THE EFFECT OF THE SANTA CRUZ RIVER RIPARIAN CORRIDOR ON SINGLE FAMILY HOME PRICES USING THE HEDONIC PRICING METHOD

By

Kimberly Lynn Bourne

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This thesis has been approved on the data shown below:

George Frisvold ____________________ 5/10/07

Dr. George Frisvold
Professor of Agricultural and Resource Economics

Date

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ABSTRACT

This thesis uses the hedonic pricing method to estimate the effect of location within and proximity to the Santa Cruz River riparian corridor on sales prices of single-family residences in Rio Rico, Arizona. The riparian area is maintained by the instream flow of treated wastewater. A von Liebig-type econometric specification of distance variables performs better than a traditional semi-log specification. Regression estimates suggest that beyond 1.1 miles, distance from riparian vegetation did not affect home values. Homes within 1.1 miles of riparian vegetation, however, received an average price premium of 3.1% with premiums ranging as high as 5.8%.

1. INTRODUCTION

1.1 Aims and Scope of Thesis

This study investigates the effects of the Upper Santa Cruz River riparian corridor on residential property prices using the hedonic pricing method. Regression results are used to derive the marginal implicit price of location within or proximity to a zone of riparian vegetation. Marginal implicit prices are also derived for house structural attributes and proximity to the nearest golf course. The data set is comprised of home sale values between 2001 and 2005 in Tubac and Rio Rico, Arizona. A semi-log functional form and a modified von Liebig specification are used with the natural log of sale price as the dependent variable.

1.2. Background

The Upper Santa Cruz River riparian corridor consists of cottonwood, mesquite, palo verde, willow and elderberry trees. The Santa Cruz River riparian corridor is part of the Tucson Audubon Society's Arizona Important Bird Areas (IBA) Program (Wilbor 2005). The riparian area is important for migratory movement and a habitat for hundreds of bird species (including gray hawks, yellow-billed cuckoos, great blue herons) and wildlife (squirrels, kangaroo rats, gophers). About 60-75 percent of all animal species in the area rely on the riparian corridor (Center for Desert Archaeology). Gila topminnow, Lesser-long nosed bat, and the Sonoran pronghorn, which are also found in the Santa Cruz River riparian corridor, are candidates for listing on the Endangered Species Act (ESA) (Sprouse 2005).

Along the Upper Santa Cruz River is the Juan Bautista de Anza Trail (Anza Trail). This trail was started by a Spanish colonization expedition in 1774-76 from Tubac, Arizona to San Francisco, California. Recently there has been an initiative to redevelop the trail. Today the trail starts in Rio Rico and goes north to Tubac Golf Resort. A 13 mile segment of this trail was just officially certified by the National Park Service.

There are several ecosystem services that the Upper Santa Cruz River riparian corridor provides (Table 1.1). Aquifer recharge and waste treatment of the effluent water are key benefits to the area. The attractive landscape provides recreation such as hiking, biking, and bird watching and gives educational value to students. There are hundreds of values placed on this region. This thesis will only examine how the amenity value of riparian vegetation is reflected in home price premiums.

Table 1.1: Ecosystem Benefits (adapted from de Groot et al.)

Functions	Ecosystem processes and components	Goods and services (examples)
Water supply	Filtering, retention and aquifer recharge	Provision of water for consumptive use (drinking, irrigation)
Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds from effluent	Pollution control/detoxification, filtering of dust particles
Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species, maintains habitat
Nursery function	Suitable reproduction habitat	Hunting, gathering of fish, game, fruits; small-scale subsistence farming & aquaculture
Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing)
Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, bird watching, hiking
Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (heritage value, Anza Trail)
Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions; Use of nature for scientific research
Option values	Use of value of area for potential use	Having the option to use area
Existence values	Value placed on knowing area exists	The knowledge of place

1.3 Who Cares?

The estimates of the effect of the riparian corridor on property values estimated in this thesis will be of interest to environmental groups such as the Audubon Society, Sonoran Institute, Nature Conservancy, and Friends of the Santa Cruz River. The Friends of the Santa Cruz River (FOSCR) is a non-profit organization formed in 1991 to "protect and enhance the flow and water quality of the Santa Cruz River."[1]

Because the Santa Cruz River is a transboundary waterway, results of this thesis may be of interest to the International Boundary and Water Commission (IBWC). There has recently been a $60 million project to improve the Nogales International Waste Water Treatment Plant (located in Rio Rico) which is overseen by many organizations including the IBWC. The Nogales International Treatment Plant (NIWTP) currently releases treated wastewater from Nogales, Arizona (5 million gallons a day) and Nogales, Sonora (10 million gallons a day) into the Santa Cruz River replenishing the aquifer supporting the riparian corridor.

Because most of the treated water comes from Mexico, Mexico maintains the rights to the water, so the effluent cannot be used as a guaranteed water supply in the United States (i.e. for golf courses, residential development, or commercial development). Options for Mexico involve taking back its share of the treated wastewater and using it in Mexico. Alternatively they may seek compensation from the United States for use of the wastewater originating in Mexico. In these cases, it would be useful to see how much the United States or the local area values the effluent. If the water were

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[1] http://www.friendsofsantacruzriver.org/FOSCR11.htm

purchased, the water might be allowed to be diverted from the Santa Cruz River, taking away from the instream flow. With the reduction of instream flows the riparian area currently supported by the effluent would be degraded (Sprouse 2005). Any major changes in instream flow would likely require an environmental impact statement and a formal benefit-cost analysis. The results from this thesis could be a complement to those reports.

1.4 Thesis Contribution

There have been numerous hedonic studies on wetlands, lakes, rivers, and riparian corridors published but there has not been any studies investigating the effects of a riparian corridor created by effluent water. This thesis will examine how “re-constructed” riparian ecosystems are valued. The effluent water released into the Santa Cruz River has lower water quality than natural stream flows. The United States Fish and Wildlife Services (USFWS) discovered toxic levels of un-ionized ammonia in the treated wastewater downstream of the NIWTP. Exposures to these levels have been associated with anomalies and mortalities in fish (King, Zaun and Velasco 1999). Untreated wastewater has been released into the Nogales Wash from overflows of the Nogales, Sonora sewage system. Consequently, Nogales, Arizona’s public water system no longer pumps water from the Nogales Wash aquifer (Sprouse 2005). When heavy rains occur, trash builds up on the Santa Cruz River (figure 3.3).

1.5 Summary of Chapters

Chapter 2 examines the components of the hedonic pricing method starting with the premise of home selling price as a function of its characteristics. This chapter then considers a number of practical problems in applying the hedonic pricing method. These include variable selection and functional form. The final section in this chapter reviews hedonic studies that have focused on valuing impacts of water-based amenities and water quality.

Chapter 3 presents background information about the study area, the Upper Santa Cruz River, and about the data used for this analysis. The final section of this chapter describes the data set used in the hedonic pricing model. Data sources and descriptions are given for the home structural data, geographic information system data, and the housing price index used to adjust sale price from nominal dollars into real terms.

The empirical model is introduced in Chapter 4. Choice of functional form is investigated with discussions and analysis of von Liebig and Box-Cox transformations. A number of preliminary tests of model specification were used to select a functional form for the hedonic model. The expected values of the independent variables are presented in this chapter.

Chapter 5 presents regression results. The marginal implicit values of the independent variables are derived and interpreted. In chapter 6, these results are examined to determine implications, future research, the implications for Tubac and Rio Rico.

2. LITERATURE REVIEW

This chapter contains a review of the hedonic pricing method. The first section of this chapter examines the components of the hedonic pricing method (HPM) and discusses common practices employed in published literature. The next section summarizes recent published hedonic studies of the effects of water-based amenities and water quality on property values.

2.1 Components of hedonic pricing method

2.1.1 Foundation

The hedonic pricing method uses market transactions to derive an implicit price for a good's characteristics or the services it provides. Many papers have been written trying to identify the founder of hedonic applications. Haas (1922), Wallace (1926), Court (1939) and Rosen (1974) have been identified as contributors to the now popularized hedonic pricing method. Andrew Court (1939) published the first article using the term "hedonics." He looked at automobile prices as a function of the characteristics of the car (Colwell and Dilmore 1999). Seventeen years prior to Court, Haas analyzed agricultural land prices as a function of distance to city center and city size. Recently the hedonic pricing method has been used most extensively to estimate effects of environmental amenities and disamenities on prices of neighboring residential properties.

The hedonic pricing method (HPM) is based on the premise that when a person buys a home, they buy a bundle of attributes associated with the home; its structural characteristics (S_i), neighborhood features (N_i), and environmental attributes (E_i).

$$\text{Sale Price}_i = f\,[S_i, N_i, E_i].$$

There is a relationship between observed prices and observed characteristics giving a consumer alternative bundles to choose from. "Econometrically, implicit prices are estimated by the first-step regression analysis (product price regressed on characteristics) in the construction of hedonic price indexes" (Rosen 1974). To derive the marginal implicit price for an individual feature of a home, the partial derivative of the function is taken with respect to the particular feature holding all other variables constant. A drawback of using the hedonic pricing method is that the values generated only capture people's willingness to pay for perceived differences in environmental attributes. If a homeowner is unaware of an environmental amenity or disamenity at the time of purchase, the value will not be captured in their decision making (home purchase price).

The hedonic pricing method captures only how much homebuyers are willing to pay to live closer to an amenity (or farther from a disamenity). It does not capture values derived from visitors, tourist spending, future generational use, option value, or groundwater recharge. Home price premiums for proximity to riparian areas represent only a portion of people's willingness to pay to maintain the amenity. Other methods need to be employed to generate a more complete estimate of the value of the services that the river provides. Other valuing methods are the contingent valuation method (CVM) and the travel cost method (TCM). The values from these studies would need to be incorporated in valuing an amenity. Home price premiums are just one type of value of the river.

2.1.2 Variable Choice

Choosing the correct variables for modeling the sale price of homes is a major challenge in hedonic studies. If the sale price of a home is dependent on a variable that is not included in the regression, the parameter estimates may suffer from omitted variable bias. When a significant variable is not included, the effect might be captured within another estimate which causes interpretations of coefficients to be problematical (Sirmans, Macpherson and Zietz 2005). The omitted variable bias may lead to a biased environmental parameter estimate (Leggett and Bockstael 2000), which can affect the magnitude and the significance of implicit prices (Michael, Boyle and Bouchard 2000). Biased and inefficient estimators may also result if unnecessary variables are included in the model. This makes variable choice for the regression models complicated, where the only tools to determine proper variables is the review of previous literature and logic. Appropriate variables will vary depending on the study area and the environmental amenity being analyzed.

Another issue with variable choice is the problem with multicollinearity. If a model includes variables that are highly correlated, coefficients will have high standard errors and it becomes difficult to determine which explanatory variable affects home prices. Multicollinearity usually occurs with the structural variables, but can also arise with the neighborhood characteristics. One option is to choose a subset of the collinear variables, but the “omitted variables can sometimes lead to a biased coefficient estimate for a critical variable in the model (Leggett and Bockstael 2000).”

Structural Characteristics:

The most common home structural variables (S_i) used in hedonic studies consist of: total square footage, lot size, number of bathrooms and bedrooms, age, garage space, presence of a pool, and number of fireplaces. All of these structural characteristics, except age, generally have positive parameter estimates (Sirmans, Macpherson, and Zietz, 2005). Several studies have also included variables such as: central air-conditioning, hardwood floors, brick walls, number of stories, and basement.

Neighborhood Characteristics:

Neighborhood characteristics consist of characteristics of the home's location. Common neighborhood variables are: crime rate (Anderson and West 2006; Acharya and Bennett 2001; Deaton and Hoehn 2002), distance to city center/central business district (Anderson and West 2006; Bin 2005), school districts, and location (Bin 2005). Location can be represented by zip codes or by relation to city center (i.e. N, NE, W, etc.). For example, a Tucson home located in the foothills will not sell for the same price as a home located on the south side of Tucson given same structural characteristics because of neighborhood differences in the crime rate and school districts. It is essential for the researcher to know the study area in order to determine the appropriate neighborhood variables to include.

Neighborhood features determine housing prices so they must be included in the regression. Some studies have also looked at including percentage of minorities (Irwin 2002; Deaton and Hoehn 2002) in the community, income level (Brasington and Hite

2005) and percentage of age groups in the neighborhood (Anderson and West 2006; Acharya and Bennett 2001).

Environmental Characteristics:

The hedonic pricing method has been used to estimate the effects of various types of environmental attributes (E_i) on single family residences in literally hundreds of studies. Some reviews of the literature include Follain and Jimenez (1985), Sheppard (1999), Malpezzi (2003), Sirmans, Macpherson, and Zietz (2005). Surveys focusing on the role of environmental characteristics include Freeman (1979) and more recently, Boyle and Kiel (2001). Common non-market goods that have been analyzed using the hedonic pricing method include: open space (Irwin 2002; Acharya and Bennett 2001; Lutzenhiser and Netusil 2001), wetlands (Mahan, Polasky and Adams 2000; Bin 2005), views (Bourassa, Hoesli and Sun 2004; Benson et al. 1998), and golf courses (Do and Grudnitski 1995; Grudnitski 2003). Studies have found that homes located near these public goods have a premium based on proximity to amenity. There have also been several studies that look at values (negative) for proximity to disamenities such as landfills (Nelson, Genereux J. and Genereux M. 1992; Hite et al. 2001; Reichert, Small and Mohanty 1992), waste disposal sites (Deaton and Hoehn 2002), and factories emitting foul odors (Anstine 2003).

2.1.3 Functional Form

In applied research, many different functional forms have been used. The most common functional forms are: semi-log (e.g. Acharya and Bennett 2001; Anstine 2003), double log (e.g. Irwin 2002; Deaton and Hoehn 2002; Brasington and Hite 2005), and the more general Box-Cox transformation (e.g. Lutzenhiser and Netusil 2001). Proper functional form might vary by study area and could differ by the problem being addressed. If an incorrect functional form is used, the results could lead to considerable underestimate or overestimates of amenity benefits.

The semi-log function consists of the natural log of price as the dependent variable with linear independent variables. The semi-log is most common functional form used in the literature. The semi-log form allows the independent variables to have different quantitative affects for a range of housing prices; a percentage change in the housing price for a one-unit change in the given variable (Sirmans, Macpherson and Zietz 2005).

The Box-Cox model can be used for testing functional form because the general model contains subsets of semi-log, log linear, and trans-log (Cassel and Mendelsohn 1985). Another method that has been used is to choose the model with the highest R-squared statistic.

2.2 Hedonic Applications to Water-based Amenities

This section reviews hedonic studies focusing on water-based amenities such as wetlands, riparian corridors, and riparian vegetation and water quality on property values. Main features and results of these selected studies are summarized in Tables 2.1, 2.2, 2.3.

Mahan, Polasky, and Adams (2000) investigated the effects of distance to wetlands, size of wetlands and type of wetlands on housing values in Portland, Oregon and surrounding areas in Multnomah County, Oregon. Data from 14,233 home sales from June 1992 through May 1994 were included in the study, with sale price adjusted to May 1994 dollars using a price index for Multnomah County, Oregon. Wetlands were categorized by type (open water, emergent vegetation, scrub shrub, and forested wetlands) and shape (linear and areal). Linear wetlands were long and narrow, while areal wetlands were polygons.

The dependent variable in Mahan, Polasky and Adam's study was the natural log of sales price and the independent variables were structural, neighborhood, wetland, and other environmental variables. The structural variables included six continuous variables (total square feet, garage square feet, lot square feet, age, number of fireplaces, baths) and four dummy variables indicating whether the property had gas heating, hardwood flooring, pool, or a sidewalk. Neighborhood variables included tax rate, distance to central business district, elevation, slope of property, natural log of distance to industrial zone and commercial zone, view quality, dummy variable for light traffic and four variables for property location relative to Multnomah County (SW, NW, SE, NW). Other environmental variables included in the models were: natural log of distance to nearest stream, river, lake, and to an improved public park.

Mahan, Polasky, and Adams estimated two models. Model I included nine wetland variables (size of nearest wetland, natural log of distance to nearest wetland of any type, six dummy variables for the type of the nearest wetland). Model II included the size of wetland and the log of the nearest distance to the wetland of each type. Models I and II had similar results for the neighborhood, structural, and other environmental variables. Model I indicated that sale price increases with an increase of the size of the nearest wetland and with a decrease in proximity to the wetland. The type of wetland did not affect home sale price. The marginal implicit price of moving from 1,000 feet (or about 0.19 miles) closer to the nearest wetland from one mile away was $436.17 for a $125,570 home. For the same home, the marginal implicit price of moving from 1,000 feet closer to the nearest stream from one mile away was $258.81. In model II the statistically significant variables suggested that “living closer to open water areal, wetlands increased house value, while living closer to open water linear, emergent vegetation linear, and scrub-shrub areal decreased house value” (Mahan, Polasky and Adams 2000).

Leggett and Bockstael (2000) investigated the effects of water quality on residential home sales in Anne Arundel County, Maryland for homes that sold between July 1993 and August 1997, adjusting prices to 1997 dollars using the consumer price index. Water quality was determined by fecal coliform counts in the Chesapeake Bay.

Assessed value of the home structure and lot size variables (acres and acres squared) were used to represent the structural characteristics of the home. Five distance variables (Baltimore, Annapolis, industrial National Pollution Discharge Elimination System (NPDES) site, marina with at least 20 boat slips, sewage treatment plant), four variables indicating percentage of land use within a three to four mile distance (percent densely developed, very low density, percent water or wetlands, open space or forest), two interaction terms (percentage of commuters times distance to Baltimore, distance to Baltimore times distance to Annapolis), whether the home was served by public water and sewer, and the median fecal coliform concentration in the year of sale were included in the regression model. Eight models were estimated using these independent variables. Four functional forms were estimated (linear, double-log, semi-log, inverse semi-log) with two separate dependent variables (market price and market price minus assessed value of structure).

In every model acres, distance to Baltimore, distance to Annapolis, interaction terms, and percentage of land that is water were significant with positive parameter estimates. The inverse distance to an industrial NPDES site and fecal coliform concentration had statistically significant, negative coefficients in all models. As fecal concentration increases, home sale price decrease; "the mean effect on the predicted price of a parcel for a 100 count change in fecal coliform ranged from a low of $5114 to a high of $9824 over the eight specifications we considered" (Leggett and Bockstael 2000). However, the coefficient for inverse distance to sewage treatment plants was significantly different from zero in only two specifications.

Leggett and Bockstael estimated the benefits from improving the water quality for the Saltworks Creek inlet northwest of Annapolis using the parameter values from the inverse semi-log model and correcting for spatial autocorrelation. A hypothetical reduction in the level of fecal coliform by 100 counts per 100mL would lead to an increase in property values of 41 parcels by a total of $230,00 (with a 95% confidence interval ranging from $105,000 to $353,000).

Mooney and Eisgruber examined the effects of riparian protection measures on residential property values evaluating 705 residential sales (lots less than 25 acres) in Mohawk watershed, western Oregon. Specifically, they examined the impacts of riparian buffers of trees adjacent to streams. Riparian buffers of trees reduce stream temperatures, improving salmon habitat.

Because of data limitations, they used market assessed values instead of actual sale prices. The following independent variables were included in the model: lot size, square footage of house, year of construction, high quality, low quality, a dummy variable for homes within local school district, distance to interstate highway, adjacent to a stream, and width of riparian buffer (measured perpendicular to the stream). The consumer price index for shelter was used to adjust all sale prices to 1996 values.

Mooney and Eisgruber estimated eight models using a variation of the Box-Cox (1964) model. Using the Ramsey's RESET test (Ramsey 1969; Ramsey and Schmidt 1976) they were able to eliminate six specifications; four used the non-transformed market assessed property values as the dependent variable while two models used the natural log of market assessed property values; failing the RESET test suggests that the models were incorrectly specified. The two remaining models had heteroskedastic errors that were corrected for, using White's method (White 1980).

Regression coefficients were statistically significant for both models with the expected coefficient signs. They found that a stream frontage increased property values by 7 percent. However, they found that an increase in width of treed riparian buffers reduced the value of streamside property. The parameter estimate for width of riparian buffer is negative in both models with coefficients of -0.0005 and -0.0006. "Evaluated at the mean market value of a riverfront property ($142,510), this generates a decrease in market value of $85.50 (.06 percent) as a result of having a riparian buffer that is one foot wider" (Mooney and Eisgruber 2001).

The two models were reexamined including an interaction term, width*(binary variable 1 if width > 30 and zero otherwise), which was statistically significant at the 10 percent level for Model II, with coefficient 0.0026. All independent variables except the dummy variable for local school district were significant with expected signs; the riparian width variable was statistically significant for both models. If the riparian buffer in greater than 30 feet wide a one foot increase would cause the market value of a home to decrease by $100 (0.07% of mean river property value of $142,510) and a decrease of $470 (0.33%) per foot for buffers less than 30 feet wide. Under this alternative specification, a stream frontage increased property values by 10 percent. The overall results of this study indicate that having a riparian buffer in Mohawk watershed, western Oregon reduces the market value of streamside properties. The authors suggest that more trees may obscure views of streams.

Colby and Wishart (2002) estimated impacts of proximity to Tanque Verde Wash and nearby riparian corridors on 7,658 single family residential homes in Tucson, Arizona, sold between 1996 and 1999. The dependent variable used in this analysis was home sale price with nine independent variables; the independent variables consisted of dummy variables indicating year of sale, parcel size, living space, age, garage spaces, and the natural log of distance in miles to the center of riparian corridor. The parameter estimates were all statistically significant at the 5% level with all expected sign; parcel size, living space and garage space had positive coefficient with age and log of distance having negative signs. The regression results indicate that a 15 year old, one car garage home with 2,000 square foot located 0.10 miles to the riparian corridor has a premium of $10,640 compared a home located 1.5 miles away. This represented a premium of six percent. The paper calculated an overall premium of $103.1 million for 25,560 single family homes located within 1.5 miles of riparian area in reference to if they were located at 1.5 miles away. This averages out to be about $4,000 per home in the area within 1.5 miles of the corridor.

Doss and Taff (1996) examined the effect of proximity to wetlands by wetland type on residential property values in Ramsey County, Minnesota. They included four wetland types in their study: forested, scrub-shrub, emergent, and open-water wetlands. The houses examined were located within 1,000 meters of each of the four wetland types. The model used the assessed value of the home as the dependent variable with 19 independent variables consisting of: lot area, bathrooms, living area, age, dummy variable of lake view, distance to lake, distance to each wetland type, squared distance to lake, squared distance to each wetland type, and four dummy variables indicating school districts. All independent variables excluding squared distance to forested wetland were statistically significant at the 0.025 level with expected signs of housing structural characteristics. The model was corrected for heteroskedasticity by using White's (1980) approach. A lake view was found to increase home's assessed value by approximately $46,000. The results indicate that scrub-shrub is preferred to all other wetlands followed by open-water wetlands. Decreasing the distance to the individual wetlands by 10 meters causes housing prices to increase by $145 for scrub-shrub, $136 for emergent-vegetation, and $99 for open-water wetlands. The only distance variable with a positive coefficient estimate was distance to forested wetland; as distance from forested wetland increases, the home assessed value increases. Decreasing the distance to forested wetlands by 10 meters causes housing prices to decrease by $145. This study concluded that homeowners value types of wetlands differently indicating possible reactions to wetland preserve policies.

Netusil (2006) evaluated impacts of riparian corridors and upland wildlife habitat in part of the Fanno Creek Watershed, Portland, Oregon. The data used for the analysis consisted of 1,665 single family residential property sales sold between January 1999 and December 2001, with the sale price adjusted to 2000 dollars. Two linear models were estimated. The independent variables age, lot square footage, building square footage, distance to nearest stream in feet, percentage of lot with a stream, percentage of tree canopy within 0.5 mile, percentage of streams within 0.5 mile, percentage of specialty parks within 0.5 miles were included in both regressions. A variable was generated to indicate how many ecological functions surrounded a property (0.5 mile radius) which was included in both models. The first model included the percentage of lot with regionally significant resources and squared term as independent variables in the regression. Model II had several independent variables detailing habitat types. In model II, riparian corridors and wildlife habitats were each broken up into three descriptive categories. Included in the regression model was percentage of lot with each riparian and habitat class, along with squared terms.

The results from Model I indicate that sale price increases with an increase in the percentage of the lot with regionally significant habitat, the percentage of the lot with a stream, the percentage of tree canopy within one-half mile of the property, and a constructed score measuring ecological functions provided by the riparian corridor (riparian functional value) within one-half mile of the property. In contrast, the coefficient for the percentage of streams within one-half mile was negative.

In Model II, the percentage of the lot with a stream and the percentage of tree canopy within one-half mile of the property were positively and significantly associated with price. The coefficient for riparian functional value was positive but insignificant. Again, the coefficient for the percentage of streams within one-half mile was negative. One of the riparian classifications was significant and two of the wildlife habitat classifications were significant. The significant riparian category had a negative parameter estimate indicating a discount in sale price. This variable represented a lowered valued habitat; the higher riparian classification had a positive estimate but was not significant. The author pointed out that results could be affected by omission of a flood plain variable.

Poor, Boyle, Taylor, and Bouchard (2001) examined how water clarity in Maine lakes affected property values. They used sales data from 1990 to 1995 to analyze four real-estate markets in Maine: Lewiston (n = 56), Augusta (n = 174), Bangor (n = 52), and Northern Maine (n = 66). Secchi disk readings (an objective measure of quality) and survey data from lakefront property owners (a subjective measure) were used as water quality variables. Two models were estimated for each real-estate market using different measures of water clarity. The dependent variable in the hedonic equation was the sale price of the property with independent variables consisting of: natural log square footage of living area, dummy for central heating system, dummy for full bathrooms, dummy for main source of water from lake, total lake frontage in feet, miles to the nearest large town, lot density, and the natural log of water clarity multiplied by lake surface area in acres.

All of the statistically significant parameters except living area in one model had the expected signs. Comparing the water quality measurements from the Augusta model indicates that the implicit price derived subjectively ($2,756) was 6% higher than derived objectively ($2,600) and in the Lewiston model the subjective measurement ($8,985) was 43% higher than the objective function ($6,279). Poor et al. determined from the Davidson and MacKinnon non-nested J-test (Greene 1997) that the objective measures for Lewiston and Augusta markets are better estimators of sale price than subjective measurements.

Bin (2005) used semiparametric estimation methods to evaluate four types of wetlands (open water, emergent vegetation, forested, and scrub shrub wetlands) in Portland, Oregon. The data consisted of 1200 single family residential home sales that sold between June 1992 and May 1994. The model used 21 variables to explain sale price; the focus variables were size of nearest wetland in acres and eight distance variables in feet (distance to nearest central business district, distance to nearest commercial zone, distance to four wetland types, distance to nearest river, distance to nearest lake). Study results suggest that housing prices increase with proximity to open water but decrease or are insignificant for emergent vegetation, forested, and scrub shrub wetlands. A distance decrease from 5,500 feet to 2,500 feet away from open water wetlands cause housing prices to increase by $18,007, property values decreases by $5.01 per distance in feet (on average) to nearest emergent vegetation wetland. Property values decrease with proximity to nearest forested wetlands within a distance of 3,900 feet. Rivers had a positive impact on home selling price. A distance change from 3,000 feet to 2,000 feet increase property by $3,720.

Table 2.1: Summary Hedonic Studies

Authors / Years covered in study / Location of study	Dependent Variable	Water-based amenity variable(s) used (e.g. lakes, washes, rivers, wetlands)	Functional Form	Distance or proximity measures used (e.g. adjacency, within x miles, distance in feet? miles?	Main findings
Leggett & Bockstael / July 1993 - Aug '97 / Arundel County, Maryland	Market price & market price minus value of structure 1997 dollars	Water quality in the Chesapeake Bay	Several Forms- linear, double-log, semi-log, inverse semi-log	Median fecal coliform concentration in the year of sale	-A 100 count decrease in fecal coliform increases parcel price by $5,114 to $9,824 (mean effect)
Mahan, Polasky & Adams / June 1992 - May '94(14,233sales)/ Multnomah County Portland Oregon	Ln(Saleprice) May 1994 dollars	Scrub-shrub, open-water, emergent vegetation, forested wetlands	Mixed- some continuous independent variables logarithmic	Model 1: size of nearest wetland, ln(distance nearest wetland), dummy variable for nearest wetland linear and areal Model 2: size nearest wetland, ln(distance nearest wetland linear and areal)-Euclidean distance from center of lot to the nearest edge of amenity	-Increase of one acre size of nearest wetland increases home value by $24.39 -Decreasing distance to nearest wetland by 1,000 ft increases home value by $436.17 -Type of wetland does not matter
Mooney & Eisgruber Mohawk / 1996 (705 residential sales) / watershed, western Oregon	Ln(Market assessed values) 1996 dollars	Mohawk watershed	Mixed- Some continuous independent variables logarithmic	Width of riparian buffer (measured perpendicular to the stream), adjacent to a stream	-A one foot wider riparian buffer of a riverfront property decreases a homes market value by .06 percent ($85.50 at mean market value)

Table 2.2: Summary Hedonic Studies

Authors / Years covered in study / Location of study	Dependent Variable	Water-based amenity variable(s) used (e.g. lakes, washes, rivers, wetlands)	Functional Form	Distance or proximity measures used (e.g. adjacency, within x miles, distance in feet? miles?	Main findings
Netusil / 1999-2001(1,665 sales) / Fanno Creek Watershed, Portland OR	Sale Price 2000 dollars)	Stream, riparian corridor, upland wildlife habitat	Linear	Distance in feet from center of property to nearest stream, percentage of lot with riparian type (3 types) and squared terms, percentage of lot with upland wildlife habitat (3 types) and squared terms, sum of riparian functional value within 0.5 mile	-Streams within 0.5 mile of property decreases sale price -One standard deviation increase in riparian score increase sale price by $10,720 in model I, $8,581 in model II
Poor, Boyle, Taylor, Bouchard / 1990-1995 (348 total sales) / Maine	Sale Price Lakefront properties Four Models (market areas)	Freshwater lakes and ponds in Maine	Mixed- Some continuous independent variables logarithmic	Objective water-quality- secchi disk readings in meters Subjective water-quality- survey data units in ft converted to meters	-As water quality increases, sale price increases. -Subjective measure estimates were 6% and 43% larger than objective estimates

Table 2.3: Summary Hedonic Studies

Authors / Years covered in study/ Location of study	Dependent Variable	Water-based amenity variable(s) used (e.g. lakes, washes, rivers, wetlands)	Functional Form	Distance or proximity measures used (e.g. adjacency, within x miles, distance in feet? miles?	Main findings
Bin / June 1992-May 94(1200 sales)/ Portland, Oregon	Sale Price May 1994 dollars	Scrub-shrub, open-water, emergent vegetation, forested wetlands	Semiparametric	Distance in feet to each nearest wetland type (4), size in acres of nearest wetland of any type, distance in feet to nearest lake and nearest river	-Decrease from 5,500 feet to 2,500 feet away from open water wetlands increase price by $18,007 - values decreases by $5.01 per distance in feet to nearest emergent vegetation wetland - decrease of 3,000 feet to 2,000 feet distance to river increase property by $3,720
Colby and Wishart / 1996-1999 (7,658 sales) / N.E. Tucson, AZ	Sale Price	A 15-mile stretch of the Tanque Verde Wash and nearby riparian corridors proposed for protection.	Mixed- ln(distance), other variables linear	Distance in miles to center line of riparian corridor	-Property values increase 3.5% moving from 1.5 miles to 0.3 miles from center line of riparian corridor. -They increase 6% moving from 1.5 miles to 0.1 miles.
Doss and Taff / 1992(32,427 sales) / Ramsey County,	Assessed home value	Scrub-shrub, open-water, emergent vegetation, forested wetlands and lake view	Mixed- Distance variables are linear and squared	Distance in 10-meter increments Distance to lake and to each wetland, squared distance to lake, squared distance to each wetland	-10 meters distance decrease causes housing prices to increase by $136 for emergent-vegetation, $99 for open-water, $145 for scrub-shrub and decrease by $145 for a ten meter decrease in distance to forested wetlands

3. SANTA CRUZ RIVER

3.1 Study Area

The Santa Cruz River starts in San Rafael Valley, Arizona and flows south into Mexico for 35 miles looping around back into Arizona, total length of over 359 miles (Figure 3.1).[2] The Santa Cruz River has perennial flows for about 16 miles downstream of the Nogales International Wastewater Treatment Plant (NIWTP) located about 9 miles north of the U.S. Mexico border. The NIWTP treats about 15 million gallons of wastewater per day and releases it into the Santa Cruz River at Rio Rico, Arizona. Two thirds of the water comes from Nogales, Sonora with one third from Rio Rico and Nogales, Arizona. Due to the flowing Santa Cruz River, Rio Rico, Tubac, and Tumacacori have a unique riparian area in the desert (Figure 3.2).

The NIWTP was built in the 1950s funded by the United States and Mexico, and maintained by both countries. With the concern of water quality in the Santa Cruz River, there has been approximately $60 million dollars designated for the improvement of the NIWTP in order to reduce the load of contaminants released into the river (Figure 3.3). The project will upgrade and expand the Nogales International Treatment Plant and replace and enlarge the International Outfall Interceptor (IOI, pipes from Mexico to NIWTP). The project was moving slowly with several organizations involved: Arizona Department of Environmental Quality (ADEQ), the city of Nogales, International Boundary Water Commission (IBWC), Environmental Protection Agency (EPA-Region

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[2] http://www.geocities.com/amigosnaturales/scriverfacts.html

9), North American Development Bank (NADB) and Border of Environment Cooperation Commission (BECC).

Figure 3.1: Upper Santa Cruz River (Sprouse 2005)

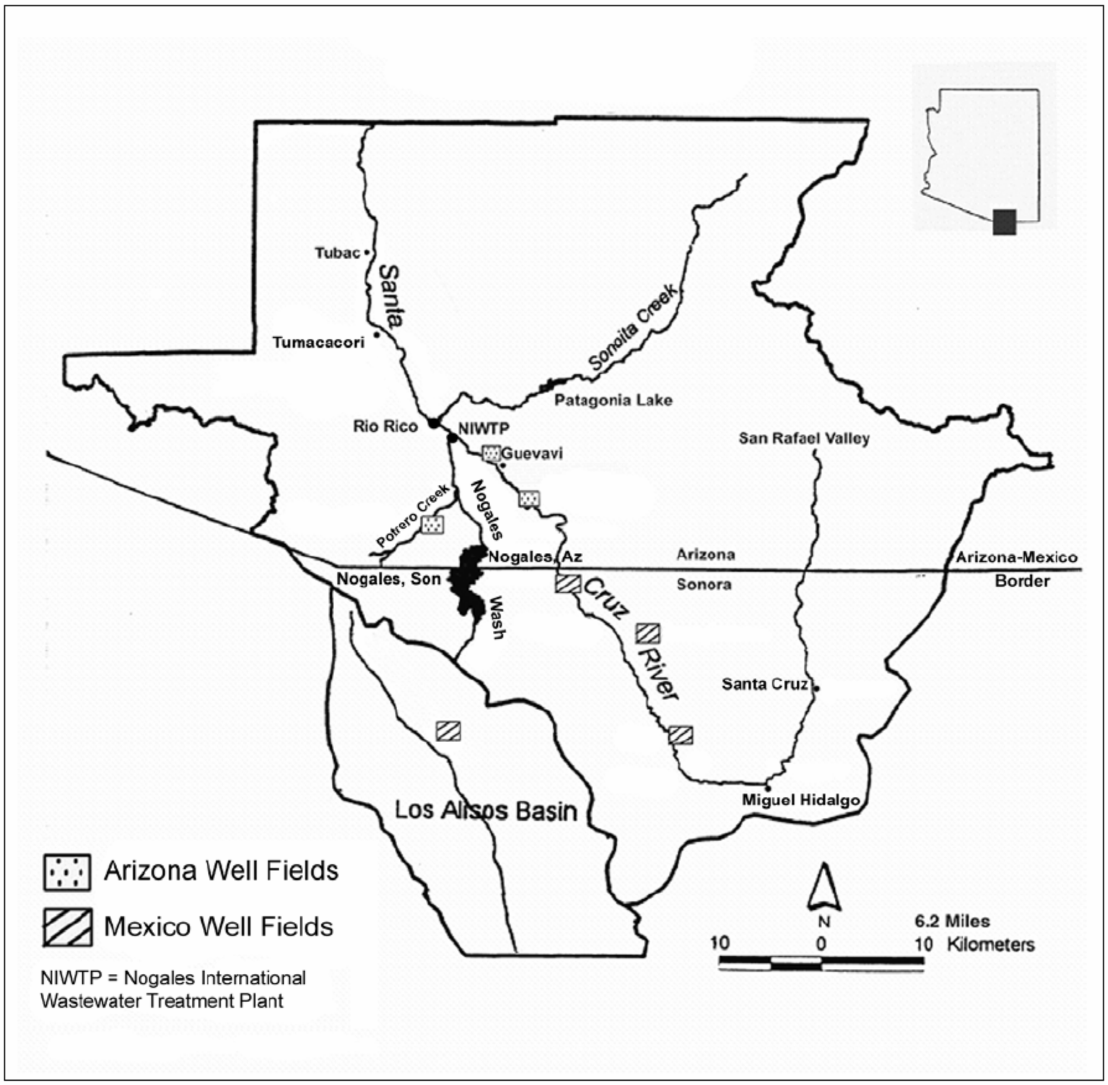
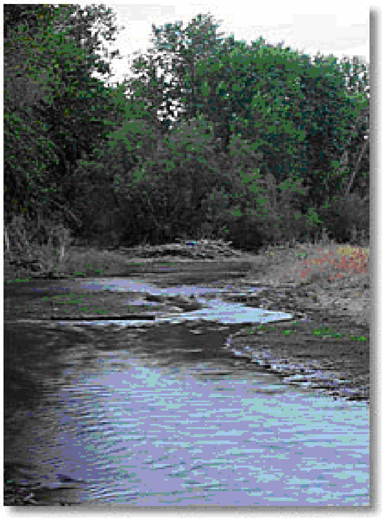
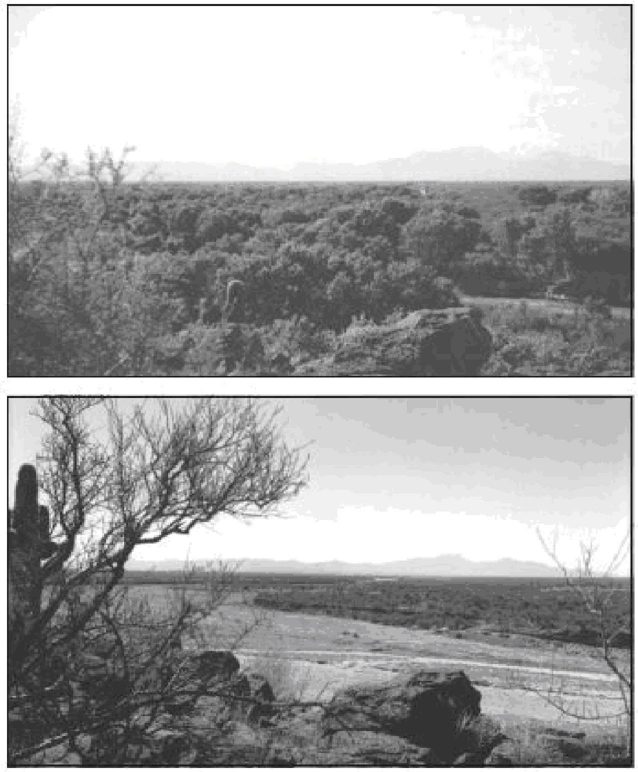


Figure 3.2: Santa Cruz River



Santa Cruz River at Tumacácori National Historical Park. © Brian Anderson



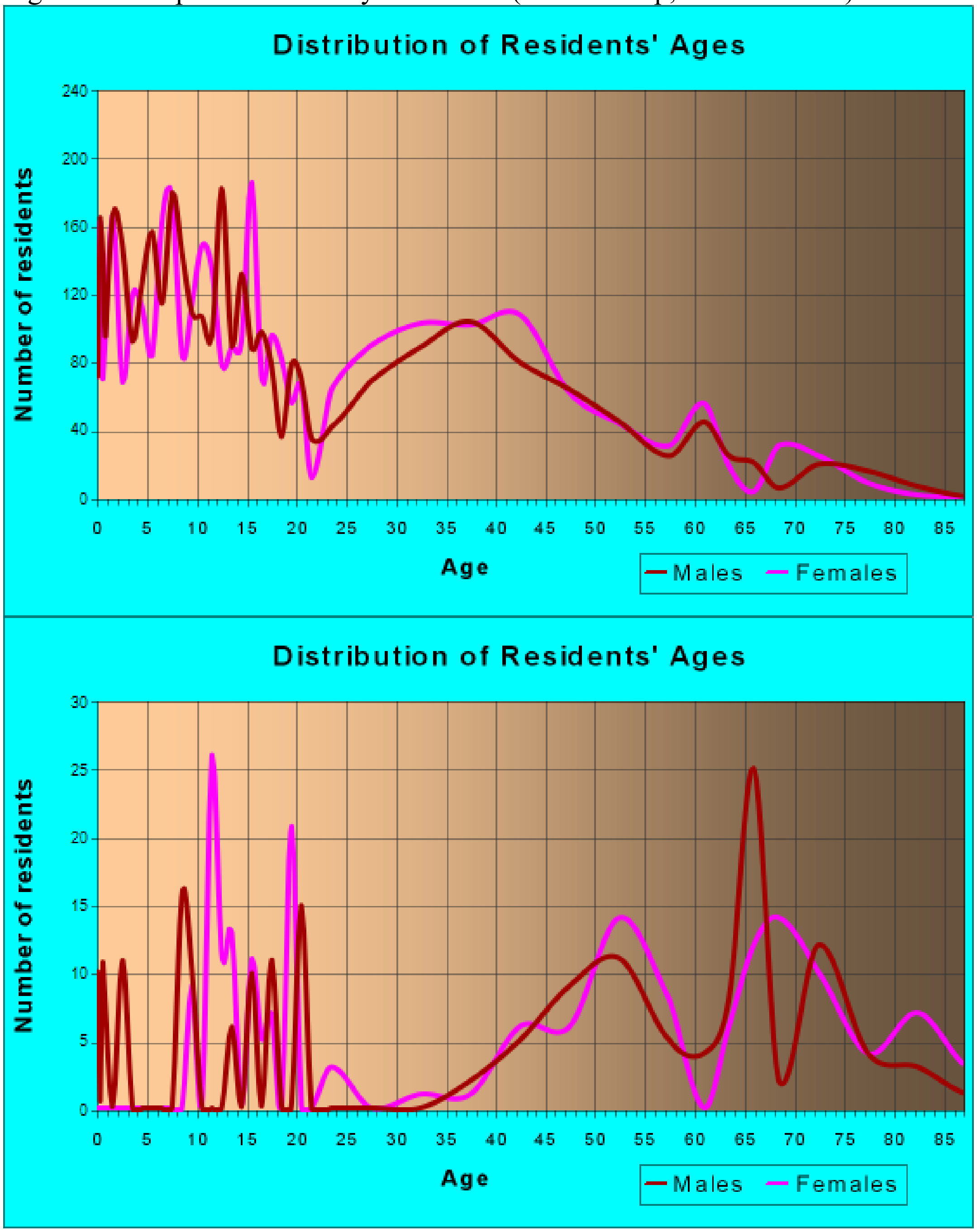
1942 (top), 1989 (bottom) S.C.R south of Tucson
Photo by Robert Webb, USGS

Figure 3.3: Santa Cruz River Trash Dam at Tumacacori (FOSCR website)

Heaps of trash pile up at a natural "dam" on the river at Tumacacori Mission National Historic Park, brought by flood waters from the Nogales Wash, which runs through both Nogales cities on the border.

The cities located within Santa Cruz County that this study will be examining are Rio Rico and Tubac, located north (downstream) of the NIWTP. Tubac is about 14 miles north of Rio Rico in the foothills of the Santa Rita Mountains. Tubac is well known for its art galleries and studios where Tumacacori is more commonly known for its National Historic Park and diverse culture. Rio Rico is a relatively newer community originating in 1969 with a population of 10,791 in 2000; Tubac's population is smaller with population of 1,074 in 2000. Tubac is a prestige location known for its arts and crafts and attracts retirees and people over the age of 55. The median age in 2000 for Rio Rico Northeast is 32.2 years, Rio Rico Northwest 24.1 years whereas Tubac's median age is 58.5 years in 2000 (Figure 3.4). Rio Rico has grown rapidly; appealing to young families possible because of affordable housing, recreational opportunities, and scenery (Carter and McCoy). Compared to Tubac residents, Rio Rico residents have lower income (Figure 3.5, 3.6) and educational attainment.

Figure 3.4: Population in Study Area 2000 (Rio Rico top, Tubac bottom)



Source: city data: http://www.city-data.com/zips/85646.html
http://www.city-data.com/zips/85648.html

Figure 3.5: Tubac Income Distribution 1999 (EPSC)

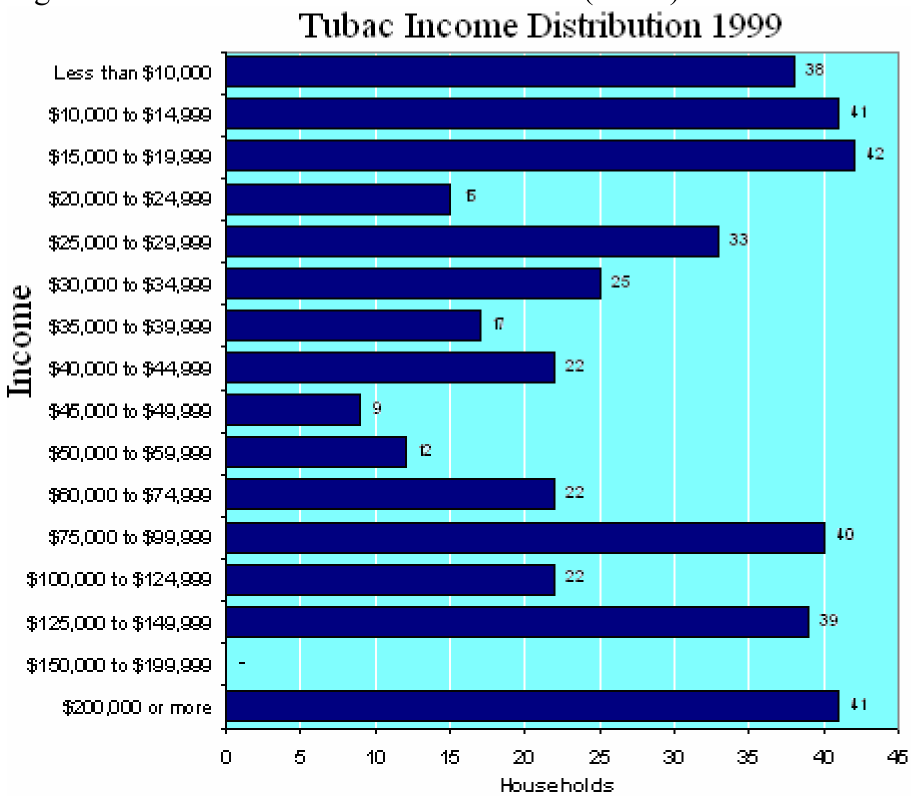
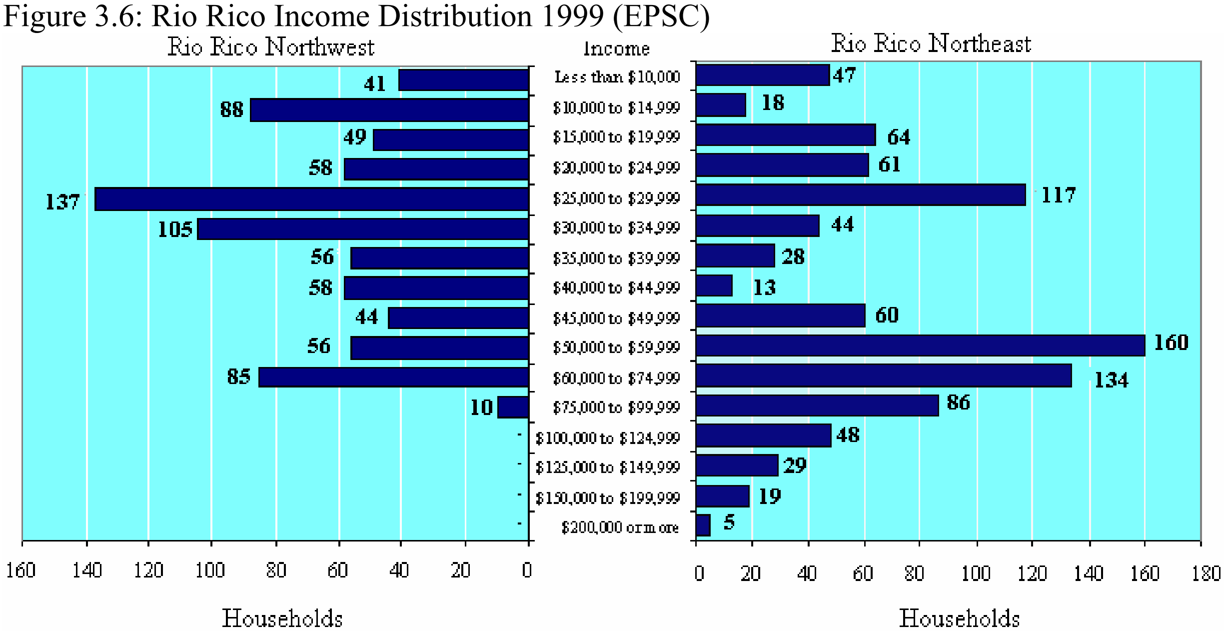


Figure 3.6: Rio Rico Income Distribution 1999 (EPSC)



Source: Economic Profile System Community (EPSC). Sonoran Institute and the Bureau of Land Management. www.sonoran.org (downloaded)

3.2 The Data

3.2.1 Home Sales and Structural Characteristics

The home sale data comes from the Arizona Department of Revenue for the following tax code areas in Santa Cruz County: 0101, 2830, 3500, 3501, and 3502. The original data set consisted of 2,289 parcels (2,518 sales) that sold between January 2001 and October 2005. After carefully going through the data, 772 parcels (831 sales) were excluded that were located outside the study area[3], had invalid identification codes or that were not single family residence. Only single family homes were included in this analysis. Literature suggests that separate markets exist for multiple family housing (duplex, apartments), townhouses/condominiums, vacant lots and other parcel uses. From this data set, 286 home sales were excluded for irregularities in structural characteristics or sale price: 29 no site address, 188 missing data, 19 room count = 0, 9 parcel size = 0, 1 bath = 0, 20 adjusted sale price < $30,000, 7 parcels with (13 sales) same sale date and different sale price, 5 with same date and price (assumed entered twice in data set), 1 irregular sale price (sale price in 2001 = $50,000, sale price in 2000 = $259,000), 1 quit claim deed.[4] The excluded observations were examined carefully to check for any bias; there were no obvious relationships between the deleted observations. The data set of housing characteristics and selling prices consisted of 1272 parcels (1401 sales) between January 2001 and October 2005.

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[3] Street addresses were provided, zip codes were determined by http://maps.google.com/ and/or http://maps.google.com/

[4] http://www.m-w.com/cgi-bin/dictionary?va=quitclaim%20deed "a legal instrument used to release one person's right, title, or interest to another without providing a guarantee or warranty of title"

3.2.2 Housing Price Index

Because the housing data was from multiple years, sale price was converted to 2001 Quarter 1 price by using the housing price index for Arizona. The housing price index (HPI) measures the movement of single-family home prices, indicating house price trends[5]. The Office of Federal Housing Enterprise Oversight (OFHEO) publishes quarterly, state-specific house price indexes for 1975 Quarter 1 to present (released about two months after the end of the quarter) on detached single-family residential properties. The index uses enterprise data on conforming mortgage transactions acquired from the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The HPI is calculated for geographical regions, states and the District of Columbia by using repeat observations of housing values on which at least two mortgages were originated and later purchased by either Freddie Mac or Fannie Mae (Calhoun 1996). The HPI is estimated using a modification of the Case and Shiller (1989) geometric weighted repeat sales methodology. The HPI is referred to as a "constant quality" house price index; estimates are generated using repeat sales on the same physical properties to control for dissimilarity in home quality within the sample. Using the OFHEO HPI deflator controls for home price appreciation generally affecting the Arizona housing market.

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[5] http://www.ofheo.gov/index.asp

3.2.3 Geocoding

House location was geo-coded by The Advanced Resource Technology (ART) Group of the School of Natural Resources at the University of Arizona. The ART group first used the ArcGIS address locator service to find the locations of the parcels which matched 687 parcels (765 sales) out of 1,272; the unmatched parcels were sent to a geocoding service at http://batchgeocode.com, matching 527 parcels (574 sales). This website is funded by donations which allow users to input addresses at no cost to be geocoded, latitude and longitude is outputted along with map locations. There were 58 parcels (62 sales) that were unable to be matched using either of the geocoding services. Once the homes were located (by either ArcGIS or batchgeocode) algorithms were used to calculate distance variables (Geographic Coordinate System: GCS_North_American_1983 _HARN, Datum: D_North_American_1983_ HARN, Prime Meridian: 0, Angular Unit: Degree, Appendix I). The data set in this analysis consisted of 1,339 home sales (1214 parcels) with 765 sales geocoded using ArcGIS and 574 sales using http://batchgeocode.com.

The distance of homes to different variables were calculated in meters by the ARTS Group; distance to nearest golf course, NWTP, nearest landfill, Santa Cruz River, riparian vegetation, and distance to the nearest wash were calculated.

3.2.4 Riparian Zone Variable

The riparian area was calculated by using a data set developed at Arizona Game and Fish Department in 1993-1994 under requirements from the Waters-Riparian Protection Program for riparian areas associated with perennial water flows (Appendix A). Areas were classified as having riparian vegetation associated with perennial flows in Arizona. Types of vegetation include cottonwood/willow stands, mesquite bosque, conifer oak, mixed broadleaf vegetation, Russian olive, wet meadow, and mountain shrub. If a home lay within this zone of riparian vegetation, the distance value was calculated as zero. For homes outside these areas, the linear distance to the edge of nearest area of riparian vegetation was calculated in miles.

3.2.5 Variables in Analysis and Expected Signs

The continuous structural variables in this analysis are: parcel size in thousand square feet (parsz), living area in square feet (living), living area squared (livsq), number of bathroom fixtures (bfix), and age of home (age). Indicator variables were included to represent homes with: a pool (pool), more than one story (mltstry), asbestos roofing (rfasb), tile roofing (rftile), and a slab concrete patio with covering (pscd). In the data set, homes were categorized with number of garage spaces, number of carport spaces and number of spaces for homes with both a garage and carport. Each of these categories is included in the model.

The location variables are distance to known riparian corridor in miles (ripmi), distance to nearest golf course in miles (golfmi), and a variable that indicates if a home is located within a 100-year flood zone (flood). If a home is located within the zone of riparian vegetation, the distance to riparian corridor equals zero (ripmi = 0). Several models are investigated in this thesis; when using the observations for Rio Rico and Tubac a dummy variable was included in the analysis for Tubac (Tubac) to represent neighborhood differences.

Table 3.7: Variables in Regression

Variable Name	Description
Dependent variable	
Price	Sale Price deflated to 2001 Q1 dollars using OFHEO HPI
Independent variables	
Parsz	Parcel square footage in thousands
MltStry	Dummy variable for two/three story homes (1 if two or three story, 0 otherwise)
Bfix	Number of bath fixtures
Living	Total living area in square feet
Livsq	(Total living area in square feet)^2
Age	Sale date minus construction date
Pool	Dummy variable for pool (1 if pool, 0 otherwise)
Garsz	Garage size in number of car spaces
Portsz	Carport size in number of car spaces
Gcarsz	Garage and Carport size in number of car spaces
Flood	Dummy variable for homes located within a known 100-year flood zone (1 if within zone, 0 otherwise)
Dummy for location	
Tubac	Dummy variable for Tubac City (1 if house located in Tubac, 0 otherwise)
Dummy for Roofing	
RfAsb	Asbestos roofing (1 if asbestos, 0 otherwise)
RfTile	Tile roofing (1 if tile, 0 otherwise)
Dummy for Patio	
Pscd	Concrete Slab and covered patio porch (1 if slab and covered, 0 otherwise)
Location *Variables*	
Golfmi	Distance to nearest golf course in miles
Ripmi	Distance to riparian corridor in miles
Golfp5	Min(Distance to nearest golf course, 0.5) in miles
Rip1p1	Min(Distance to nearest known riparian area, 1.1) in miles (0 if inside riparian corridor)

Given results from past studies, we expect parcel size, bath fixtures, garage size, and living area to have positive parameter estimates for all models. A home having a pool and/or a patio will have a positive effect on sale price. Garage and carport size will also have a positive effect on home sale price. The effect of homes with tile roofing has a positive expected value while homes with asbestos roofing will sell for less (Table 3.8, 3.9).

Table 3.8: Descriptive Statistics-Continuous Variables (n = 1,339)

Variable Name	Mean	Minimum	Maximum	Median	Standard Dev.	Expected Sign
RealPrice	112,859.54	30,643.41	899,156.43	93,165.78	67,087.22	
Parsz	38.0284389	3.0492	633.798	27.578	44.100931	+
Bfix	6.4294249	3	16	6	1.3185127	+
Living	1683.71	552	5208	1525	514.5932653	+
Age	7.1254668	0	66	3	9.1802626	-
Garsz	1.6191187	0	7	2	0.9802804	+
Portsz	0.2419716	0	4	0	0.6291387	+
Gcarsz	0.0492905	0	6	0	0.4465001	+
Golfmi	2.4803551	0.1135881	7.0731830	2.2608426	1.4119666	-
Ripmi	0.9325078	0	4.9074769	0.7521610	0.7619976	+

Table 3.9: Descriptive Statistics-Dummy Variables (n = 1,339)

Variable Name	Mean	Standard Deviation	Expected Sign
Tubac	0.0821509	0.2746970	+
Rfasb	0.0059746	0.0770931	-
RfTile	0.2576550	0.4375064	+
Pscd	0.4451083	0.4971634	+
Pool	0.0575056	0.2328931	+
MltStry	0.0702016	0.2555820	+/-
Flood	0.0560119	0.2300307	-

4. EMPIRICAL MODEL

4.1 Functional Form

Hedonic results depend on the type of functional form used in the analysis. For this analysis different functional forms will be used to determine the effects of the Santa Cruz River riparian corridor on single-family residences. Specification tests were conducted using Box-Cox transformations (Appendix B). A log-log specification was rejected in all cases. A semi-log specification including as quadratic term for living space could not be rejected when tested against a more general Box-Cox specification. We begin with this semi-log specification:

$$\text{(4.1)} \qquad \ln(y_i) = \beta_0 + s_i' \beta_1 + e_i' \beta_2 + u_i$$

where:

y_i = sale price in 2001 Quarter 1 dollars for home i

β_0 = intercept

β_1, β_2 = parameter vectors

s_i = house structural characteristics

e_i = environmental characteristics for ith sale (distance from amenity in miles)

u_i = error term for the ith home sale

Two amenities considered in this analysis are golf courses and the riparian corridor. Intuition tells us that, beyond a certain distance from an environmental amenity, there should be no effect of distance on sale price (Figure 4.1). It follows, then, that treating price as a strictly linear function of distance may be inappropriate. Yet under a semi-log specification, with reasonable elasticities of price with respect to distance, $\partial^2 y / \partial e^2$ will be very small, so that the relationship between price and distance is essentially linear. In applied hedonic price analyses, one approach to address this problem often employed is to use the log of distance as an explanatory variable. This presents problems, however, if the distance variable has observations with zero distance (as this study does). The premium for proximity to an amenity approaches infinity as distance approaches zero.

4.1.2 Von Liebig Distance Functions

As an alternative to either using linear distance or log of distance, we specify a von Liebig functional form. The von Liebig model has been used for crop production (Holloway and Paris 2002):

(4.2) $$y = \min\{f_N(N, u_N), f_p(P, u_P), f_K(K, u_K), ..., f_C(C, u_C)\}$$

where:

y = level of crop production

N, P, K, C = levels of fertilizer nutrients

u_N, u_P, u_K, u_C = random disturbances.

A von Liebig-type specification of the distance variable is considered:

(4.3) $$\ln(y_i) = \beta_0 + s_i^{'} \beta_1 + \beta_2 \min(ripmi_i, \delta) + \beta_3 \min(golfmi_i, \alpha) + u_i$$

where:

$\ln(y_i)$ = log of sale price in 2001 Quarter 1 dollars for sale i

β_0 = intercept

$\beta_{1,}\beta_{2,}\beta_3$ = parameters to be estimated

s_i = housing characteristics for ith sale

$ripmi_i$ = distance to the riparian corridor in miles for home i

$golfmi_i$ = distance to the nearest golf course in miles for home i

δ = parameter for maximum riparian distance effect

α = parameter for maximum golf course distance effect

u_i = error term for sale i

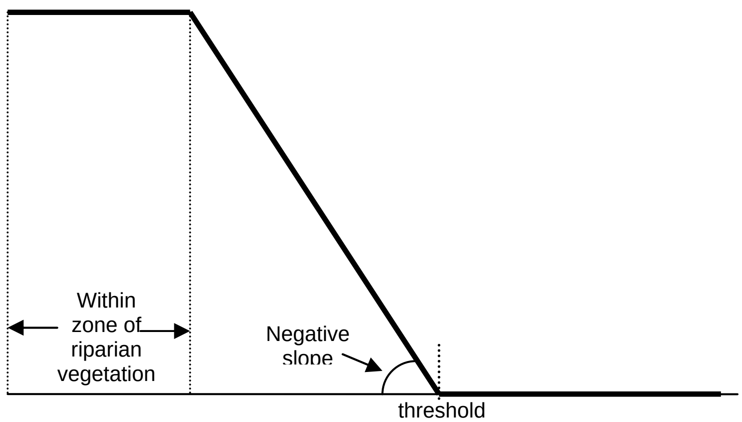
This specification implies that for $\beta_{2,} < 0$, sales price declines as distance from the riparian corridor increases up to distance δ. Beyond δ, greater distance has no further negative effect on price. The price premium relationship is shown as Case 1 in Figure 4.1. A similar interpretation follows for β_3 and α with respect to distance from the nearest golf course.

Values for δ and α were derived by estimating equation (4.3) using SAS 9.1 to run a linear regression that minimized the sum of squared errors (SSE) of the regression equation. Estimates that minimized the SSE also maximized the log of the likelihood function.

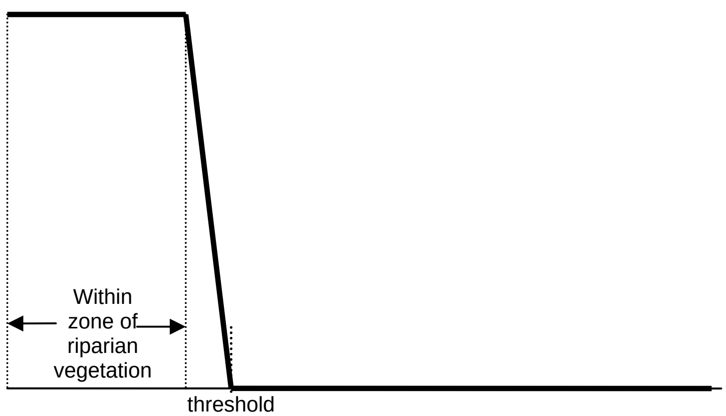
The semi-log function was treated as a special case where the values of δ and α were set equal to the maximum values of distance from the riparian corridor and distance from the nearest golf course observed in the data. This corresponds to Case 3 in Figure 4.1. The semi-log model with linear distance variables is nested within a more general specification where maximum likelihood estimates of the threshold values δ and α are estimated. The semi-log specification can then be tested against the more general distance specifications with a likelihood ratio test.

Figure 4.1. Price Premium for Location within and Proximity to Riparian Zone

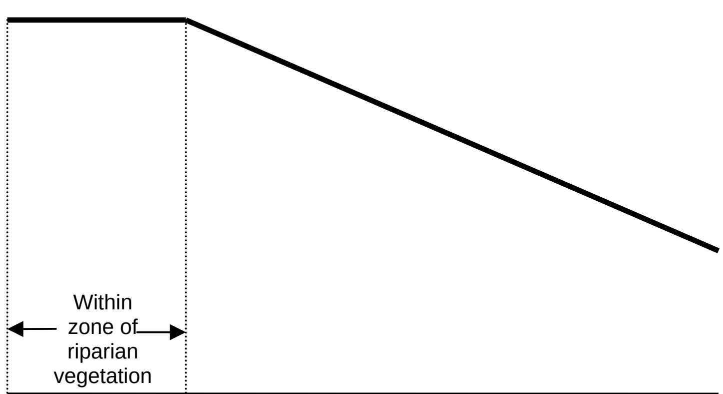
Case 1. "Negative slope with threshold



Case 2. Near-dummy variable specification



Case 3. Negative slope – no threshold



Case 2 in Figure 4.1 also approximates a dummy variable specification of distance effects common in the literature. With pure dummy variables, there is a single effect for all observations within some area or defined adjacency to an amenity. As the slope of the function gets steeper (Case 2) the von Liebig specification approaches the dummy variable case. A difference is that, with the von Liebig function, the distance that characterizes adjacency is estimated rather than being arbitrarily chosen.

Before discussing the comparison between the linear-distance versus the von Liebig distance variables, two specifications are addressed. First, it was noted that the populations and potentially the housing markets for Rio Rico and Tubac are quite different. The question arises about whether pooling data from these two towns is appropriate. Second, it was also noted earlier that two geo-coding methods were used to generate distance variables. One question to consider is, does the source and method of geo-coding matter? In particular, is it appropriate to pool data for the two geo-coding procedures?

4.2 Tubac vs. Rio Rico

Rio Rico and Tubac may represent two distinct housing markets (Table 4.4). To test this possibility, a Chow test was conducted to test whether there is a structural break in the data (Chow 1960). The data is separated and tested to see if the regression coefficients for Tubac equal those for Rio Rico. The Chow statistic is:

$$\frac{(SSE_{all} - (SSE_1 + SSE_2))/k}{(SSE_1 + SSE_2)/(N_1 + N_2 - 2k)}$$

where:

SSE_{all} = Sum of squared errors from combined data (Rio Rico and Tubac observations pooled together)

SSE_1 = Sum of squared errors from regression of Rio Rico sub-sample

SSE_2 = Sum of Squared errors from regression of Tubac sub-sample

K = number of parameters

N_1 = number of observations from Rio Rico

N_2 = number of observations from Tubac

Using SAS 9.1, the model pooling Tubac and Rio Rico observations was rejected at the 99% confidence level for the semi-log model (p-value = <.0001, F-statistic = 53.55) and the von Liebig model (p-value = <.0001, F-statistic = 56.73). This implies the data from the two towns cannot be pooled in a single model. Tubac has a sample size of 110 home sales, while Rio Rico has a sample of 1,229 home sales. To research the effect of the Santa Cruz River riparian corridor, we focus our attention on the Rio Rico observations. The Tubac sub-sample is much smaller than those commonly used in hedonic studies.

Table 4.2: Descriptive Statistics for Tubac and Rio Rico

	Tubac (n = 110)				Rio Rico (n = 1,229)			
Variable	Mean	Standard Dev.	Min	Max	Mean	Standard Dev.	Min	Max
Age	18.918	13.918	0	66	6.07	7.8141	0	35
RealPrc	248,160	0.12753×10^6	68,903	899,160	100,750	40911	30643	642,400
Parsz	56.634	70.268	3.0492	435.6	36.363	40.584	4.4670	633.8
Pscd	0.4727	0.5015	0	1	0.4426	0.4969	0	1
Bfix	6.7091	1.7988	3	16	6.4044	1.2647	3	15
Living	2,190.3	770.56	552	5,208	1638.4	459.10	984	5028
Garsz	1.6364	1.2615	0	7	1.6176	0.9517	0	6
Portsz	0.3455	0.7715	0	3	0.2327	0.6143	0	4
Gcarsz	0.0909	0.5510	0	4	0.0456	0.4360	0	6
Pool	0.2818	0.4519	0	1	0.0374	0.1899	0	1
Mltstry	0.0182	0.1342	0	1	0.0749	0.2633	0	1
Rftile	0.2273	0.4210	0	1	0.2603	0.4390	0	1
Rfasp	0.0182	0.1342	0	1	0.0049	0.0697	0	1
Flood	0.0455	0.2093	0	1	0.0570	0.2319	0	1
Golfmi	1.0609	0.8216	0.1136	4.2995	2.6074	1.3841	0.1455	7.0732
Golfp5	0.4762	0.0729	0.1136	0.5	0.4823	0.0739	0.1455	0.5
Ripmi	0.5647	0.5918	0.0014	4.2995	0.9654	0.7671	0	4.9075
Ripp9	0.4652	0.3549	0.0014	0.9	0.6447	0.2946	0	0.9

4.3 Geocoding Issue

Since the houses were located by two different methods, ArcGIS and batchgeocode.com, we tested to make sure the location variables were not affected by the locating method; for the semi-log model and the von Liebig model a joint test was conducted for the three variables determined by GIS.

Semi-log

$$\log(yi) = \alpha_0 + x_i'\alpha_1 + z_1\beta_1 + z_2\beta_2 + z_3\beta_3 + z_1D\gamma_1 + z_2D\gamma_2 + z_3D\gamma_3 + u_i$$

Von Liebig

$$\log(yi) = \delta_0 + x_i'\delta_1 + v_1\beta\varphi_1 + v_2\varphi_2 + v_3\varphi_3 + v_1D\xi_1 + v_2D\xi_2 + v_3D\xi_3 + \varepsilon_i$$

y_i = sale price in 2001 Quarter 1 dollars for sale i

x_i = Structural variables for sale i

z_1, z_2, z_3 = location variables (ripmi, golfmi, flood)

v_1, v_2, v_3 = location variables (ripp9, golfp5, flood)

D = 1 if home located using ArcGIS, 0 if located using batchgeocode.com

$\alpha_0, \alpha_1, \beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3, \delta_0, \delta_1, \varphi_1, \varphi_2, \varphi_3, \xi_1, \xi_2, \xi_3$ = parameter estimate

u_i, ε_i = error term for sale i

Using the joint test for the semi-log model (γ_1=0, γ_2=0, γ_3=0) the Wald Chi-Square Statistic = 4.23 with 3 degrees of freedom gives a p-value of 0.238; this implies we fail to reject the null at 5% significance level (SHAZAM); for the von Liebig model (ξ_1=0, ξ_2=0, ξ_3=0) the joint test gives us the same conclusion (Wald Stat = 2.048 with 3 degrees of freedom, p-value = 0.56262). When separating the data for town (Tubac and Rio Rico) the results also lead to failing to reject the null hypothesis.

Table 4.5 compares regression results from two competing models. In the first, semi-log model, the maximum distance parameters are restricted to equal the maximum values observed in the data, so that the riparian distance threshold parameter, δ, is restricted to equal 4.9, while the golf distance threshold parameter, α, is restricted to equal 7.1. The von Liebig specification minimizes the SSE and maximizes the log-likelihood function and has a slightly higher adjusted R-squared, compared to the restricted semi-log model. The values of δ and α that minimized the SSE in the regression were $\delta = 1.1$ and $\alpha = 0.5$ for the Rio Rico sub-sample. This implies that distance from the riparian corridor ceases to have a marginal negative effect beyond 1.1 miles and distance from the nearest golf course ceases to have an effect beyond one half mile.

The restricted, semi-log specification $\delta = 4.9$ and $\alpha = 7.1$ is a restricted case of the von Liebig model. The two models can be tested against each other using a likelihood ratio test based on the value of the likelihood functions from the two models (Appendix B). The value of the test statistic has a Chi-square distribution with two degrees of freedom. It equals 2[13854.6 – 13843.1] = 23. With two degrees of freedom, the critical value for the Chi-square statistic is 9.22 at the 0.01 level and 13.69 at the 0.001 level. So, the null hypothesis that there is no threshold effect is rejected.

The models were tested for heteroskedasticity using the Breusch-Pagan/Godfrey test (BP test). The Breusch-Pagan (1980) test assumes the errors are normally distributed and has four steps: estimate the model using OLS and obtain the squared OLS residuals, û, run a new regression where the squared OLS residuals are regressed on variables suspected of causing heteroskedasticity, then compute the F statistic and p-value, using this R^2 to determine if you reject homoskedasticity (H_o) (Wooldridge 2003). Using this approach, we reject homoskedasticity at 95% confidence level but fail to reject at 99% confidence (von Liebig p-value = 0.0136, semi-log p-value = 0.0168). To correct for heteroskedasticity, White's method is used. The standard errors reported in Table 4.6 and Table 5.1 are conditional on choice of δ and α, however.

The regression coefficients for the non-distance variables are quite similar for the two specifications. The slope coefficients for the distance variables are quite different, however (Table 4.5). The slope coefficients for the distance variables for golf distance and riparian corridor distance are more steeply negative. Under the restricted semi-log specification, the coefficient for riparian distance is not statistically significant.

Table 4.3: Estimates Semi-log vs. Von Liebig (Rio Rico)

	Semi-log (Adj.R^2 =0.6341, SSE = 49.514) Log-Likelihood = -13854.6			Von Liebig semi-log (Adj.R^2 = 0.6409, SSE = 48.605) Log-Likelihood = -13843.1		
Variable	Coefficient	Standard Error	P-value	Coefficient	Standard Error	P-value
Parsz	0.9802×10^{-3}	0.1490×10^{-3}	<0.001	0.10674×10^{-2}	$0.\ 1500 \times 10^{-3}$	<0.001
Bfix	0.018164	0.6301×10^{-2}	0.004	0.011786	$0.\ 6395 \times 10^{-2}$	0.066
Living	0.56877×10^{-3}	0.6014×10^{-4}	<0.001	0.55031×10^{-3}	$0.\ 5849 \times 10^{-4}$	<0.001
Livsq	-0.5097×10^{-7}	0.1355×10^{-7}	<0.001	-0.4639×10^{-7}	$0.\ 1302 \times 10^{-7}$	<0.001
Age	-0.7681×10^{-2}	0.1166×10^{-2}	<0.001	-0.7749×10^{-2}	$0.\ 1193 \times 10^{-2}$	<0.001
Pscd	0.028775	0.01271	0.024	0.026877	0.01262	0.033
Mltstry	-0.033806	0.02507	0.178	-0.030869	0.02498	0.217
Rftile	0.14879	0.01376	<0.001	0.13080	0.01424	<0.001
Rfasb	-0.13584	0.06943	0.051	-0. 14420	0.06978	0.038
Garsz	0.094259	0.01044	<0.001	0.092596	0.01039	<0.001
Portsz	0.049004	0.01454	0.001	0.047305	0.01447	0.001
Gcarsz	0.047950	0.01340	<0.001	0.044013	0.01369	0.001
Pool	0.11455	0.04273	0.007	0.12259	0.04325	0.005
Flood	-0.026768	0.02438	0.272	-0.028787	0.02468	0.224
Golfmi/ Golfp5	-0.9431×10^{-2}	0.4004×10^{-2}	0.019	-0.39165	0.05531	<0.001
Ripmi/ Rip1p1	-0.9964×10^{-2}	0.7863×10^{-2}	0.205	-0.054554	0.01600	0.001
Constant	10.387	0.06230	<0.001	10.645	0.07422	<0.001

In the von Liebig model, all the structural variables have the expected sign. Two variables are insignificant at the 5% level (bathroom fixtures and multiple stories). A home located within the 100-year flood plane does not have a significant effect on selling price, although the sign is negative (Table 5.1). When examining the von Liebig model, it was determined that homes located within one half mile of a golf course and homes located within 1.1 miles from the riparian corridor where affected by these amenities. The results indicate that home selling prices decrease as distance increases from golf courses and riparian corridors; both variables are statistically significant at the 1% level.

From Sirman's summary of hedonic studies (2005) we compare the coefficient results from studies using the semi-log functional form with our analysis, looking at the southwest region. In past studies, coefficients found for parcel size were 0.000007 and 0.00020; our estimate is 0.001067, but this is for thousand square feet adjusting the measurement makes the coefficient 0.000001067, which is reasonably close to previous studies. In this analysis we used number of bath fixtures, parameter estimate 0.011786, where previous studies used number of bathrooms, parameter estimates 0.161, 0.015, 0.044, and 0.18; the average bathroom consists of three bath fixtures giving us an estimate of 0.0354 (0.011786*3) for each bathroom. The addition of a pool causes home price to change by eight to thirteen percent in the Southwest (Sirmans, Macpherson and Zietz 2005). In our study the effect is a little more than twelve percent. Parameter estimates for age, living area (Graph 5.3) and garage spaces are also consistent with the literature (age -0.015 to -0.0002, living area 0.0004 to 0.0007, garage spaces 0.057 to 0.107). According to Sirmans (2005) covered porch, tile roofing, and homes in flood zone have been used once as independent variables with porch having a positive effect, tile insignificant effect, and flood zone having a negative effect on home sale price. Variables for asbestos roofing and multiple story homes have not been used in previous studies; two-story homes have resulted in four positive, one negative, and one insignificant effect on sale price with number of stories having four positive, seven negative and two insignificant results. Carport size and number of spaces for both garage and carport has not been used in hedonic studies. An indicator variable has been used to represent carport which resulted in one positive, one negative and two insignificant estimated.

5. MARGINAL IMPLICIT PRICES (von Liebig specification)

From Halvorsen and Palmquist (1980) and Kennedy (1981) the percent impact of dummy variables on the home sale price can be computed by:

$$g = 100*[\exp(b - v(b)/2) - 1].$$

Where:

g = estimate percentage impact of the dummy variable on price

b = estimated coefficient of dummy variable

$v(b)$ = estimated variance of dummy variable coefficient.

To estimate the percent change in sale price for a one unit change in a continuous variable Wooldridge (2003) states:

$$\%\Delta\hat{y} = 100*[\exp(\hat{\beta}_k) - 1].$$

Where

$\%\Delta\hat{y}$ = percent change in estimated sale price

$\hat{\beta}_k$ = parameter estimate for kth variable

For a quadratic term (in our case living area) the change in price is estimated by:

$$\Delta\hat{y} \approx (\hat{\beta}_1 + 2\hat{\beta}_2 x)\Delta x.$$

Where

$\Delta\hat{y}$ = the change in estimates sale price

$\hat{\beta}_1$ = the parameter estimate for the variable (on linear term)

$\hat{\beta}_2$ = the parameter estimate for the variable (on quadratic term)

x = the average value of x in the sample or median or mode

Δx = the change in x value

Table 5.1 presents the regression coefficients, coefficient standard errors, percent change in home price responses to changes in binary, categorical and continuous variables and marginal implicit prices for home structural and distance attributes. Marginal implicit prices are calculated for an "average" home. Home attributes are calculated at sample means for continuous variables and at the sample modes for binary and count variables. This "average" home is a: one story house, that is 6 years old, on a 36,363 square foot parcel, with 6 bathroom fixtures, 1638 square feet of living area, a 2 car garage, a distance to the nearest golf course greater than 0.5 miles (0.5 used in calculation), and a distance to nearest riparian corridor of 0.9654 miles. Using the estimated parameter coefficients and adjusting for the log-transformation of the regression, the predicted price of this average home is:

Estimated price = $\exp(\ln\hat{y})*\exp(\sigma^2/2) = \exp[0.10674\text{x}10^{-2}*(36.363) + 0.011786*(6) + 0.55031\text{x}10^{-3}*(1638) - 0.46394\text{x}10^{-7}*(1638^2) - 0.77490\text{x}10^{-2}*(6) + 0.092596*(2) - 0.39165*(.5) - 0.054554*(0.9654) + 10.657]*\exp(0.040099/2)$ = \$93,127 in 2001 dollars deflated by the Office of Federal Housing Enterprise Oversight (OFHEO) Housing Price Index for Arizona.

Table 5.1: Regression Results for Rio Rico von Liebig (n = 1,229) corrected for heteroskedasticity, adjusted R^2 = 0. 6409

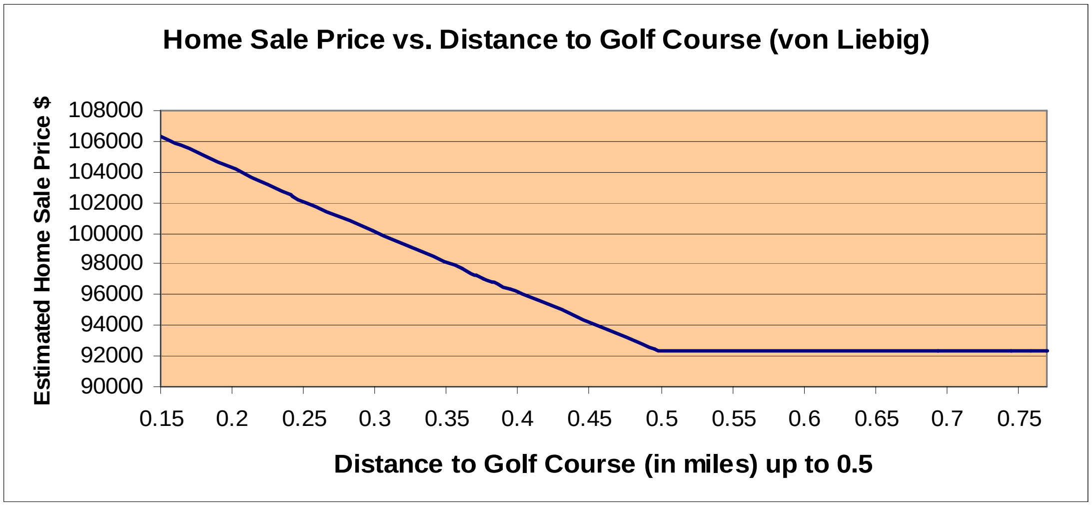
Name	Parameter Estimate	Standard Error	P-value	Percent Impact on Price	Marginal Implicit Value (at mean sale price)**
Parsz	$0.10674x10^{-2}$	$0. 1500x10^{-3}$	<0.001	0.106797	99.45655
Bfix	0.011786	$0. 6395x10^{-2}$	0.066	1.185573	1,104.085
Living	$0.55031x10^{-3}$	$0. 5849x10^{-4}$	<0.001	0.055046	37.09109*
Livsq	$-0.46394x10^{-7}$	$0. 1302x10^{-7}$	<0.001	$-4.6x10^{-6}$	
Age	$-0.77490x10^{-2}$	$0. 1193\ x10^{-2}$	<0.001	-0.77191	-718.85
Pscd	0.026877	0.01262	0.033	2.724144	2,536.907
Mltstry	-0.030869	0.02498	0.217	-3.03974	-2,830.81
Rftile	0.13080	0.01424	<0.001	13.97398	13,013.51
Rfasb	-0. 14420	0.06978	0.038	-13.4285	-12,505.6
Garsz	0.092596	0.01039	<0.001	9.701845	9,035.011
Portsz	0.047305	0.01447	0.001	4.844174	4,511.221
Gcarsz	0.044013	0.01369	0.001	4.499594	4,190.325
Pool	0.12259	0.04325	0.005	13.04209	12,145.67
Flood	-0.028787	0.02468	0.224	-2.83766	-2,642.62
Golfp5	-0.39165	0.05531	<0.001	-32.4059	-3719.67***
Rip1p1	-0.054554	0.01600	0.001	-5.30926	-509.43***
Constant	10.645	0.07422	<0.001		

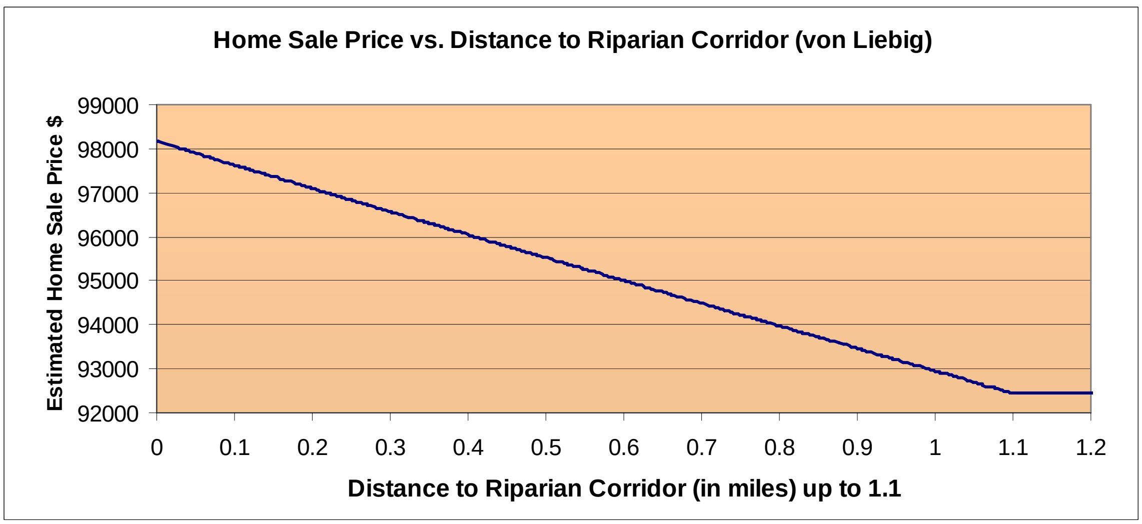
*effect of living area using mean living area = 1638.4, Δ = 1unit,
Impact = $0.55031x10^{-3}+ 2(-0.46394x10^{-7}*1638.4)$
** Estimated mean sale price in Rio Rico is $93,126.73
***Golfp5 MIP change from 0.4 to 0.5 miles, Rip1p1 change from 0.8654 to 0.9654 (one tenth of a mile out)
Variance= 0.040099

From 0.9654 miles from the zone of riparian vegetation, moving the average home 0.1 miles closer to riparian vegetation increases the home value by $509. If this same home were moved from 1.1 miles away from the zone of riparian vegetation to inside this zone, the sales price would increase by $5,718, from $92,445 to $98,163 (Figure 5.4). This represents an increase in home sales price of 5.8%. There were 786 homes within 1.1 miles of the riparian corridor. Premiums varied with distance from the zone of riparian vegetation. In this sample of homes, the average premium was $3,814, adding on average of 3.1% to the sales price of these homes.

From 0.5 miles from the nearest golf course, moving the average home 0.1 miles closer to the nearest golf course increased price by $3,720. There were 72 homes in the sample within 0.5 miles of a golf course. The average premium for the sample of homes was $16,565, adding an average of 11.4% to the sales price of these homes.

Graph 5.2: Home Sale Price vs. Distance Variables (von Liebig, Rio Rico)





Graph 5.3: Home Sale Price vs. Living Area (von Liebig, Rio Rico)

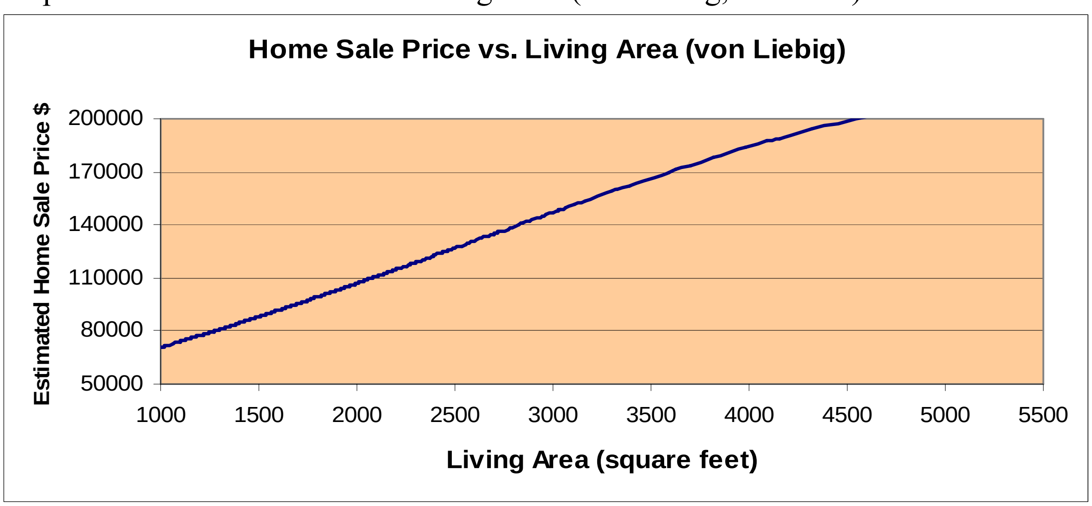
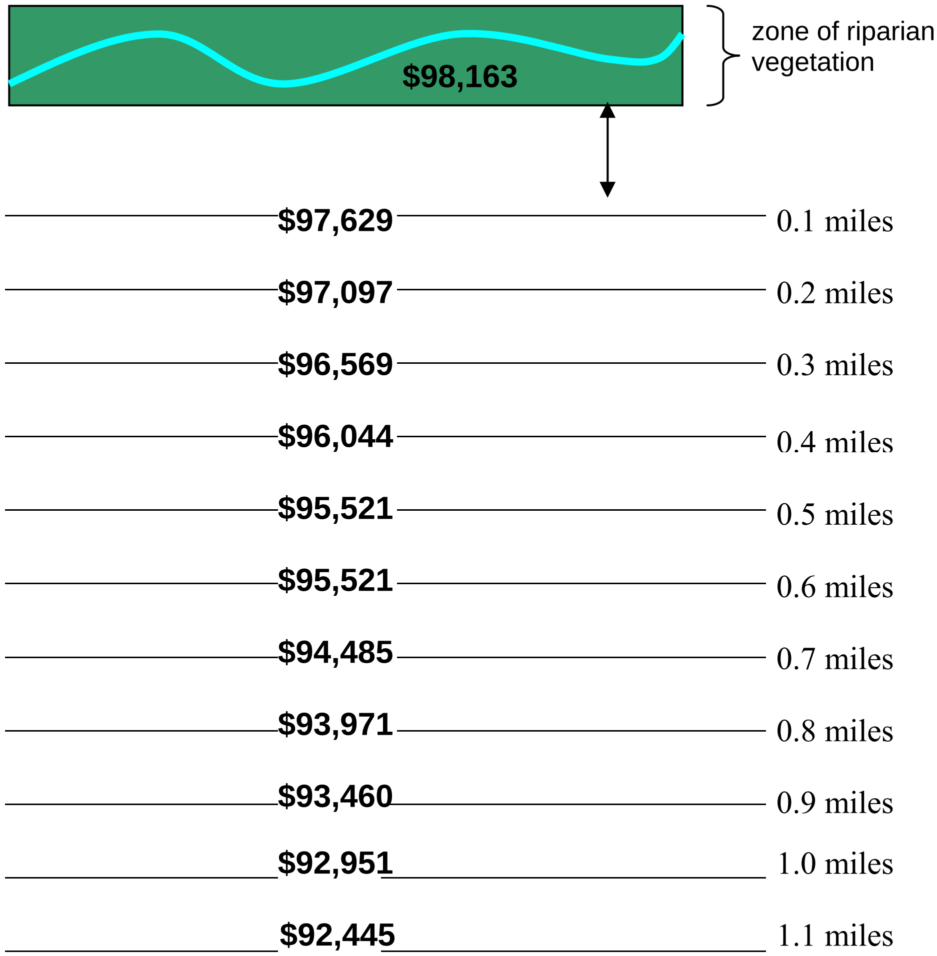


Figure 5.4: Distance to Santa Cruz River Riparian Corridor, Rio Rico (von Liebig)*



*One story house, 6 years old, parcel size 36,363 square feet, 6 bathroom fixtures, 1638 square feet of living area, 2 car garage, distance to nearest golf course is greater than 0.5 miles (0.5 used in calculation),

6. CONCLUSION

Two hedonic models were examined to estimate the effect of the Santa Cruz River riparian corridor on single-family residences in Rio Rico. The semi-log model resulted in an insignificant effect. Based on a likelihood ratio test, however, the standard semi-log functional form was rejected (at the 0.1% level) in favor of a specification using a von Liebig-type distance equation. Under the von Liebig distance specification, model indicated that distance to the riparian corridor did have an effect on home selling price. It was estimated that home price premiums increased with proximity to a zone of riparian vegetation and declined with distance. Regression results suggest that home price premiums became zero beyond 1.1 mile of the zone of riparian vegetation. The data set included 786 homes within 1.1 miles of the riparian corridor. It was estimated that proximity to the riparian corridor increased sales prices of these 786 homes by $2,529,959 (in 2001 dollars deflated by the Office of Federal Housing Enterprise Oversight Housing Price Index for Arizona). In home price-inflation-adjusted 2001 dollars, this amounts to an average premium of $3,219 per home. The average home price premium was 3.1%, but premiums ranged as high as 5.8%. These estimates are just a small part of the overall value of the Santa Cruz River riparian corridor.

6.1 Future Research on Santa Cruz River

This thesis looks at the value that homeowners have for living near the Santa Cruz River riparian corridor but other values need to be assessed. Other methods for valuing non-market goods involve the contingent valuation and travel cost method. The hedonic pricing method does not account for values people place on recreational activities (hiking, bird watching) or the worth of future generation use. In order to determine the overall effect of the Santa Cruz River riparian area other evaluations must be conducted along with an Environmental Impact Statement. Treated wastewater from Nogales International Wastewater Treatment Plant is supporting the riparian area and has recently been allocated $60 million to upgrade the facility. Valuing the use of the treated wastewater is a way of determine the value of the facility. For now, the water is solely used for instream flows in the Santa Cruz River bed because the majority of the treated water belongs to Mexico. If the United States became the sole owner of the water, the water could be diverted for other uses; the value of the effluent would have to be measured for all possible uses which include the instream flow.

6.2 Future Hedonic Studies

Throughout the literature many functional forms have been considered when using the hedonic pricing method. However there has been no published work using the von Liebig model. Intuition suggests that at some point the distance to an amenity will have no effect on a home’s value, any model that does not account for this would be inappropriate. The von Liebig function controls for this effect. Future hedonic studies should consider using the von Liebig function and look into other types of functional forms. The literature provides no definitive guidance about choice of the best functional forms, so researchers should consider multiple specifications and report their findings.

Appendix A Data Description

A.1 Geocoding Description (Department of RNR at University of Arizona)

Amanda Jackson
May 2006
Rio Rico Project for George Frisvold
===
File Name File Type Description
===
DERIVED DATA

File Name	File Type	Description
readme.txt	TXT file	List of products and their descriptions
riorico_calculations_notes.txt	TXT file	Notes about calculations, methods, and scripts used
Addresses.xls	Excel Spreadsheet	Data exported from ArcMap after calculations were completed. SEE MORE BELOW.
address_webcoded_project.dbf	GDB Table	Data exported from ArcMap in dbf format. Corresponds to a worksheet in "addresses.xls".
address_webcoded_project.dbf.xml		File supporting "address_webcoded_project.dbf" file
addresses.dbf	GDB Table	Data exported from ArcMap in dbf format. Corresponds to a worksheet in "addresses.xls".
addresses.dbf.xml		File supporting "addresses.dbf" file
parcel_elev	XLS file	Spreadsheet containing elevation (in meters) for each parcel ID, when able to derive
tables	folder	Tables exported from ArcMap as evidence of calculations results

NOTES:
All given measurements are in meters.
Nulls in the E/W fields indicate that some addresses had no assigned X,Y pair and could therefore not be calculated.
Digitized lines of railroads are disjointed in some areas, so distances and E/W values should be evaluated for acceptability.
===********
"Addresses" worksheet in "addresses" XLS file -
This represents all addresses and attributes that were matched using an ArcGIS address locator service with specified parameters and matching against a known collection of roads reference data.
****
Projected Coordinate System: NAD_1983_HARN_UTM_Zone_12N
Projection: Transverse_Mercator
False_Easting: 500000.00000000
False_Northing: 0.00000000
Central_Meridian: -111.00000000
Scale_Factor: 0.99960000
Latitude_Of_Origin: 0.00000000
Linear Unit: Meter

Geographic Coordinate System: GCS_North_American_1983_HARN

Datum: D_North_American_1983_HARN
Prime Meridian: 0
Angular Unit: Degree
=======================
column list:
OBJECTID - unique identifier for each address in ArcMap
Status - M for 'matched' by ArcGIS address locator, "h" for hand-digitized based on visual location of the address on a web mapping service.
Score - percentage score for address match to known street arc
Side - side of road address was located to
X - X coordinate assigned to address based on its location along the road
Y - y coordinate assigned to address based on its location along the road
ARC_Street - the unique identifier of the arc in the roads table that this address was matched to
ID - the ID of the address given to ART in spreadsheet form (to serve as unique identifier before DB assigned one)
PARCEL_ID - (not generated by ART)
ADDRESS - (not generated by ART)
ZIP - (not generated by ART)
YR - (not generated by ART)
EW_SCR - E or W indicates address is east or west of the Santa Cruz River
DIST_SCR - Distance from address to its closest point along the Santa Cruz River
EW_RR - E or W indicates address is east or west of the railroads tracks
DIST_RR - Distance from address to its closest point along railroad tracks
EW_I19 - E or W indicates address is east or west of Interstate 19
DIST_I19 - Distance from address to its closest point along Interstate 19
Dist_NIWF - Distance from address to the point of the wastewater treatment facility
Dist_LF - Distance from address to the point of the landfill
Dist_Golf - Distance from address to the closest known golf course
Addr_Ripa - Boolean value indicates 1 if address is within a known riparian area
Flood - Boolean value indicates 1 if address is within a known 100-year flood zone
Dist_Tum - Distance from address to the point of Tumacacori visitor center (this point was verified by DOQQ aerial images)
Dist_Wash - Distance from address to the closest point along the nearest known wash
Dist_Bridg - Distance from address to the closest bridge (bridge points were interpolated by intersecting the roads with the Santa Cruz River)
Dist_Ripa - Distance from address to the edge of the closest known riparian area
=======================
****
"Address_webcoded_project" worksheet in "addresses" XLS file -
This represents all addresses and attributes that were matched using the web geocoding service at "http://www.batchgeocode.com/". Please notice that there are several addresses that were matched at exactly the same point on the map. This could be due to precision of coordinates, or another cause such as acceptance by the web service of matches with lower percentage score. Calculations values should be evaluated with this in mind. While all the same calculations were done using the same algorithms, these addresses were kept separate in ArcMap and in this spreadsheet so that the different geocoding method (outside our precise control) could be factored into future analyses.
****
=======================
column list:
OBJECTID - unique identifier for each address in ArcMap
ID - the ID of the address given to ART in spreadsheet form (to serve as unique identifier before DB assigned one)
PARCEL_ID - (not generated by ART)

ADDRESS - (not generated by ART)
ZIP - (not generated by ART)
BG_LAT - latitude in WGS84, the decimal degrees version of the coordinate system commonly used in GPS devices, generated by "batchgeocode.com" web tool (NOT used for distance calculations)
BG_LONG - longitude in WGS84, the decimal degrees version of the coordinate system commonly used in GPS devices, generated by "batchgeocode.com" web tool (NOT used for distance calculations)
EW_SCR - E or W indicates address is east or west of the Santa Cruz River
Dist_SCR - Distance from address to its closest point along the Santa Cruz River
POINT_X - X coordinate assigned to address after projecting it to the same coordinate system used for the "addresses" worksheet
POINT_Y - y coordinate assigned to address after projecting it to the same coordinate system used for the "addresses" worksheet
EW_RR - E or W indicates address is east or west of the railroads tracks
DIST_RR - Distance from address to its closest point along railroad tracks
EW_I19 - E or W indicates address is east or west of Interstate 19
DIST_I19 - Distance from address to its closest point along Interstate 19
Dist_Tum - Distance from address to the point of Tumacacori visitor center (this point was verified by DOQQ aerial images)
Dist_NIWF - Distance from address to the point of the wastewater treatment facility
Dist_LF - Distance from address to the point of the landfill
Dist_Golf - Distance from address to the closest known golf course
Dist_Bridg - Distance from address to the closest bridge (bridge points were interpolated by intersecting the roads with the Santa Cruz River)
Dist_Wash - Distance from address to the closest point along the nearest known wash
Dist_Ripa - Distance from address to the edge of the closest known riparian area
Addr_Ripa - Boolean value indicates 1 if address is within a known riparian area
Flood - Boolean value indicates 1 if address is within a known 100-year flood zone

Amanda Jackson
May 2006
Rio Rico Project for George Frisvold

EAST/WEST CALCULATIONS:

```
/*
==============
Using Near(analysis) tool with the "Location" option checked, the X,Y pair and Euclidean distance are calculated for the address in relation to the nearest point on one target line feature.

The following new fields were added to the Addresses table to store east/west attributes:
EW_SCR = whether address is east or west of Santa Cruz River
EW_RR = whether address is east or west of SP Railroad Tracks
EW_I19 = whether address is east or west of Interstate 19

East/West attribute was added to the new field using the following SQL scripts. NOTE: "NEWFIELD" is variable depending on the calculation, and was replaced with the respective field name listed above each time the update was run.
===============
ADDRESS IS WEST OF THE TARGET POINT IF NEAR_X is greater
===============
*/
UPDATE Addresses
SET addresses.NEWFIELD='W'
WHERE Addresses.NEAR_X>Addresses.X And Addresses.status='M';
```

```
/*
==============
ADDRESS IS EAST OF THE TARGET POINT IF NEAR_X is smaller
===============
*/

UPDATE Addresses
SET addresses.NEWFIELD='E'
WHERE Addresses.NEAR_X<Addresses.X And Addresses.status='M';
/*
==============
The new fields in the address table calculated by the Near tool were then exported to a dbf file for
archiving:
Near_SCR
Near_RR
Near_I19
and all new columns were then deleted from addresses except for the near_dist field and the new manually-
created EW_ field. The near_dist field in addresses was renamed (see below) to make it more specific to
the target line feature, and to prevent overwrites with the next Near tool usage. New names of the near_dist
for each calculation:
Dist_SCR
Dist_RR
Dist_I19
The entire calculation process was repeated 2 more times (one each for Santa Cruz River, Railroad, and I-
19).
===============
*/
RIPARIAN CALCULATIONS:
/*
Used Intersect tool with Addresses and SC_Riparian as inputs to find the 14 addresses that fall within a
specified riparian area, with "Addresses_Riparian" as output FC. Created new field "Addr_Ripa" to hold
Boolean value specifying whether each address falls within a riparian area. Used SQL scripts below to
automatically populate the values in the new field. Opened FAT for Addresses_Riparian and Compared to
FAT for Addresses.Addr_Ripa to verify the Updates ran properly, as a quality control measure.
*/
UPDATE  Addresses
SET Addresses.Addr_Ripa=1
WHERE Addresses.OBJECTID IN
(SELECT  Addresses.OBJECTID
FROM Addresses INNER JOIN Addresses_Riparian ON Addresses.OBJECTID =
Addresses_Riparian.FID_Addresses);

UPDATE  Addresses
SET Addresses.Addr_Ripa=0
WHERE Addresses.OBJECTID NOT IN
(SELECT  Addresses.OBJECTID
FROM Addresses INNER JOIN Addresses_Riparian ON Addresses.OBJECTID =
Addresses_Riparian.FID_Addresses);

FLOODPLAIN CALCULATIONS:
/*
```

First selected only rows from FEMA shapefile that had a value of "IN" in the SFHA attribute (those rows also had a value of "A" in the Zone attribute) into a new feature class called "flood_area" that contains only polygons of 100-year floodplains.
Used Intersect tool with Addresses and flood_area as inputs to find the addresses that fall within a specified flood area, with "Addresses_flood" as output FC.
Created new field "flood" in Addresses to hold Boolean value specifying whether each address falls within a flood area. Used SQL scripts below to automatically populate the values in the new field.
*/

```
UPDATE  Addresses
SET Addresses.flood=1
WHERE Addresses.OBJECTID IN
(SELECT  Addresses.OBJECTID
FROM Addresses INNER JOIN Addresses_flood ON Addresses.OBJECTID =
Addresses_flood.FID_Addresses);

UPDATE  Addresses
SET Addresses.flood=0
WHERE Addresses.OBJECTID NOT IN
(SELECT  Addresses.OBJECTID
FROM Addresses INNER JOIN Addresses_flood ON Addresses.OBJECTID =
Addresses_flood.FID_Addresses);
```

BRIDGES:
/*
Used Intersect tool with output type set as Point to create a new feature class (Interp_Bridges) of points where Santa Cruz River is crossed by roads.
Used Near Tool to calculate distance from each address to each interpolated bridge on the Santa Cruz.
*/
RIVERDISTANCE TO NIWF==> Instead using DISTANCE TO RIPARIAN VEG
/*
George wanted to interpolate nearness to greater vegetation by getting distance along river to the wastewater facility. He approved using distance to riparian vegetation instead. I converted the polygons of riparian vegetation into lines to get the vegetation boundaries, then used the near tool to calculate distance to the closest riparian area boundary. Note: George specified that he would like to know distances to any designated riparian area, and not only the riparian areas along the Sanat Cruz River.
*/
========================
GEOCODING UNMATCHED ADDRESSES:
Web site http://www.batchgeocode.com/ allows geocoding against yahoo maps reference data set. Requires tab-delimited file with a header row, and cannot geocode in batches over 500 rows at a time. I exported the unmatched addresses and broke them into 2 text files for use. I was able to match all but 47 of the remaining 590 unmatched addresses. It produced lat/long coordinates: "The name of the coordinate system used is WGS84, this is the decimal degrees version of the coordinate system commonly used in GPS devices."

Add X,Y data to map
create shapefile from X,Y data
Project the shapefile so that address coordinate systems match
Make new FC in ArcCatalog and import new projected shapefile
Add X,Y to new FC to get new projected coordinates (cannot do E/W calcs without adjusted X coordinate)

NAME OF DATA SET: RIPARIAN

DATA TYPE: Vector; polygon

DESCRIPTION OF CONTENT:
This data set consists of riparian vegetation associated with perennial waters of Arizona.

FORMAT: Arc/Info

DATA SIZE:	Data Set	7.5" quad
Approximate Megabytes:	3.2	N.A.

HISTORY:
This data set was developed at Arizona Game & Fish Department in 1993 - 1994. It identifies riparian vegetation associated with perennial waters mapped in response to the requirements of the Waters - Riparian Protection Program (Laws 1992, Ch. 298). Maps were created using two major sources of imagery - Landsat Thematic Mapper digital satellite data and Multiple Resolution Aerial Videography. The data set was distributed in June 1994.

MAINTENANCE:
Arizona Game & Fish Department will continue to update the information in this database. Contact AGFD for update status.

PROJECTION: NAD 27, UTM Zone 12, meters

RESOLUTION: 60 meters

ITEMS:
Item name: RIPARIAN#
Description: This is a unique internally assigned identification number for each polygon
Format: 4,5,B

Item name: RIPARIAN-ID
Description: User assigned identification number for each polygon
Format: 4,5,B

Item name: ACRES
Description: Acres calculated as acres = area / 4047.
Format: 8,8,N,2

Item name: GFVEG
Description: Vegetation community classes.
Format: 4,5,C
Code Table:
a - Cottonwood Willow
b - Mesquite

c - Tamarisk
d - Strand
u - Marsh
o - Conifer Oak
x - Mixed Broadleaf
m - Wet Meadow
n - Russian Olive
y - Agriculture
f - Flood Scoured
z - Areas not ground verified
w - Mountain Shrub

Appendix B Box-Cox Transformation

The Box-Cox transformation (Box and Cox 1964) is a general functional form which allows positive non-zero variables to be transformed. Estimation of the transformation is done by maximum likelihood assuming normally distributed errors.

Box-Cox transformation: $$Y^{(\lambda)} = \frac{Y^{\lambda} - 1}{\lambda} \quad \lambda \neq 0$$

$$= \ln Y \qquad \lambda = 0$$

Since the limit as λ approached zero is lny, the transformation is lny when λ = 0 (Kennedy 2003).

We investigate several models; the first two models considered are the semi-log function and the von Liebig specification. The estimated equations were compared using the Likelihood Ratio Test, goodness-of-fit test between two models with chi-square distribution (Table B.1). The test is used to see if one functional form is statistically better than the other.

$$LRT = -2\log(\frac{L_R}{L_{UR}}) = -2(Log(L_R) - Log(L_{UR}))$$

Where L_R = Likelihood function restricted model
L_{UR} = Likelihood function unrestricted model

Table B.1 Log-Likelihood Ratio Test for Semi-Log vs. Von Liebig for Rio Rico

Models Compared	Log-likelihood Ratio Test Statistic	Critical Value	Conclusion
Semi-log vs. von Liebig	2(13854.6– 13843.1) = 23	$\chi^2_{1,.05} = 3.84$	Reject Semi-log, in favor of von Liebig

From Table B.1 we conclude that the von Liebig functional form is a better fit for the data than the semi-log specification

Using the Box-Cox transformation for the von Liebig specification, five functional forms are investigated (Table B.2) when not including the variable livsq (living area squared), and three functional forms are considered when including livsq (Table B.3). In models I, II, III the dependent variable is transformed by $\lambda = 0$ (natural log) with positive non-zero independent variables transformed by λ, $\lambda = 0$, and $\lambda = 1$. In models IV and V the dependent variables are transformed by λ with positive non-zero independent variables transformed by λ and $\lambda = 1$. The λ was calculated using SHAZAM for Windows – Standard Edition 2001.

Table B.2: Box-Cox Transformations Von Liebig(n = 1,339) excluding variable livsq

Model	Dependent Variable	Independent Continuous Variables	Adjusted R^2	Log-Likelihood	λ
I	$Y^{(0)}$	$X_1^{(\lambda)}$, $X_2^{(\lambda)}$, $X_3^{(\lambda)}$, $X_4^{(\lambda)}$	0.7635	-15195.6	0.66
II	$Y^{(0)}$	$X_1^{(0)}$, $X_2^{(0)}$, $X_3^{(0)}$, $X_4^{(0)}$	0.7564	-15215.5	N/A
III	$Y^{(0)}$	$X_1^{(1)}$, $X_2^{(1)}$, $X_3^{(1)}$, $X_4^{(1)}$	0.7613	-15201.8	N/A
IV	$Y^{(\lambda)}$	$X_1^{(\lambda)}$, $X_2^{(\lambda)}$, $X_3^{(\lambda)}$, $X_4^{(\lambda)}$	0.7517	-15214.1	-0.05
V	$Y^{(\lambda)}$	$X_1^{(1)}$, $X_2^{(1)}$, $X_3^{(1)}$, $X_4^{(1)}$	0.7593	-15201.6	-0.02

* X_1=bfix, X_2=living, X_3=parsz, X_4=min(golf,0.5)

Table B.3: Box-Cox Transformations Von Liebig (n = 1,339) including variable livsq

Model	Dependent Variable	Independent Continuous Variables	Adjusted R^2	Log-Likelihood	λ
I	$Y^{(0)}$	$X_1^{(\lambda)}$,$X_2^{(\lambda)}$,$X_3^{(\lambda)}$,$X_4^{(\lambda)}$,$X_5^{(\lambda)}$	0.7642	-15193.1	0.964
III	$Y^{(0)}$	$X_1^{(1)}$,$X_2^{(1)}$,$X_3^{(1)}$,$X_4^{(1)}$,$X_5^{(1)}$	0.7642	-15193.1	N/A
V	$Y^{(\lambda)}$	$X_1^{(1)}$,$X_2^{(1)}$,$X_3^{(1)}$,$X_4^{(1)}$ $X_5^{(1)}$	0.7588	-15191.5	-0.06

* X_1=bfix, X_2=living, X_3=parsz, X_4=min(golf,0.5), X_5=livsq

In Model I the dependent variable is logged with continuous non-zero variables transformed with λ = 0.66; when considering livsq as an independent variable the independent variables are transformed with λ = 0.964. The estimate of λ was computed by iterated maximum log-likelihood estimation. Model II illustrates the double-log form where the dependent variable and continuous non-zero independent variables are transformed, λ = 0 (this cannot occur when livsq is included). Model III is the semi-log function, the dependent variable is the only variable transformed, λ = 0. Model IV allows all continuous non-zero variables, independent and dependent, to be transformed by the same transformation; λ = -0.05 was calculated with the maximum log-likelihood function (this can only be calculated for model excluding livsq). The final model considered in this analysis allows the dependent variable to be transformed (λ = -0.02 and lambda = -0.06), with all independent variables linear (λ= 1). The estimated equations were compared using the Likelihood Ratio Test, goodness-of-fit test between two models with chi-square distribution (Table B.4, B.5).

Table B.4: Log-Likelihood Ratio Test (n = 1,339) excluding variable livsq

Models Compared	Log-likelihood Ratio Test Statistic	Critical Value	Conclusion
I & II	2(15215.5 – 15195.6) = 39.8	$\chi^2_{1,.05} = 3.84$	Reject II, in favor of I
I & III	2(15201.8 – 15195.6) = 12.4	$\chi^2_{1,.05} = 3.84$	Reject III, in favor of I
V & III	2(15201.8 – 15201.6) = 0.4	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, III ~ V

Table B.5: Log-Likelihood Ratio Test (n = 1,339) including variable livsq

Models Compared	Log-likelihood Ratio Test Statistic	Critical Value	Conclusion
I & III	2(15193.1– 15193.1) = 0.0	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, I ~ III
V & III	2(15193.1– 15191.5) = 3.2	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, III ~ IV

The Likelihood Ratio Test indicates that model I is a better fit than model II and III when not including livsq as an independent variable. Looking at equation including livsq we fail to reject that III is equally preferred to model I. When comparing model V and III for both regressions, we fail to reject the null that model III is acceptable. From these results model I is the better fit for the data when excluding livsq but model III cannot be rejected when including variable livsq; therefore for this analysis the semi-log functional form is used with livsq included. Looking at the data for Tubac and Rio Rico separately leads to similar results (Tables B.6 – B.9).

Table B.6 Box-Cox Transformations for Rio Rico (n = 1,229) excluding variable livsq

Model	Dependent Variable	Independent Continuous Variables	Adjusted R^2	Log-Likelihood	λ
I	$Y^{(0)}$	$X_1^{(\lambda)}, X_2^{(\lambda)}, X_3^{(\lambda)}, X_4^{(\lambda)}$	0.6402	-13844.9	0.657
II	$Y^{(0)}$	$X_1^{(0)}, X_2^{(0)}, X_3^{(0)}, X_4^{(0)}$	0.6323	-13858.1	N/A
III	$Y^{(0)}$	$X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, X_4^{(1)}$	0.6375	-13849.4	N/A
IV	$Y^{(\lambda)}$	$X_1^{(\lambda)}, X_2^{(\lambda)}, X_3^{(\lambda)}, X_4^{(\lambda)}$	0.6296	-13857.3	-0.05
V	$Y^{(\lambda)}$	$X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, X_4^{(1)}$	0.6347	-13848.7	-0.05

* X_1=bfix, X_2=living, X_3=parsz, X_4=min(golfmi,0.5)
* livsq is not included in this analysis

Table B.7 Box Cox Transformation for Rio Rico Von Liebig (n = 1,229) including livsq

Model	Dependent Variable	Independent Continuous Variables	Adjusted R^2	Log-Likelihood	λ
I	$Y^{(0)}$	$X_1^{(\lambda)}, X_2^{(\lambda)}, X_3^{(\lambda)}, X_4^{(\lambda)}, X_5^{(\lambda)}$	0.6410	-13843.0	0.906
III	$Y^{(0)}$	$X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, X_4^{(1)}, X_5^{(1)}$	0.6410	-13842.9	N/A
V	$Y^{(\lambda)}$	$X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, X_4^{(1)}, X_5^{(1)}$	0.6364	-13843.6	-0.07

* X_1=bfix, X_2=living, X_3=parsz, X_4=min(golfmi,0.5), X_5=livsq

Table B.8 a Log-likelihood Ratio Test for Rio Rico (n = 1,229) excluding livsq

Models Compared	Log-likelihood Ratio Test Statistic	Critical Value	Conclusion
I & II	2(13858.1– 13844.9) = 26.4	$\chi^2_{1,.05} = 3.84$	Reject II, in favor of I
I & III	2(13849.4– 13844.9) = 9	$\chi^2_{1,.05} = 3.84$	Reject III, in favor of I
V & III	2(13849.4– 13848.7) = 1.4	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, III ~ V

Table B.9 Log-likelihood Ratio Test for Rio Rico (n = 1229) including livsq

Models Compared	Log-likelihood Ratio Test Statistic	Critical Value	Conclusion
I & III	2(13843.0– 13842.9) = 0.2	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, I ~ III
V & III	2(13843.6– 13842.9) = 1.4	$\chi^2_{1,.05} = 3.84$	Fail to Reject III, III ~ IV

Appendix C Regression Results

Table C.1 Regression Results for All Data Semi-log (n = 1,339), corrected for heteroskedasticity Adjusted $R^2 = 0.6095$

Name	Parameter Estimate	T-statistics	P-value	Percent Impact on Price	Marginal Implicit Value (at mean sale price)**
Tubac	0.69502	0.05586	<0.001	100.2968	113195
Parsz	0.8449×10^{-3}	0.1385×10^{-3}	<0.001	0.08453006	95.40063
Bfix	0.01635	0.5847×10^{-2}	0.005	1.648124	1860.073
Living	0.5506×10^{-3}	0.5118×10^{-4}	<0.001	0.000403**	45.49095
Livsq	-0.4381×10^{-7}	0.1083×10^{-7}	<0.001		
Age	-0.7818×10^{-3}	0.9441×10^{-3}	<0.001	-0.7787801	-878.931
Pscd	0.03002	0.01230	0.015	3.039279	3430.13
Mltstry	-0.04033	0.02614	0.123	-3.985442	-4497.97
Rftile	0.13502	0.01323	<0.001	14.44615	16303.92
Rfasb	-0.1270	0.05581	0.023	-12.06399	-13615.4
Garsz	0.09382	0.969×10^{-2}	<0.001	9.847380	11113.75
Portsz	0.04594	0.01347	0.001	4.701216	5305.792
Gcarsz	0.04410	0.01217	<0.001	4.509044	5088.907
Pool	0.1024	0.03383	0.003	10.71749	12095.76
Flood	-0.02886	0.02295	0.209	-2.870073	-3239.16
Golfmi	-0.7934×10^{-2}	0.3988×10^{-2}	0.047	-0.7902712	-891.9
ripmi	0.01869	0.7755×10^{-2}	0.161	-1.081056	113195
Constant	10.416	0.05586	<0.001		

*effect of living area using mean living area = 1683.7, Δ = 1unit,
Impact = $0.5506 \times 10^{-3} + 2(-0.4381 \times 10^{-7} * 1683.7)$
**112,860

Table C.2 Regression Results for All Data von Liebig (n = 1,339), corrected for heteroskedasticity Adjusted $R^2 = 0.7642$

Name	Parameter Estimate	T-statistics	P-value	Percent Impact on Price	Marginal Implicit Value (at mean sale price)**
Tubac	0.6961	0.07165	<0.001	100.5105	113436.2
Parsz	0.9321×10^{-3}	0.1421×10^{-3}	<0.001	0.0932572	105.2501
Bfix	0.011328	0.5968×10^{-2}	0.058	1.139288	1285.8
Living	0.5370×10^{-3}	0.5154×10^{-4}	<0.001	0.000399*	45.06959
Livsq	-0.4088×10^{-7}	0.1094×10^{-7}	<0.001		
Age	-0.7796×10^{-2}	0.9569×10^{-3}	<0.001	-0.7766083	-876.48
Pscd	0.027969	0.01227	0.023	2.828630	3192.392
Mltstry	-0.03796	0.02609	0.146	-3.758048	-4241.33
Rftile	0.1205	0.01348	<0.001	12.79666	14442.31
Rfasb	-0.1425	0.05922	0.016	-13.43640	-15164.3
Garsz	0.09240	0.9790×10^{-2}	<0.001	9.679966	10924.81
Portsz	0.04471	0.01354	0.001	4.571910	5159.858
Gcarsz	0.04087	0.01247	0.001	4.171436	4707.883
Pool	0.1056	0.03398	0.002	11.07021	12493.84
Flood	-0.02888	0.02315	0.212	-2.872512	-3241.92
Golfp5	-0.3610	0.05984	<0.001	-30.29862	-34195
Ripp9	-0.06960	0.01896	<0.001	-6.723628	113436.2
Constant	10.654	0.07165	<0.001		

*effect of living area using mean living area = 1683.7 , Δ = 1unit,
Impact = $0.5370 \times 10^{-3} + 2(-0.4088 \times 10^{-7} * 1683.7)$
**112,860

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