaries from the year 2000 that possessed 2005 assessment data. Again, while there is a five-year difference in the age of this data, this did not cause any error since the parcels were only used as a means of attaching assessment data to the newly created point features.

The second join was spatially-based rather than attribute-based. Data from the parcel feature layer containing 2005 assessment data was joined to point features located within each parcel. Each point was thus given all of the attributes of the polygon (a parcel) that it fell inside. Prior to conducting this join, each point represented the location of a structure, yet lacked any attribute information relating it to its respective property. However, after the join, each point
possessed assessment data critical to the overall study. Figure 11 shows a portion of northwest Sandwich where approximately twenty of the digitized points can be seen.

FIGURE 11: Map of Northwest Sandwich showing the satellite imagery used in this project and examples of structures digitized as points. Points are shown in red and parcel boundaries are outlined in yellow.

Thus far, the database only contained information on the structural characteristics of properties throughout Sandwich. Attributes still had to be created to describe the environmental characteristics of each home. The first step in creating these attributes was delineating a 2005 shoreline.

Using the same methods as those used to delineate the 1994 shoreline in the Massachusetts Shoreline Change Project, two indicators were used to manually digitize a beach shoreline in Sandwich: 1) the local wet/dry line on the beach, indicated by the tonal change between wet and dry beach material, and 2) the high-tide wrack line, created when the high tide deposits seaweed and
debris on the upper beach (Thieler et al., 2001). Thieler et al. (2001) found through numerous field checks that “the wet/dry line was subject to substantial (up to 15-meters) horizontal movement during a tidal cycle,” particularly in areas where sediment was course in size. Therefore, the shoreline was more commonly delineated using the high-tide wrack line.

Not only did this technical report serve as an outstanding resource for Massachusetts shoreline delineations done in the past, but it is important for the purpose of establishing accurate rates changes in the future that the 2005 shoreline be determined using the same indicators. If different features of the beach profile were used for 1994 versus 2005, say a vegetation line versus a wrack line, then changes in shoreline position would be inconsistent.

Using the previously described indicators, 2005 shoreline positions were identified on 309 transects, located approximately forty meters apart, throughout Sandwich. Figure 12 shows an example of how they were used to mark 2005 shoreline positions. A shoreline was then digitized connecting the 2005 shoreline position points at each transect.
With a 2005 shoreline in place, the Distance to ERF variable was calculated for each home using the “NEAR” tool in ArcGIS 9.2. This tool determined the distance from each input point (a structure) to the nearest polyline feature (2005 shoreline).

Each transect possessed an attribute with a historical shoreline change rate. Using a spatial join, this data was passed to the 2005 shoreline position points. Using a second spatial join, each structure was then assigned the historical shoreline change rate held by its nearest 2005 shoreline position point. Following these joins, each structure had an attribute containing information on the distance to the mean high water line and the nearest shoreline change rate. Geotime was calculated for each structure by dividing its Distance to ERF variable by its shoreline change rate. Geotime^2 was calculated simply by taking the second power of each Geotime value.
`Beach Width` was calculated by digitizing the landward most point of stable vegetation on each 40-meter transect. Like the 2005 shoreline delineation, these points were connected through manual digitization. The “NEAR” tool was used again to calculate the distance from the line of stable vegetation to the 2005 MHWL. This determined the distance from each input point (stable point of vegetation) to the nearest polyline feature (2005 shoreline). Using a spatial join, each structure was then assigned a `Beach Width` attribute based on the width calculation made for its nearest transect.

The remaining three environmental variables were applied to each structure using `IN/OUT` identifiers. With respect to the `Dune Re-construction` variable, properties adjacent to the Springhill Beach, MA dune re-construction area were assigned a `1`, while properties outside of the dune re-construction area were assigned a `0`. With respect to the `Beachfront` variable, properties identified as being beachfront were assigned a `1`, while non-beachfront properties were assigned a `0`. Lastly, with respect to the `V-Zone` variable, properties within a velocity flood-zone were assigned a `1`, while properties outside of a velocity flood-zone were assigned a `0`.

At this point, the database contained attribute information for all thirteen variables used in the hedonic model. The final step in building the database involved running several clean operations that removed properties from the sample whose data was missing, incomplete, or incompatible. In addition, two of the six structural attributes required alteration. The attributes `sales date` and `year built` required modification in order to be used in the model. The model required data on the number of years since buildings were sold and built, rather than the dates or years of sale or construction. Several database queries were used to make these conversions.
DATA SOURCES

2005 Digital Orthophoto Imagery

Shoreline Transect Data
James O’Connell of the Woods Hole Oceanographic Institution Sea Grant Program. 2006

Historical Shoreline Change Data (current to 1994)
James O’Connell of the Woods Hole Oceanographic Institution Sea Grant Program. 2006.

2000 Property Parcel Boundaries
Ben Smith of the Cape Cod Commission. 2006.

2005 Property Assessment Data
SOFTWARE USED


LITERATURE CITED


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