AN ECONOMIC ANALYSIS OF STREAM RESTORATION IN AN URBAN WATERSHED: AUSTIN, TEXAS

A Thesis

by

CHI-YING HUANG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2012

Major Subject: Water Management and Hydrological Science

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Approved by:

Chair of Committee,	John R. Giardino
Committee Members,	Ralph A. Wurbs
	Robert R. Coulson
Interdisciplinary Faculty Chair,	Ronald A. Kaiser

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ABSTRACT

An Economic Analysis of Stream Restoration in an Urban Watershed: Austin, Texas.

(May 2012)

Chi-Ying Huang, B.S., National Taiwan University;

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Chair of Advisory Committee: Dr. John Giardino

By 2006, the U.S. government has spent $15 billion to address the degradation of urban streams, including erosion of stream banks, disconnection of rivers from the floodplain, and disturbance of surface runoff pathways. Bank stabilization is one of the most prevalent restoration activities in urban stream restoration. Unfortunately, most stream restoration projects have been undertaken without a pre- or post-evaluation of the impact of stream restoration on real value in the area. All restoration projects beg the question: Did the money spent on the project result in greater benefits to stream stability as well as to adjacent properties? The Walnut Creek watershed, located in Austin, Texas, has experienced varying stages of urbanization since the 1990s. One of the streams, the Walnut Creek tributary, was restored in 2003. The purpose of this study is to assess the impact of stream restoration on housing values. We applied the hedonic pricing method to evaluate the changes in housing value associated with housing and environmental characteristics. Repeat ground photography was utilized to assess stream restoration activities at spatial and temporal scales. Our results suggest that the stream restoration project resulted in significant positive impacts on housing values in the periods of restoration (8.3%) and restoration adjustment (10.7%). However, the project did not enhance the values of houses on the floodplain. In addition, results show that erosion had continuous negative impacts on housing values. Overall, the restoration project contributed to the greater benefits during the restoration adjustment period right after restoration by an increase of 1% of the average housing value for each property on the restoration site. In this study, the benefits of stream restoration project were minimal since bank stabilization was the main activity considered in this stream restoration project. Nevertheless, restoration enhances the stability of the stream banks, minimizes erosion problems, and presents an enhanced aesthetic beauty of the stream in Austin, Texas.

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1. INTRODUCTION

Urban rivers in the U.S. are impacted by many problems, and one of the most serious and overarching of these is degradation of the fluvial system. This degradation includes erosion of stream banks, accumulation of sediments in streams, disconnection of rivers from the floodplain, and the disturbance of surface runoff pathways. Urbanized river corridors can deteriorate in at least two ways. First, population growth causes dramatic changes of land use and land cover. As an example, increased impervious cover on the watershed can change water pathways over time. Where there is little or no vegetation, as a result of structures, surface flow is increased. Second, urban and agricultural development contributes to contaminated and toxic flows, which result in pollutants entering the rivers. Landscape modification and change of land use cause not only nonpoint source water pollution (FISRWG, 1998; Poor et al., 2007), but also increase peak flow discharge (Schumm et al., 1984). Thus, the aforementioned impacts the river system resulting in degradation of water quality and stream hydrology.

In this thesis, stream restoration is defined as “the return of an ecosystem to a close approximation of its condition prior to disturbance” (Fischenich, 2001). Sustainability of a dynamic system, such as a river, is complex, yet achievable. For this study, sustainability assumes that the river system is not static, and erosion and channel adjustment will occur over time. Sustainable development of a river system requires consistent maintenance. This maintenance includes bank stabilization, vegetative cover reestablishment, and the stability of hydrologic conditions establishment. This

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This thesis follows the style of Journal of Environmental Management.

continuous maintenance comes with a price tag. And, this can lead one to ask: Did the money spent on the project result in greater benefits to the stream and adjacent properties? Simply asked, was the river restoration project worth it? Unfortunately, most river restoration projects have been undertaken without a post-evaluation of the impact of stream restoration on real value in the area. The City of Austin, Texas, is no exception. Thus, this study examined a restoration project from this perspective.

The primary objective of this study was to estimate the impact of an urban stream restoration project on the values of houses adjacent to the Walnut Creek tributary in Austin, Texas. To achieve this objective, an evaluation covered both spatial and temporal scale is needed. First, the study examined the causes of urban stream bank erosion. Second, the study used repeat ground photography to provide visual evidence to assess stream conditions. Third, a hedonic pricing method was applied to examine the changes of housing value associated with environmental and housing characteristics from before and to after the restoration.

1.1 Research Hypotheses

The goal of this study was to evaluate the effect of stream restoration projects on housing values across different locations and in varying restoration stages. We compared the changes in value at two locations along the stream. One location was houses adjacent to the eroded banks, whereas the other location was houses away from the eroded banks. Four periods of restoration time were identified as (1) pre-restoration, (2) restoration, (3) restoration adjustment, and (4) post-restoration. More specifically, this research suggested the following testable hypotheses.

Hypothesis 1: In pre-restoration, changes in value of houses in proximity to eroded banks will be significantly different than those of houses in other areas.

The rationale for hypothesis 1 is that houses adjacent to eroded stream banks are more likely to result in damage than houses in other areas. We conjecture that changes in value of houses adjacent to eroded banks will differ from houses in other areas.

Hypothesis 2: In restoration, changes in value of houses on the restoration site will be significantly greater than those in other areas.

The rationale behind hypothesis 2 is that the implementation of restoration projects will resolve erosion successfully. Enhanced environmental amenities will result in higher housing values in the neighborhood. We predict that houses on the restoration site will experience a greater change in value than houses in other areas.

Hypothesis 3: In restoration adjustment, changes in value of houses on the restoration site will be significantly greater than those in other areas.

The rationale for hypothesis 3 is that the completion of restoration projects can stabilize stream banks over time. The period of adjustment balances vegetative cover reestablishment and bank stabilization. We predict that houses on the restoration site will be more likely to experience a greater change in value than houses in other areas.

Hypothesis 4: In post-restoration, changes in value of houses on the restoration site will be as same as those in other areas.

The rationale for hypothesis 4 is that stable stream banks can be achieved as houses in other areas. We conjecture that change in value of houses on the restoration site will be no different from those in other areas.

This thesis is organized as follows. Section II provided the literature review of stream restoration in the United States, the environmental impacts on housing values, and the analytical models to evaluate stream restoration projects. Section III provided the information of research area and data sources. Section IV addressed the analytical procedures to value the stream restoration. Section V addressed results of the analyses and hypotheses tests. Section VI summarized the research findings and addressed research limitations.

2. LITERATURE REVIEW

2.1 Stream Restoration in the United States

Restoration projects are diverse, depending on project goals and scales (Allan et al., 2005). In the U.S., the most common restoration goals for small scale projects are to enhance water quality, manage riparian zones, improve in-stream habitats, and stabilize river banks (Bernhardt et al., 2005a), whereas for large scale projects are to reconnect floodplains, modify stream flows, and restructure stream channels (Allan et al., 2005). Humans alter physical and biological conditions of streams at varying degrees. Research suggests that river system should be repaired and maintained by itself in the natural flow regime for restoration (Poff et al., 1997). This strategy is considered to be the most effective and the least expensive to achieve the equilibrium of a dynamic geomorphic and ecological river system (Stanford et al., 1996; Poff et al., 1997).

The costs of restoration projects are significant. A broad body of research indicates that costs are proportional to the project size (Bernhardt et al., 2005). The median cost of restoration activities ranges from $15,000 to $82,000 (Bernhardt et al., 2005). According to the Environmental Protection Agency (EPA), costs include capital cost and operating cost. Capital cost includes project planning, land purchasing, and construction. Operating cost covers site maintenance, monitoring, and construction repair. Research addresses that restoration projects with higher costs are more likely to be monitored than those with lower costs (Bernhardt et al., 2005a; Alexander et al., 2006). Thus, the rate of monitoring varies in the states. For example, Colorado and

South Carolina monitor approximately 50% of the projects, whereas Montana and Oregon only monitor less than 1% of the projects (Bernhardt et al., 2005a).

Unfortunately, most restoration projects are rarely evaluated (Allan et al., 2005). There are two reasons for this. First, post-restoration assessments, monitoring, or distribution of data are not included in the project goals (Bernhardt et al., 2005a). Second, financial budgets are insufficient. Budget constraints prevent agencies from collecting field data and assessing long-term condition of streams. In resolving to these problems, setting up clear restoration goals is essential. Goal setting should involve multifaceted perspectives from river scientists, fluvial geomorphologists, and interest stockholders (Poff et al., 1997). In some cases, data are only available upon request from consulting firms or local agencies; in other cases, government agencies cannot distribute monitoring data (Bernhardt et al., 2005b). Thus, more attention and resources are still needed from national and state agencies or regional nongovernmental organizations to advance stream restoration practice and to integrate the validation of databases.

The complexity of restoration projects and the pressing need for monitoring, assessing, and quantifying the outcome restoration projects have been recognized (Holl and Howarth, 2000; Anand and Desrochers, 2004). Three common restoration goals are (1) restoration of species (Beechie et al., 2008), (2) restoration of landscape changes or ecosystem (Sedell et al., 1990; Beechie et al., 2008), and (3) restoration of ecosystem services for recreational and aesthetic values (Slocombe, 1998; Beechie et al., 2008). According to Woolsey et al. (2005), evaluating restoration projects should take multiple indicators into consideration. Criteria range from hydrologic to physical and socioeconomic aspects. Hydrologic factors include precipitation and stream regime (Poff et al., 1997). Physical factors include the linkage of land use to habitat conditions in a watershed (Beechie et al., 2008). Socioeconomic factors involve costs of actions and economic constraints of restoration projects (Slocombe, 1998; Alexander et al., 2006; Beechie et al., 2008).

To assess whether a restoration is successful, several studies have indicated that (1) goals for restoration project should be clearly identified (Palmer et al., 2005; Beechie et al., 2008), (2) the river system should be able to achieve a more stable and resilient sustainable system itself (Holling, 1973; Walker et al., 2002; Palmer et al., 2005), and (3) detailed documentary of pre- and post-assessments should be implemented, completed, and made available for the public (Palmer et al., 2005). Previous lessons from restoration projects of either successes or failures can help enhance the future design of restoration plan and a success in the restoration process (Kondolf and Micheli, 1995; Landers, 1997; Lake, 2001; Palmer et al., 2005; Jenkinson et al., 2006). This success can be achieved by communication and the exchange of information among scientists, practitioners, and interest stakeholders for a better understanding of scientific stream restoration practice (Leopold, 1997; Kershner, 1997; FISRWG, 1998; Palmer et al., 2005). The aforementioned factors are essential in contribution to a successful stream restoration project. To sum up, achieving sustainable development of a river system requires the seeking of the dynamic equilibrium of the fluvial system at all times.

2.2 Stream Bank Erosion

Erosion of stream banks is a serious problem in urbanized areas. The main forces of erosion include reduced bank stability, increased channel incision, and increased erosional forces (Schumm et al., 1984; Dahl et al., 2009). Table 1 addressed the aforementioned factors of bank erosion associated with hydrological, socioeconomic, and ecological impacts. Humans alter land use and land cover, such as urbanization and agricultural cultivation, contributing to increased discharge of surface flow and leading to higher flood peaks. The increased erosional forces can widen stream channels and erode the banks, which result in unstable river systems (Hammer, 1972; Schumm et al., 1984; Poff et al., 1997). Also, reduced vegetative cover on the surface makes soil susceptible to erosion.

River engineering for flood control can affect streamflow through straightening, widening, and deepening stream channels (Bridge, 2003). Stream channelization straightens waterways and deepens their water bed level, resulting in considerably increased rates of erosion (Schumm et al., 1984). The impacts and responses of erosion are diverse. Increased sedimentation resulting from eroded banks reduces aesthetic and preservation values of streams and rivers. Sedimentation from streams degrades stream quality and decreases aquatic and wildlife habitats and recreational opportunities (fishing, swimming, etc.). Also, houses adjacent to the streams can be severely impacted by this hydrologic degradation slowly for decades.

Table 1. Effect of stream bank erosion

	Type of Impact		
Erosion Factors	**Hydrological impacts**	**Socioeconomic impacts**	**Ecological impacts**
Accelerated erosion rate	Incised channels, damage to adjacent properties	Damages to structures and properties, loss of storages in lakes and reservoirs	Decreased vegetation cover
Increased sedimentation	Reduced streamflow	Reduced aesthetics and preservation values	Decreased aquatic and wildlife habitats
Increased runoff	Concentration of runoff, rejuvenation of drainage network	Increased maintenance of stormwater drainage for flood control	Disconnections of floodplain and riparian areas
Increased flood peak	Lower water base-level	Losses of recreational opportunities	Degraded water quality

(Adjusted from Schumm et al., 1984)

Besides human induced disturbances, changing weather patterns can also trigger the variability of streamflow on the surface, particularly in arid and semiarid areas (NRC, 2010). Variations in streamflow are geographically diverse. In some areas, snowmelt is the main source that contributes to the streamflow, whereas in other areas, rainy seasons and flood events are the main sources (Poff et al., 1997). Increased runoff results in concentration of runoff, rejuvenation of drainage networks, as well as disconnection from floodplain and riparian areas (Schumm et al., 1984). Also, increased flood peaks can lower water base-level, decrease recreational opportunities, and degrade stream quality. The impacts of erosional factors in the streams depend on the varying climate conditions and precipitation magnitude, frequency, duration, and timing (NRC, 2010).

The processes of physical weathering caused by wind, water, or ice are main sources contributing to erosion. The erosion process is slow and it takes a long period of time for people to realize the damages of erosion. In the U.S., many restoration projects have been implemented to stabilize eroded stream banks for protecting adjacent residential properties. Once restoration projects are completed, vegetation and the fluvial systems are adjusting themselves in the ecosystem and are continuously finding their dynamic equilibriums at all time.

2.3 Hedonic Pricing Method to Value Stream Restoration

Several studies have attempted to apply the hedonic pricing method to evaluate the impacts of environmental amenities and disamenities on urban residential properties. The method can estimate the implicit price of each environmental characteristic and determine its impact on housing values (Brookshire et al., 1982; Smith and Huang, 1993; Hitzhusen, 2006; Hurd, 2009). Research indicates that people are willing to pay higher prices for houses adjacent to environmental amenities because of the advanced recreational opportunities and better quality of living environment and views (TyrvBinen, 1997; Earnhart, 2001; Hamilton and Morgan, 2010). Those urban amenities include forests and parks (TyrvBinen, 1997; Bolitzer and Netusil, 2002; Jim and Chen, 2006; Conway et al., 2010), streams and lakes (Pompe and Rinehart, 1994; Lansford and Jones, 1995; Poor et al., 2007; Hitzhusen et al., 2007a), riparian zones (Mooney, 2001; Qie et al., 2006), open spaces (Nicholls and Crompton, 2005; Qie et al., 2006; Brander and Koetse, 2011), and beaches (Hamilton and Morgan, 2010).

Research suggests using proximity variables to represent spatial effects on housing values (Nicholls and Crompton, 2005; Conway et al., 2010). For a case study in Austin, Texas, Nicholls and Crompton (2005) use the hedonic pricing method to analyze the greenbelt proximity effects on housing values in Barton, Lost Creek, and Travis areas. Results indicate that houses in half-mile to the greenspace are insignificant in all three cases. They further use increments of quarter-mile in proximity to the greenspace. No locations reveal significant impacts of the proximity to the greenspace except houses in Lost Creek area. This investigation suggests that the greenspace proximity providing visual benefits on houses in Lost Creek and posing increased values in houses. As for houses in Barton and Travis areas close to downtown, people already have many other accesses to parks and recreational opportunities provided by the City of Austin. So the amenity of greespaces has less impact on housing values.

Other research examines the values of houses in proximity to unpleasant living environment, such as degraded water quality (Poor et al., 2007), sewage treatment plants (Leggett and Bockstael, 2000), waste landfills (Kinnaman, 2009; Mhatre, 2009), airport noises (Mieszkowski and Saper, 1978), gravel mines (Ayalasomayajula et al., 2007), and beaches erosion (Pompe and Rinehart, 1994; Bin and Kruse, 2006). All of which indicate that environmental disamenties decrease the values of the houses at some certain level, depending on peoples' perceptions toward those disamenties. On the other hand, proximity to streams can be seen as an amenity if people perceive the value of it. Thus, findings of the impacts of amenities and disamenties on housing values are not consistent.

To value the benefits of the stream restoration project, we can compare the changes in value of houses adjacent to the eroded stream banks with houses away from this disamentiy over time. We specifically look at four periods of the restoration: (1) pre-restoration: the erosion has been occurred in the neighborhood and before any restoration project is implemented, (2) restoration: the restoration project is in implementation, (3) restoration adjustment: the restoration project is completed and the fluvial systems and revegetation in the area are finding their equilibriums, and (4) post-restoration: the continuous status of the fluvial systems and the ecosystems are finding their equilibriums up to date.

3. MATERIAL AND METHODS

3.1 Research Area

Since the 1990s, the City of Austin (COA), Texas, has attempted to implement several stream restoration projects. Most restoration projects aim to mitigate erosion problems in stream channels and to lessen the impacts of flooding events (City of Austin, 1995; Meier, 2008; Chin et al., 2010). One of the streams—the tributary of Walnut Creek—was restored in July 2003 by the Watershed Protection Department of the city, and the project was completed by the end of the year. Figure 1 displays the study area.

The Walnut Creek watershed is one of the fast developing urbanized watersheds in Austin (City of Austin, 2004). The drainage area of this watershed is 43.5 square miles and the length of the main creek is 22.3 miles, along with a total length of tributaries of 105 miles (Clamann, 2007; City of Austin, 2011a). From 1990 to 2008 (See Figure 2), open areas (such as rural uses, vacant lands, and parks) decreased by 63% whereas transportation uses increased by 360%. Table 2 assessed the land use and land cover within the watershed. In particular, Interstate 35 contributes to 25% of the impervious surface in the area, dissecting the upper watershed from the north to the south (City of Austin, 2011b).

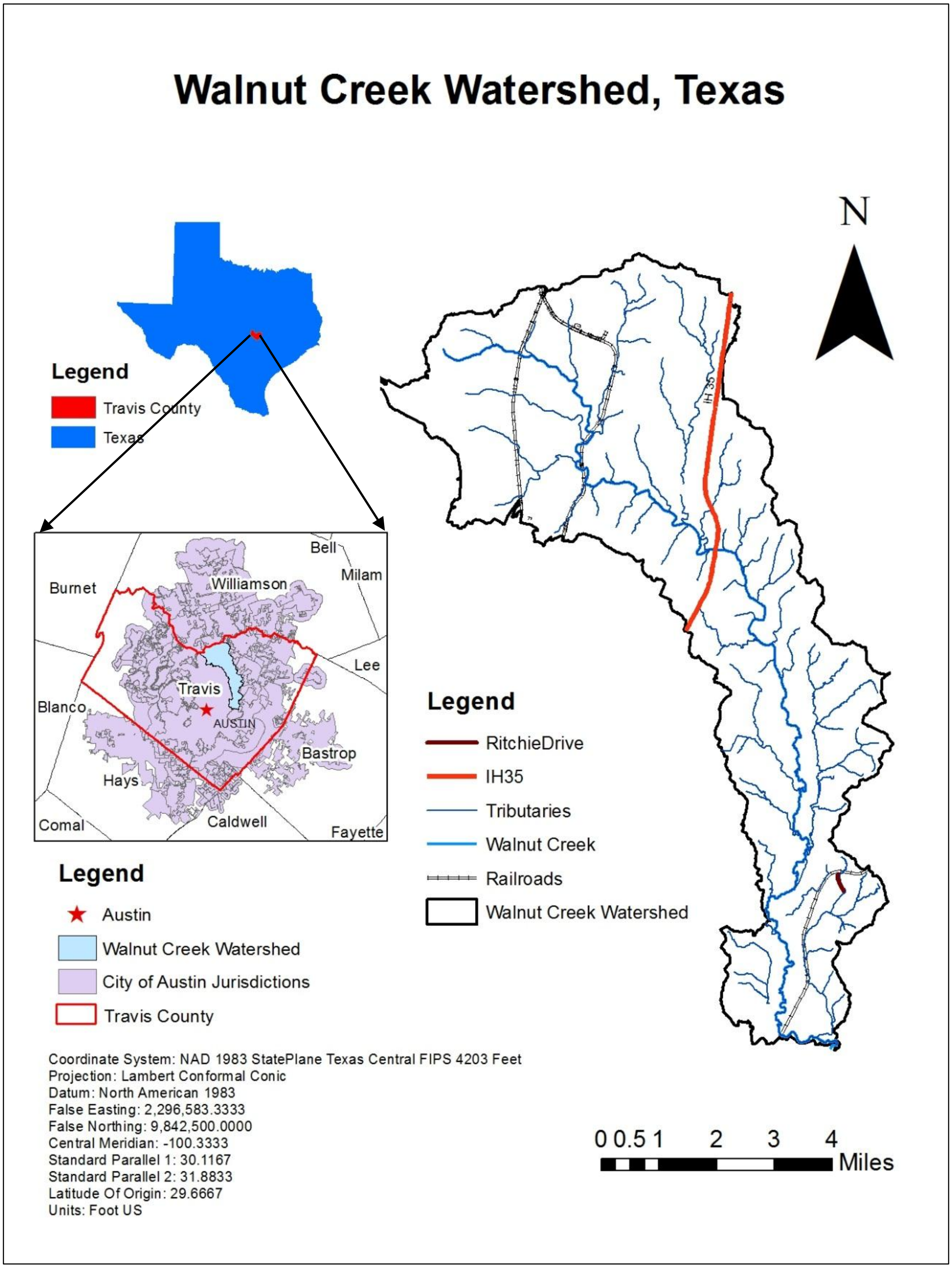

Figure 1. Study area.

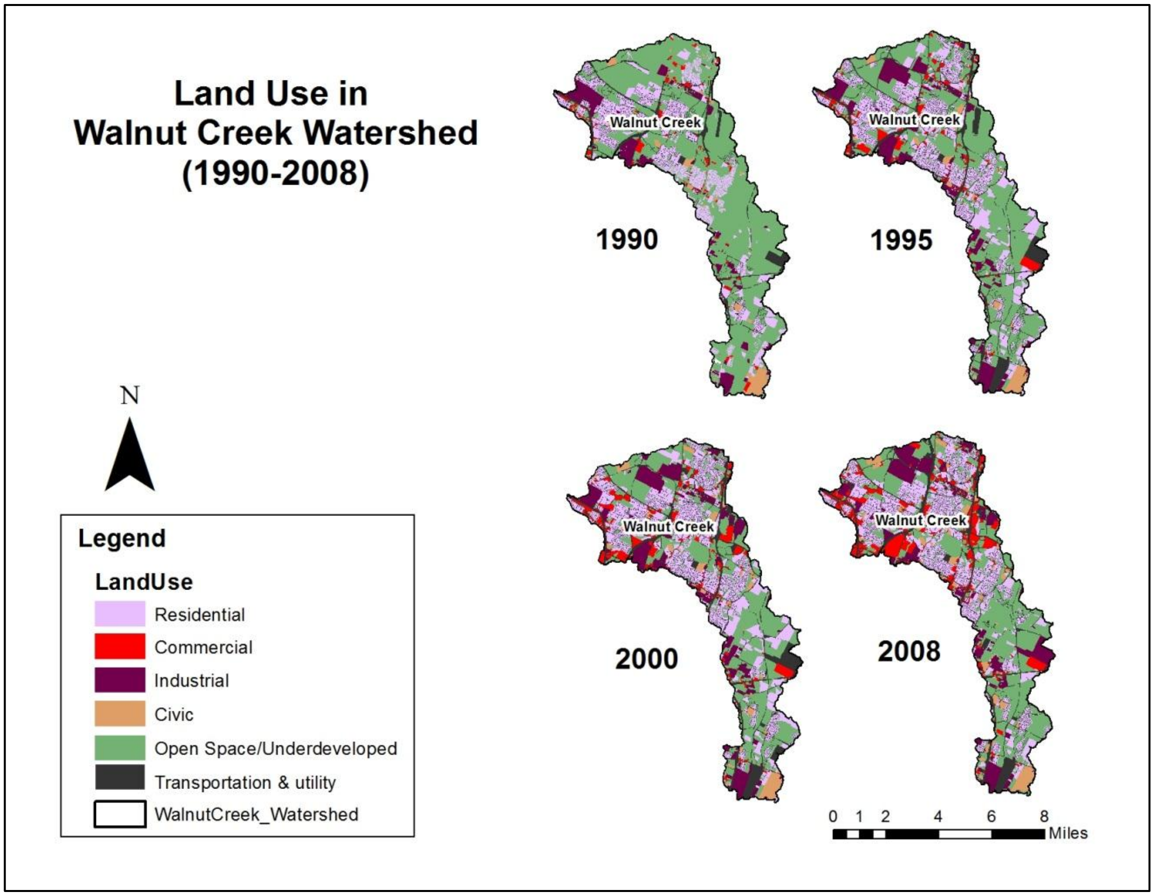

Figure 2. Land use from 1990-2008.

Table 2. Land use changes from 1990-2008.

	Year			
Land Use Activity	1990	1995	2000	2008
Residential (%)	15.32	24.18	23.81	14.99
Commercial (%)	2.14	3.40	4.59	5.14
Industrial (%)	5.49	8.45	9.28	7.10
Open/Underdeveloped Space (%)	61.31	42.58	28.86	22.19
Transportation (%)	10.26	18.19	28.47	47.26
Civic (%)	2.95	3.04	3.85	3.28
Others (%)	2.53	0.16	1.14	0.03
	100%	100%	100%	100%

(Reference: GIS data set)

The climate in Austin has an average precipitation of 33.5 inches and the temperature varies from 50^{o} F to 85^{o} F (NWS, 2011). The geology soil of the area is predominantly associated with Austin-Houston Black-Stephen (City of Austin, 2011b). Vegetation is covered mostly by the winter grassland (City of Austin, 2011b). Figure 3 presents the topographic values of geology soils, vegetation cover, land use/land cover, and floodplain (City of Austin, 2011b). The Walnut Creek has ephemeral flow, thus, the stream only flow when there is a precipitation event.

The restoration project of the Walnut Creek tributary at Ritchie Drive took five months to complete. The goal of the restoration project was to protect residential properties adjacent to eroded stream banks (Figure 4). After the restoration (Figure 5), the banks were stabilized for a length of 300 feet along the stream channel with limestone blocks, vegetative soil layers, and vinyl netting to minimize erosion (Figure 6 and Figure 7, City of Austin, 2004).

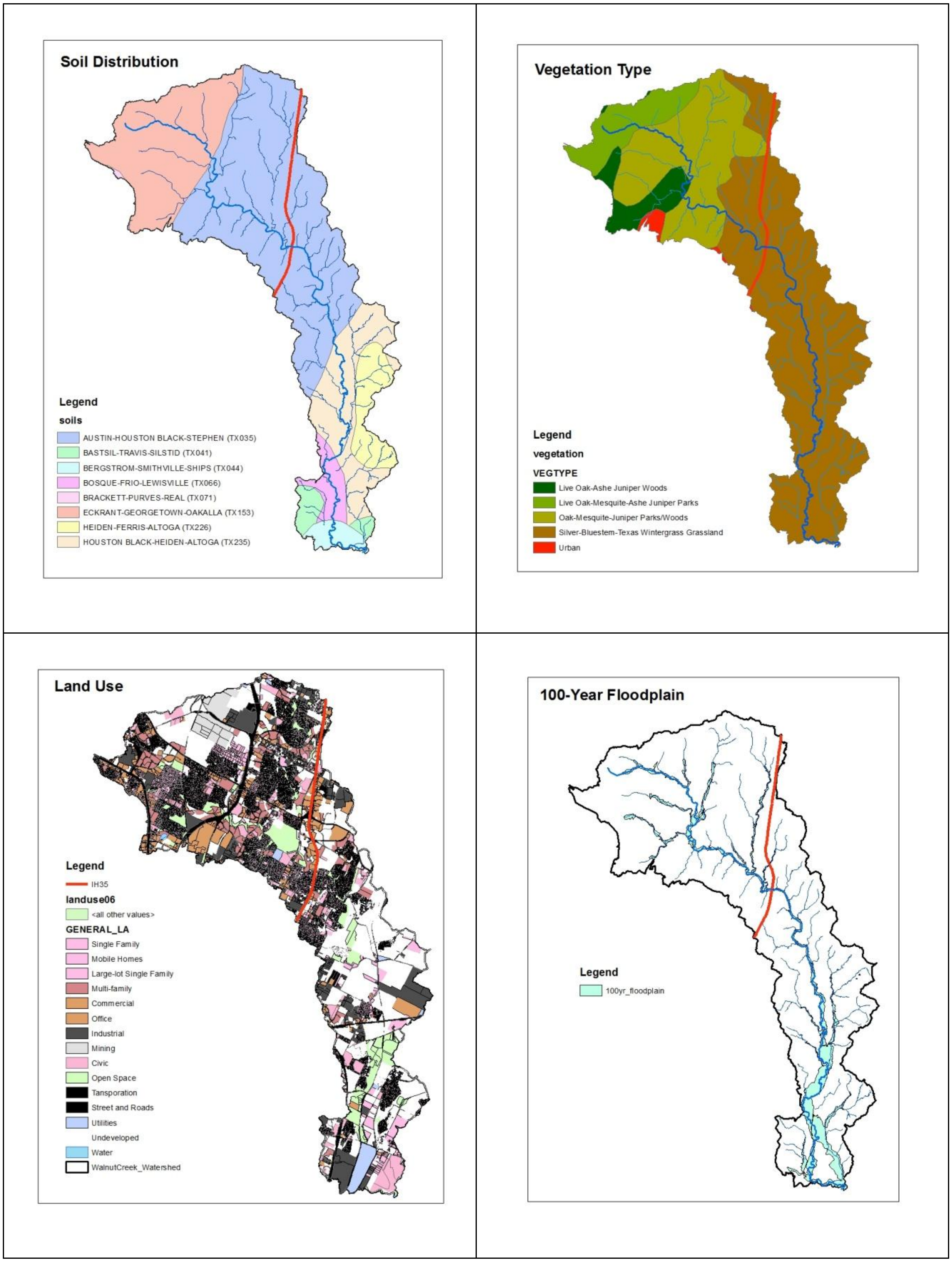

Figure 3. Topographic maps.

Figure 4. Houses adjacent to the eroded bank before restoration in 2003 (City of Austin).

Figure 5. After stream restoration in 2008 (City of Austin).

Figure 6. The bank was stabilized with rocks, vegetative layers, and soils.

Figure 7. Vinyl netting to minimize erosion problem.

Furthermore, the bank opposite the houses was graded to a stable slope and revegetated with native grasses (City of Austin, 2004). In addition to bank stabilization and channel grade control, a natural thalweg was constructed along the channel and with portions of the stream bed being filled (City of Austin, 2004). Lastly, an exposed petroleum pipeline in the area was covered with a limestone rock riffle both for protection of the pipeline as well as an attempt to enhance the aesthetics of the stream beauty (Figure 8 and Figure 9).

3.2 Data Preparation

This study evaluated the economic impacts of the stream restoration project on housing values in Austin, Texas. Data of housing values were obtained from the Travis Appraisal County District (TACD) in Texas. Property value includes the dwelling and land values. To compare the same year dollar value from 2001 to 2011, we employed the Consumer Price Index (CPI) approach to eliminate inflation effect. Housing values of each year was converted to the real dollars in 2001. The real price was calculated by the following formula:

$$\text{Real price} = \text{Current price} * \frac{\text{CPI of the base year}}{\text{CPI of the current year}}$$

Figure 8. Front view of limestone rock riffle covered the petroleum pipeline, after restoration, 2011.

Figure 9. Side view of limestone rock riffle covered the petroleum pipeline, after restoration, 2011.

As shown in Table 3, CPIs from 2001 to 2011 were obtained from the U.S. Bureau of Labor Statistics (BLS). Specifically, the value of a dollar in 2011 lost 23.4 percent of its value. That is, the value of a dollar in 2011 was equivalent to 77 cents in 2001.

To examine spatial and temporal patterns of data in this study, the geographic information system (GIS 10) was utilized. The upper stream was where the restoration project implemented. The Colony Park consists of 77.8 acres (City of Austin, 2011c) in the upper stream and the 100-year floodplains mostly locate in the middle and downstream of the tributary (City of Austin, 2011b).

Data were collected from single-family dwellings along the Walnut Creek tributary for 4,500 feet (from GIS calculation). The selection of residential properties were those adjacent to the stream and within 150-feet buffer of its both sides and properties located on the floodplains and within a 150-feet buffer on the both sides of the floodplains. Houses adjacent to the bank stabilization within 600 feet were selected as restoration site. In addition, each housing value was joined with the ArcMap and matched up with housing ID number provided by the TCAD. Figure 10 shows the selection of houses along the Walnut Creek tributary in this study.

Table 3. CPIs of 2001-2011.

Year	CPI (1982-1984=100)	CPI (2001 as the base year)	Annual rate of inflation	Cumulative inflation rate since 2001
2001	176.4	100.0	-	-
2002	180.3	102.2	2.2	2.2
2003	184.8	104.8	2.6	4.8
2004	189.5	107.5	2.7	7.5
2005	195.7	111.0	3.5	11.0
2006	203.2	115.2	4.2	15.2
2007	209.6	118.8	3.6	18.8
2008	216.3	122.6	3.8	22.6
2009	217.1	123.1	0.4	23.1
2010	216.3	122.6	-0.5	22.6
2011	217.6	123.4	0.8	23.4

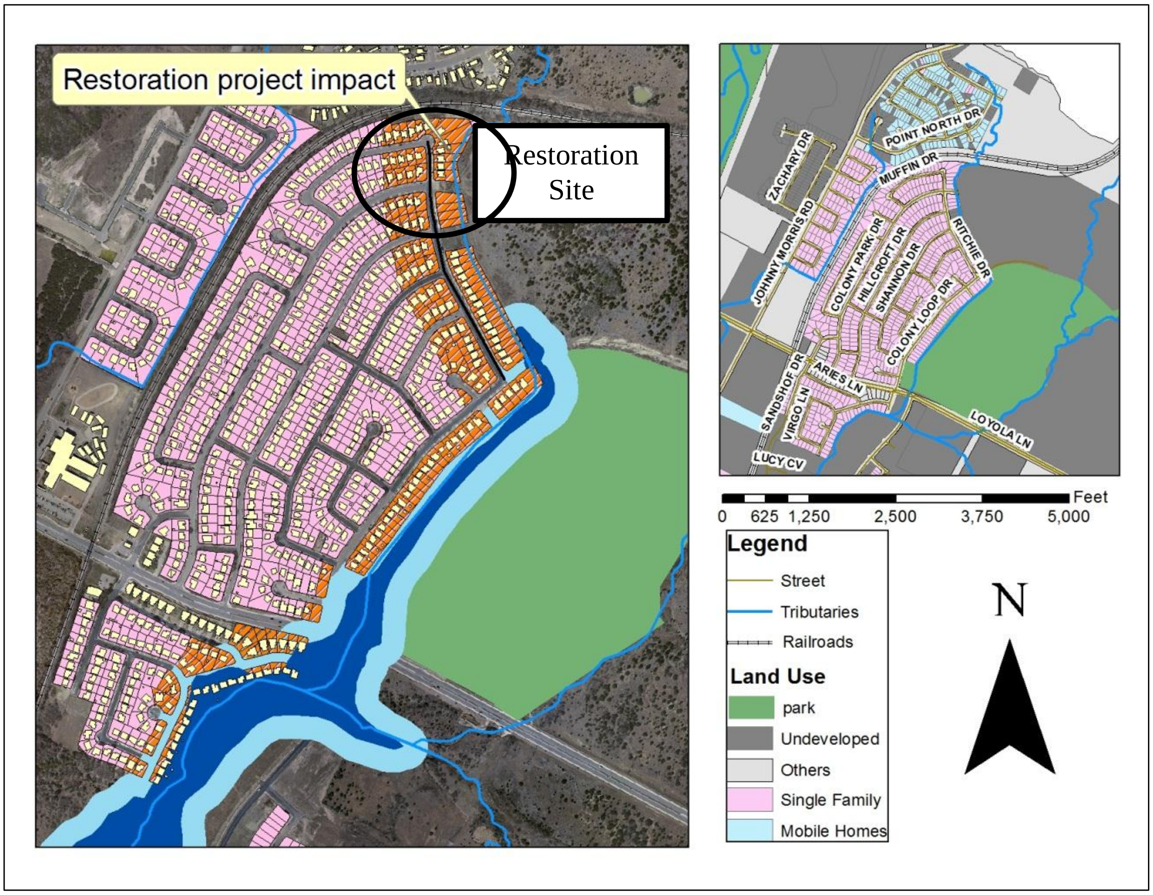

Figure 10. Housing selection along the Walnut Creek tributary.

Table 4 provides the list of the variables of the sample, and the descriptions of housing and environmental characteristics. Data of housing characteristics (such as garage, driveway, fence, etc.) were collected from the TCAD. Other environmental characteristics such as open space, park, and restoration site were obtained from the City of Austin (COA). The distances of houses in proximity to the stream and to the restoration site were generated in the GIS application. Specifically, stream proximity refers to the distance to the stream from houses whereas erosion proximity refers to the distance to the eroded stream banks from houses. The map of the 100-year floodplain was acquired from the Federal Emergency Management Agency (FEMA).

According to the TCAD, appraised housing values were based on the value of the property as of January 1st of that current tax year (personal communication, 21 April, 2011, TCAD). Thus, housing value of a property in June 2003 was reflected in the 2003 appraisal roll. Since the restoration project was completed in December, 2003, we determined that the 2004 appraisal roll can mostly reflect the value of a property in restoration. As for housing values before the restoration, we determined that the appraisal roll from 2001 to 2003 can reflect the values of the properties in pre-restoration since the erosion problem was first reported to the City of Austin in early 2002 (personal communication, 6 May, 2011, COA),

Table 4. List of variables and descriptions.

Variable	Definition	Sources
Housing Price	Appraised value adjusted in 2001 dollars	TCAD
Garage	Dummy variable: 1 if houses with garages; 0 otherwise	TCAD
Driveway	Dummy variable: 1 if houses with fences; 0 otherwise	TCAD
Fence	Dummy variable: 1 if houses with driveways; 0 otherwise	TCAD
Fireplace	Dummy variable: 1 if houses with fireplaces; 0 otherwise	TCAD
Land Size	Land size measured in square footage	TCAD
Living Area	Total interior space in square footage	TCAD
Bathroom	Number of bathrooms	TCAD
Age of Structure	Age of the residential home	TCAD
Water	Dummy variable: 1 houses next to the stream; 0 otherwise	COA
Open space	Dummy variable: 1 houses next to open spaces; 0 otherwise	COA
Park	Dummy variable : 1 houses adjacent the park; 0 otherwise	COA
Floodplain	Dummy variable: 1 houses on the 100-year floodplain; 0 otherwise	FEMA
Erosion	Dummy variable: 1 houses adjacent to the eroded banks; 0 otherwise	COA
Restoration	Dummy variable: 1 if houses next to the restoration site; 0 otherwise	COA
Erosion Proximity	Distance in feet to the eroded stream bank from houses	Generated in GIS
Stream Proximity	Distance in feet to the stream bank from houses	Generated in GIS

4. ANALYTICAL PROCEDURES TO VALUE THE STREAM RESTORATION

To capture the economic impact of the stream restoration project, we used the student's t test to test our hypotheses, applied the hedonic pricing method to analyze the economic impact of stream restoration on housing values, and applied the repeat ground photography to study visual changes of the stream banks at spatial and temporal scales. In this study, we assumed that erosion of stream banks is continuously present, even though the rate of erosion varies geographically, depending on the stability of the river system.

4.1 T-test Specification

We implemented the independent-samples T-test to compare the means (the changes in value) of two groups: houses on the restoration site and houses in other areas. Three assumptions were made as follows for the T-test:

(1) The dependent variables of housing values were normally distributed. We checked for the normal distribution with a Q-Q plot from pre-restoration to post-restoration (See Figure 11).

(2) Equal or unequal variances of the two groups were determined by the Levene's test. The results were presented in section 5.3.

(3) The two groups of houses were independent of one another.

All tests and statistical analyses were performed using the IBM SPSS 19, the Statistical Package for the Social Sciences.

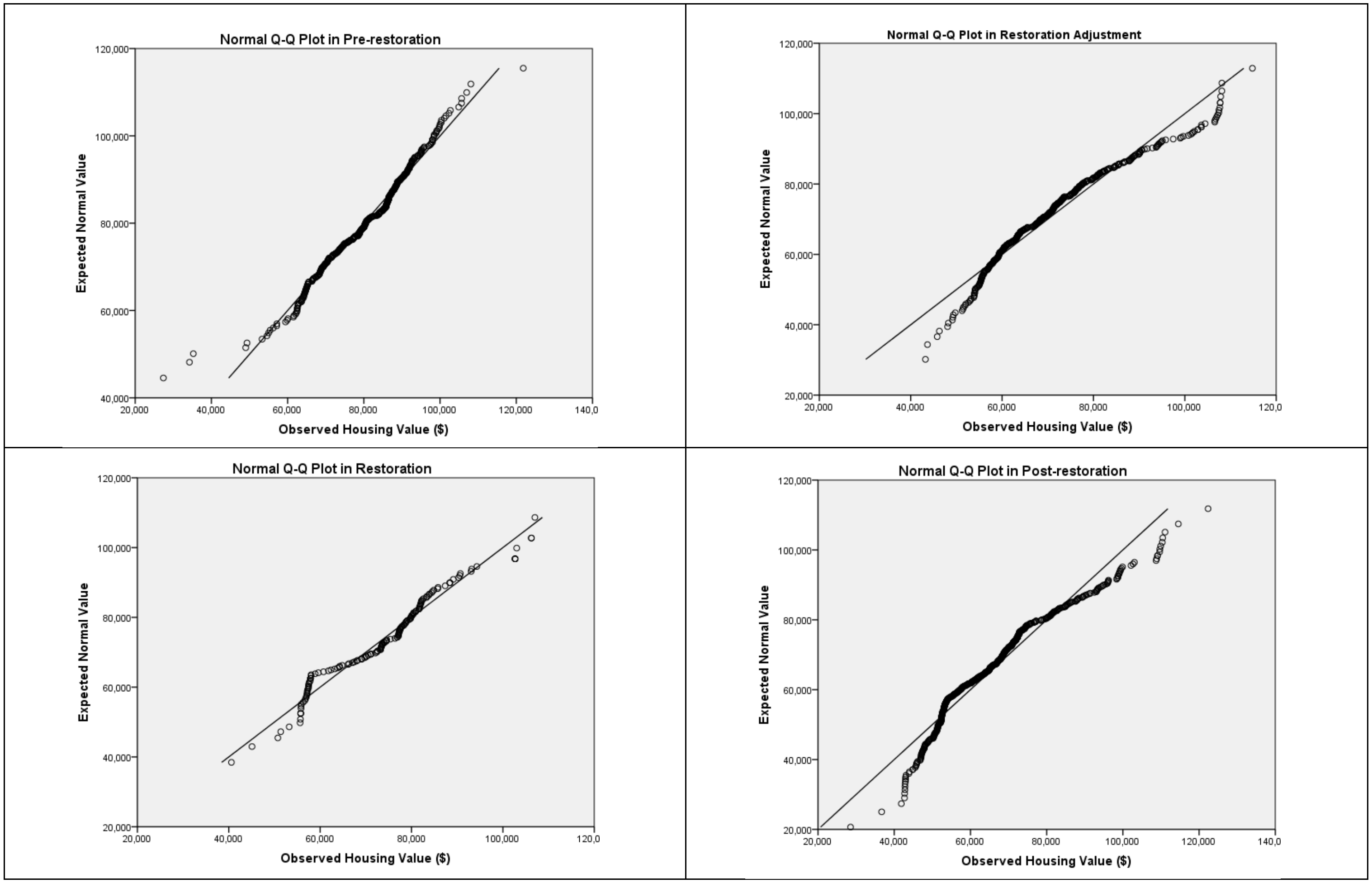

Figure 11. QQ-plots of housing values from pre-restoration to post-restoration.

4.2 Repeat Ground Photography

To assess the stream conditions along the eroded banks during the periods of pre-restoration and post-restoration, repeat ground photography was used to study the visual changes of restored stream banks of the Walnut Creek tributary. Repeat ground photography can document temporal and spatial changes of stream conditions (Rasmussen and Voth, 2001). Meier (2008) applied repeat ground photography to analyze and evaluate stream stability of Waller Creek and Tannehill Branch in Austin, Texas. To show the current condition of the restored stream in this study, photographs were taken based on the techniques of repeat ground photography. Photography taken before the restoration was obtained from the City of Austin. Photographs from before and to after the restoration were presented in the Appendix A.

4.3 Hedonic Pricing Method Construction

This study empirically applied the hedonic pricing method to evaluate the economic impact of stream restoration on housing values. The hedonic pricing method was used to evaluate the non-market value with regard to environmental and housing characteristics (Hitzhusen et al., 2007b). In this study, neighborhood characteristics were not included in the regression based on a judgment that houses along the Walnut Creek tributary were in the same tax code (TCAD, 2011). Thus, the variations among households were small and can be determined homogeneous. While other approach suggested by other researchers using the log-linear function form, we used the simple linear multiple regression because it is the most practical method to interpret the results of regression (Nicholls and Crompton, 2005).

To comprehend how housing values can be affected by an individual variable from before and to after the restoration, housing and environmental characteristics were used as independent variables. Housing values were used as dependent variables. The regression model can be constructed as $P_i = f(H_i, E_i)$, where H_i represents a vector of housing characteristics. E_i represents a vector of environmental characteristics. P_i represents the value of individual residential property i. (Hitzhusen et al., 2007a). For this regression model, housing characteristics included land size, living area, number of bathrooms, the age of the structure, and four dummy variables (e.g. garage, driveway, fence, and fireplace). Environmental characteristics included six dummy variables and two proximity variables. Dummy variables included houses (1) next to water, (2) next to open spaces, (3) in the vicinity of the Colony Park, (4) located on the extent of 100-year floodplains, (5) adjacent to the eroded stream banks, and (6) located on the restoration site. The other two variables were erosion proximity and stream proximity, which were measured in distance in feet from houses to the eroded stream banks and to the stream. More specifically, the regression model was constructed as the following:

$$\begin{aligned}P_i = \beta_0 &+ \beta_1\text{Garage} + \beta_2\text{Driveway} + \beta_3\text{Fence} + \beta_4\text{Fireplace} + \beta_5\text{Land Size} \\ &+ \beta_6\text{Living Area} + \beta_7\text{Bathrooms} + \beta_8\text{Age of Structure} + \beta_9\text{Water} \\ &+ \beta_{10}\text{Open Space} + \beta_{11}\text{Park} + \beta_{12}\text{Floodplain} + \beta_{13}\text{Erosion} \\ &+ \beta_{14}\text{ Restoration} + \beta_{15}\text{Erosion Proximity} + \beta_{16}\text{Stream Proximity}\end{aligned}$$

β_0 to β_{16} are regression coefficients. Coefficient β estimates the changes in housing value, as a result of a unit change in any characteristic, while all other characteristics are held constant. This change was measured by the understandardized coefficient β of the variable by the unit change of that characteristic.

To determine the model specification, Pearson correlation was used to examine the relationship between dependent variables and independent variables. Then, regressions were run using all data sets of housing values from the periods of pre-restoration to post-restoration. Housing values estimated less than $5,000 was excluded from the data set because no structures were built on the land yet. The housing value only accounted for land value itself. Also, we excluded houses within less than $28,000 because those houses were in the process of being built or just right at the stage of completion of construction.

5. RESULTS

Four regressions were run and applied to the hedonic pricing method. We presented the descriptive statistics, correlation analysis, t-tests, and regression analysis as follows.

5.1 Descriptive Statistics

Table 5 displays the descriptive statistics of all variables from pre-restoration to post-restoration. The values of housing characteristics (garage, driveway, fence, fireplace, land size, living area, and number of bathrooms) remained unchanged except the age of the structure. The age of the structure increases by year. Based on the GIS data sets of land use and land cover (City of Austin, 2011b), the values of environmental characteristics such as water, park, and floodplain remained the same. Only the values of open space were slightly varied over time. The value of the house coded as “1,” indicating that a new house was being built next to it. In addition, we assumed that values of stream proximity and erosion proximity remain the same because erosion is a slow moving process along the stream banks.

Figure 12 categorizes four periods of the restoration as pre-restoration (2001-June 2003), restoration (July-December 2003), restoration adjustment (2004-2007), and post-restoration (2008-2011). In general, the average housing value on the restoration site was higher than that in other areas. The reasons could be the average age of structure on the restoration site was 9 years younger than that in other areas (TCAD, 2011). Also, the land size of houses on the restoration site was larger than that in other areas (TCAD, 2011).

Figure 12 shows that from 2002 to 2003, the average housing value of all properties was declined as well as those adjacent to the eroded banks. The average housing value on the eroded banks remained about the same in restoration, but then it dropped abruptly from 2004 to 2005 right after restoration. During restoration adjustment, from 2005 to 2006, housing values on the restoration site increased from about $76,000 to $81,000 by 6.6% whereas the average housing in other areas remained the same at $67,000. From 2006 to 2007, the changes in value of houses on the restoration site and in other areas increased by 11.5% and 11.1%, respectively. In post-restoration, the changes in housing value of houses on the restoration site and in other areas remained similar.

Table 5. List of variables and descriptive statistics.

	Pre- restoration (2001-2003) (N=449)		Restoration (2003-2004) (N=153)		Restoration Adjustment (2004-2007) (N=465)		Post-restoration (2007-2011) (N=624)	
Variables	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Housing Price	80022.507	11860.382	73540.924	13264.959	71531.061	13779.094	66231.404	14749.858
Garage	0.840	0.367	0.843	0.365	0.843	0.364	0.840	0.367
Driveway	0.474	0.500	0.464	0.500	0.458	0.499	0.455	0.498
Fence	0.247	0.432	0.242	0.430	0.239	0.427	0.237	0.426
Fireplace	0.345	0.476	0.340	0.475	0.346	0.476	0.346	0.476
Land Size	8002.428	2033.054	8023.296	2036.553	8032.370	2022.086	8030.677	2016.394
Living Area	1220.771	200.388	1220.732	198.643	1220.434	196.965	1220.096	196.350
Bathrooms	1.920	0.426	1.922	0.422	1.923	0.418	1.923	0.417
Age of Structure	13.982	7.210	15.680	7.386	17.492	7.548	20.885	7.679
Water	0.481	0.500	0.484	0.501	0.488	0.500	0.487	0.500
Open Space	0.519	0.500	0.516	0.501	0.516	0.500	0.513	0.500
Park	0.194	0.396	0.190	0.393	0.187	0.390	0.186	0.389
Floodplain	0.381	0.486	0.373	0.485	0.368	0.483	0.365	0.482
Erosion	0.033	0.180	0.033	0.178	0.032	0.177	0.032	0.176
Restoration	N.A.	N.A.	0.137	0.345	0.146	0.354	0.147	0.355
Erosion Proximity	2204.606	1316.376	2181.484	1325.369	2164.230	1327.429	2164.487	1326.508
Stream Proximity	196.639	97.687	196.216	97.684	195.493	97.301	195.667	97.196

N.A. stands for not applicable

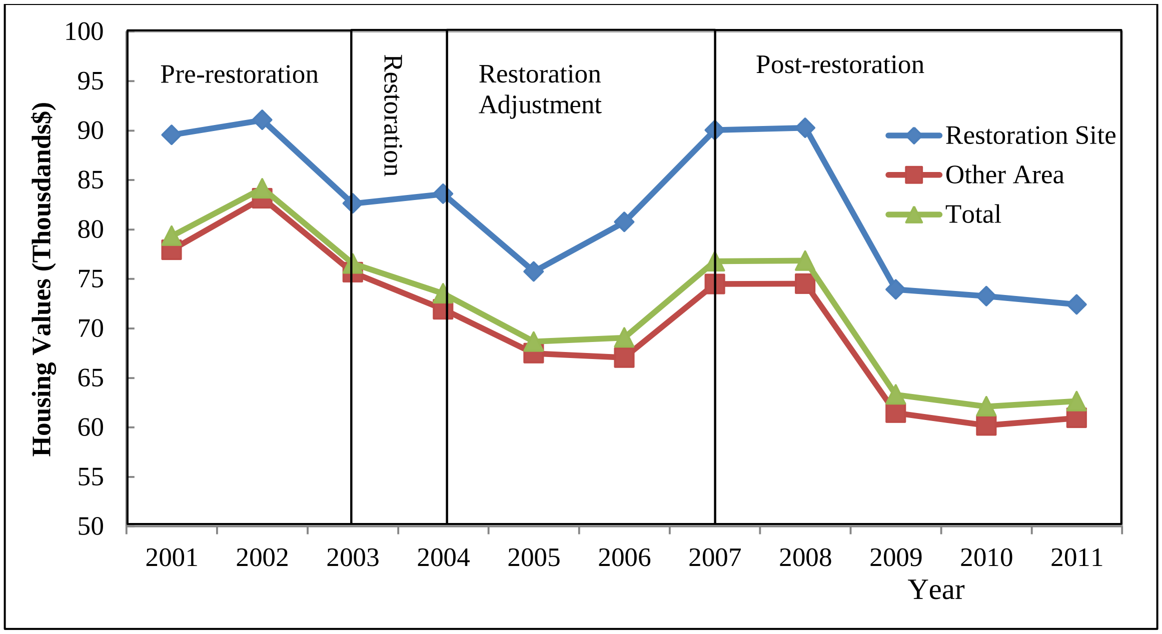

Figure 12. Average mean housing values associated with location.

5.2 Correlation Analysis

Table 6 present the correlation coefficients among variables in the four periods of stream restoration (pre-restoration, restoration, restoration adjustment, and post-restoration). Variables included housing characteristics, environmental characteristics, and housing values. Results show that age of the structure had negative correlations with housing values from pre-restoration to post-restoration at 1% significant level. The age of structure had correlations of -.492, -.531, -.476, and -.606 with housing values (Tables 6-Table 9, row 9 and column 1). Land size and living area were positively correlated with housing values at 1% significant level. This is consistent with the finding that the more living area and land size, the higher property value (O'sullivan, 2009).

Four variables of housing characteristics, garage and driveway, had negative correlations with living area at 1% significant level (-.465, -.236 for pre-restoration; -.464, -.234 for restoration; -.459, -.231 for restoration adjustment; -.450, -.229 for post-restoration, respectively). This indicates that houses with garages, driveways, and fences are more likely to have less living space. Driveway had negative correlations of -.347, -.406, -.407, and -.470 with housing values at 1% significant level (row 3 and column 1, Tables 6-Table 9). Garage had a correlation of .238 with housing values at 1% significant level in pre-restoration (row 2 and column 1, Table 6). In the periods of restoration and restoration adjustment, the magnitude of the correlation of garage with housing values was relatively small, negative, and insignificant. For post-restoration, the correlation of garage and housing values was -.07 at 5% significant level (row 2 and

Table 6. Intercorrelation among variables during pre-restoration.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Housing Price	1														
2. Garage	.238***														
3. Driveway	-.347***	-.168***													
4. Fence	-.123***	-.087**	.572***												
5. Fireplace	.386***	.202***	-.240***	-.025											
6. Land Size	.174***	-.048	-.195***	-.070*	-.034										
7. Living Area	.282***	-.465***	-.236***	-.081**	-.064*	.299***									
8. Bathrooms	.229***	.089**	-.293***	-.329***	.071*	.155***	.421***								
9. Age of Structure	-.492***	-.297***	.798***	.421***	-.382***	-.218***	-.190***	-.337***							
10. Water	.042	.129***	.023	.130***	.004	.190***	-.132***	-.039	.001						
11. Open Space	.025	.126***	.049	.118***	.024	.123***	-.141***	-.003	.029	.927***					
12. Park	.158***	.122***	.177***	.346***	.142***	-.051	-.210***	-.265***	.060	.509***	.472***				
13. Floodplain	-.091**	-.032	.274***	.316***	-.049	-.044	-.144***	-.111***	.271***	.759***	.700***	.625***			
14. Erosion	.052	.081**	-.177***	-.107**	.100**	.391***	-.015	.123***	-.232***	.193***	.179***	-.091**	-.146***		
15. Erosion Proximity	-.449***	-.295***	.649***	.253***	-.401***	-.162***	-.073*	-.069*	.833***	.041	.126***	-.043	.337***	-.295**	
16. Stream Proximity	-.018	-.123***	.029	-.070*	.023	-.248***	.080**	.000	.023	-.939***	-.856***	-.408***	-.712***	-.190***	-.055

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 7. Intercorrelation among variables during restoration.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Housing Price	1															
2. Garage	-.022															
3. Driveway	-.406***	-.175**														
4. Fence	-.043	-.092	.576***													
5. Fireplace	.271***	.196***	-.225***	-.019												
6. Land Size	.251***	-.043	-.200***	-.075	-.043											
7. Living Area	.525***	-.464***	-.234***	-.080	-.065	.296***										
8. Bathrooms	.161**	.090	-.294***	-.330***	.068	.155***	.421***									
9. Age of Structure	-.531***	-.304***	.802***	.429***	-.346***	-.228***	-.184**	-.333***								
10. Water	-.107*	.130*	.017	.125*	-.004	.204***	-.129*	-.037	-.009							
11. Open Space	-.142**	.122*	.035	.119*	.004	.141**	-.141**	-.025	.017	.937***						
12. Park	.101	.117*	.185**	.350***	.146**	-.055	-.210***	-.267***	.078***	.500***	.468***					
13. Floodplain	-.258***	-.039	.286***	.323***	-.039	-.051	-.143**	-.113*	.292***	.742***	.692***	.628***				
14. Erosion	.056	.079	-.171**	-.104	.101	.385***	-.015	.122*	-.217***	.190***	.178**	-.089	-.142***			
15. Restoration	.303***	.172**	-.371***	-.225***	.355***	.212***	-.026	.165**	-.550***	-.120*	-.146**	-.193***	-.307***	.461***		
16. Erosion Proximity	-.541***	-.298***	.649***	.258***	-.385***	-.178***	-.072	-.071	.826	.020	.100	-.033	.343***	-.287***	-.577***	
17. Stream Proximity	.109*	-.124*	.032	-.067	.026	-.258***	.079	.000	.030	-.939***	-.866***	-.401***	-.698***	-.187*	.071	-.034

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 8. Intercorrelation among variables in restoration adjustment.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Housing Price	1															
2. Garage	-.045															
3. Driveway	-.407***	-.173***														
4. Fence	-.136***	-.091**	.579***													
5. Fireplace	.245***	.202***	-.234***	-.026												
6. Land Size	.259***	-.038	-.203***	-.077**	-.035											
7. Living Area	.525***	-.459***	-.231***	-.079**	-.064*	.296***										
8. Bathrooms	.274***	.090**	-.294***	-.331***	.070*	.156***	.420***									
9. Age of Structure	-.476***	-.292***	.797***	.429***	-.356***	-.229***	-.175***	-.328***								
10. Water	-.125***	.138***	.009	.119***	.013	.209***	-.128***	-.035	-.026							
11. Open Space	-.128***	.150***	.035	.118***	.008	.155***	-.147***	-.025	.009	.946***						
12. Park	-.106**	.116***	.190***	.352***	.138***	-.057	-.209***	-.267***	.087**	.491***	.465***					
13. Floodplain	-.284***	-.039	.292***	.326***	-.049	-.054	-.141***	-.115***	.302***	.727***	.685***	.629***				
14. Erosion	.073*	.079**	-.168***	-.102**	.097**	.383***	-.015	.121***	-.206***	.187***	.177***	-.088**	-.139***			
15. Restoration	.323***	.179***	-.380***	-.232***	.377***	.218***	-.026	.164***	-.564***	-.088**	-.111***	-.199***	-.316***	.441***		
16. Erosion Proximity	-.392***	-.302***	.651***	.262***	-.398***	-.183***	-.071*	-.073*	.817***	.003	.077**	-.027	.348***	-.282***	-.588***	
17. Stream Proximity	.091**	-.131***	.039	-.062*	.012	-.262***	.079**	-.002	.043	-.940***	-.880***	-.395***	-.686***	-.185***	.045	-.020

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 9. Intercorrelation among variables in post-restoration.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Housing Price	1															
2. Garage	-.070**															
3. Driveway	-.470***	-.162***														
4. Fence	-.192***	-.085**	.580***													
5. Fireplace	.196***	.208***	-.232***	-.026												
6. Land Size	.311***	-.033	-.202***	-.077**	-.032											
7. Living Area	.553***	-.450***	-.229***	-.078**	-.063*	.296***										
8. Bathrooms	.328***	.087**	-.295***	-.331***	.070**	.155***	.420***									
9. Age of Structure	-.606***	-.263***	.791***	.428***	-.347***	-.222***	-.168***	-.324***								
10. Water	-.108***	.146***	.011	.120***	.019	.211***	-.126***	-.036	-.020							
11. Open Space	-.120***	.169***	.041	.121***	.008	.161***	-.149***	-.026	.019	.950***						
12. Park	-.191***	.108***	.192***	.305***	.120***	-.095***	-.190***	-.268***	.124***	.342***	.326***					
13. Floodplain	-.291***	-.031	.296***	.328***	-.048	-.053*	-.139***	-.116***	.305***	.725***	.686***	.476***				
14. Erosion	.086**	.079**	-.166***	-.101***	.097***	.383***	-.014	.121***	-.199***	.187***	.177***	-.087**	-.138***			
15. Restoration	.317***	.182***	-.380***	-.232***	.382***	.220***	-.025	.164***	-.556***	-.080**	-.101***	-.199***	-.316***	.438***		
16. Erosion Proximity	-.400***	-.306***	.647***	.261***	-.401***	-.185***	-.072**	-.073**	.798***	-.002	.068**	-.029	.346***	-.281***	-.590***	
17. Stream Proximity	.047	-.138***	.037	-.063*	.006	-.264***	.077**	-.002	.038	-.940***	-.887***	-.261***	-.685***	-.185***	.039	-.015

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

column 1, Table 9). Fence had significant negative correlations of -.123, -.136, and -.192 with housing values (row 4 and column 1) in pre-restoration, restoration adjustment, and post-restoration. Houses with fireplaces and bathrooms were positively correlated with housing value.

As for environmental characteristics, water feature had significant negative correlations of -.107, -.125, and -.108 with housing values in restoration, restoration adjustment, and post-restoration. Similarly, floodplain had negative correlations of -.091, -.258, -.284, -.291 with housing values (row 13 and column 1) at 5% significant level or better, indicating that houses on the floodplain had lower values. The correlations between park and housing values were not consistent. In particular, park had a significant correlation of .158 in pre-restoration, -.106 in restoration adjustment, and -.191 in post-restoration (row 12, column 1). Open space had significant negative correlations of -.142, -.128, -.120 for restoration, restoration adjustment, and post-restoration (row 11, column 1).

Erosion had positive correlations of .073 and .086 with housing values in restoration adjustment and post-restoration at 5% significant level or better (row 14 and column 1, Tables 8-Table 9). Rrestoration had positive correlations of .303, .323, and .317 with housing values at 1% significant level for restoration, restoration adjustment, and post-restoration (row 15 and column 1, Tables 7-Table 9). Erosion proximity had negative correlations with housing values at 1% significant level, indicating that increased distance of restoration from houses had lower values. Specifically, erosion proximity had correlations of -.449, -.541, -.392, -.400 with housing values in pre-restoration (row 15 and column 1, Table 6), restoration, restoration adjustment, and post-restoration (row 16 and column 1, Tables 6-Table 9).

In summary, changes of correlation suggest that multiple variables can affect housing values at different level over time. To further assess causal relationships of housing and environmental characteristics on housing values and their impacts on real value during restoration, student's t-test was implemented and regression analyses were presented in the next section.

5.3 Interpretation of Changes in Value

Table 10 presents the group statistics of the sample. Samples were houses on the restoration site (n=37 in pre-restoration; n=19 in restoration; n=66 in restoration adjustment; and n=92 in post-restoration) and houses in other areas (n=262 in pre-restoration; n=131 in restoration; n=396 in restoration adjustment; and n=532 in post-restoration). In addition, the mean of change in value of houses in the restoration site (-0.042, SD=0.066) was greater than those in other areas (0.003, SD=0.208). In restoration, the mean of changes in value of houses in other areas (-0.056, SD=0.059) was greater than those on the restoration site (-0.017, SD=0.015). Right after the restoration, the mean of changes in value of houses on the restoration site was greater and positive (0.03, SD=0.128) than those in other areas (0.018, SD=0.122). As for the post-restoration, the mean of changes in value of houses on the restoration site (-0.049, SD=0.092) was about the same as those in other areas (-0.042, SD=0.125). The results of each independent samples t-test were presented in Table 11.

Table 10. Group statistics.

Period	Site	N	Mean	Std. Deviation	Std. Error Mean
Pre-restoration	Restoration Site	37	-0.0421	0.0662	0.0109
	Other Area	262	0.0025	0.2076	0.0128
Restoration	Restoration Site	19	-0.0169	0.0148	0.0034
	Other Area	131	-0.0562	0.059	0.0052
Adjustment	Restoration Site	66	0.0299	0.1282	0.0158
	Other Area	396	0.0178	0.1218	0.0061
Post-restoration	Restoration Site	92	-0.0489	0.0922	0.0096
	Other Area	532	-0.0417	0.1249	0.0054

Table 11. Results of independent samples t-test.

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper
Pre-restoration	Equal variances assumed	5.078	0.025	-1.294	297	0.197	-0.045	0.034	-0.112	0.023
	Equal variances not assumed			-2.648	162.258	0.009	-0.045	0.017	-0.078	-0.011
Restoration	Equal variances assumed	23.42	0	2.879	148	0.005	0.039	0.014	0.012	0.066
	Equal variances not assumed			6.365	113.634	0	0.039	0.006	0.027	0.053
Adjustment	Equal variances assumed	1.043	0.308	0.743	460	0.458	0.012	0.016	-0.012	0.044
	Equal variances not assumed			0.716	85.711	0.476	0.012	0.017	-0.022	0.046
Post-restoration	Equal variances assumed	0.705	0.401	-0.527	622	0.598	-0.007	0.014	-0.034	0.02
	Equal variances not assumed			-0.651	155.245	0.516	-0.007	0.011	-0.029	0.015

In pre-restoration

We hypothesized that changes in value of houses in proximity to eroded banks will be significantly different than those in other areas. Table 11 shows that the variances of houses on the restoration site were significantly different than those in other areas ($p < .05$). We assumed that the variances are not equal. In addition, the significant value (2-tailed) for t-test is .009 ($p < .01$), indicating that there is a statistically difference between changes in value in two locations. Thus, hypothesis 1 is accepted at the 95% significant level.

Restoration

We hypothesized that changes in value of houses on the restoration site will be significantly greater than those in other areas. Table 11 shows that the variances of houses on the restoration site were significantly different than those in other areas ($p < .05$). We assumed that the variances are not equal. Furthermore, statistically significant greater differences were found on houses on the restoration site and houses in other areas ($p < .01$). Thus, we conclude that changes in value of houses on the restoration site are significantly greater than those in other areas. Hypothesis 2 is accepted at the 95% significant level.

Restoration Adjustment

We hypothesized that changes in value of houses on the restoration site will be significantly greater than those in other areas. Since the variances of houses on the restoration site are not significantly different than those in other areas ($p > .05$), the equal variances for two locations are assumed. The significant value (2-tailed) for t-test is .458 ($p > .05$), indicating that changes in value of houses on the restoration site is not significantly greater than those in other areas. Thus, hypothesis 3 is rejected.

Post-restoration

We hypothesized that changes in value of houses on the restoration site will be as same as those in other areas. Since the variances of houses on the restoration site are not significantly different than those in other areas ($p > .05$), we assumed equal variances for two locations. The significant value (2-tailed) for t-test is .598 ($p > .05$), indicating that there is no statistically difference between the changes in value in two locations. In post-restoration, we conclude that changes in value are no different for houses on the restoration site and houses in other areas. Hypothesis 4 is accepted at the 95% significant level.

5.4 Regression Analysis

A linear regression approach was implemented to determine the impacts of the stream restoration on housing values associated with housing characteristics and environmental characteristics. Signs of housing characteristics and environmental characteristics associated with expected signs were summarized in Table 12. Signs of housing characteristics were in the direction expected except driveway and fence. As for environmental characteristics, all signs were in the direction we expected except erosion proximity and stream proximity.

Tables 13-Table 16 show results of the linear regressions of pre-restoration (2001-2003), restoration (2004), restoration adjustment (2005-2007), and post-restoration (2008-2011). The regression yielded an adjusted R^2 of 0.434 (pre-restoration, Table 13), 0.619 (restoration, Table 14), 0.483 (restoration adjustment, Table 15), and .62 (post-restoration, Table 16), indicating all models were indicative of the characteristics contributing to housing values.

Pre-restoration

For housing characteristics, coefficients of garage and fireplace had positive impacts on housing values at 1% significant level, contributing to 11.8% and 7.1% of the average housing value. Houses with fences and an additional bathroom decreased by 2.3% (equivalent to $1,805) and 0.7% ($540) of the average housing value and were insignificant. Driveways had positive impacts on housing values but were not significant. The age of the structure had a negative impact on housing values at 5% significant level;

Table 12. Signs of housing and environmental characteristics.

Variables	Pre-restoration	Restoration	Restoration Adjustment	Post-restoration	Expected
Garage	+	+	+	+	+
Driveway	+	-	-	+	+
Fence	-	+	+	+	+
Fireplace	+	+	+	+	+
Land Size	+	+	+	+	+
Living Area	+	+	+	+	+
Number of Bathrooms	-	-	-	-	-
Age of Structure	-	-	-	-	-
Water	+	+	-	-	+ or -
Open Space	+	-	+	+	+ or -
Park	+	+	+	+	+
Floodplain	-	-	-	-	-
Erosion	-	-	-	-	-
Restoration	N.A.	+	+	+	+
Erosion Proximity	-	-	+	+	-
Stream Proximity	+	+	-	-	+

N.A. stands for not applicable.

Table 13. Regression results of pre-restoration.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	34344.714	6539.053		5.252	0.000
Garage	9458.704	1562.699	0.293***	6.053	0.000
Driveway	2132.319	1604.080	0.090	1.329	0.184
Fence	-1805.167	1326.242	-0.066	-1.361	0.174
Fireplace	5674.095	1014.940	0.228***	5.591	0.000
Land Size	0.421	0.255	0.072*	1.649	0.100
Living Area	25.751	3.171	0.435***	8.121	0.000
Number of Bathrooms	-540.277	1372.534	-0.019	-0.394	0.694
Age of Structure	-356.467	154.944	-0.217**	-2.301	0.022
Water	3132.571	4023.883	0.132	0.778	0.437
Open Space	2582.440	2538.451	0.109	1.017	0.310
Park	6574.562	1635.913	0.219***	4.019	0.000
Floodplain	-2494.020	1981.052	-0.102	-1.259	0.209
Erosion	-5202.914	2949.430	-0.079*	-1.764	0.078
Erosion Proximity	-0.701	0.793	-0.078	-0.884	0.377
Stream Proximity	25.297	13.682	0.208*	1.849	0.065

R square= 0.453; Adjusted R square= 0.434

Average housing value=$80,023; Std. Dev=$11,860

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 14. Regression results of restoration.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	29419.992	11011.094		2.672	0.008
Garage	3225.118	2489.715	0.089	1.295	0.197
Driveway	-655.190	2593.231	-0.025	-0.253	0.801
Fence	3317.779	2105.271	0.107	1.576	0.117
Fireplace	2270.242	1616.919	0.081	1.404	0.163
Land Size	0.257	0.404	0.039	0.635	0.527
Living Area	40.208	5.128	0.602***	7.841	0.000
Number of Bathrooms	-3604.907	2172.782	-0.115*	-1.659	0.099
Age of Structure	-428.319	237.358	-0.238*	-1.805	0.073
Water	6631.056	6611.743	0.251	1.003	0.318
Open Space	-2947.509	4246.558	-0.111	-0.694	0.489
Park	12542.333	2640.495	0.372***	4.750	0.000
Floodplain	-9664.936	3119.229	-0.353***	-3.099	0.002
Erosion	-8238.770	4957.944	-0.111*	-1.662	0.099
Restoration	6125.900	2942.494	0.159**	2.082	0.039
Erosion Proximity	-0.526	1.238	-0.053	-0.424	0.672
Stream Proximity	13.989	21.768	0.103	0.643	0.522
R square= 0.660; Adjusted R square= 0.619					
Average housing value=$73,541; Std. Dev=$13,265					

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 15. Regression results of restoration adjustment.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	28869.184	7636.010		3.781	0.000
Garage	3125.262	1717.990	0.083*	1.819	0.070
Driveway	-2166.829	1791.831	-0.078	-1.209	0.227
Fence	2646.251	1468.897	0.082*	1.802	0.072
Fireplace	3437.971	1123.100	0.119***	3.061	0.002
Land Size	0.341	0.281	0.050	1.212	0.226
Living Area	37.781	3.554	0.540***	10.630	0.000
Number of Bathrooms	-1761.801	1510.019	-0.053	-1.167	0.244
Age of Structure	-436.760	150.950	-0.239***	-2.893	0.004
Water	-2227.522	4561.407	-0.081	-0.488	0.626
Open Space	2897.908	3081.380	0.105	0.940	0.347
Park	5323.915	1842.239	0.151***	2.890	0.004
Floodplain	-7437.989	2119.652	-0.261***	-3.509	0.000
Erosion	-6946.430	3361.726	-0.089**	-2.066	0.039
Restoration	7669.898	1984.141	0.197***	3.866	0.000
Erosion Proximity	1.300	0.813	0.125	1.600	0.110
Stream Proximity	-5.133	15.120	-0.036	-0.339	0.734

R square= 0.501; Adjusted R square= 0.483

Average housing value=$71,531; Std. Dev=$13,779

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 16. Regression results of post-restoration.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	54107.349	6004.502		9.011	0.000
Garage	1221.287	1339.965	0.030	0.911	0.362
Driveway	2643.686	1406.716	0.089*	1.879	0.061
Fence	3112.263	1161.381	0.090***	2.680	0.008
Fireplace	2347.514	888.893	0.076***	2.641	0.008
Land Size	0.509	0.223	0.070**	2.288	0.022
Living Area	36.601	2.787	0.487***	13.133	0.000
Number of Bathrooms	-3248.839	1191.635	-0.092***	-2.726	0.007
Age of Structure	-1464.406	108.502	-0.762***	-13.497	0.000
Water	-7734.625	3644.756	-0.262**	-2.122	0.034
Open Space	2481.356	2517.505	0.084	0.986	0.325
Park	525.303	1216.017	0.014	0.432	0.666
Floodplain	-4548.257	1552.797	-0.149***	-2.929	0.004
Erosion	-2545.807	2649.909	-0.030	-0.961	0.337
Restoration	2123.181	1554.908	0.051	1.365	0.173
Erosion Proximity	3.014	0.614	0.271***	4.908	0.000
Stream Proximity	-32.030	11.900	-0.211***	-2.692	0.007
R square= 0.630; Adjusted R square= 0.620					
Average housing value=$66,231; Std. Dev=$14,750					

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

an increase in one year decreased the average housing value by $356. Increased land size resulted in higher housing values by $42 per 100 square feet at 10% significant level, contributing to 4.2% of the average housing value (equivalent to $3,369 for about 8,000 square feet). In addition, more living space resulted in higher value as well, contributing to 39.3% of the average housing value (equivalent to $31, 436 for 1,221 square feet).

As for environmental characteristics, park had a positive impact on housing values at 1% significant level, contributing to 8.2% of the average of per single family residential. Houses adjacent to the open space had higher values but were insignificant. Homes on the floodplain had lower valuation by 3.1% and was insignificant. Housing values increased by $25 for one foot away from the stream at 10% significant level, generating 6.2% of the mean housing value. Houses directly adjacent the eroded bank were associated with $5,203 decrease in property value at 10% significant level, representing 6.5% of the average value of all houses adjacent to this disamenity. However, the impact of erosion proximity on houses was negative but was insignificant.

In Restoration

Most of the coefficients of housing characteristics were insignificant. Houses with improvements, such as garages, fences, and fireplaces, resulted in higher values but were insignificant. Only living area had a positive statistical significance at 1% level and consisted of 66.7% of the average value for all houses (increased by $40.2 per square feet for an average house of 1,221 square feet). One year increased of the age of the structure decreased the average housing value by $428 at 10% significant level. Result indicated that an additional bathroom decreased the average housing value by 4.9% (equivalent to $3,605) at 10% significant level.

Park had a statistically positive impact on housing values at 1% significant level, contributing to 17.1% of the average home value. Houses on the floodplain were decreased by 13.1% of the mean value at 1% significant level. Houses adjacent to the open space had lower values by 4% but the impact was insignificant. Homes on the floodplains had lower values by 13.1% (equivalent to $9,665) at 1% significant level. Houses adjacent to the eroded bank were associated with $8,239 decrease in property value at 10% significant level, representing 11.2% lower of the average housing value of houses adjacent to this disamenity. In addition, the implementation of the restoration project resulted in a positive impact on the average housing value by 8.3% (equivalent to $6,126 in value). Still, properties adjacent to the eroded bank resulted in lower values by 2.9% (equivalent to $2,113) of the average housing value.

Restoration adjustment

Houses with garages, fences, and fireplaces had positive impacts on housing values at least at 10% significant level, contributing to 4.4%, 3.7%, and 4.8% of the average value of all houses. The age of the structure had negative impact on housing value at 1% significant level; an increase in one year decreased by $437 in average housing value. Houses with driveways and additional bathroom had negative impacts on housing values by 3% ($2,167) and 2.5% ($1,761) and were insignificant. Our results suggested that increased living area had positive impacts on housing values by $38 per square foot at 1% significant level, contributing to 64.5% of the average housing value.

Increased land size had a positive impact on housing values by $34 per 100 square feet but was insignificant.

Park had a positive impact on housing values at 1% significant level, increased by 7.4% of the mean housing value (or $5,324 in value). Houses on the floodplain had lower housing values at 1% significant level, decreased by 10.4% (equivalent to $7,438 in value) of the mean value. Open space had a positive impact on home values but was insignificant. Houses next to the stream had lower values by 3.1% of the average value, but the stream impact on houses was insignificant. On the restoration site, housing values increased by 10.7% (equivalent to $7,670) at 1% significant level. Erosion still had a negative impact on houses at 5% significant level, contributing to 9.7% (equivalent to $6,946) of the average housing value. To sum up, the restoration project resulted in $724 increased in value for each property adjacent to the previous eroded bank, representing a 1% increase in average housing value.

Post-restoration

In post-restoration, most housing characteristics variables were significant. Coefficients of driveway, fence, and fireplace were at least at the 10% significant level, contributing to 4%, 4.7%, and 3.5% of the average housing value per property with these improvements. The size of the land had positive impacts on housing values by $51 per 100 square feet at 5% significant level, indicating that the larger the land size, the higher the housing values. Our result suggested that the average land size (about 8,031 square feet) contributed to 6.2% of the average housing value per house. The age of the structure had negative impact on housing values at 1% significant level. Results suggested a one year increase in age of the structure decreased the average housing value by $1,464. Houses with an additional bathroom decreased the value by 4.9% (equivalent to $3,249) of the average housing value at 1% significant level. Garages had positive impacts on houses by$1,221 but were insignificant.

Houses adjacent to the water and floodplain resulted in lower housing values by 11.7% ($7,735) and 6.9% ($4,548) respectively at least at 5% significant level. Houses in proximity to open spaces and the park had higher values but those impacts on houses were insignificant. Restoration was perceived to increase $2,123 to the value of the property adjacent to the restoration site. Previous erosion was still perceived by $2,546 decrease in value to each home adjacent to the eroded banks. Even though the impacts of restoration and erosion were insignificant on housing values, the average housing value decreased by $423 per house in the area.

We further investigated the variable of erosion proximity. Erosion proximity had a positive impact on housing values by $301 per 100 feet (or $3 per foot) at 1% significant level. Increased distances from houses to the previous eroded stream banks had resulted in higher housing value. While comparing to the mean housing value, this indicated that the average distance to the bank, 2,164 in feet, contributed to 9.8% (equivalent to $6,524) of the mean housing value. Thus, erosion proximity resulted in positive impact on values for houses close to or on the restoration site.

6. CONCLUSIONS

6.1 Summary

The aim of this study was to evaluate the changes in housing value from pre-restoration to post-restoration (2001-2011) of houses adjacent to and away from the stream banks of the Walnut Creek tributary, Austin, Texas. The stream restoration resulted in a statistically significant positive impact on housing values in restoration (8.3%) and restoration adjustment (10.7%). However, the impact of the stream restoration was insignificant in post-restoration. Overall, the restoration contributed to greater benefits in restoration adjustment by 1% of the average housing value for each property on the restoration site.

Consistent with the literature review (Pompe and Rinehart, 1994; Bin and Kruse, 2006; Poor et al., 2007), environmental disamenities have negative impacts on housing values. In this study, erosion had significant negative impacts on housing values in pre-restoration (-6.5%), restoration (-11.2%), and restoration adjustment (-9.7%). In addition, the restoration project did not improve the values of houses on the floodplain because houses built on the floodplain were more susceptible to flooding.

This research suggests that the stream had a negative impact on housing values in post- restoration at 5% significant level. Also, stream proximity had statistically significant impacts on housing values in pre-restoration and post-restoration ($25 per foot and -$32 per foot, respectively). Specifically, housing values were negatively impacted by an average of $7,735 in post-restoration. This may be attributed to the fact that houses adjacent to the stream were more susceptible to erosion.

Based on repeated ground photography, the stream banks of the Walnut Creek tributary have been stabilized and the presence of vegetation has been reestablished in the area. In addition, the residents built fences to extend their backyards (see Appendix A, Figure A-2, Figure A-4, Figure A-6). Regardless of the minimal impact of stream restoration on housing values, the project resulted in greater benefits to stream stability as well as to the safety of the adjacent properties.

6.2 Research Limitations

This study has several limitations. We only studied a specific time period before and after the restoration. For pre-restoration, we only have a three-year record of housing values began in 2001. It would be ideal to study a longer record of housing values before the restoration since erosion occurs over time. Furthermore, the sample was only representative of single-family dwellings. This limitation suggests caution when generalizing results to different forms of housing, such as duplexes, multi-family residential structures, and condominiums. Lastly, our results depend on the nature of the restoration project of the Walnut Creek tributary. The project predominantly focused on bank stabilization. Thus, we only evaluate bank stabilization as one element of stream restoration. This may limit the larger scope of stream restoration activities' effects on property values. Despite these research limitations, we came to the final conclusion that the urban stream restoration project in Austin, Texas, needed to be evaluated using repeat ground photography and the hedonic pricing method.

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APPENDIX A

Figure A-1. Walnut Creek at 7315 Ritchie Drive before restoration in February 2003 (City of Austin, 2003).

Figure A-2. Walnut Creek at 7315 Ritchie Drive after restoration in May 2011. Residents extended their fences to their backyards.

Figure A-3. Walnut Creek at 7315 Ritchie Drive before restoration in February 2003 (City of Austin, 2003).

Figure A-4. Walnut Creek at 7315 Ritchie Drive after restoration in May 2011.

Figure A-5. Walnut Creek at Ritchie Drive before restoration in February 2003 (City of Austin, 2003).

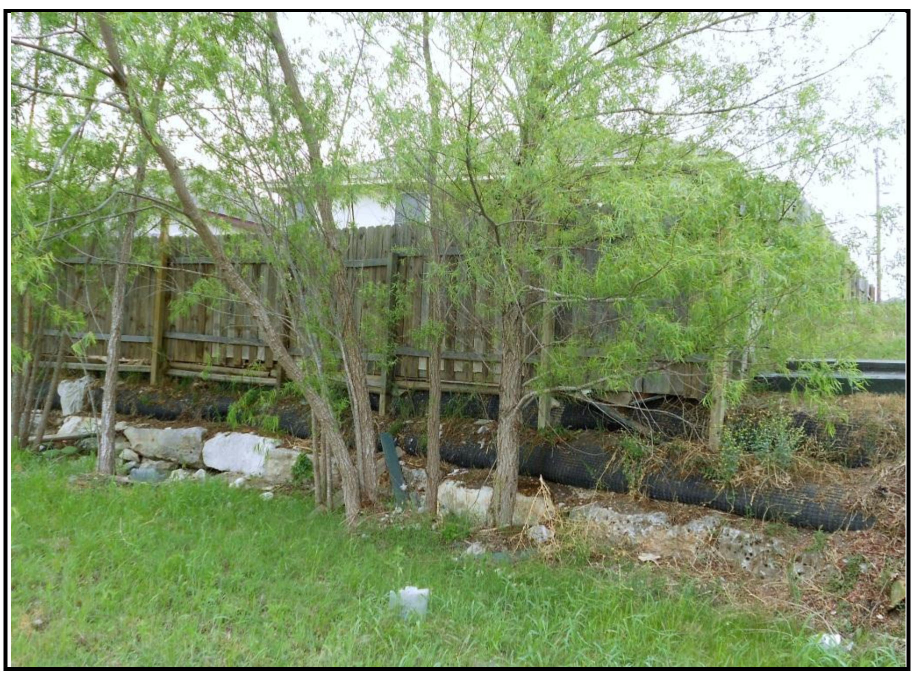

Figure A-6. Walnut Creek at 7315 Ritchie Drive after restoration in May 2011.

Figure A-7. Walnut Creek at Ritchie Drive before restoration in February 2003 (City of Austin, 2003).

Figure A-8. Walnut Creek at Ritchie Drive after restoration in May 2011.

Figure A-9. Walnut Creek at Ritchie Drive before restoration in May 2003 (City of Austin 2003).

Figure A-10. Walnut Creek at Ritchie Drive after restoration in May 2011.

Figure A-11. Walnut Creek at Ritchie Drive after restoration in July 2004 (City of Austin 2004).

Figure A-12. Walnut Creek at Ritchie Drive after restoration in May 2011.

Figure A-13. Walnut Creek at Ritchie Drive after restoration in July 2004 (City of Austin 2004).

Figure A-14. Walnut Creek at Ritchie Drive after restoration in May 2011.

Figure A-15. Walnut Creek at Ritchie Drive after restoration in October 2007 (City of Austin, 2007).

Figure A-16. Walnut Creek at Ritchie Drive after restoration in May 2011.

Figure A-17.Walnut Creek at Ritchie Drive after restoration in June 2010 (City of Austin, 2010).

Figure A-18. Walnut Creek at Ritchie Drive after restoration in May 2011.

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