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Land Transformations in the Bastrop County Colorado River Valley

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Land Transformations in the Bastrop County Colorado River Valley

by

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Report

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Abstract

Land Transformations in the Bastrop County Colorado River Valley

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The University of Texas at Austin, 2011

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This study is an investigation of land transformations along the Colorado River in Bastrop County, Texas, and a presentation of planning suggestions to protect and improve the ecology of the river corridor. The rapid population growth experienced in central Texas over the last few decades has manifested itself in extensive land use changes. The Colorado River Valley in Bastrop County has experienced this development in some areas, although, as a whole, it has remained largely agricultural in nature, with more extensive changes occurring in adjacent Travis, Hays, and Williamson Counties to the west. As land values increase and the stock of undeveloped land dwindles, developers are turning their attention east to Bastrop County.

This study primarily utilizes historic aerial maps to identify changes along the Colorado River corridor in Bastrop County. The choice of the river corridor as the extent of the study area was made because of the disproportionate importance of this land area

for environmental systems services, the myriad contributions that the ecological community provides to humanity and agriculture.

This study's primary purpose is to create a baseline documentation of the corridor's existing condition and a menu of recommendations to promote intelligent growth. The study pays special attention to the present and historic extent of the riparian forest (the forest that brackets the river), as this is the "natural" land use that existed prior to Anglo settlement. The study identifies specific instances and trends in land use, which, due to their degree and extent, are having adverse ecological and hydrological impacts. These include industrial, commercial, and residential development, as well as gravel mining and large infrastructure projects.

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Chapter 1: Introduction

OVERVIEW OF THE RIPARIAN CORRIDOR

This study focuses on the riparian corridor of the Colorado River as it winds its way through central Bastrop County. (See Figure 1 for the extent of the study area.) Riparian corridors are common to nearly all rivers and are particularly pronounced in arid areas where their rich vegetation stands in stark contrast to the meager surrounding vegetation. The riparian corridor is an ecological transition zone, or buffer, between terrestrial and aquatic habitats, which brackets a river. A rich density of life forms can be found in the corridor, owing to its abundant water, fertile alluvial soils, and protected moderate climate. When undisturbed, the area is generally characterized by luxuriant vegetation and towering old-growth trees. In turn, this vegetation provides habitat and food for terrestrial and aquatic animals as well as those found exclusively in the riparian zone. (See Figure 2 for images of general riparian characteristics.)

The riparian zone responds to the river much like a sandy beach responds to the ocean; change is always occurring. Floods may alter the riverbed, wash away banks, or build islands. On a day-to-day basis, fluctuating water levels, now controlled by dam releases on the Colorado River, create hydrologic changes in the groundwater as well as the visible level of the river's flow.

The Colorado's riparian corridor extends the length of the river, from its headwaters in West Texas all the way to its mouth at Matagorda Bay. What is less

evident is its width at any given point in the river. The zone's breadth may be best defined by physiographic features, such as the subterranean hydrology — the pattern of the water's movement through the alluvial floodplain. In areas where humans have not significantly altered the riparian corridor, this hydrology is evidenced by characteristic vegetation. Because the riparian corridor along the Colorado has been substantially altered by human activity in the form of concentrated settlements, such as cities, and by agricultural activities, such as farming and ranching, the true extent of the natural riparian corridor is difficult to establish and requires some detective work.

In relation to its area of coverage, the riparian corridor has tremendous value to the larger ecological and hydrological systems. It provides many environmental systems services, the value of which are becoming increasingly apparent. They include filtering pollution, providing food and habitat, moderating terrestrial and aquatic temperature, stabilizing the stream bank, dissipating flood energy, trapping and utilizing nutrients, improving water quality, recharging groundwater, and enhancing recreation. Literature concerning the riparian zone is summarized in a table that is Appendix C to this document.

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

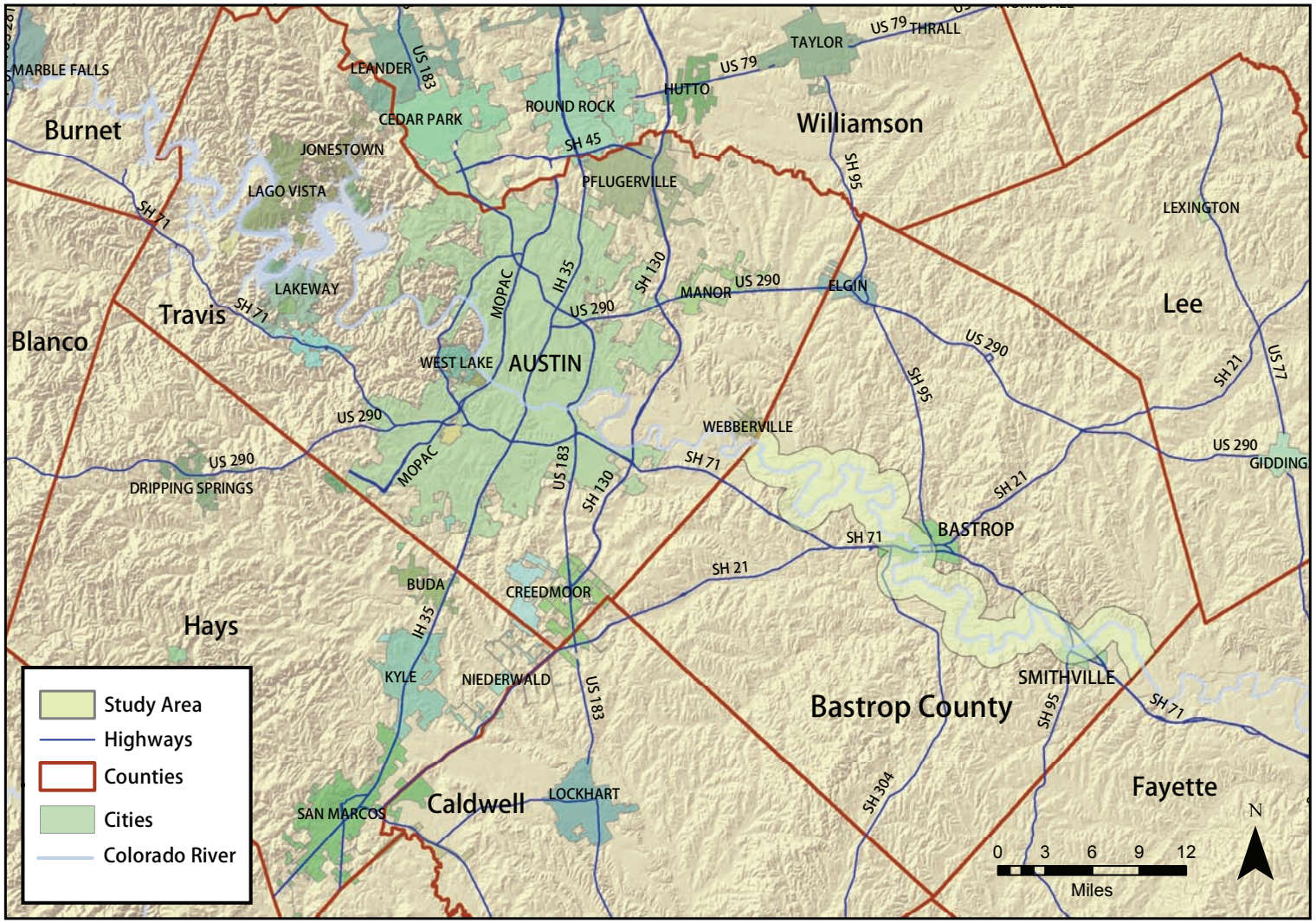

Figure 1: Regional Context Map

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

Figure 2: Riparian Characteristics

THREATS TO THE BASTROP COUNTY RIPARIAN CORRIDOR

The riparian corridor along the Colorado River has been affected by the presence and activities of humans for thousands of years. Today agriculture, gravel mining, industrial discharges, and residential development threaten to disrupt the continuity of the river and its riparian zone on an unprecedented scale. The physical, chemical, and hydrologic changes that are occurring affect ecological communities well beyond the river's reach.

Two factors form the primary threats to the Colorado's riparian area in Bastrop County. The first is population growth in Central Texas. The second is technological development that allows increasingly ready access to power and resources, which in turn accelerate physical and chemical alteration of the landscape. (Alterations, once limited to those doable by human and animal physical power, accelerated once a single person with a front-end loader could substantially alter the face of a piece of land in an afternoon.) Combined, population and technological advances have resulted in tremendous change over a short period.

Native Americans arrived in this area thousands of years ago, and had substantial impacts on the ecology, most notably by hunting to extinction a number of the macro fauna. Subsequently, human presence integrated itself into the regional ecology, continuing to affect it and be affected by it. Technological advances and population growth surely played a role in this interaction. Around 1700 A.D. Europeans, initially

Spanish explorers and eventually Spanish colonization, began to impact the area. During this period, population levels of native populations remained relatively stable, if not reduced, because of disease and conflicts. (Baumgartner et al. 1997) Technological advances, however, rapidly transformed the human engagement with the landscape: disease (human, animal, and plant); power and transportation (horse/donkey, sailing ships, wheeled carts); and, weaponry (guns, armor, tactics, cavalry). Accordingly, the landscape was substantially changed, primarily by introduction of large-crop agricultural practices and grazing impacts of introduced species (hogs, sheep, goats, and cattle). Change continued, as the population increased with Anglo settlement. This in-migrating population also brought rapidly changing technology and cultural practices associated with the wetter forested temperate climate of the Eastern United States and Northern Europe. This change continues today — at an increasingly rapid rate. While humans have inhabited the riparian corridor in the Bastrop area for thousands of years, the combination of increasing population, increased technological power, and lack of internal and external restraints create a situation ripe for eventual environmental catastrophe. Without self-imposed or government-imposed restraints, nothing is safe from the bulldozer. Environmental threats along the river can be grouped into four categories, each presenting a common pattern of disturbance: residential development; agriculture; sand and gravel mining; commercial and industrial development; and polluted effluent.

Residential Development

The impacts from suburban residential development represent a distinct threat to

the riparian corridor ecology — one that is likely to grow as the area's population increases. Clearing of riparian vegetation and construction of homes and docks are ubiquitous in residential areas on the Colorado River. In some instances, only a thin strip from five to 20 feet of riparian vegetation is left untouched. It is common for lots to be mowed to the waterline. Increased runoff, habitat destruction, chemical pollution, sewage, and solid waste are among the looming threats from this sort of development.

Impacts stemming from population centers, such as Bastrop and Smithville, are no less concerning. Petroleum from leaking underground tanks, hydrocarbon-laden street runoff, chemicals from assorted businesses, and even discharge from municipal water systems all flow into the river and affect water quality. It can be expected that Bastrop and Smithville will be the epicenters from which further growth and development radiate, as people move out from the Austin metropolitan area. (See Figure 3 for illustrations.)

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

Figure 3: Residential Development

Agriculture

Agriculture, in its modern industrialized form, is a relatively recent land use in the river corridor. The fertile, level, and well-watered alluvial soils of the river terraces drew farmers and ranchers to the region and served as the economic base into the 20th Century. This use was far from benign. In an effort to increase crop area, the great riparian forest or "Monte Grande," as the early Spanish dubbed it, fell to the ax for timber and fuel. (Baumgartner et al. 1997) Eventually, unsustainable farming practices destroyed the soils' fertility, forcing a large-scale switch to ranching. Today, both farming and ranching are common along rural stretches of the river, but they are giving way to the temptations of land developers.

Large-scale mono-crop industrial agriculture along the river is replete with all the problems commonly ascribed to it. Of this, chemical pollution from fertilizer and pesticides, habitat destruction, and sedimentation of the river due to erosion are top concerns for the Colorado River's health.

Grazing of cattle is a common practice along the river. It is not unusual to see cattle wading into and defecating in the river. Cattle can have serious water quality impacts stemming from erosion of the riverbanks and wholesale destruction of the riparian vegetation. The ubiquity of this practice should raise public drinking water concerns. While this is a worrying issue, it is one that has been addressed in other places. Simply fencing off the riparian zone to livestock and practicing rotational grazing can allow the resilient riparian vegetation to regenerate. (See Figure 4 for illustrations.)

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

Figure 4: Agriculture

Sand and Gravel Mining

Sand and gravel mining has occurred along the river since early Anglo settlement. Used for construction of buildings and roads, the population growth and development of the Austin metropolitan area has greatly increased mining. In eastern Travis County, the mining industry owns vast acreages along the river, where gravel is found under the alluvial topsoil. As old areas are mined out, pits are left in a barren landscape or filled with construction rubble. There is a clear movement eastward toward the Bastrop County line, with some mining already occurring in the county.

Mining immediately adjacent to the river is of special concern; it has resulted in breaches of the river wall and subsequent sediment pollution of the river. No other activity produces the wholesale destruction that aggregate mining has, and mining along the Colorado River is the most acute and pressing threat to the riparian zone ecology. (See Figure 5 for illustrations.)

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

Figure 5: Sand and Gravel Mining

Commercial and Industrial Development

Today, commercial and industrial land uses immediately adjacent to the river are minimal. However such uses are common just upstream, on the east side of Austin. Bastrop, in recent years, has seen rapid commercial growth along Highway 71, and it is likely to continue. The construction of the Hyatt Lost Pines Resort, west of Bastrop, and a planned regional private airport are precursors of the type of development likely to be seen in the near future. (See Figure 6 for illustrations.)

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

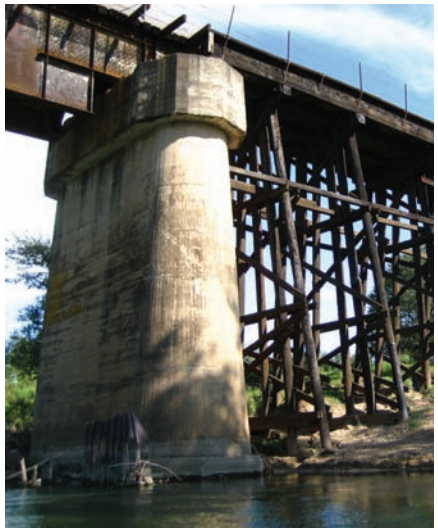

Figure 6: Commercial and Industrial Development

Polluted Effluent

Polluted effluent entering the river as point source pollution constitutes a major concern for water quality below the Austin urban area. (The type of runoff pollution discussed above in the Residential Development section is typically considered non-point source pollution.)

Discharges from both the City of Austin and the City of Bastrop water treatment facilities were observed in summer 2010 and again in spring 2011. They exhibited chemical odors and foamy plumes. Figure 6 presents photographs, taken in the summer of 2010. They show effluent being discharged from a City of Austin structure, just upstream of the Bastrop County line. While these discharges are believed to be in compliance with regulation, they raise the question of weather regulations reflect scientific standards or political compromises.

In areas where heavy industry is present, industrial discharges are a major concern. While the river basin has not yet seen the level of impacts experienced in northeastern areas of the United States, there is reason for concern. Rachel Carson's ground breaking book, *Silent Spring*[1] (Carson 1962), describes a 1961 incident in Austin where significant discharges of insecticides from a chemical plant caused a wave of aquatic extermination through the river corridor in Bastrop County down to the Gulf of Mexico. As Austin pushes eastward, vigilance will be needed to limit such discharges from industry. (See Figure 7 for illustrations.)

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[1] Carson, Rachel. 1962. Silent Spring. Boston: Houghton Mifflin

Created by Ben Prince 4.20.11

Source: Google Maps, Photos by Ben Prince

Figure 7: Polluted Effluent

REGIONAL TRENDS

Reflecting on larger scale trends of Bastrop County and the central Texas area provides a greater context for these threats to the Colorado River. Chart 1 illustrates the rapid population growth of Bastrop County. Starting with a population of less than 17,000 in 1960, that number had risen to nearly 85,000 by 2010. It is projected that, by 2060, there will be 288,000 residents in Bastrop County. This staggering increase will generate significant developmental impacts of the sort outlined in the preceding sections.

Region K, as designated by the Texas Water Development Board, has generated these population projections in an effort to anticipate future water demand. Chart 2 depicts these, showing a rise from 20,000 acre-feet per year in 2000 to 40,000 acre-feet per year by 2020 and to 65,000 acre-feet per year by 2060. It remains to be seen how this additional demand for water will be met, as surrounding areas continue to grow as well. If the figures of these two charts are accurate, then protecting water quality and quantity is vital. But to protect water, the riparian corridor and its environmental systems services must be protected. The strategies outlined in the following sections are meant to achieve just this.

The process will be difficult and development pressures already are being felt. Agricultural real estate information produced by Texas A&M for the region, including Bastrop County and the river corridor, suggests trends toward subdivision of parcels and increase in price per acre. (See Charts 3 and 4) As land is divided and divided again, it becomes ever more difficult, both logistically and financially, to protect tracts large enough to maintain healthy habitat and ecological systems. Chart 4 indicates that the price per acre of land has risen sharply in the past decade. Now, with the real estate market pacified by the recession, there is a window in which to act.

Source: years 2010 to 2060: www.regionk.org/#Information, years 1960 to 2000: www.census.gov/population/cencounts/tx190090.txt. Retrieved 4/20/11

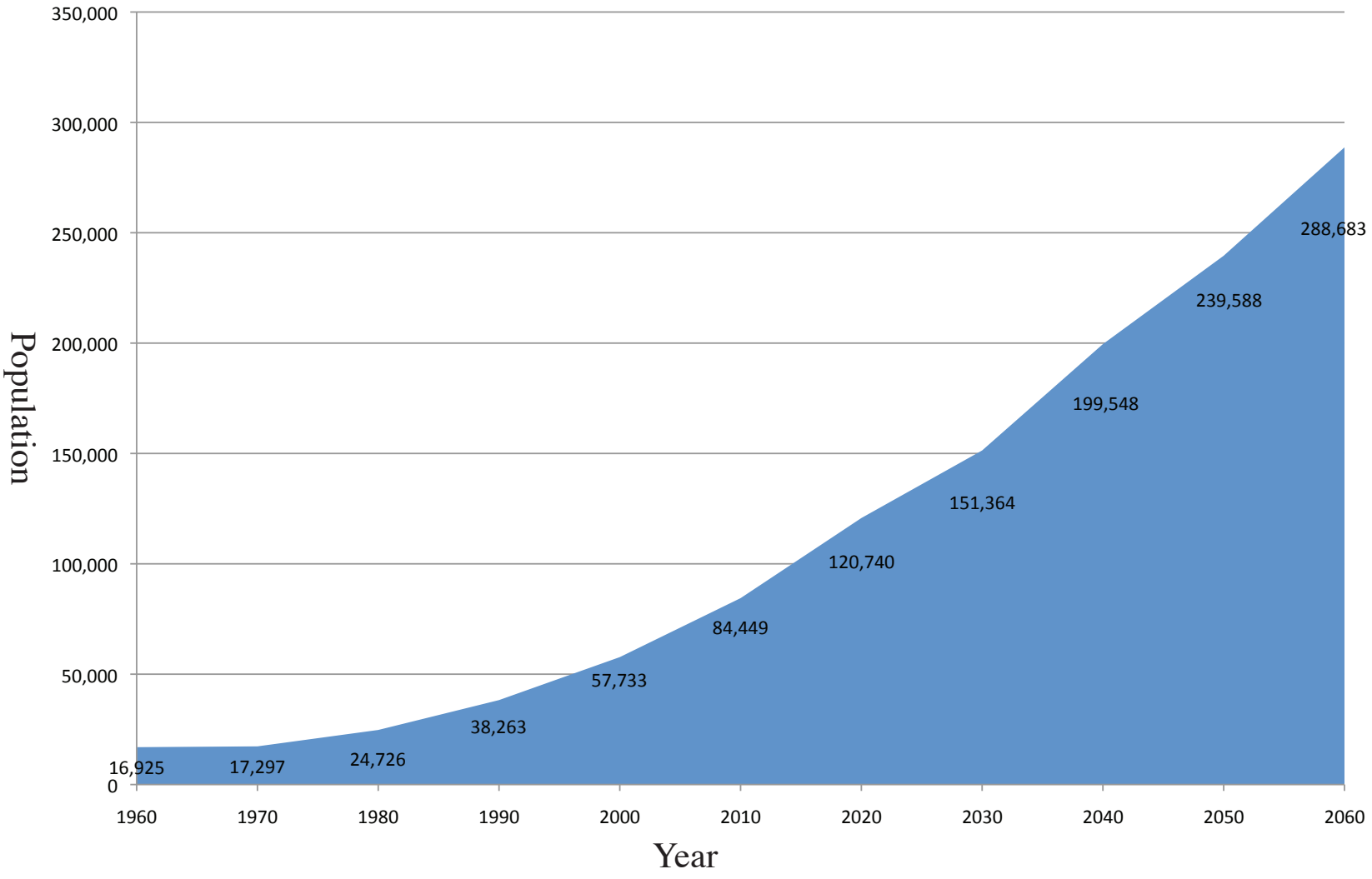

Chart 1: Bastrop County Population Projections

Source: www.regionk.org/#Information, Retrieved 4/20/11

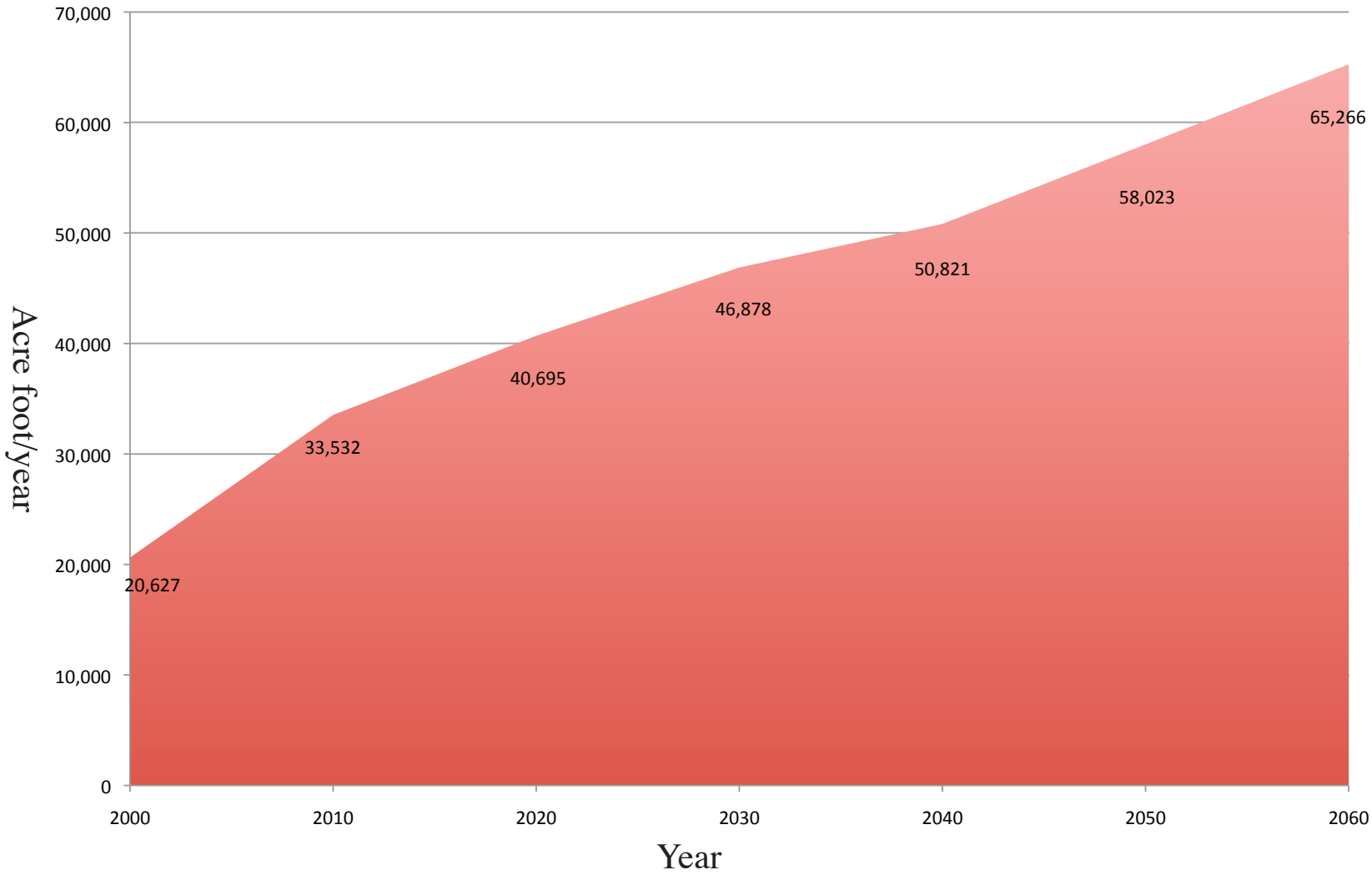

Chart 2: Bastrop County Water Demand Projections (Acre foot/year)

Source: Real Estate Center at Texas A&M University © 2010, Retrieved 4/20/11

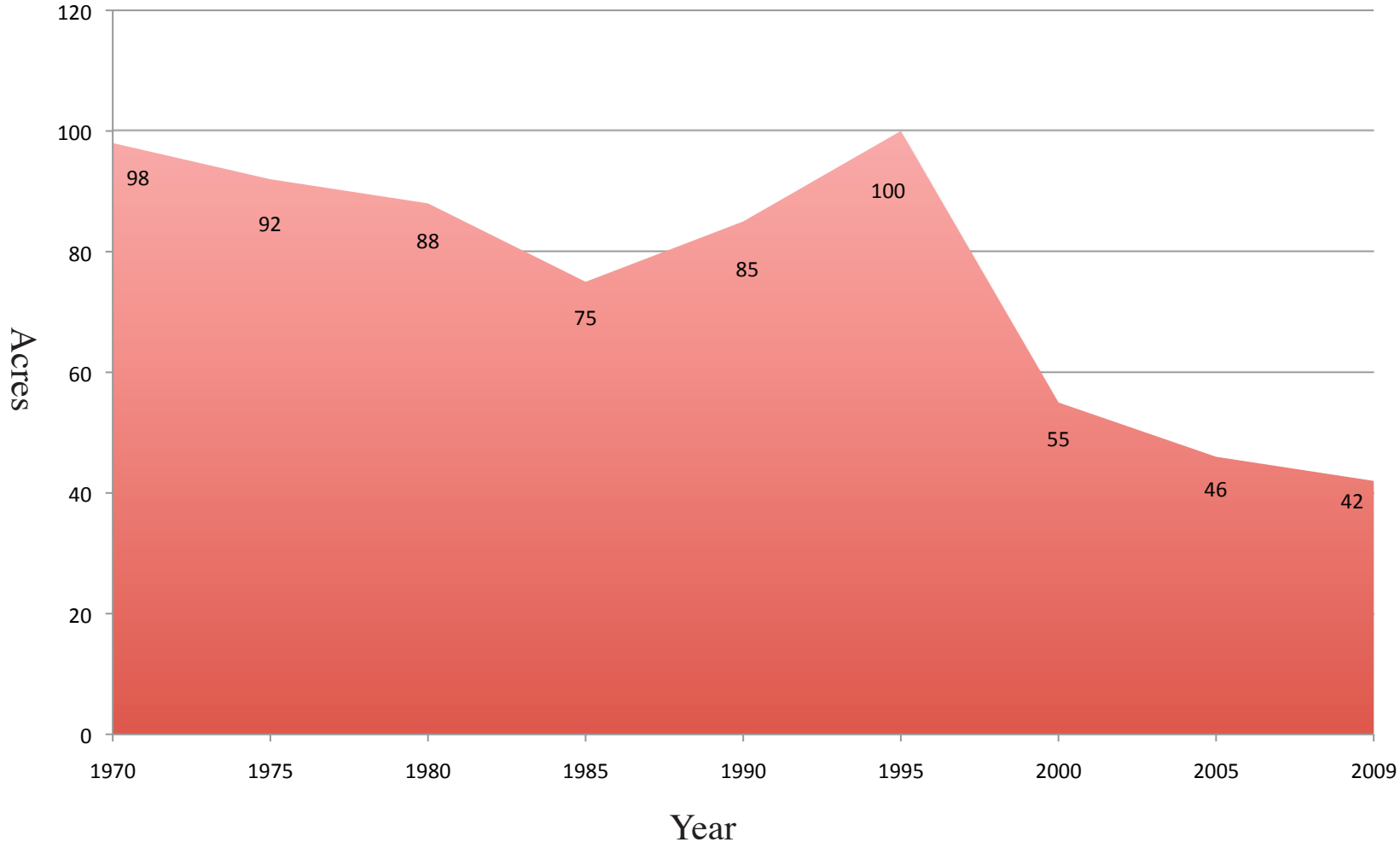

Chart 3: Regional Median Tract Size (Acres)

Source: Real Estate Center at Texas A&M University © 2010, Retrieved 4/20/11

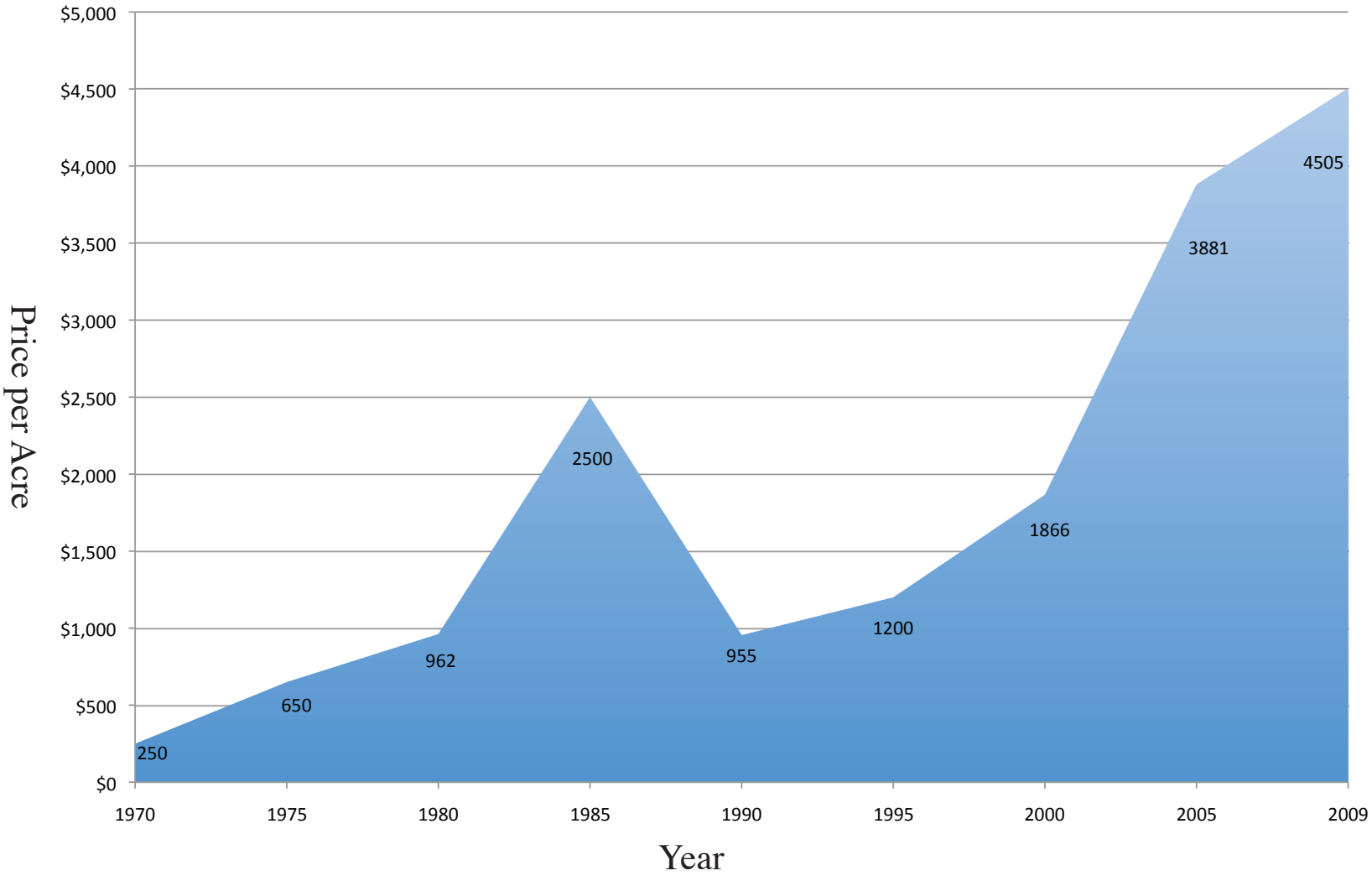

Chart 4: Regional Median Tract Price (Dollars)

Chapter 2: Research Question

The central hypothesis of this study is that rapid development is changing the landscape of the Colorado River Valley in Bastrop County. The analysis is meant to document this change. Using 1970's, 1990's, and 2008 aerial maps, this study identifies areas of growth and development, and the changes in land use and cover that have occurred in this period.

The secondary hypothesis is that this growth is reducing the area of riparian forest and agricultural lands. The study maps the extent of the riparian forest and agricultural lands, using the same aerial maps, and it identifies growth or reduction in both land types.

Stemming from these, the study offers a less analytical, but hopefully compelling, argument and set of strategies for preservation of these lands and, where possible, expansion of protected riparian areas by implementing a host of programs, plans, and regulations. It is my belief that destruction of these open lands for "development" is unwise and weakens the structure of the ecological community, degrades water quality, and perpetuates a system of rapid consumption that is unsustainable.

Central questions:

- How is the riparian corridor identified?
- What was the extent of the pre-European riparian forest?
- How much area has been developed for residential uses in the past thirty years?
- How much area has been developed for commercial uses in the past thirty years?
- How much area has been mined in the past thirty years?
- How has the coverage area of the riparian forest changed over the last thirty years?
- How has the coverage area of agricultural lands changed over the last thirty years?

Chapter 3: Methodology

Initially, I observed a section of the Colorado River corridor, attended a riparian workshop in Junction, Texas, talked with Kevin Anderson of the City of Austin's Center for Environmental Research at Hornsby Bend, and began attending meetings of the Austin-Bastrop River Corridor Partnership, a platform through which various stakeholders with an interest in the Colorado River corridor share information.

Thereafter I conducted a first person survey, by kayak, of the Colorado River, beginning below Longhorn Dam (at the point where the river flows freely after traveling through the series of Highland Lakes) in east Austin and continuing through eastern Travis County and the entire length of the Colorado in Bastrop County. I used this trip to make personal observations and photographs. Photographs were cataloged by identification numbers and then identified locations of the photos on aerial maps. This will allow time-lapse photos to be taken at the same locations at future dates to document changes. (See Figure 26 for an example of this documentation.)

In the process of preparing for the river survey, I closely studied aerial maps and Lower Colorado River Authority (LRCA) River Trail maps. While I was on the river, I realized I did not have the vantage point I needed to understand the riparian corridor as a whole, because I was surrounded by luxuriant vegetation that limited my view. I knew then that I would need a larger scale understanding.

I read a considerable amount of literature, and consulted regularly with Sherri Kuhl, Manager of Environmental Stewardship for the LCRA, who wanted a survey done of the riparian area. (Ms. Kuhl and Mr. Anderson were instrumental in shaping this project, and I am grateful to them. However, any opinions I state herein are my own and should not be attributed to them.)

I settled on searching for three categories of information: identifying the likely extent of the historic riparian forest, identifying road construction as a proxy for development, and identifying the riparian forest and changes in it over the near past.

I began to search for maps and photographs. In an effort to eliminate as much error as I could, I searched for primary sources. I had hoped to find aerial photographs dating back to the 1940s or property parcel maps dating back as far as possible and tied to their land use. While I learned that the aerial photographs exist, I found that they were too expensive for this academic project. The property parcel maps also exist, but only as disaggregated information; it was time-prohibitive for me to use them. In place of that information, I was able to find 2008, 1997, and 1975 aerial photos of the river corridor. The 2008 and 1997 aerial images already had been compiled by the Capital Area Council of Governments (CAPCOG), but I scanned the 1975 aerial photos from the 1975 Bastrop County soil survey created by the U.S.D.A.'s Soil Conservation Service. (These three allowed me to identify changes in the riparian forest.) That information, plus 1961 and 1940 county highway maps, allowed me to identify road development, which I correlated with land use changes. From CAPCOG, I obtained a soils map and the pertinent Federal Emergency Management Agency (FEMA) 100-year flood plain map. By selecting

riparian soils and combining them with the flood plain map, I was able to roughly identify the historic riparian forest area. All this information was obtained via the Internet.

To supplement the aerial photographs, I collected secondary source information: hand-drawn soil survey maps and highway maps dating back to 1907. While not as accurate or precise as the photographs, they provide a deeper historical context and reveal information about infrastructure and residential development. I supplemented these with historical accounts of the area, which serve as anecdotal data to indicate the general character and timeframe of events in the region.

Finally, I gathered general reference information about riparian areas and more specific information about the Colorado River corridor from literature on riparian vegetation, hydrology, and management.

While I attempted to conduct a thorough, analytical study, I was limited by the data I was able to obtain. I often improvised in my techniques and, inevitably, was influenced by strong personal sentiments in favor of riparian protection.

Steps I took to conduct my analysis:

- Information collected
- Historic extent of the riparian forest identified by combining FEMA flood plain and hydric soils files
- 1975 Soil Survey aerials scanned, cropped, and georeferenced
- 1997 aerial images georeferenced
- 2008 aerial images georeferenced
- Riparian forest polygon file produced from trace of 1975, 1997, 2008 aerial images
- Property parcels file overlaid on 1975, 1997, 2008 aerial images; agricultural lands identified
- 1907 soils, 1940 highway, 1961 highway maps georeferenced

- New infrastructure, commercial, residential, and mining developments identified on the 1907, 1940, 1961, 1975, 1997, and 2008 maps
- Resulting data analyzed

Additional information detailing source data and methods is included in Appendix A.

Created by Ben Prince 12.5.10

Source: Google Maps, Photos by Ben Prince

Figure 26: Sample River Photo Survey Map

Chapter 4: Findings and Analysis

RIPARIAN FOREST COVER

This study analyzes quantitative changes in the distribution of the riparian forest. By using aerial photos of varying quality to generate data over the extent of the study area, a choice was made to concentrate on breath of the whole corridor rather than depth of one or a few particular sample areas. The result is that qualitative features, outside of identifying a few general threats, have not been investigated. Keying in on a few study sites would be an important next step, or next project, to detail specific changes in the riparian corridor condition.

Questions that might be answered in a more detail-oriented study include:

- What is the existing plant species configuration, and what was a likely historic species mix, and what new species are spreading in the corridor?
- What is the species configuration of post-agricultural sites (ranch and crop land) as compared to areas known to have been in wild lands?
- How do young regrowth areas compare to older established areas of riparian forest in terms of environmental system services such as flood mitigation and habitat?

These and many other questions pertaining to hydrology, chemical and nutrient cycling, and flora and fauna are in need of investigation. A more extensive outline of the potential shortcomings and sources of error which could lead to refined studies is included as Appendix B

Figures 8, 9, 10, 11, and 12 represent the changing extent of the riparian forest along the river in Bastrop County. Figure 8 is an image of the potential extent of the river prior to Anglo settlement. The historical riparian forest was identified by selecting by attributes from the CAPCOG Soils file (*soils.shp).* The selection was developed by adding together the NRCS 'hydric' soils + the 1907 alluvial area soils + the 1975 USDA SCS map of soil associations + any additional areas in the 2010 FEMA 100-year floodplain not covered by these areas, and soil types lying just above the floodplain, but surrounded on all sides by probable forest. (See Appendix A for detailed methodology.) The map then is a representation of what the soils and proximity to the river might produce without industrialized human intervention, i.e. the pre-Anglo condition. While the native and Spanish populations did impact the forest, the intensity was not of an industrial scale. (Baumgartner et al. 1997) The extent of the riparian forest could be used as a baseline to indicate where forest could be expected and the change in forest cover.

Figure 9 is a sample comparison of the overlain aerial images used to document changes in riparian forest cover between 1975 and 2008. The image serves to illustrate the minute changes occurring to the forest. These changes are difficult to register on a first-hand basis, which is one reason why time-lapse aerial images were used.

Figures 10, 11, and 12 depict the forested area in 1975, 1997, and 2008 respectively. When viewed at this study-area-wide scale, the differences are hard to identify. It became clear that, in order to generate viable comparisons from this data, smaller study areas would need to be delineated, which could provide information as to

forest cover change and where it was occurring.

Figure 13 and Chart 5 represent the results of this process. Concentric buffer zones were made extending inland from the riverbanks, and the area identified as riparian forest in each buffer area was measured. The buffers were cumulative, ie the 25-foot to 500-foot buffers were contained within the 100-foot buffer, as were both sides of the river. Chart 5 summarizes the calculated area findings. The buffer zones allow for a more nuanced look at the forest area change and reveal the following trends. From the 25-foot to the 250-foot buffer zone, the forested area grew over the study period. Greater changes were observed in the smaller zones immediately adjacent to the river, and changes decrease as this area expands away from the river's edge. Within 500 feet of the river, the area of riparian forest was found to have remained constant in the study period between 1975 and 2008. Conversely, the 1000-foot buffer zone shows a reduction in forested area.

To further investigate land use changes, an analysis of the riparian forest lying within the 100-year floodplain was performed. (See Figure 14) While the floodplain is a product of political boundaries as much as hydrologic forces, to a large degree it reflects the area most likely to coincide with the historic riparian forest. This, then, may be a more accurate area in which to study changes in the riparian forest. A breakdown of the change in forested area in this zone is presented in Chart 6. The numbers indicate a steady, if small, decrease in the riparian forest over the study period.

The results ran counter to the presumed findings. They indicated that the riparian forest immediately adjacent to the river is growing while the forest farther away is

shrinking. Larger trends may help to explain this. The reduction in cultivated lands, starting in the 1940's, may have allowed land adjacent to the river to return to its native riparian forest. Concurrently, as land has been developed for other purposes, areas set back from the river's edge and less prone to flooding may increasingly be cleared of their forests.

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

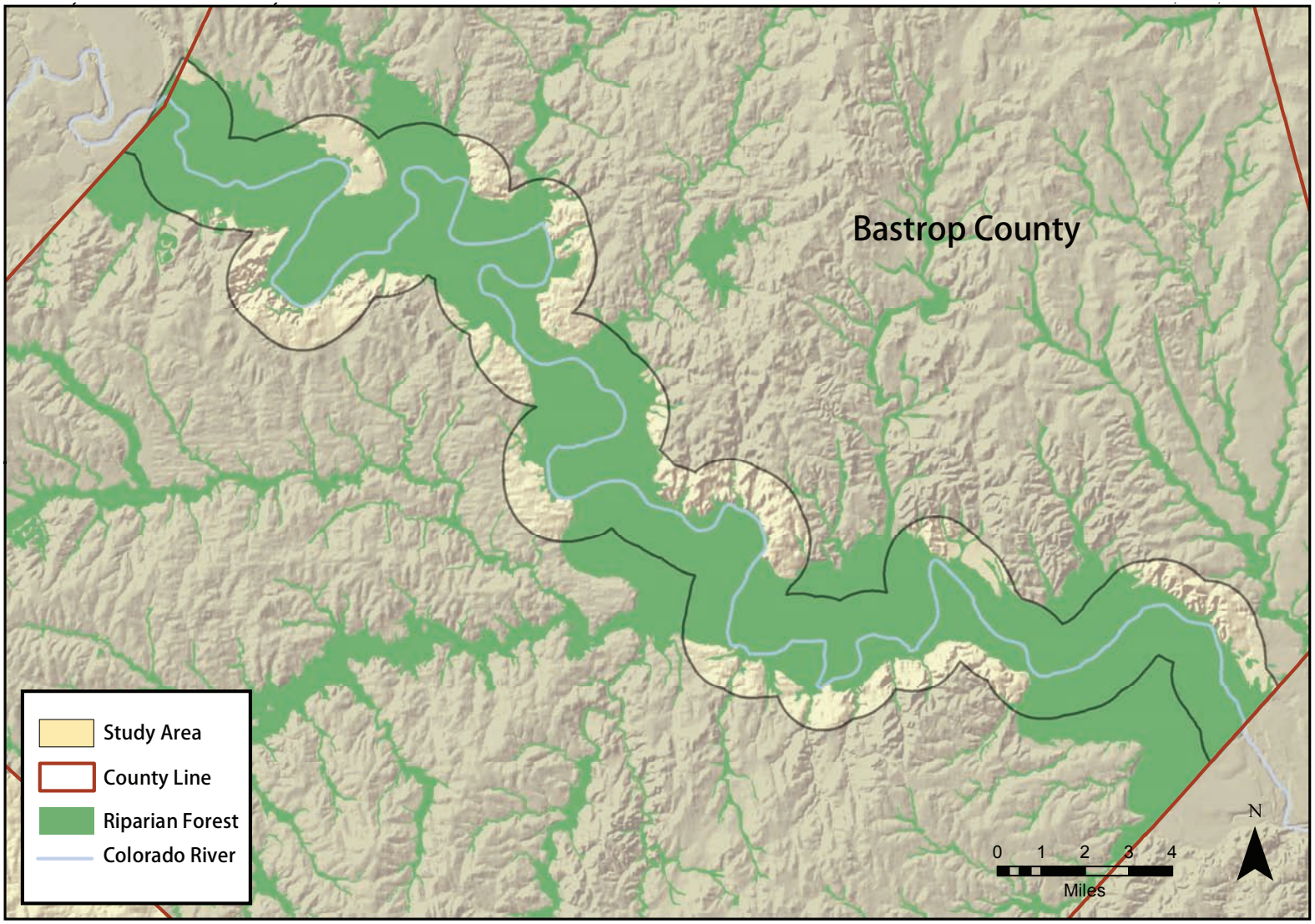

Figure 8: Possible Historic Extent of the Riparian Forest

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

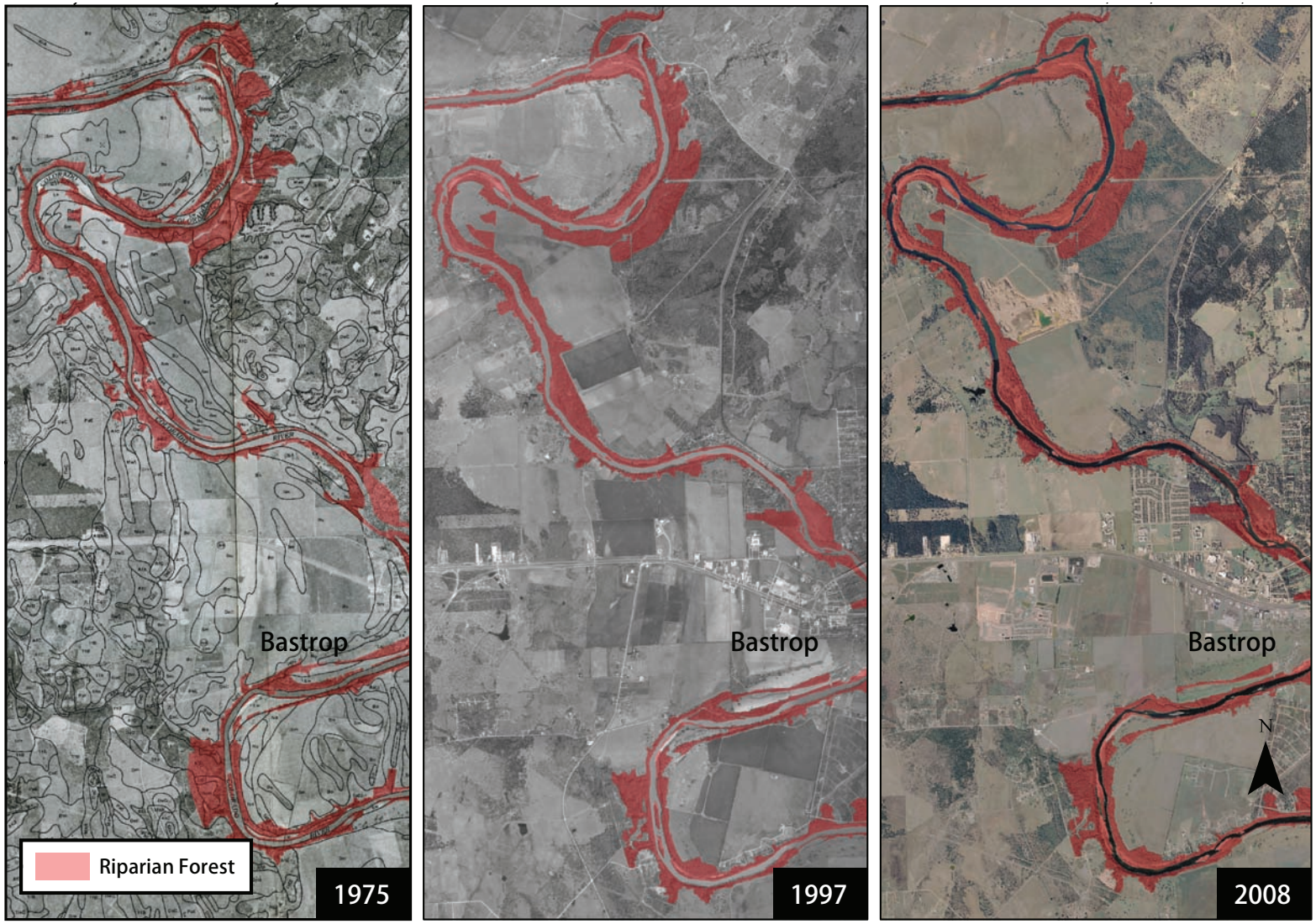

Figure 9: Riparian Forest Over Time

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

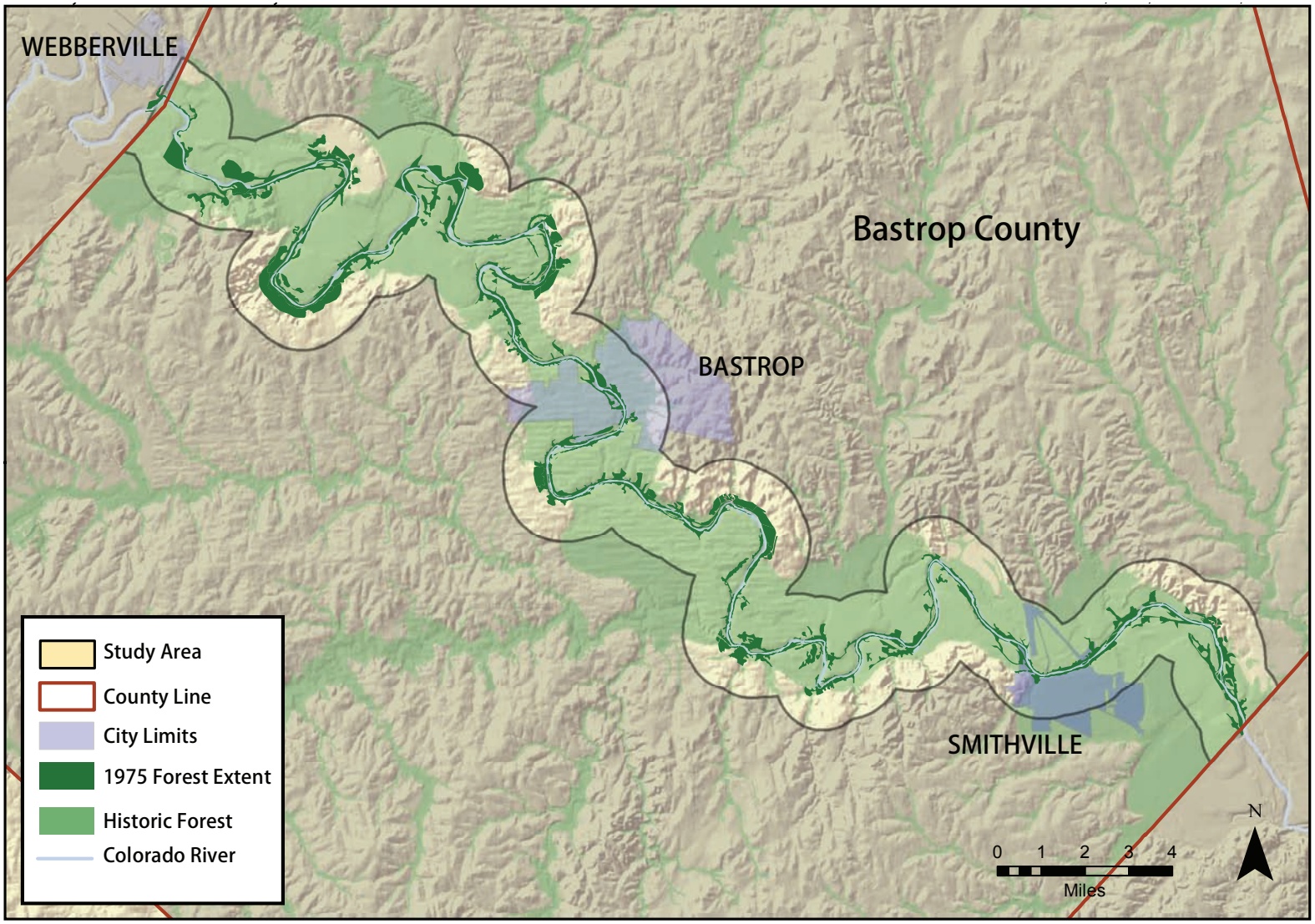

Figure 10: 1975 Extent of the Riparian Forest

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

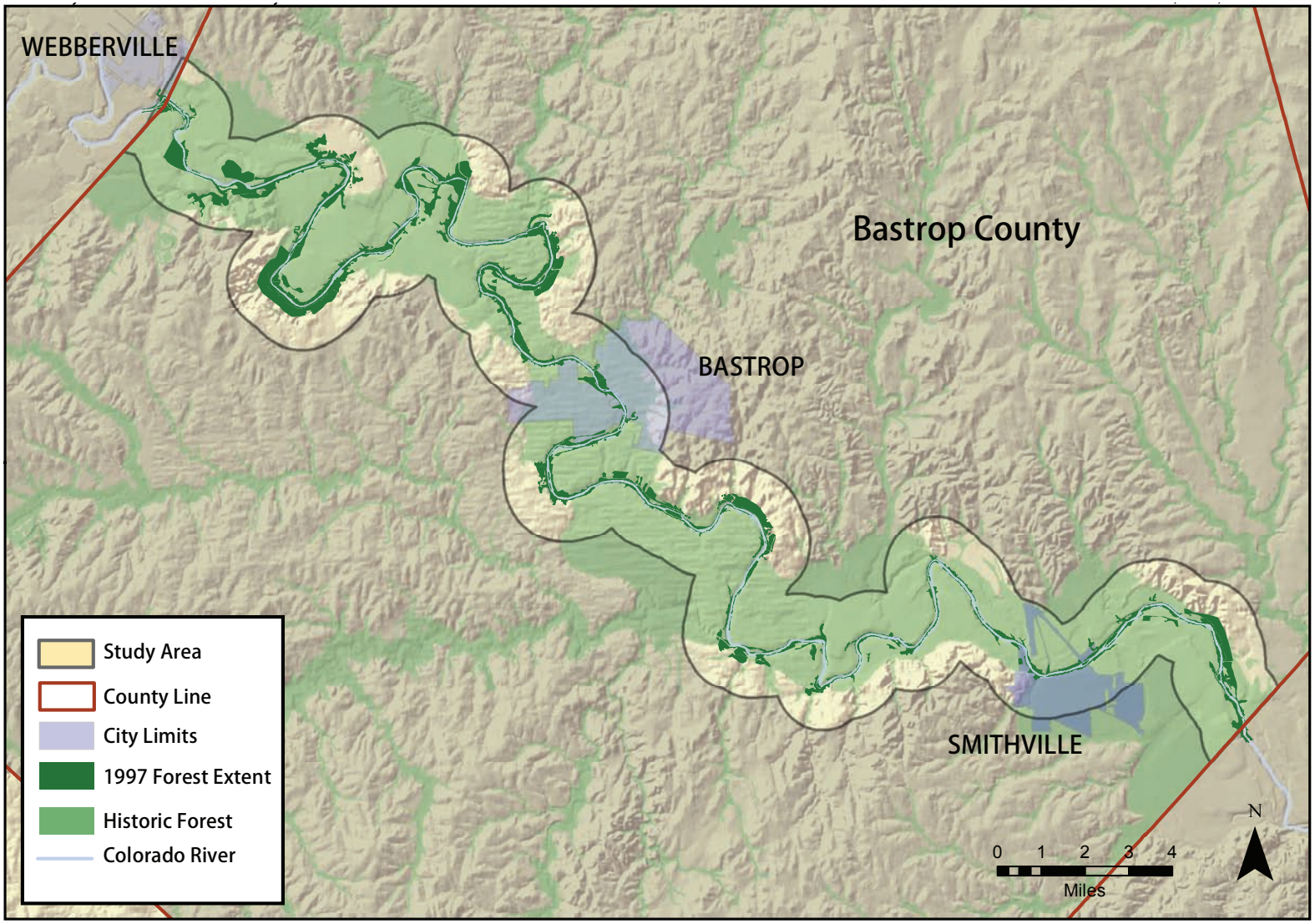

Figure 11: 1997 Extent of the Riparian Forest

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

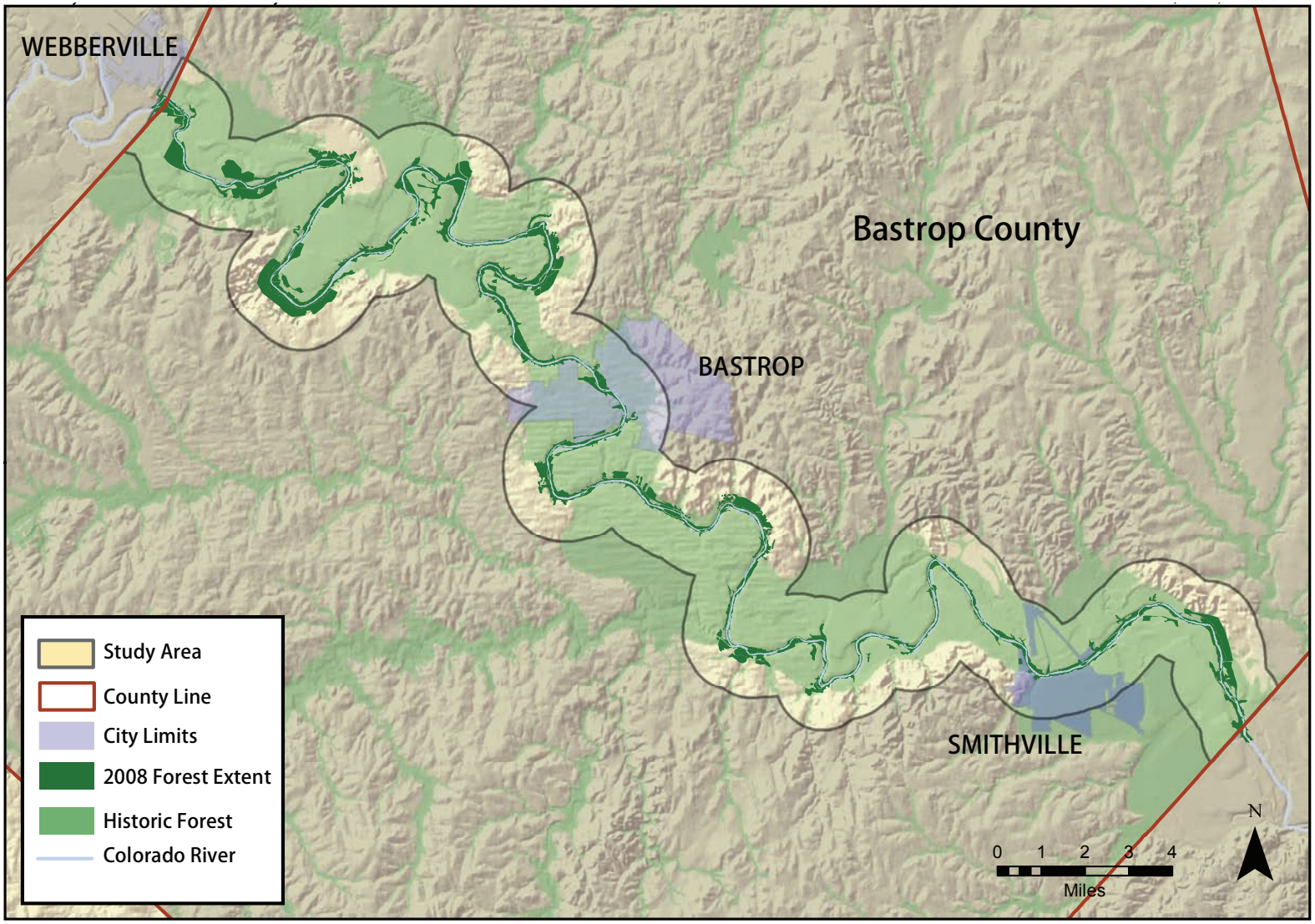

Figure 12: 2008 Extent of the Riparian Forest

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

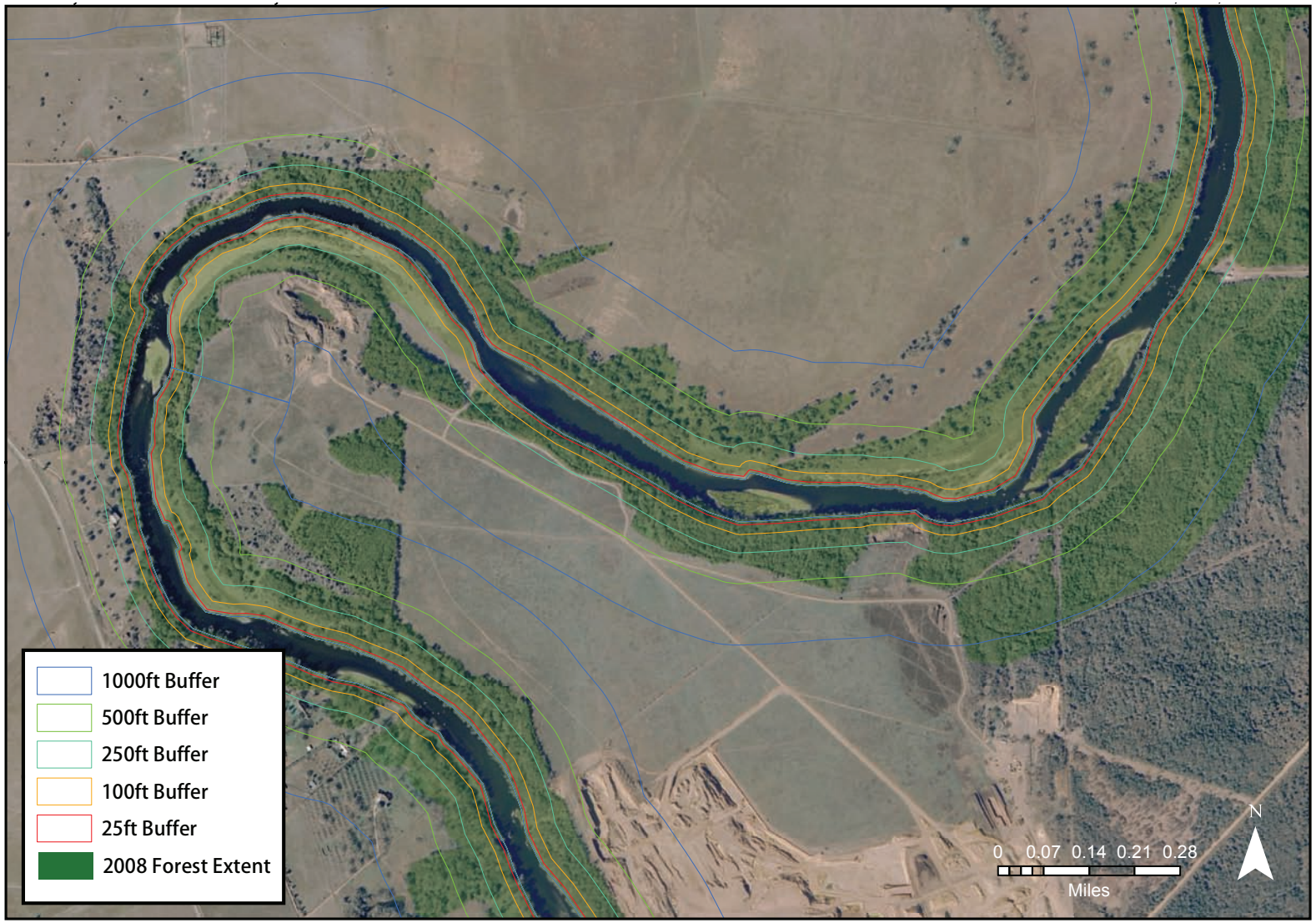

Figure 13: Measuring the Forest with Concentric Buffers

Source: CAPCOG,TWDB,UT GIS Server, Retrieved 4/20/11

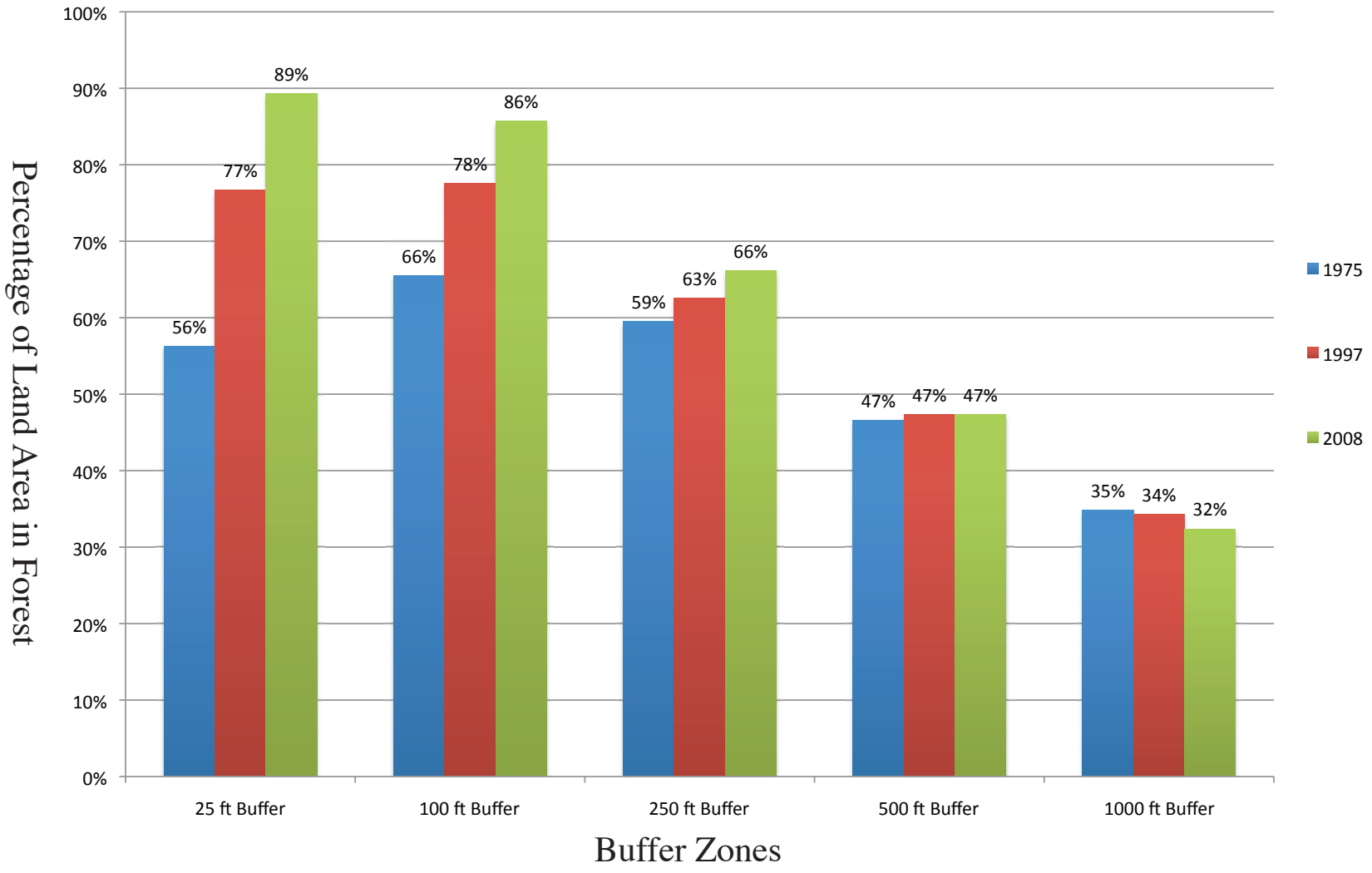

Chart 5: Percentage Riparian Forest Cover in Study Area Buffers

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

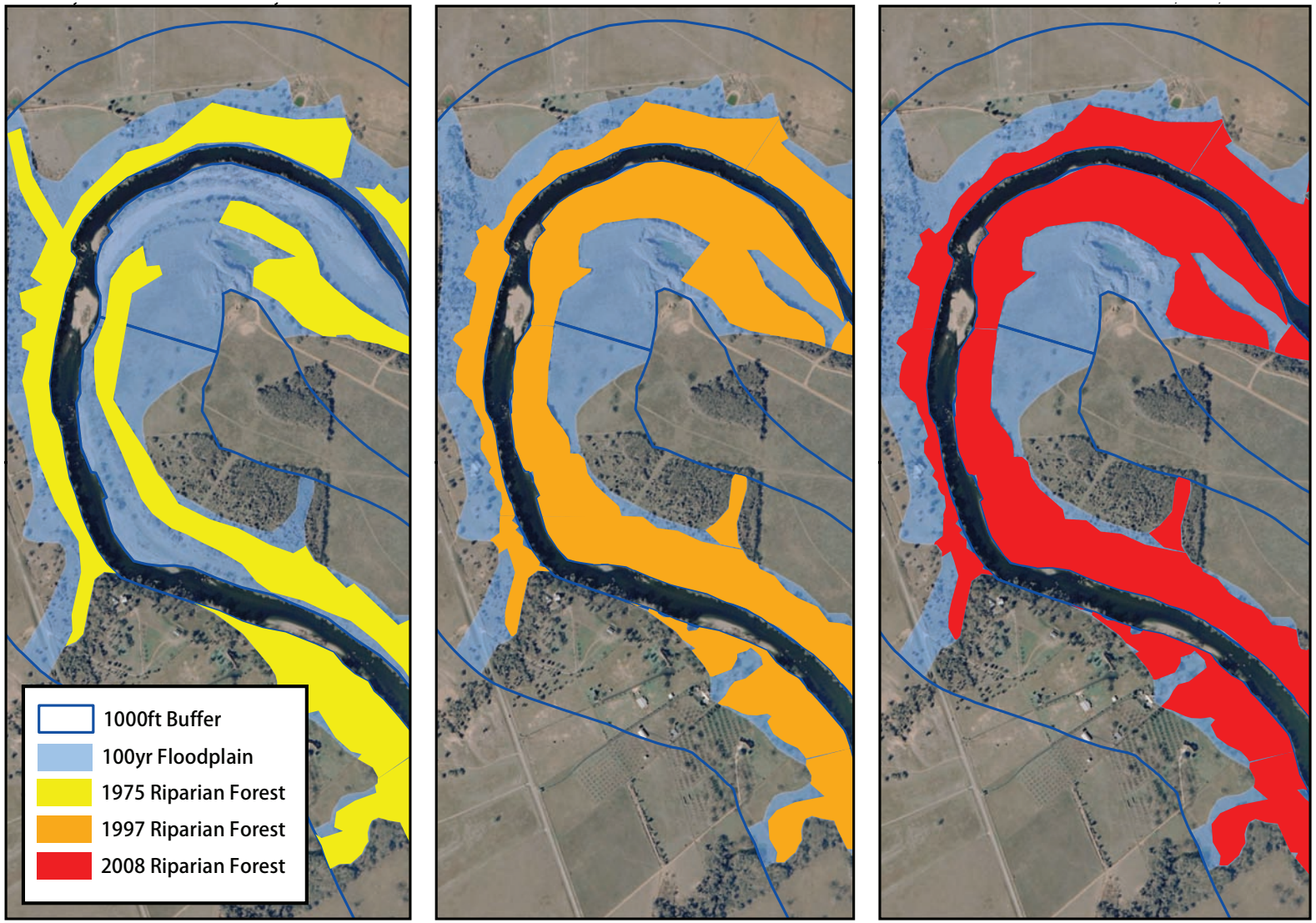

Figure 14: Riparian Forest Within the Floodplain

Source: CAPCOG,TWDB,UT GIS Server, Retrieved 4/20/11

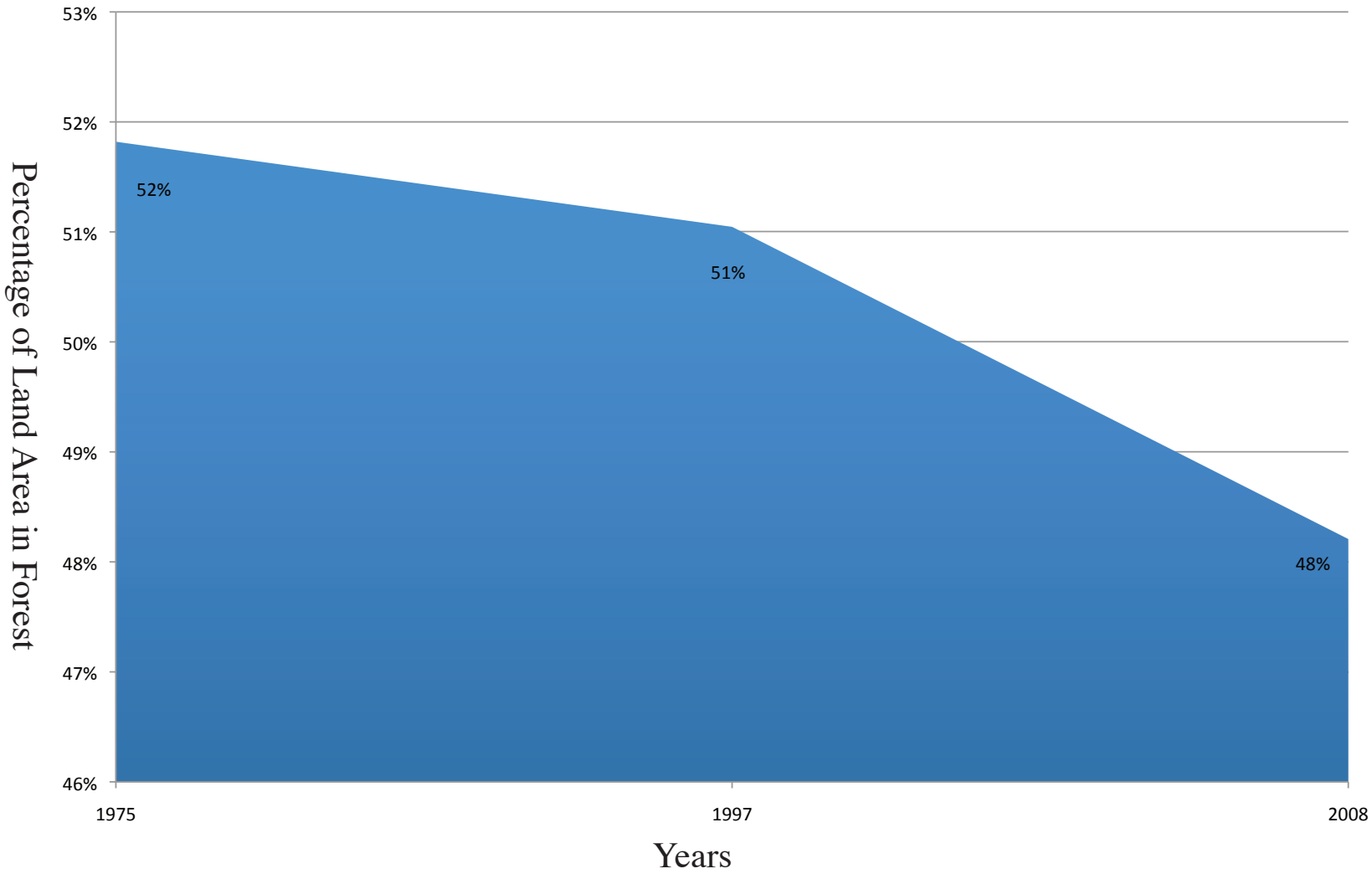

Chart 6: Percentage Riparian Forest Cover in the 100-Year Floodplain

ROAD DEVELOPMENT

Construction of road infrastructure is a common precursor to land use change. When rural lands are to be converted to non-agricultural uses, roads are needed to access the land (initially, to transport construction workers and materials). To quantify development of roads in the study area, historic highway maps and aerial images were compiled and digitized, and the linear miles of road way were calculated. Figure 15 provides a graphic illustration of the mapping process, while Figures 16, 17, 18, 19, and 20 document road development in the study area from 1940 to 2008. Chart 7 summarizes the findings.

Figure 15 is presented to illustrate the overlay process and a closer look at road development in the City of Bastrop. An inspection of the images reveals not only the construction of new roads but also the associated development occurring on the periphery of the city along Highway 71 (identifiable here as the thick red line running across the image). Bastrop and Highway 71 are the epicenters of growth in the study area, and present the most striking visual example of development.

Figures 16 through 20 document road development within the study area from 1940 to 2008. When they are reviewed in succession, it is clear that corridor has experienced steady road construction during the study period. As the two major communities on the river, Smithville and Bastrop are focal points for this development. The dense cluster of roads Below Bastrop appearing, initially, on Figure 18 is the Tahitian Village subdivision.

Chart 7 quantifies the linear road miles in the study area, by year. As a reflection of the maps, these numbers are not surprising. However, the doubling of road miles between 1940 and 2008 has facilitated considerable development. While it is not clear whether roads are the cause and development are the effect — or vice versa, the two are closely correlated. It, thus, seems reasonable to use these numbers as a proxy for land use changes occurring in the riparian corridor. The next analysis provides evidence to support this conclusion.

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

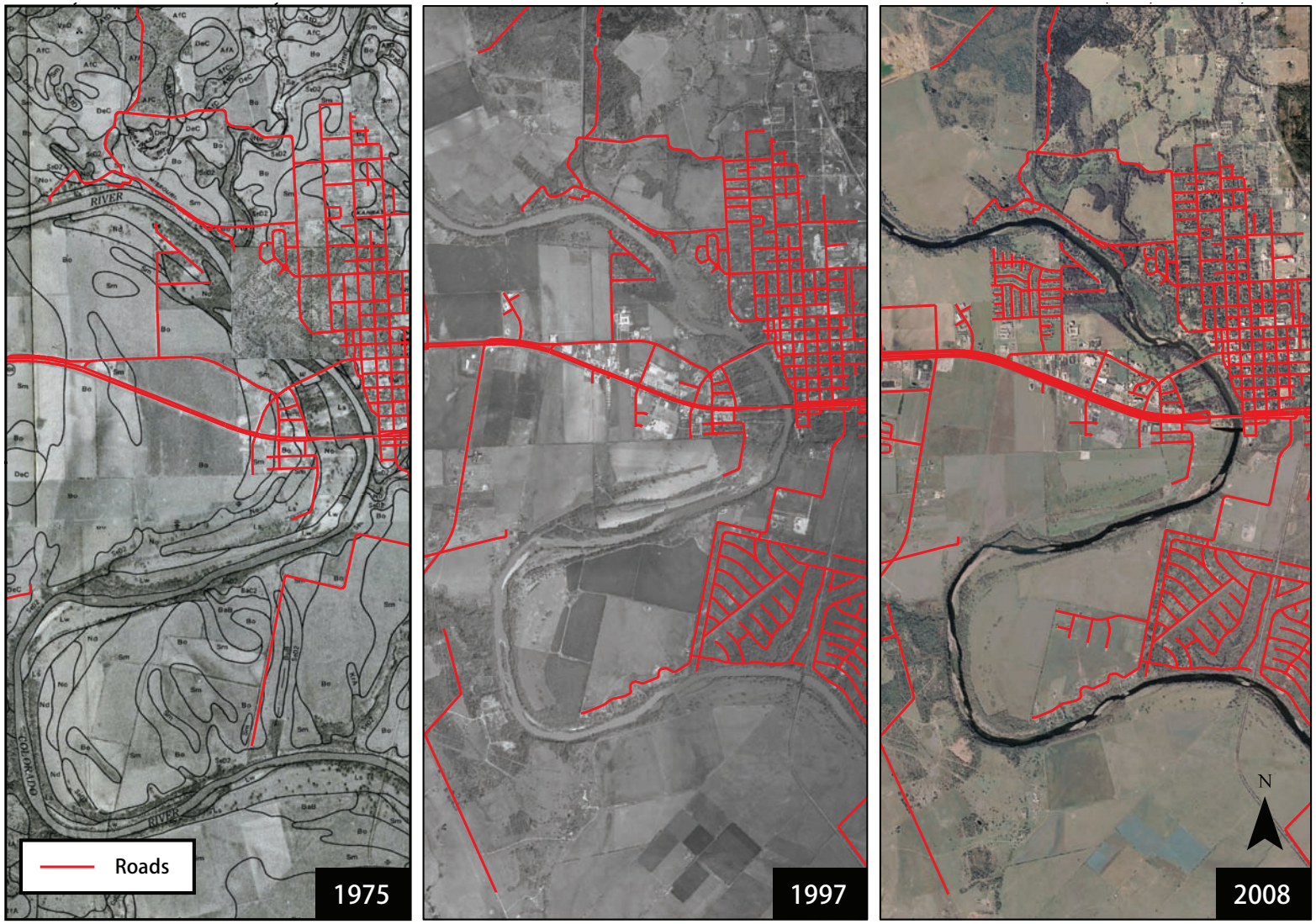

Figure 15: Roads Over Time

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, Texas State Library, UTGIS Server

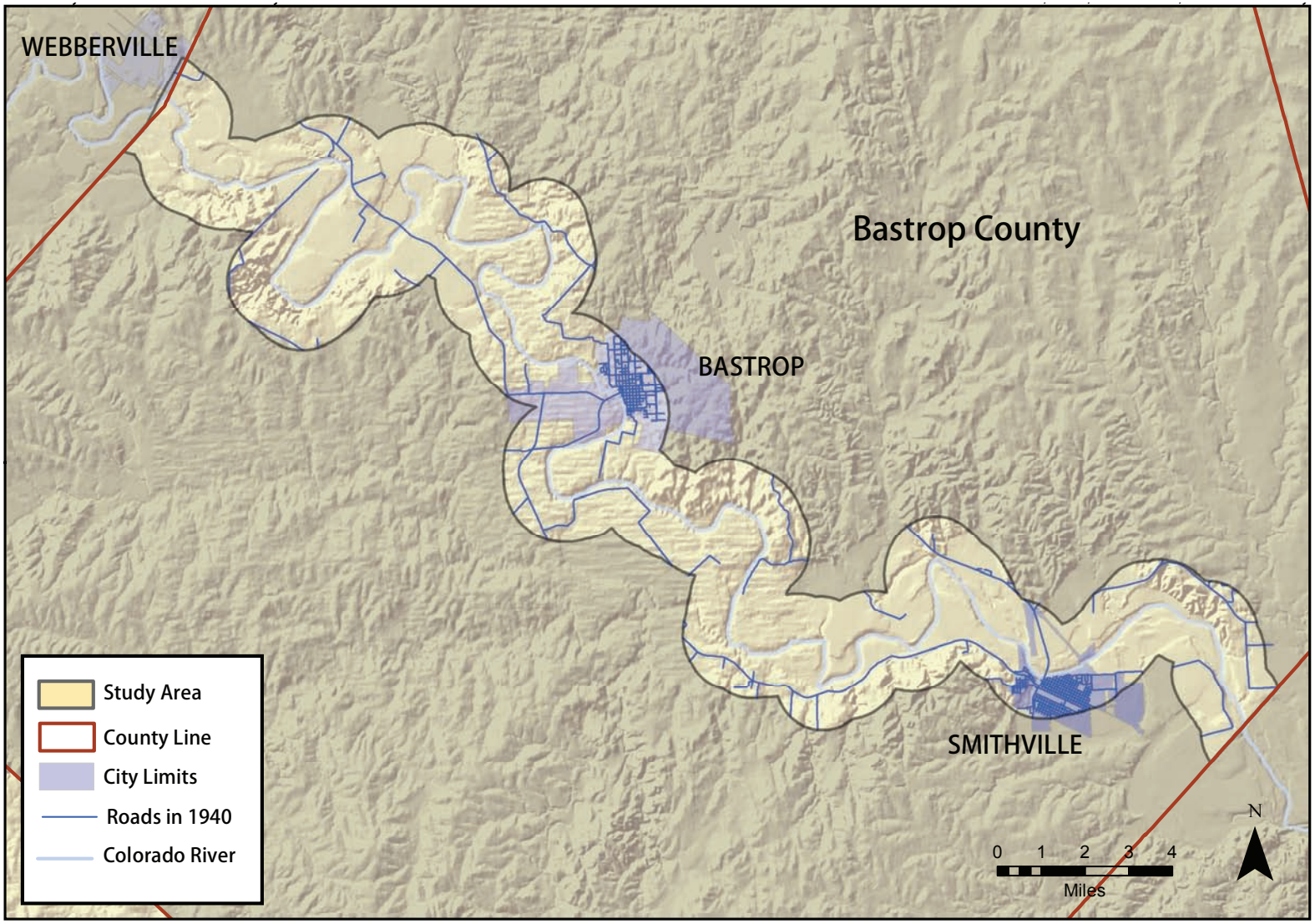

Figure 16: 1940 Roads Within One Mile of the River

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, Texas State Library, UTGIS Server

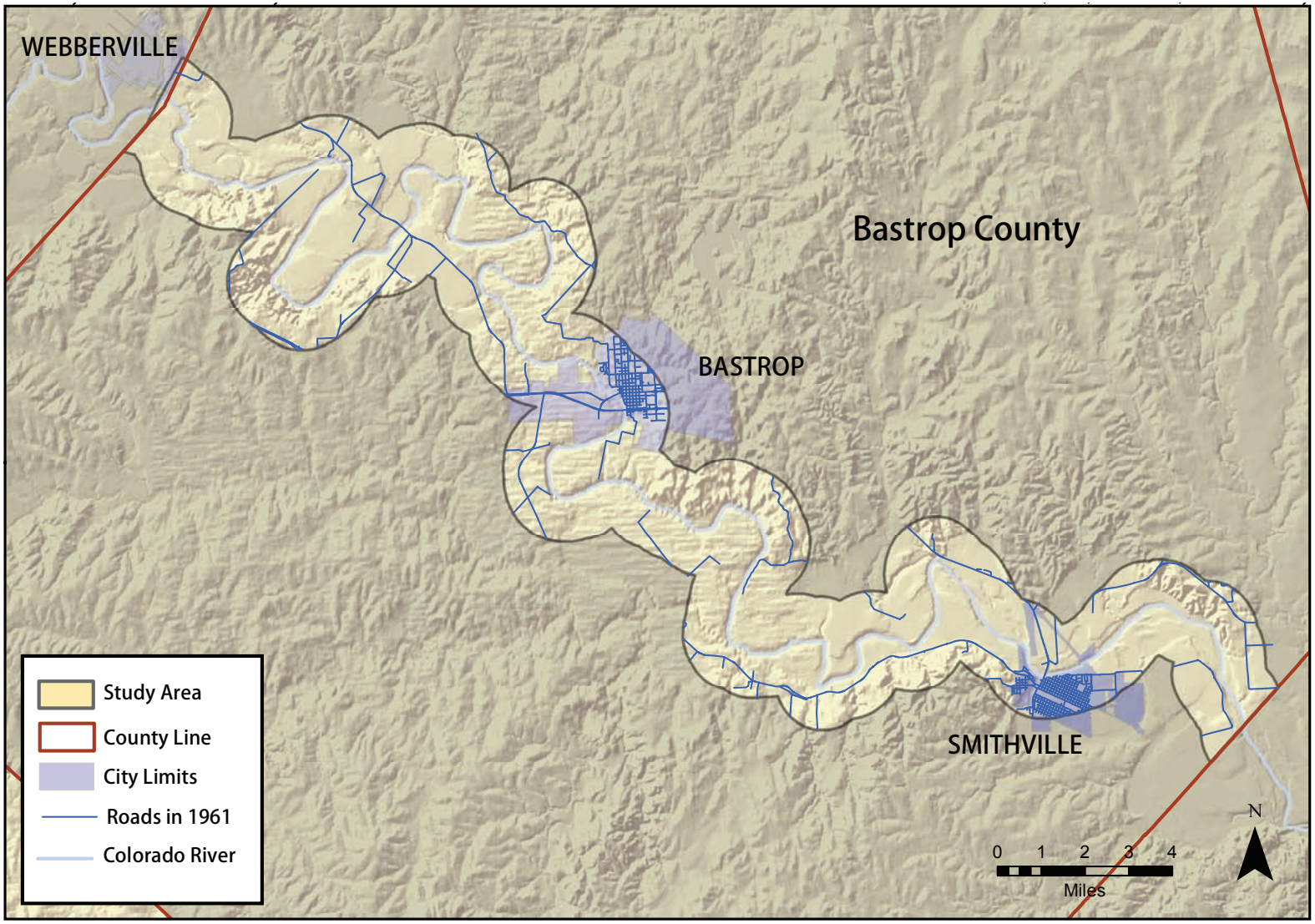

Figure 17: 1961 Roads Within One Mile of the River

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

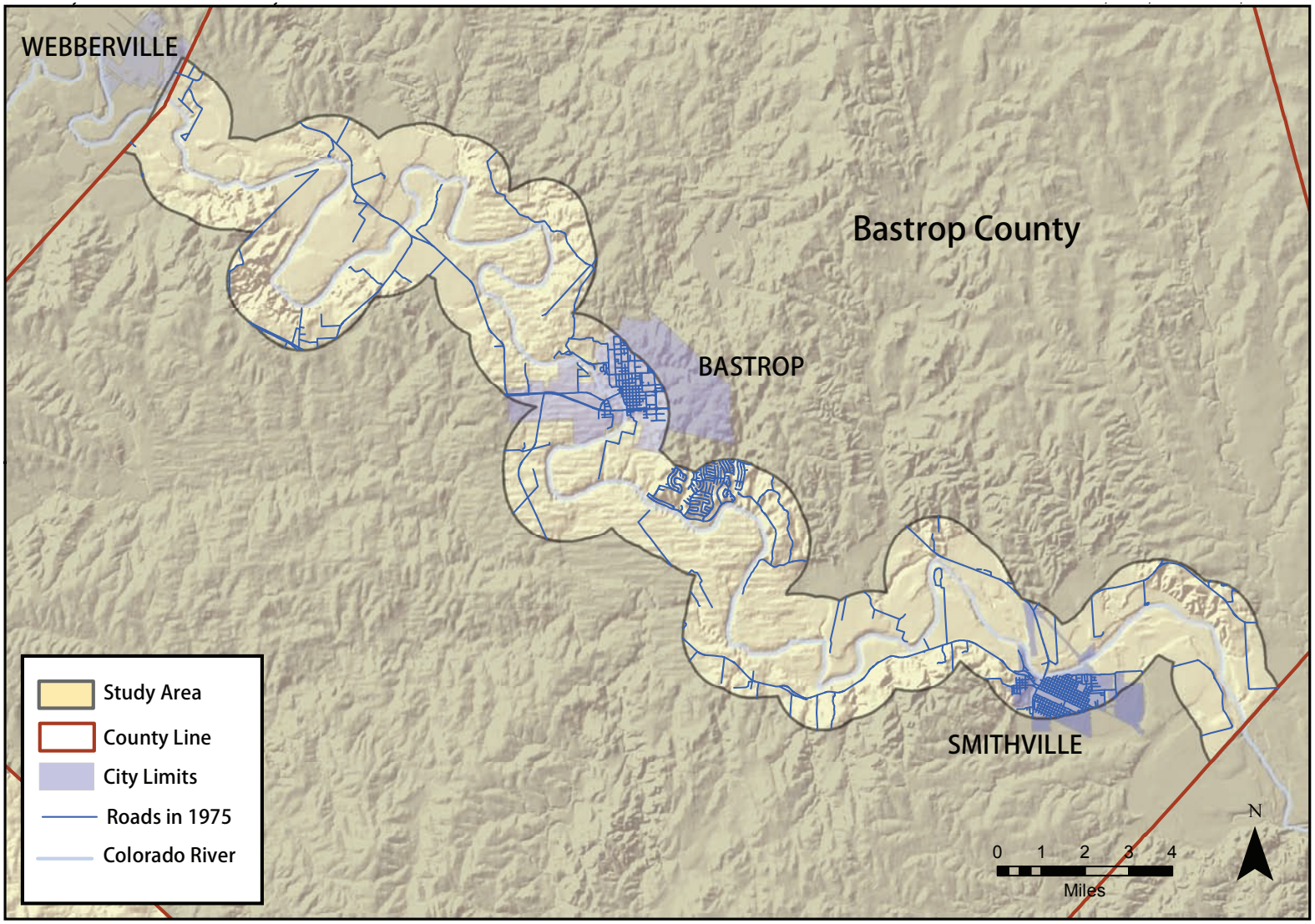

Figure 18: 1975 Roads Within One Mile of the River

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

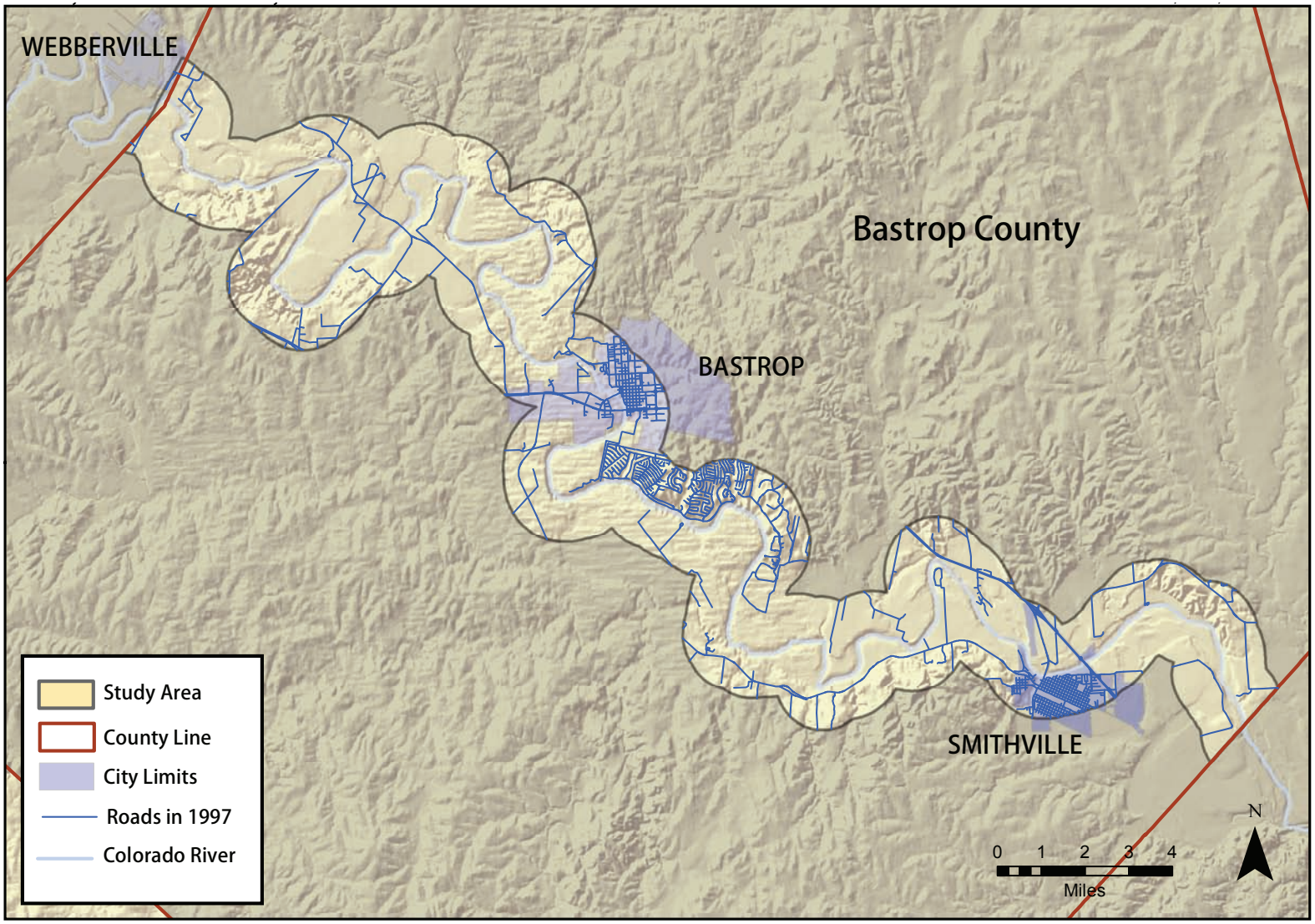

Figure 19: 1997 Roads Within One Mile of the River

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

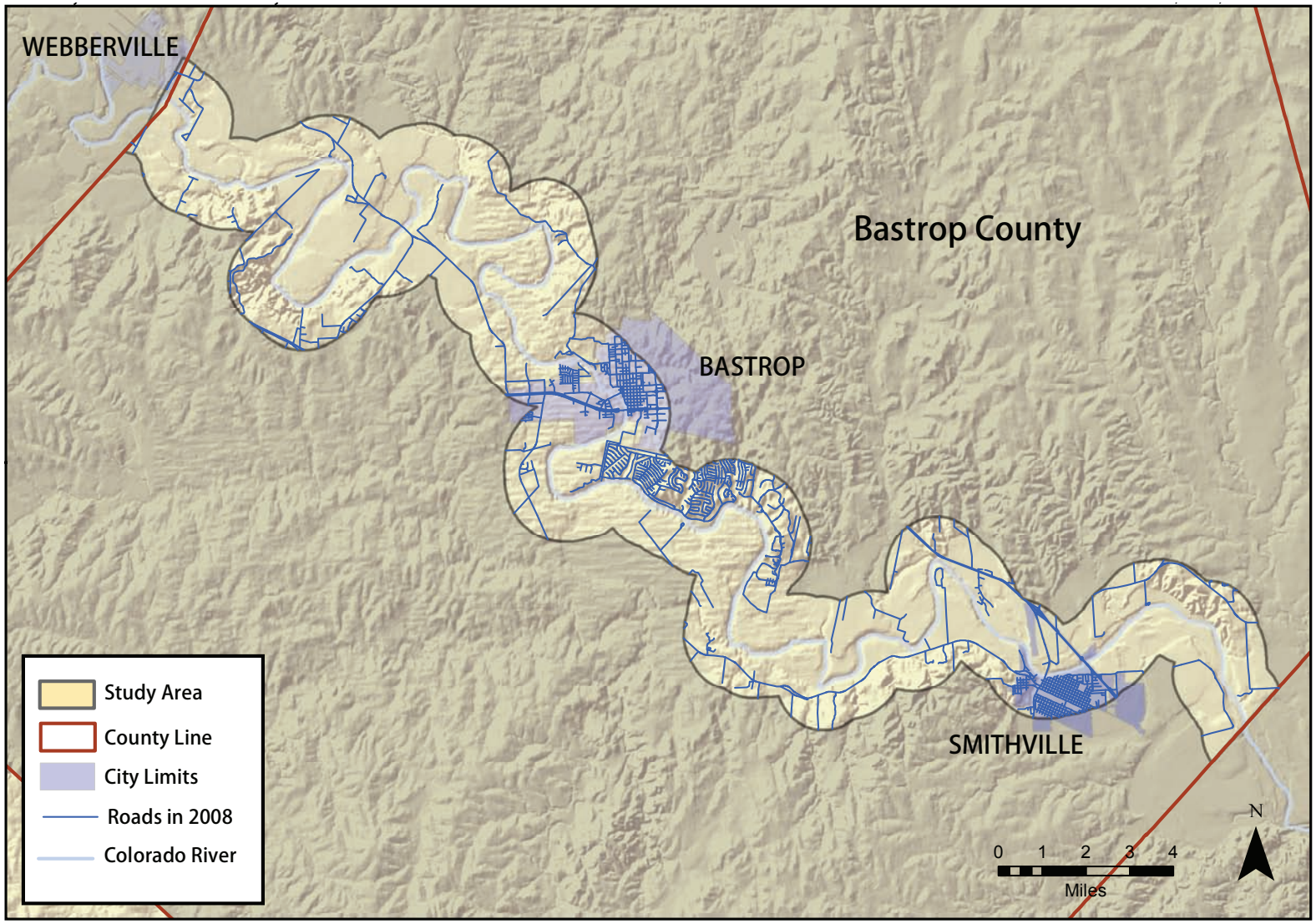

Figure 20: 2008 Roads Within One Mile of the River

Source: CAPCOG,TWDB,UT GIS Server, Texas State Library, Retrieved 4/20/11

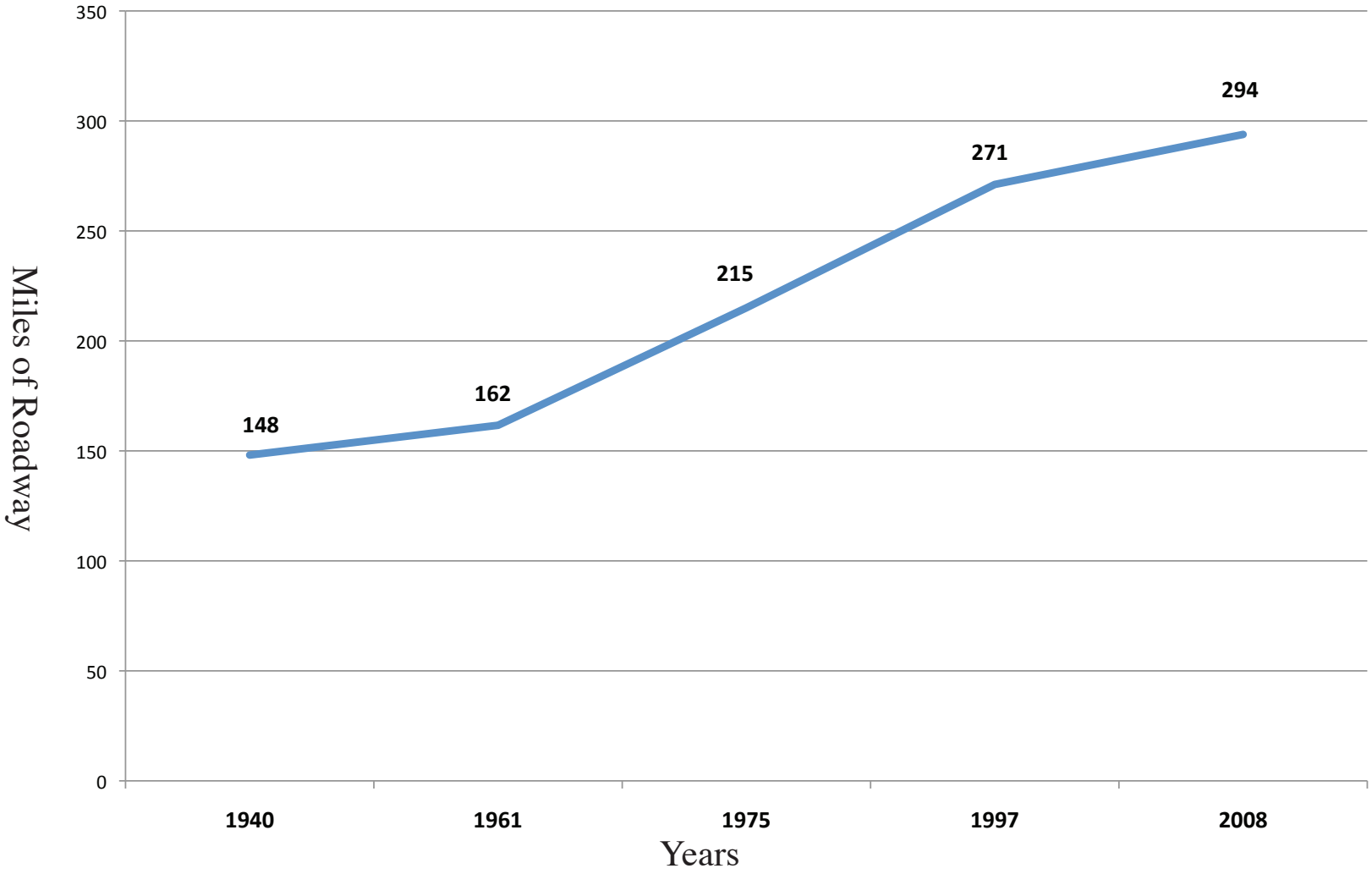

Chart 7: Miles of Roadway within One Mile of the River

LAND USE CHANGE

Changes in land use are presented in Figures 21, 22, 23, and 24. The maps were created by overlaying 2008 GIS maps atop aerial images and systematically worked backwards in time to document the evolution in land uses. For example, the 2008 aerial image shows a parcel with buildings and a parking lot; that same parcel in 1997 and 1975 was a pasture. Therefore the parcel would be identified as developed in 2008, and undeveloped prior to this. The maps reflect only general rural (agricultural or undeveloped) or developed (commercial, residential, or industrial uses) categories. They do not necessarily reflect zoning or subdivision platting, merely what is evident on the aerial images. Figure 21 provides an example of this process centered on the City of Bastrop. The development on the left side of the images between 1975 and 1997 correlates to an expansion of Highway 71 and a boom in big box retail and suburban residential construction.

Reviewing the changes mapped between 1975, 1997 and 2008 paints a striking picture of development in the river corridor. The small clusters of developed lands around Bastrop and Smithville expand virally in the intervening decades. Chart 8 quantifies these maps, and the numbers are telling. Between 1975 and 2008, developed lands tripled from nearly 5,000 acres to nearly 15,000 acres. Conversely the stock of undeveloped rural land declined by this 10,000 acres.

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

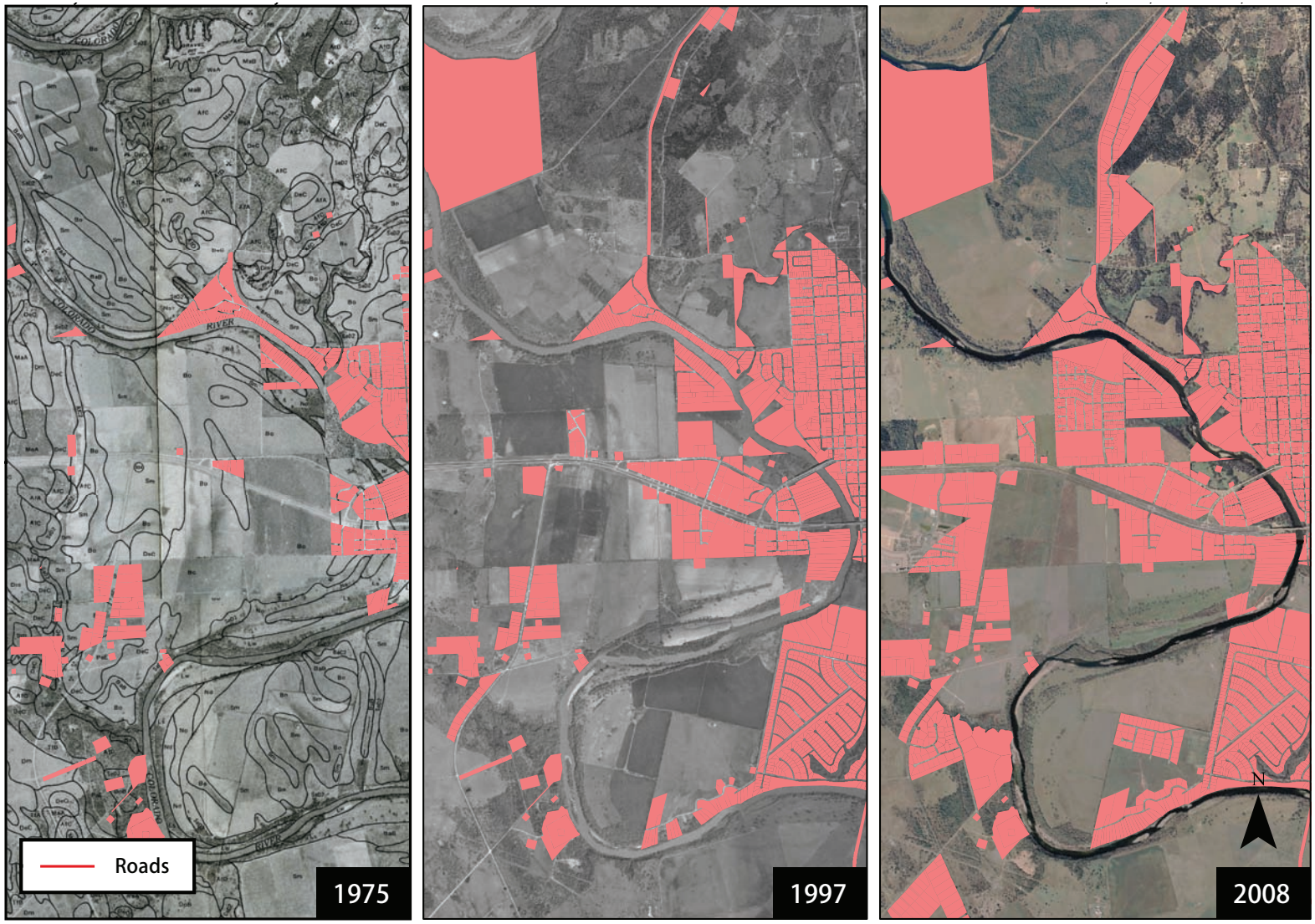

Figure 21: Changing Land Uses

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, USDA SCS, UTGIS Server

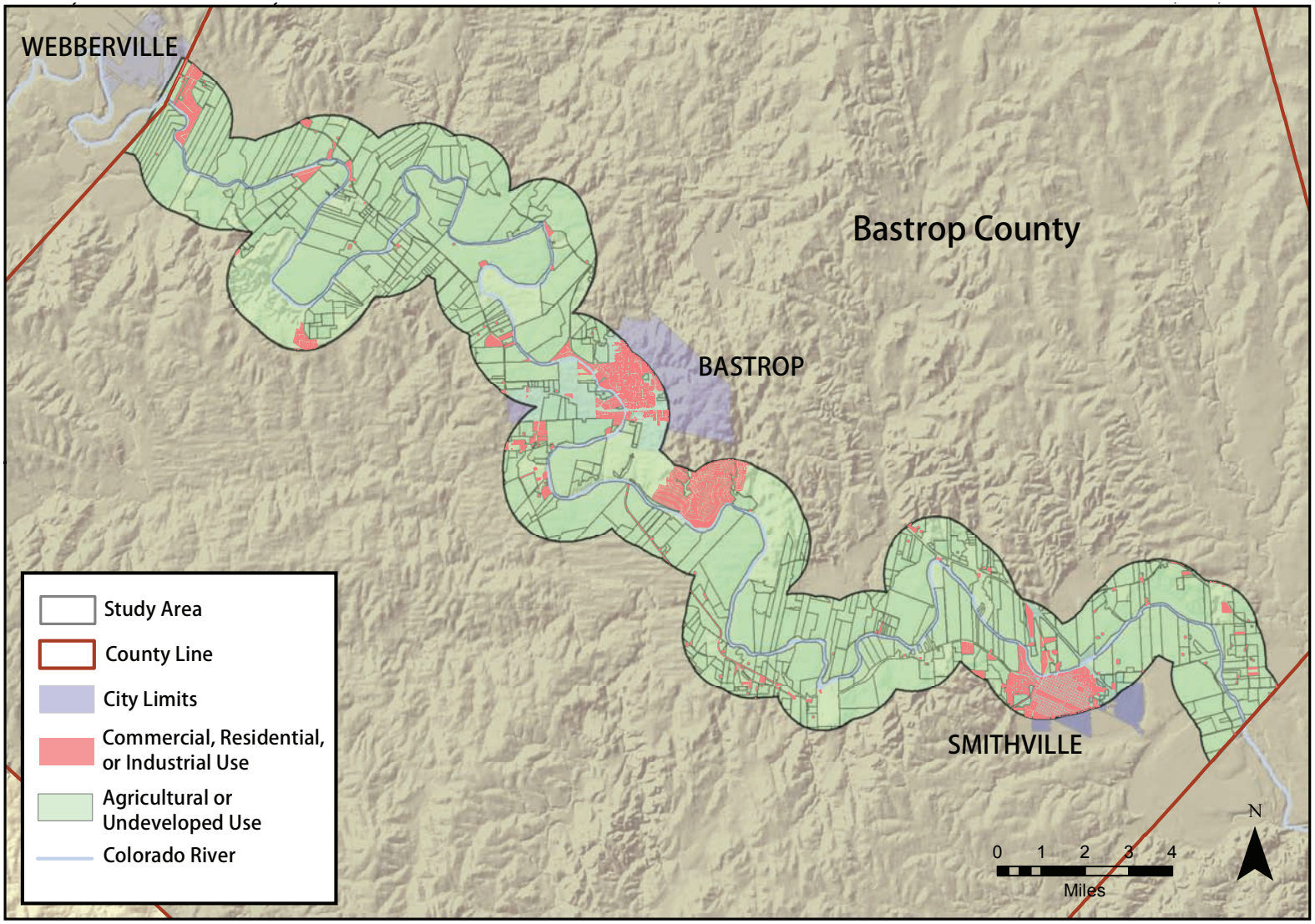

Figure 22: 1975 Land Use

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

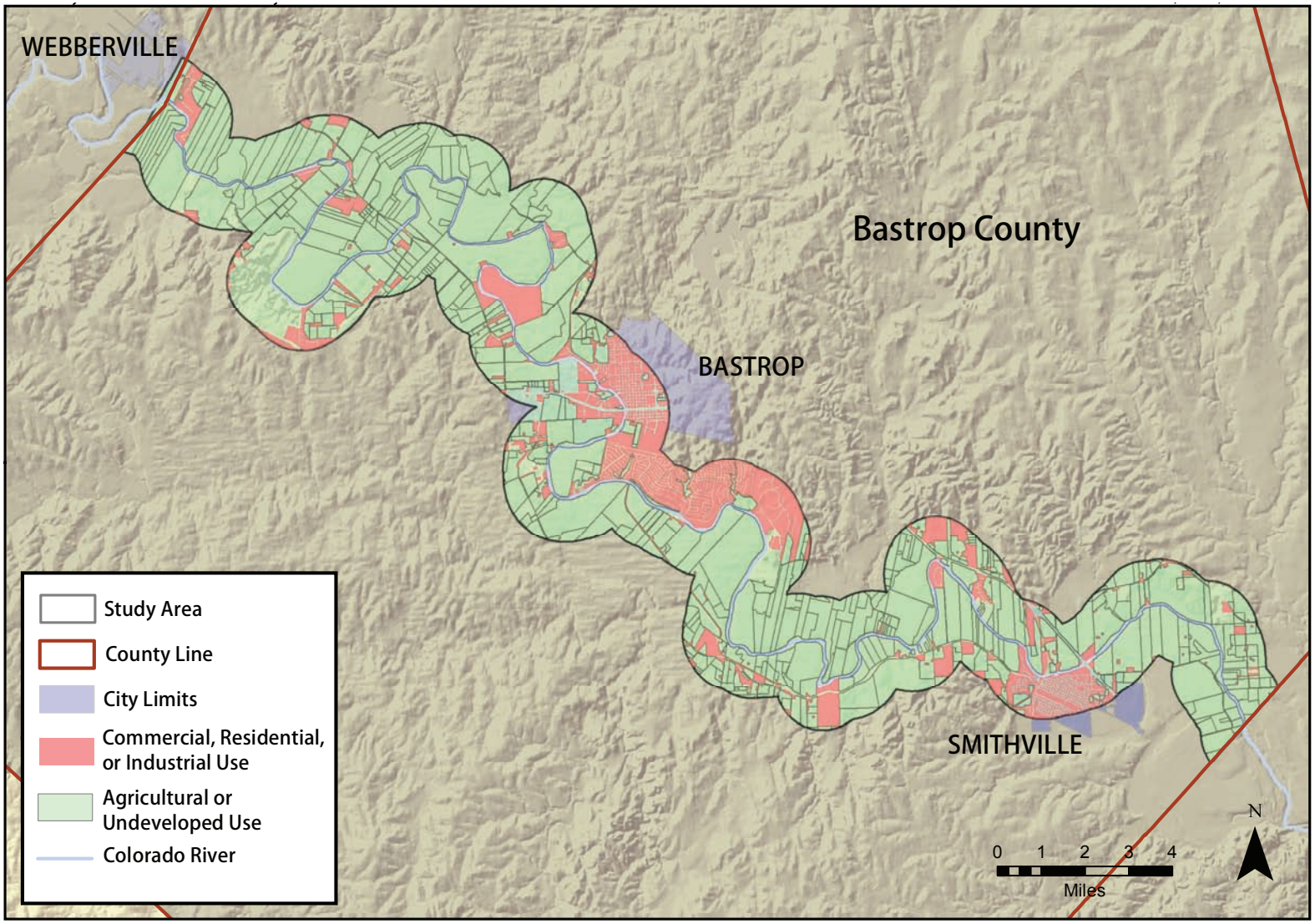

Figure 23: 1997 Land Use

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

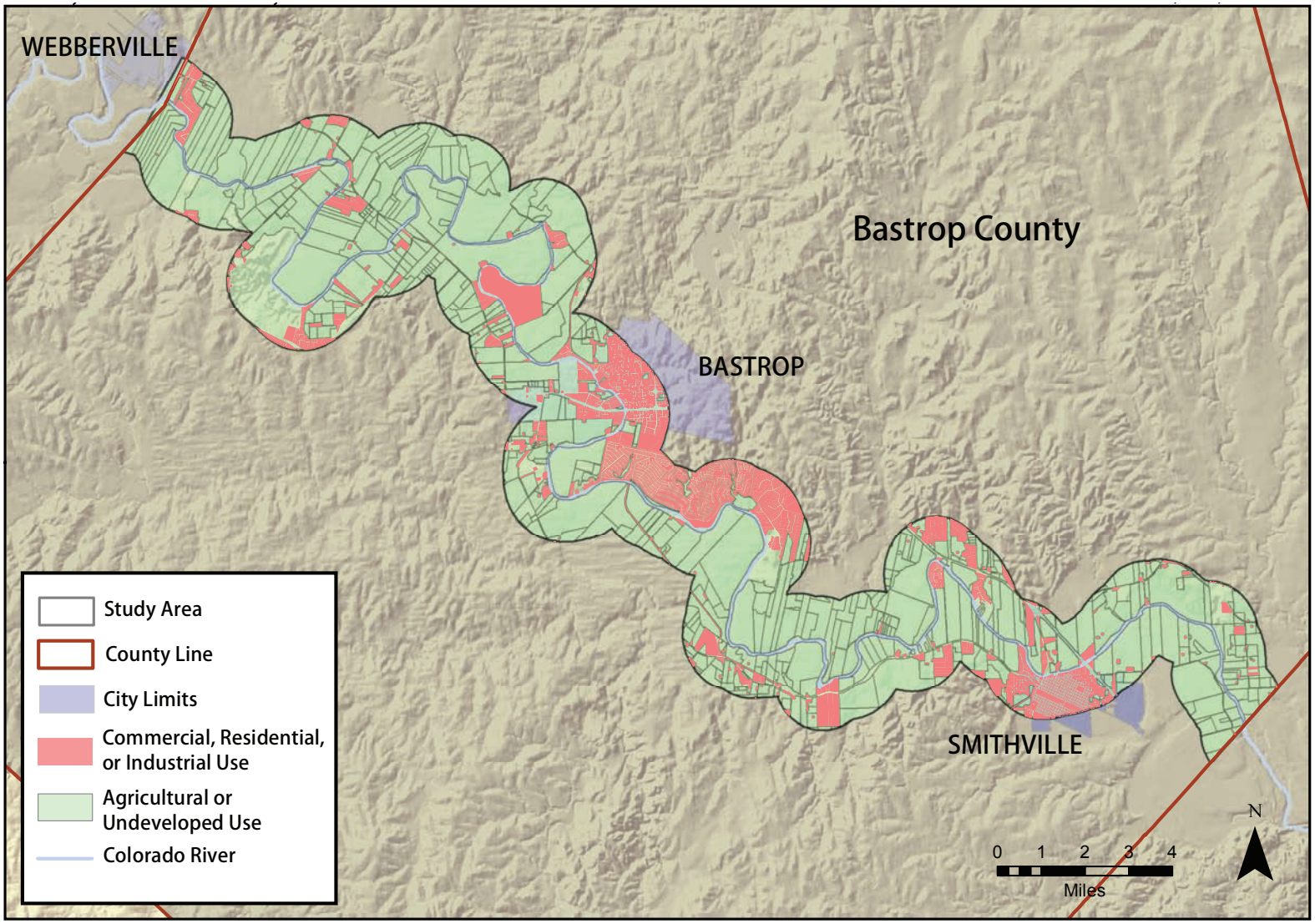

Figure 24: 2008 Land Use

Source: CAPCOG,TWDB,UT GIS Server,USDA SCS, Retrieved 4/20/11

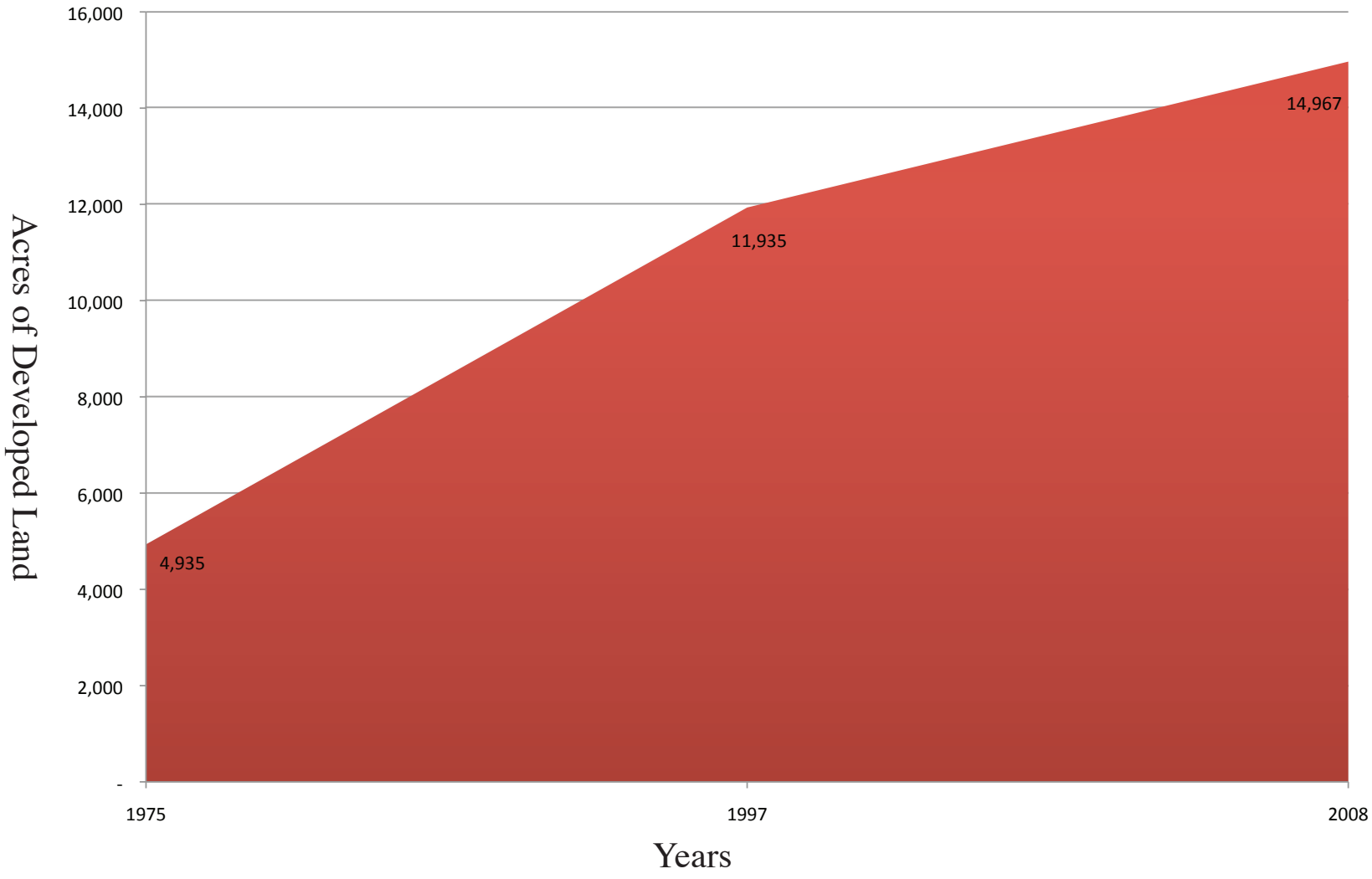

Chart 8: Acres of Developed Land in the Study Area

COMPREHENSIVE ANALYSIS

Reviewing the mapping results in their entirety, some trends are clearly evident. The central hypothesis of this study is that rapid development is changing the landscape of the Colorado River Valley in Bastrop County. This proved to be true to a considerable degree. Between 1975 and 2008 the non-agricultural land uses nearly tripled in area from around 5000 acres to nearly 15,000 acres. Additionally, miles of roadway within the study area increased from nearly 150 miles in 1940 to nearly 300 in 2008. Together this rapid increase of road miles and developed acres point to the degree of change the area has experienced.

My secondary hypothesis was that growth is reducing the area of riparian forest and agricultural lands. After reviewing the maps and area statistics I generated, it appears that my hypothesis was incorrect. While growth is indeed occurring within the river corridor, the riparian forest has increased in the area during the period between 1975 and 2008. Within a 25-foot buffer of the river, the forested area of the buffer has grown from 56 percent in 1975 to 89 percent in 2008. However, due to the small scale of this area, data creation error, or lack of consistency in process may have skewed this. A more accurate measure may be the 100-foot river buffer, where the forested area has grown from 66 percent in 1975 to 86 percent in 2008. This, at first, seems contrary to the general pattern of growth in the area. However, it may be explained by the reduction in agriculture land use and the tendency for development to occur outside of the floodplain.

The second part of the hypotheses was that agriculture land use has declined, replaced by residential, commercial, and industrial activities. The land use and road development mapping statistics support this conclusion. The trends toward reduced tract size and increasing land values also support this conclusion and provide anecdotal evidence of the chipping-away effect of non-agricultural development.

CONCLUSIONS

Population and water-consumption projections point toward a rapid acceleration of the human impacts in Bastrop County over the next fifty years. This influx of people will need access to clean water and the environmental systems services provided by functioning ecosystems. It is therefore critical to establish cultural practices and policy frameworks for maintaining these systems.

Review of the maps, charts, and firsthand observations presented in the preceding sections supports projections of sustained growth in regional population and resource demand in the Bastrop County riparian corridor. This growth has included and will continue to include a mix of aggregate mining, residential, commercial, and industrial development, with commensurate reductions in the land area of agriculture. The patterns of this growth will radiate from population centers including Austin, Bastrop, and Smithville and existing infrastructure such as Highway 71 and Farm to Market Road 969. However, the specific design and layout of new developments and infrastructure have yet to be set in stone. This, then, is a critical phase in which long-term efficiencies, or inefficiencies, will be locked into the land's layout. This is where the push for growing

smart is needed. Through a multi-pronged strategy of education, regulation, and cooperation, a regional strategy could be developed that would lay the foundation of a more energetically, economically, and ecologically conducive land-development pattern. Outlined below is a framework for this strategy.

Chapter 5: Planning for Growth

While the trends illustrated in the mapping process do not force the conclusion that the riparian corridor is at risk or that there is an urgent need to impose limitations on development and agricultural practices, the remainder of this paper assumes that a healthy riparian corridor is valuable and at risk. In order to build, improve, and maintain the corridor, the report suggests an array of available actions.

Through a concerted effort involving the conservation strategies outlined below erosion and pollution can be controlled, habitat can be protected to maintain biodiversity, and an amazing scenic, cultural, recreational, and economic resource cam be maintained.

THE PRECAUTIONARY PRINCIPLE

Conservation is conservative, cautious, and reflective at its core. It involves the application of wisdom to action. Conservation rests on the age-old bedrock of the Precautionary Principle,

> The Precautionary Principle. Environmental problems frequently arise at the cutting edge of human knowledge, areas of vigorous scientific inquiry that may be fraught with uncertainty. Environmental risks in such situations, while not precisely known from a scientific point of view, may represent immense potential for harms…Precautionary approaches counsel taking early policy action to avoid uncertain or poorly understood risks, particularly in situations where the consequences may be catastrophic. (Plater et al. 2004)

The exact extent of development and change that will occur in Bastrop County and the greater Colorado River basin are unknown. However, this lack of precise knowledge

should not inhibit conservation action. While we may not know on which parcel the next major commercial development or infrastructure project will occur, this should not stand in the way of preserving the critical environmental systems services that we all currently enjoy and that ecological health requires. These are vital services provided by the living and nonliving components of a system that has existed in continuous change for millions of years. Humans are a part of this system, but the sheer weight of humanity and the degree of turbulence that technological and cultural change has wrought is outpacing the system's ability to recycle our waste.

The precautionary principle then would have us advance with caution and with eyes wide open. Where we can reduce our footprint, it would behoove us to do so. Even if a good portion of the Bastrop River corridor will eventually be developed more densely, a restrained progression may allow the necessary time for cultural and environmental systems to adapt to meet the needs of each.

Out of the countless possible forms that development could take in the basin, some invariably would have less harmful impacts and would be more economically and energetically efficient. These are the ones we must encourage for the community's benefit. And here is the crux of the problem: the thing that may be best for the human and ecological communities is not necessarily best for the individual property owner.

Especially in Texas, a strong private property rights state with an ethos of individuality, directing private interests within the realm of public good is often difficult. And yet, as awareness grows and an environmental ethic becomes more widespread,

there arises a hope for a future where a broader understanding of membership in a community guides actions.

MUTUAL COERCION MUTUALLY AGREED UPON

In a society or community, we (sometimes grudgingly) accept development controls as a means of fairly taking part in a system that, through common physical infrastructure, such as roads and electricity, and social institutions, such as the legal system and schools, provides the foundation for all of our prosperity. The environmental movement, and our country's legislative reaction to it (e.g. the federal Clean Air Act, Clean Water Act, and state and local laws), illustrate the concept of mutual coercion mutually agreed upon — through limitations on human activities, including development, that we as a people agree are necessary to maintain the clean air and water we require for life. (Plater et al. 2004)

Most people, when faced with the possibility of a factory or airport moving in next-door, will readily embrace this general principle. But the details and strictness of acceptable restraints are much in debate. The following sections delineate a wide menu of devices and strategies that could help to maintain and enhance the environmental systems services while supporting both rural lifestyles and conservative development. Resources to help communities, individuals, and organizations shape the river basin are numerous. Outlined below are potential mechanisms to affect change. It will take a concerted effort from a dedicated community employing many of these tools to affect the scale of change that is needed, but local organizations such as the Austin Bastrop River Corridor

Partnership[2], and Austin Youth River Watch[3] are already engaged in the process. The Central Texas Greenprint for Growth has been developed by the Trust for Public Land, Capitol Area Council of Governments, and Envision Central Texas.[4] This collaborative plan uses GIS to provide information to prioritize and support land use and conservation decisions, including to identify areas of greatest need for conservation and many individuals from anglers to county judges are opening to the need for action, (See Figure 23 for Greenprint designations in the river corridor.)

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[2] This is an informal partnership of stakeholders, including governmental agencies, businesses and citizens, concerned with future development of the Colorado River corridor from Austin to Smithville. The group gathers regularly for an ongoing conversation about their concerns and vision. See http://environmental-stewardship.org/education.aspx., accessed April 18, 2011.

[3] The mission of this organization is to promote "community-based environmental monitoring, awareness and education while inspiring and advancing personal and scholastic achievement . . . ." http://www.ayrw.org website accessed March 15, 2011.

[4] See http://envisioncentraltexas.org/resources/CenTexReport.pdf, accessed April 18, 2011.

Created by Ben Prince 12.5.10 Projection: State Plane Texas Central Source: CAPCOG, TWDB, UTGIS Server

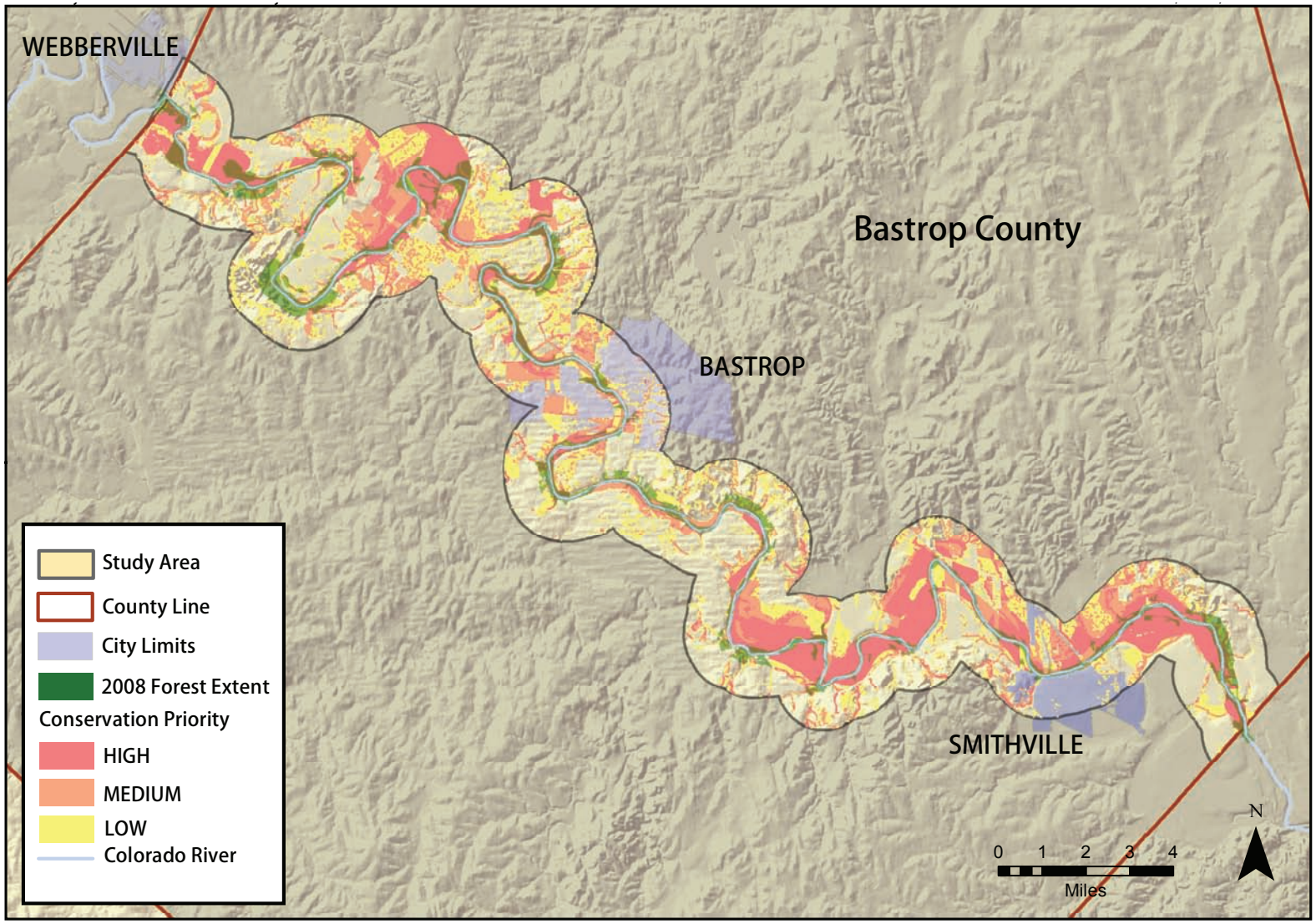

Figure 25: Greenprint Conservation Priority Map

Chapter 6: Strategies for Guiding Change

The strategy for guiding change has been grouped into three parts: education; regulation; and cooperation. While each component may be pursued individually, they have the potential to be much more effective when viewed as a set of synergetic moves working in concert toward the goal of riparian corridor conservation. As the process unfolds, new tools and old strategies should be reviewed for effectiveness and adapted to better facilitate the desired outcome.

EDUCATION

Educating landowners and river users about the important functions of riparian systems and how they can protect the corridor is a critical first step in changing behavior. Such programs have a precedent here in Texas. The *Don't Mess With Texas* anti-littering push is a successful example of a public awareness campaign that changed a common cultural practice (throwing trash from vehicles) for the good of the community. The idea of a river awareness campaign follows this successful model.

Three groups stand out as the logical targets of an educational campaign. The first is landowners in the river corridor — including those who own land fronting the river and those who own land in the immediate vicinity. The owners and the managers of these lands are a vital first line of defense in maintaining and improving riparian habitat. The second group is the river users. The Colorado River and its waters are property of the state, and as such the river is an invaluable public space. Recreational users from birders to Boy Scouts use the river every day of the year. Educating these users will greatly

expand the body of stakeholders and expand this from a localized issue to a regional issue. The third group comprises community leaders, politicians, and business leaders. Talking with them about the short- and long-term benefits of a healthy riparian corridor is a means of going directly to the center of decision-making. Person for person, changing these peoples' minds may be the most important step toward corridor wide changes. Each group has a different set of interests in the river corridor, so it is important to tailor information to each groups' interests.

Landowners: Considering the state's historic focus on private ownership rights, the aim from a community benefit standpoint would be to educate and develop responsible land managers (from residential scale to ranches) living on the land and caring for it under an informed and adaptive set of Best Management Practices. While this aspiration may be lofty, examples abound of people engaging their land in just this way. The book *Farming with the Wild* (Imhoff 2003) provides an overview of farmers and ranchers throughout the country managing land for the long-term health of the ecosystem and their bottom line. Providing working examples of sustainable management practices is an important tool in convincing owners to switch from long-established uses. Protecting the economic viability and supporting a new generation of agriculturalists is central to preserving rural communities. Without these basic economic foundations of education and economics, the temptation to sell one's land to developers may surpass the desire to pass working lands to the next generation. Congress's 2008 Farm Bill, administered by the U.S. Department of Agriculture and detailed later in this report,

includes a number of funding programs aimed at overcoming the short-term financial obstacles to implementing conservation measures.

Recreational users: The Colorado River corridor is ripe with recreational opportunities. Upstream, the Highland Lakes provide entire cities and industries with their livelihood. In Austin, the river is a centerpiece of activities from concerts to sporting events. The river downstream of Austin is just as special, if less utilized. The recreational users of the river include anglers, campers, swimmers, and naturalists. Educating such a disparate group of users is a challenge, but their impacts are more easily addressed. Developing a well-distributed system of river parks with public access, and using the parks as platforms for public education, will help engage this group.

Community leaders: This group is less likely to have direct experiential contact with the river corridor, and that is precisely where the educational campaign must start. Getting these people on the river in a boat is the heart of this strategy. Providing leaders with personal experiences on the river is a direct means of lobbying for regulatory change. Emphasis should be placed on the potential for achieving multiple objectives (environmental, recreational, economic, etc.) simultaneously through river corridor protections.

Techniques for Educating Stakeholders

There are countless ways to disseminate information and raise awareness. This list provides examples of techniques to engage stakeholders. Just as messages should be adapted to specific stakeholders, so too should the means of education.

Educational Workshops

In an effort to broaden awareness of riparian issues and the use of conservation easements (discussed below), organizations such as the Lower Colorado River Authority and the Texas Riparian Association have sponsored educational workshops. Ranging from a few hours to a few days, these sessions bring together experts from various fields to educate landowners, students, government employees, and the general public. These workshops are a powerful tool; they provide detailed, succinct information to a self-selected audience. The workshops also provide a platform for interested people to develop a community, and invariably the information and enthusiasm generated spreads well beyond the event. While the organizational effort can be daunting, the financial resources necessary to sponsor these workshops are minimal. Judging from experience at these workshops, the return on investment is significant. Training citizens to lead their own workshops or creating a formula for program development could expand this sort of educational outreach.

Creating Community

Bringing interested people together to have a conversation about the river corridor is a simple way of increasing knowledge and generating enthusiasm. The community inherently has a collective knowledge that will increase the depth and breadth of knowledge beyond individual activists. Community groups, with limited expenditure of funds, can play a pivotal role in linking people and information. Internet resources abound on every subject from riparian ranching to watershed-scale planning. Working

together, community groups can digest this overwhelming volume of information and distill the vital elements. Two groups that have created a community around river issues are the Texas Riparian Association and the Austin Bastrop River Corridor Partnership. Kevin Anderson of the Center for Environmental Research at Hornsby Bend has held monthly lunchtime lectures for many years. The congenial atmosphere of conversation over lunch has proven a powerful tool in creating a group of concerned citizens.

Experiential Education

Getting people out on the river is the best way of generating appreciation for the corridor. Encouraging people to engage the place through a few hours walking a riverside trail or a week of canoe camping brings the river into the realm of personal connection. Generating this shift, from idea to experience, is the most powerful tool in raising riparian corridor awareness. The river has something to offer everyone, young and old, rich and poor, and of all ethnicities and cultures. The goal is to get people out and enjoying this public asset whether it is a group of elders for a picnic or a flock of teenagers for a paddle. By far the most effective way of generating substantial long-term shifts in awareness and informed decision-making is getting children on the river. These future citizens, leaders, and teachers will set the tone of environmental engagement for generations. Organizations like Austin Youth River Watch are critical to carrying the message forward to the next generation. This program gets teenagers from Austin out on the river on a daily basis, with a goal of monitoring the river's health and engaging the city's youth in constructive hands-on environmental education. Bastrop and other Bastrop

County communities could easily duplicate such an organization. But youth education need not be limited to programs such as this. Riparian education activities can be integrated into classroom projects, Boy Scout canoe trips, or weekend family camping trips. Ways of engaging the river are limited only by access to minimal funds and creativity.

REGULATION

All the existing advantages and disadvantages attributed to regulations and ordinances can be applied to riparian oriented ones as well. That said, few devices are as effective at quickly producing large-scale results as a set of well-formulated rules. Below is a set of regulatory strategies that in part or parcel would contribute significantly to the preservation and reclamation of the river corridor. A holistic regulatory strategy would necessarily require the coordination of many departments and levels of government, each with a role to play.

Discharge Standards

While the United States Environmental Protection Agency (EPA) and Texas Commission on Environmental Quality already set standards for point source discharges, there is room for improvement. Water quality in the Bastrop County reach of the river is monitored by the LCRA at three gauging stations (Utley, Bastrop, and Smithville) for a number of indicators.[5] Taken together, these form the basis of a water quality index of

[5] http://waterquality.lcra.org/

Poor, Fair, Good, or Excellent. For the month of February 2011, the Utley monitoring station reported that

> The Colorado River at Bastrop earned a good score this month. Dissolved oxygen was high enough to sustain a viable fishery. Bacteria levels were low. At this time of year wastewater effluent dominated the flow in the river, therefore nutrients were elevated. When flows increase, conditions should improve. The water temperature was 59°F and transparency was greater than the total depth, two and a half feet.

Monitoring reports such as this provide a quick reference of existing conditions. Additional records of the monitoring reports are available in two-month increments on LCRA's webpage.[6] These reports are a valuable tool for citizen monitoring efforts, but discharges of pollutants into the river is evident even to the casual observer. As discussed in the Threats to the Bastrop County Riparian Corridor section, above**,** a plume of white foamy chemical smelling discharge can be seen on aerial maps coming from the South Austin Regional Water Treatment plant in eastern Travis County. (See Figure 6 for photos) A similar, although smaller, discharge was observed from the Bastrop water treatment facility in the summer of 2010. While this effluent is likely within the permitted standards, it begs the question whether the standards are tough enough. Lobbying for tightened standards is a long and difficult battle, but stakeholders with special expertise and adequate resources may be able to make headway if a detrimental impact could be established.

[6] http://www.lcra.org/water/quality/state.html

In-channel Watering

Cattle ranching is big business in Texas and is ingrained in the state's identity; however, this does not mean that ranching techniques cannot be improved. A significant body of literature exists to encourage the movement of cattle out of rivers and riparian vegetative zones. River access is ubiquitous to ranching as a means of watering and cooling cattle. If access were to be restricted, funding would need to be available for the construction of watering facilities. Additional research should be performed to more precisely identify the impacts of cattle grazing, compacting, and eroding banks, and defecating in the river.

Comprehensive Setback Requirements

Common among riparian planning schemes is a three-tiered zone system corresponding to allowed uses. Such a system permits minimal disturbance in the zone immediately adjacent to the river, increasing allowed activities and impacts in each successive zone away from the river. The logic is straightforward: the closer to the river, the greater the likelihood that the river will be adversely impacted. This type of regulatory scheme could be integrated into a Bastrop County Floodplain Development Ordinance, an LCRA Watershed Ordinance, or a city's Critical Water Quality Protection Ordinance.

Mining Regulations

Currently there are few regulations governing the aggregate (sand and gravel) mining industry. For the sake of the rivers and riparian corridors throughout Texas, the industry needs to be regulated just as other types of mining operations are. It is an unfortunate coincidence that significant, economically-accessible deposits of aggregate underlie the alluvial soils of the riparian corridor of the Colorado River. Industry has long used these deposits as a vital source of the construction material. The process of gravel mining involves clearing the land of vegetation, scraping away the topsoil and excavating the underlying sand and gravel. Generally pits are dug down to, or below, the groundwater table. They are often left open, or filled with demolition rubble, and abandoned.

The rapid development of Central Texas has resulted in expansive development of new mines along the river. The power and wealth of these businesses allow them to buy multi-thousand acre tracts of prime agricultural land in the river corridor and effectively destroy any future agricultural potential. Without restraints, the industry is the single greatest threat to the ecology of the riparian corridor.

Legislation is required on at least two fronts. First and foremost, setback requirements for all operations, roads, and development need to be established. This will reduce the currently common practice of mining so close to the river that floodwaters breach the bank. When this happens, waves of sediment pollution are washed into the river and the channel is drastically altered by shifting gravel. The second major need is standards for the fill and reclamation process of closing a mine. The hydrological and

ecological impacts of these options need to be the subject of a scientific study, with ample opportunity for public input and review.

Development Impact Regulations

The river does not stop and start at county lines. Rather, all downstream users are affected by their upstream counterparts. It therefore behooves citizens of Bastrop County to encourage tighter development impact and pollution discharge controls in the entire contributing basin. Unifying such an area through disparate municipal or even county ordinances would be unwieldy and sporadically enforced. A logical entity to take up such a responsibility is the organization already legislatively empowered to do so, the LCRA. While currently politically unpalatable, there will come a day when a unified watershed protection system for the entire basin, overseen in some way by the LCRA will be required to protect the river.

County Development Regulation

But for its lack of authority, the Bastrop County government would be in an ideal position to set riparian regulations for the river in Bastrop County. Under existing state law, counties have very little authority over development. Accordingly, the development that occurs in the regions of counties not controlled by cities (outside the city limits and their extra-territorial jurisdiction, or ETJs) is done with little regulatory oversight. Although the results range widely, it is often the case that developers take advantage of this lack of oversight and build low quality subdivisions that maximize profit and

externalize problems to the community. Routinely these are net resource drains on local governments due to the infrastructure burden they create. If the Legislature were to grant increased oversight powers to the counties, however unlikely in this political climate, counties could enact conservation measures such as a no-development water quality protection zone similar to those being established by municipalities.

County Floodplain Ordinances

One way counties could take action under their existing regulatory powers is through the adoption of floodplain development ordinances. Floodplain development ordinances, such as one developed through the joint efforts of FEMA, the Texas Colorado River Floodplain Coalition, and LCRA[7] seek to ensure that all future development in areas known to be prone to flooding be as flood resistant as possible. The idea is to limit the damage caused by flooding and resultant insurance liability, of which everyone with insurance bears the burden. An ordinance such as this effectively limits development in the floodplain and floodway, which significantly overlaps the riparian corridor. This would provide the county, which administers the ordinance, with a planning regulatory tool with teeth. The ordinance, in essence, recognizes and protects the flood dissipation properties of a working riparian corridor.

[7] See Flood Dmage Prevention Ordinance 60.3 (d); http://www.twdb.state.tx.us/wrpi/flood/nfip.asp.

Municipal Riparian Buffer

Cities may use their power to regulate development to protect the riparian areas within their jurisdiction. In Texas,

> [w]hen a city's charter expressly provides for it, a city may exercise its police powers, which include reasonable protection of public health, safety or morals. The broad authority that home-rule cities have to protect public health includes water quality protection. Home-rule cities also find authority to protect water quality in the Texas Water Code (section 26.177) and the Texas Local Government Code (section 401.002)[8]

Bastrop and Smithville, the two home-rule cities in Bastrop County located along the river, could enact a protective buffer ordinance under their existing authority akin to the Critical Water Quality Zone Development Ordinance established by the City of Austin (See Appendix D) . Ordinances such as this are in place throughout the country. The City of Napa, California, has an ordinance on riparian habitat areas, prohibiting development within 50 feet of the bank unless a riparian habitat management plan has been created. (See Appendix D)

LCRA Watershed Ordinance

The final regulatory strategy is a bold, broad stroke to protect the river corridor in its entirety. The LCRA, which oversees the river basin in Bastrop County, could enact a watershed ordinance similar in intent to the Highland Lakes Watershed Ordinance it maintains upstream. The Legislature has granted the river authority the power to do so through the LCRA Enabling Act, specifically in Texas Water Code Section 222.004(a),

[8] http://www.ci.austin.tx.us/watershed/ordinances.htm, accessed April 18, 2011.

(d), (e), and (q).[9] Such an ordinance would have huge pushback from some stakeholders, but that is a product of the degree of protection it potentially generates. A riparian ordinance could create a blanket setback, or a tiered buffer zone system of regulation (as discusses earlier.) It could strengthen setbacks or development impact mitigation infrastructure, specifically targeted at nonpoint source pollution. Or, it could facilitate transfer of development rights out of the riparian buffer. Its potential is limited only by the degree of political will and creative thinking. This is a long-term strategy, and the community should begin to discuss and plan for its development, passage, and implementation in the years to come.

COOPERATION

In addition to education and regulation, cooperation among private landowners, nonprofits, and the various branches of government can create a vastly expanded array of conservation possibilities. As a public space, the river represents a corridor that passes through many governmental jurisdictions and abuts over eight hundred individual property parcels in Bastrop County alone. This will invariably create not only conflicts among competing interests but also the chance to create partnerships and bring together stakeholder groups. To facilitate conservation, funding and technical support are available from a number of government and private-sector organizations. Opportunities for interested landowners range from outright sale of their property, to donation of conservation easements, to financial assistance through grants. This trifecta offers

9 See Lower Colorado River Authority Highland Lakes Watershed Ordinance at http://www.lcra.org/library/media/public/docs/water/HighlandLakesWatershedOrdinance.pdf

avenues for land protection to a broad array of landowners. Cumulatively, these tools can contribute to a patchwork protection of the river corridor.

2008 Farm Bill Assistance Programs

Approximately every five years, the U.S. Congress enacts a Farm Bill. Since the mid-1980s Farm Bills have included important funding and technical assistance programs for conservation. The most recent Farm Bill is formally titled the Food, Conservation, and Energy Act of 2008 (H.R. 6124). The current bill includes programs to preserve farmland, restore habitats on farmland, protect wetlands and wildlife habitat, and prevent soil erosion. *Farming with the Wild* (Imhoff 2003). Additional information can be found in the online publication *Conserving Habitat Through the Federal Farm Bill (*Weldon, 2010). Listed below are several of the many 2008 Farm Bill conservation programs.

Conservation Reserve Program (CRP).[10] This is one of a suite of United States Department of Agriculture conservation reserve and wetland reserve programs. Through the CRP program, owners and operators of farmland receive financial assistance in the form of annual rental payments and cost-share assistance to establish long-term resource conserving vegetative cover. Restoring wetlands, establishing riparian buffers, and converting cropland to native grassland are some of the practices supported by the program. Participants enter into ten or fifteen year contracts with the U.S. Department of

[10] For additional information about the eight Farm Bill programs discussed in this section, and their use and applicability in Texas, see the Texas Parks and Wildlife Department website at www.tpwd.state.tx.us/landwater/land/private/farmbill. Questions specific to Bastrop County, and individual parcels of property, may be directed to the District Conservationist, USDA Bastrop Service Center, Bastrop, Texas, phone (512) 321-2489.

Agriculture (USDA). A purpose of the program is to address conservation issues raised at the state or national level.

Continuous Conservation Reserve Program (CCRP). This program focuses on using grasses, trees, and wetlands to protect soil, improve water and air quality, and enhance fish and wildlife habitat through the use of buffers, filter strips, windbreaks, and wildlife corridors. The CCRP focuses on using grasses, trees, and wetlands to protect soil, improve air and water quality and enhance fish and wildlife habitat through the use of buffers, filter strips, windbreaks, and wildlife corridors. As in the CRP program, participants enter into ten or fifteen year contracts with the USDA. They receive an initial payment then annual rental payments plus cost-share assistance on qualifying conservation projects. The sorts of project commonly developed under this program include riparian buffers and filter strips to intercept sediments, pesticides and other pollutants.

Wetlands Reserve Program (WRP). This program funds projects to restore degraded wetlands on agricultural land. A WRP priority is restoration of wetland wildlife habitat. Under the program, the Secretary of Agriculture may purchase permanent easements and fund the full cost of restoring wetlands or purchase long-tem easements and share costs with landowners who agree to restore wetlands.

The Farmland Protection Program (FPP). Formerly the Farm and Ranchland Protection Program, this program's is aim is to protect against non-farm development of productive farmland. Toward this end, it provides funds to states, local governments and certain other entities to help purchase easements.

Grassland Reserve Program (GRP). Along with the FPP, this is an agricultural land preservation program. Through the program, the government assists landowners in restoring grassland and conserving virgin grassland through the mechanisms of long-term rental agreements and easements. Priority is given to expiring CRP land.

Conservation Stewardship Program (CSP). The objective of this program is to encourage a wide range of conservation management practices that address water, soil and wildlife habitat on privately owned cropland and grazing land. Payments compensate landowners for adding, improving or maintaining conservation activities.

Environmental Quality Incentive Program (EQIP). Along with CSP and a few other programs, this is considered a working land conservation program. EQIP provides technical assistance, incentive payments and cost-share payments to crop and livestock producers to assist with conservation and environmental enhancements. A portion of the program's money is reserved for beginning and socially disadvantaged farmers. Money may be used for organic production. A stated purpose is to "promote agricultural production, forest management, and environmental quality as compatible goals."

Wildlife Habitat Incentive Program (WHIP). Through this program, the government shares in costs and provides technical assistance to develop and improve wildlife habitat on private agricultural lands and non-industrial private forestland.[11]

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[11] Sources of information: (1) the website of the U.S. Department of Agriculture accessed on October 8, 2010, at www.ers.usda.gov/FarmBill/2008/Titles/TitleIIConservation.htm and (2) the website of the Texas Parks and Wildlife Department accesses on October 10, 2010, at www.tpwd.state.tx.us.landwater/land/private/farmbill/ccrp/.

Land Trusts and Conservation Easements

"A land trust is a local, state, or regional nonprofit conservation organization involved in protecting land for its natural, recreational, scenic, historic, open space or educational value."[12] In pursuit of their stewardship interests, land trusts often use conservation easements, a legal tool whereby they, in a very specific sense, share ownership and control of parcels of land with the persons normally thought of as the owners. Conservation easements are a means of dividing the components of a piece of land, and donating or selling the right to develop to a not-for-profit organization such as a land trust or a government entity.

The owner gains certain advantages or benefits by conferring an easement: the taxable base value of the property and therefore the property taxes are reduced; the land is protected in perpetuity from specified development; and, there can be a certain peace of mind or sense of satisfaction that may arise from knowing that the property forever will remain in a rural, agricultural, or wildlife habitat use. There are, however, potential disadvantages to conservation easements. Such easements are permanent; land trusts hold and enforce them. Once placed in a land trust, the particular property right is owned by the land trust and the terms of the easement are locked in. The landowner, and all future owners, are bound in a partnership with the easement holder and must abide by the terms of the easement. This may, in turn, diminish the resale vale of the property (or it may increase it) or limit future, as yet unforeseen, uses.

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[12] Definition found at http://www.texaslandtrustcouncil.org.

The Nature Conservancy and the Trust for Public Lands are two nationally known not-for-profit land trust organization. Most land trusts, however, are local or statewide organizations established to hold easements in a targeted area or type of landscape. An example is the Hill Country Conservancy of Central Texas. In Bastrop County, the Pines and Prairies Land Trust holds easements. Headquartered just outside of the city of Bastrop, it is well situated to oversee conservation easements along the Colorado River in Bastrop County.

Conservation easements can be powerful tools because they stretch valuable conservation funds and allow owners to continue to live on their lands and continue their agricultural operations while ensuring that the lands will forever remain open. Generally speaking, land trusts do not solicit conservation easements. Rather, they engage owners who come to them expressing an interest in selling or donating an easement. The federal Farm Bill includes programs that can be used to help fund the easement development process.

State Property Tax Incentive

Texas encourages certain wildlife management activities by providing for property owners to qualify their rural land as agricultural land for property tax purposes. For land to be included in this preferentially (i.e. substantially reduced) taxed category, the owner must perform wildlife management activities such as habitat control, erosion

control and making census counts to determine population. The land must be used primarily for wildlife management purposed and meet other stringent requirements.[13]

Land Acquisition

Fee simple purchase is the most straightforward means of conserving valuable land. A governmental entity, such as the City of Bastrop, the Lower Colorado River Authority, or Texas Parks and Wildlife, may have funds to buy land from a willing seller (or funds to manage donated land). The advantage land acquisition is that a single entity will have full ownership and the ability to establish the limits of its use (e.g. open to the public or closed for wildlife habitat). The limitations are the difficulty of finding sellers or donors in high priority areas, higher initial costs of purchase, and the continued expense of management.

If the actions of various governmental bodies were coordinated, a patchwork of public river-access points and preserves could be developed in the river corridor. This would allow a broader segment of the public to use the river and create a stepping stone pattern of habitat for wildlife. A foundation for this process already has been laid. The LCRA has created educational material and signage for the Colorado River Trail. However, this paddling trail from Austin to the Gulf of Mexico is only partially complete. Additional access points, camping facilities, and a more robust public education campaign could greatly enhance this intriguing idea. In addition, the Central Texas Greenprint for Growth has identified areas of high conservation priority along the river.

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[13] See www.tpwd.state.tx.us/landwater/land/private/agricultural_land, accessed April 18, 2011.

The potential of applying the Greenprint to the acquisition goals of the river trail could multiply the effectiveness of work and financial outlays.

Chapter 7: The First Step

STAKEHOLDER IDENTIFICATION PROCESS

The first step toward taking meaningful action to protect the riparian corridor in Bastrop County is to identify stakeholders. The most obvious and natural (but not yet organized) group is those who own property along the Colorado River in Bastrop County. Having a contact list of riverfront stakeholders is essential to a large-scale planning initiative. A property owner contact list will enable engagement with these stakeholders. The owners can be invited, via mail-outs, to community forums. In that setting, they can begin to discuss their observations and concerns, listen to various experts, and establish tentative near-term and long-term objectives. From there, the owners can identify other collaborative partners, including those who already are engaged in riparian issues in the region, e.g. the Austin-Bastrop River Corridor Partnership and other community groups and government officials.

In an effort to begin the plan development stage, I obtained owner information as follows using GIS techniques. The property shape files and ID numbers were obtained from the online CAPCOG Information Clearinghouse. In GIS, a 25-foot buffer off the riverbanks was applied to the property shape file layer. The resulting selected properties were then isolated as representing riverfront properties. Property owner information, however, was not included in the attribute table. To get this information, telephone requests and, ultimately, a visit to the office of the Bastrop Central Appraisal District

were necessary. When this public information was obtained, it was in an unreadable .txt format. To use this in GIS, it was first opened in Excel. Then, using the data delimited function, the .txt information was sorted into individual cells. Next, in GIS the riverfront property attribute table was joined to the Excel property owner list. The result was a useful geolocated list of property owners and contact addresses. (see Figure 27)

Created by Ben Prince 4.20.11 Projection: State Plane Texas Central Source: Google Maps, CAPCOG, Bastrop County Central Apprasil Discrict

R110710	DOUBLE EAGLE ESTATES LTD	4705 SPICEWOOD SPRINGS RD	AUSTIN	TX	78759
R110801	THE W & E HIGGINS LTD	110 OLD AUSTIN HWY	BASTROP	TX	78602
R111674	MOORE, BILLY RAY	451 FM 969	BASTROP	TX	78602
R112508	HOFFEREK, MARK W & STEPHANIE L	453 FM 153	SMITHVILLE	TX	78957
R11387	SMITH, JUDITH GALE	2514 FM 969	ELGIN	TX	78621
R11390	HUMPHRIES, LONNIE, Jr	C/O JENKINS HUMPHRIES, SR.	ELGIN	TX	78621
R11393	HUMPHRIES, ROY LEE	C/O JENKINS HUMPHRIES, SR	ELGIN	TX	78621
R11618	HARDY, CAROL J	164 MEADOWS DR	ELGIN	TX	78621
R11618	HARDY, CAROL J	164 MEADOWS DR	ELGIN	TX	78621
R11622	THURSTON, JUDY	DONALD R GOLDSTEIN	BASTROP	TX	78602
R11626	GREEN, RICHARD A & SANDRA E	392 WATEREDGE TERRACE	ELGIN	TX	78621
R11628	R HUNTER GROUP LLC	219 N COMANCHE	SAN MARCOS	TX	78666

Figure 27: Sample River Landowner Map

LOOKING AHEAD

The next pages in the movement to protect the Colorado River and its riparian corridor are as yet unwritten. What will befall this beautiful, verdant land is uncertain. The pressures to develop this part of central Texas are undeniable, and the quick profits to be had are tempting, but there are many reasons to actively work to maintain and reclaim the river and its environs for the good of the community and the ecological systems at work. This paper is a partial story — an outline of what was, what is, and the means of stewarding what may be. In the end, the fate of the river rests in the hands of those willing to work tirelessly for conservation of the river corridor, and it is my hope that this information will aid that cause.

Appendices

APPENDIX A: DATA CREATION AND ANALYSIS

Analysis Process

1. Preliminary Data Management
2. Identifying the extent of the historic Colorado River riparian forest in Bastrop County
3. Compiling Aerial photographs to identify changes (1940, 1961, 1975, 1997, 2008)
4. Documenting Road Network Growth
5. Documenting Changes in Land Use
6. Greenprint for Growth

1. Preliminary Data Management

a. Files were collected from various Internet sources

b. Files were projected into a common projection system (Texas Central State Plane NAD83 (feet).

2. Identifying the extent of the historic Colorado River riparian forest in Bastrop County

The historical riparian forest was identified by selecting by attribute from the CAPCOG Soils file (*soils.shp).* The selection was developed by adding together The NRCS 'hydric' soils + the 1907 Alluvial area soils + the 1975 USDA SCS map of Soil Associations +any additional areas in the 2010 FEMA 100-year floodplain not covered by these areas.

NRCS 'hydric' soils

Lw: Gad loamy fine sand, 0 to 1 percent slopes, frequently flooded

Sm: Smithville fine sandy loam, 0 to 1 percent slopes

SeD2: Shep clay loam, 3 to 8 percent slopes, eroded

Sg: Ships silty clay, 0 to 1 percent slopes, occasionally flooded

1907 Alluvial area soils

BSl: Bastrop Silt Loam

BS: Bastrop Fine Sandy Loam

BC: Bastrop Clay

BI: Bastrop Sandy Loam

M: Meadow

On 1977 and later maps Bastrop soils are BaA, BaB, BaC2

1977 SCS Soil Associations

Bosque-Smithville-Norwood: Nearly Level soils that have a loamy surface layer and permeable lower layers; on low terraces and flood plains.

Bo: Bosque

Sm: Smithville

Nd,No: Norwood

Combined soils are then

BaA, BaB, BaC2, Bo, Lw, Nd, No, SeD2, Sg, & Sm

Using the 'Select by Attribute' function the following expression was written:

"MUSYM" = ' BaA ' OR "MUSYM" = 'BaB' OR "MUSYM" = 'BaC2' OR "MUSYM" = 'Bo' OR "MUSYM" = 'Lw' OR "MUSYM" = 'Nd' OR "MUSYM" = 'No' OR "MUSYM" = 'SeD2' OR "MUSYM" = 'Sg' OR "MUSYM" = 'Sm'

The resulting selection was then added to the 2010 FEMA 100 year floodplain shape file through the "Union" tool

The 2010 FEMA 100 year floodplain

The FEMA 100-year floodplain is the flood event that has a 1% chance of being equaled or exceeded in any single year.

When these were compiled, a map of the potential historical forested riparian area began to take shape, but there were some conspicuous omissions. Some soil types lying just above the flood plain, but surrounded on all sides by probable forest, stood out as areas that were likely forested. Therefore I made the assumption that anything completely enclosed in this polygon should also be included in the potential historical forested riparian area. The resulting map (historic_riparian.shp) identifies what I believe to be the pre-Anglo riparian forest of the Colorado River.

3. Compiling aerial photographs to identify changes (1940, 1961, 1975, 1997, 2008)

One of the central tasks of my analysis was to identify changes in the landscape over time. To do this I acquired aerial images from 1975, 1997, and 2008 and county highway maps from 1940 and 1961. The 1997 and 2008 aerial images were already created and projected as raster files. The other three required processing to be usable.

A. Digitizing maps

1. 1975 paper map was scanned and cropped

2. It was overlain on projected 2008 map and common points identified

3. Using the Geolocate tools the 1975 jpeg images were spatially located and projected

4. This process was repeated for the predigitized 1961 and 1940 highway maps

B. Creating river buffer study areas

1. *(River_Banks.shp)* was created by overlaying a blank projected line shape file over the county boundary and raster files for the 2008 aerials.
2. Using the editor function, the north bank and then the south bank of the river were traced. During the outlining, a consistent map scale of 1:3500ft was maintained.
3. *(river_bank.shp)* was made as lines for both sides, but to perform the buffering the files had to be divided into *(Left_river_bank.shp)* and *(right_ river_bank.shp)* shape files to work properly. The buffering tool allows for specification of which side of the line to buffer off of, but I wanted to buffer off the left side of the left bank and the right side of the right bank and therefore needed two separate files at this point. After the files were made the buffering analysis tool was used at five intervals for each side. This produced a 25 ft.,100 ft., 250 ft., 500 ft., and 1000 ft. buffer corridor down the length of each bank of the river in Bastrop County. The right and left-hand buffers were recombined by cutting and pasting, and the files were saved as: *(1Mile_river_buffer.shp, 1000ft_river_buffer.shp , 500ft_river_buffer.shp , 250ft_river_buffer.shp , 100ft_river buffer.shp , and 25ft_river_buffer.shp)*
4. Once the buffers were created there were some places where the adjoining polygons need some editing to bring them squarely in line.

C. Identifying the Riparian Forest

1. The raster files for the 1975 aerials were added *(1975_aireals.shp)*

2. A polygon shape file (*1975_riparian_forest.shp)* was created in ArcCatalogue and added to arc map

3. A 1000 foot buffer file (*1000ft_river_buffer.shp)* was added

4. Using the Editor function, a polygon trace of the riparian forest was made over the aerial map within the 1000ft buffer

5. This process was repeated for 1997 (*1997_riparian_forest.shp) and 2008 (2008_riparian_forest.shp)*

6. The (*1000ft_river_buffer.shp , 500ft_river_buffer.shp , 250ft_river_buffer.shp , 100ft_river buffer.shp , and 25ft_river_buffer.shp)* files were added and the (*1975_riparian_forest.shp,1997_riparian_forest.shp, & 2008_riparian_forest.shp)* were each clipped to these extents. This produced 15 shape files that represented the riparian forest in a given year within a given buffer distance of the river. In the attribute table a new 'RFarea' field was created and the geometry was calculated. From this, statistics about percentage cover could be determined.

D. Riparian Forest within the 100 Year Floodplain and 1000ft River Buffer

1. The riparian forest files *(1975_RiparianForest_1000ft.shp, 1997_RiparianForest_1000ft.shp, 2008_RiparianForest_1000ft.shp)* that had been previously clipped to the (*1000ft_river_buffer.shp)* and the *(100year_flood.shp)* were added to a map.

2. The *(1975_RiparianForest_1000ft.shp, 1997_RiparianForest_1000ft.shp, 2008_RiparianForest_1000ft.shp)* were clipped to the extent *of (100year_flood.shp)*. To these new files *(1975_RiparianForest_1000ft_flood.shp, 1997_RiparianForest_1000ft_flood.shp, 2008_RiparianForest_1000ft_flood.shp)* a new 'RFareaFlood' field was created and the geometry was calculated. From this statistics about percentage cover could be determined.

4. Documenting Road Network Growth

1. The raster base map files for 1940, 1961, 1975, 1997, and 2008 and the 2008 CAPCOG road centerline files were added to a map

2. A copy of the road line shape file was created *(1997_roads.shp)*

3. The *(1Mile_river_buffer.shp)* was added to deleniate the extent of the study area

4. The *(1997_roads.shp)* was clipped to the *(1Mile_river_buffer.shp)* extent

5. Using the Editor function the 2008Roads copy file was changed to reflect the roads present in 1997

6. This process was repeated sequentially backwards from the 1997 roads back to the 1940s roads. This created (1940_roads.shp, *1961_roads.shp,* 1975_roads.shp &1997_roads.shp)

5. Documenting Changes in Land Use

1. The raster base map files for 1975, 1997, and 2008 and the 2008 CAPCOG parcels, one mile buffer files were added to a map

2. The parcels file was clipped to the one mile buffer extent

3. In the attribute table under the 'AgLand' field a selection for 'Y' was made and then one for 'N' or '*empty*'. The results were saved as two separate shape files. One for agricultural lands and one for non-agricultural lands.

4. A copy of the non-Ag parcels shape file was created *(1997_nonag.shp)* and overlain on the 1997 map. Using the Editor function the file was changed to reflect the land use present in 1997.

5. This was repeated for 1975.

6. Greenprint for Growth

1. The one mile buffer and Greenprint files were added to a map.

2. The Greenprint file was clipped to the 1 mile buffer extent.

APPENDIX B: SOURCES OF ERROR

Error occurred at each step of this study. In an attempt to maintain the highest level of precision and accuracy, I reflected upon where this error might occur and how I might minimize it. Areas of identified error include:

Base Data Error or lack of precision. The data produced by my analysis could only be as precise as the base data it started with.

New Data Creation Error. Working from the base data, any new data will inherently be less precise and accurate, as small omissions or inclusions will slowly chip away at edges of my data quality over the course of the creation process

Analysis Error or Logic Error. Making assumptions about causes and effects and the way in which data is analyzed may produce non-sequitur and other logic errors that stem, not from data or user, but from the presumptions of the modeler.

User interface Error. This may stem from misapplication or misunderstanding of the study. Error occurs at all stages and this would be the transmission stage between the creator and the public. It is often fraught with miscommunications.

If this process were repeated, error could be reduced by:

Procuring higher resolution aerial images. These are available through (TINRIS) and date back to the 1940's in roughly ten year increments. A much more complete and precise study could be performed with this base data; however it is expensive and therefore out of reach for this project.

Procuring aerial images from multiple times of the year. The clarity of where tree canopy starts and stops could be enhanced by reviewing aerial images from different seasons of the year. It is believed that the canopy might be most readily identifiable in the summer, when leaves are full and grass has faded in color. This would need to be investigated.

Working at a smaller map scale. With higher resolution aerial images and more time, it would be reasonable to work at a much smaller scale to eliminate the incremental error that occurs at the margins when determining what to include in the riparian forest.

Having my work reviewed by others with knowledge in the field. This could address the Analysis and Logic Errors, and help to streamline the document presentation and public engagement aspects.

APPENDIX C: RIPARIAN LITERATURE SURVEY

Definitions of Riparian Areas or Zones.

(Some synonyms and closely related terms are riparian buffer zone, riparian vegetation, riparian buffer ecosystem, vegetated riparian buffer, vegetated filter strip, river watershed, riparian corridor, riparian ecosystem, river corridor, floodplain, stream bank setback, setback from high water mark.)

Texas Parks and Wildlife publication[14]	Riparian areas are "the margins of streams, rivers and intermittent draws, where vegetation is strongly influenced by the presence of water."
Austin-Bastrop River Corridor Partnership publication coordinated by the National Park Service RTCA/LCRA[15]	Riparian zone is the "ecological term for waterway margins, which includes river bottomlands." Quotes from R.L. Smith's Ecology and Field Biology, 3rd ed., Harper and Row, New York, 1980, which describes a riparian ecosystem as a "halfway world between terrestrial and aquatic ecosystems that exhibit some characteristics of each."
Southeast Watershed Forum[16]	The riparian zone is "[r]ich vegetation growing along the edges of a stream" and a buffer that creates "a transition area between water and land that allows for habitat corridors as well as the natural, meandering curves in a river or stream, slowing the speed of water and stabilizing stream banks."

[14] Wagner, Matt (technical guidance biologist), Texas Parks & Wildlife Department, Managing Riparian Habitats for Wildlife, http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_br_w7000_0306.pdf.
[15] Discovering the Colorado: A Vision for the Austin-Bastrop River Corridor, especially page 23.
[16] Riparian Buffer Zones, publication found online on June 10, 2010 at www.watershed-assistance.net/resources/files/SEWF_WetlandFactsheet_RiparianBuffer.pdf

NRCS Planning and Design Manual[17]	A riparian forest buffer along a stream or river is "an area of trees, usually accompanied by shrubs and other vegetation."
Alliance for the Chesapeake Bay[18]	A riparian corridor is "a perennial or intermittent body of water, its lower and upper banks, and the vegetation that stabilizes its slopes. It includes the channel plus an adjoining strip of the floodplain, usually 100 feet on each side of the channel."
U.S. Environmental Protection Agency[19]	Defined operationally, riparian buffers are the zone of vegetation adjacent to streams, rivers, creeks, and wetlands.
U.S. Department of Agriculture[20]	"A riparian buffer is a band of dense vegetation (grasses, sedges, forbs, shrubs and trees) adjacent to creeks and rivers."
U.S. Department of Agriculture Natural Resource Conservation Service[21]	Riparian areas are "ecosystems that occur along watercourses or water bodies. They are different from surrounding lands because of unique soil and plant characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecosystems occupy the transitional area between the terrestrial (dry) and aquatic (wet) ecosystems."
Cows and Fish Program of Lethbridge, Alberta, Canada[22]	**"Clue 1**: Lots of **water** is present, seasonally or regularly and that water is either on the surface or it's close to the surface." **"Clue 2: Vegetation** is present that

[17] Riparian Buffer Preservation, found online June 15, 2010 at www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf.
[18] Riparian Buffer Preservation, found online June 15, 2010 at www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf.
[19] Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. Pg. 1. EPA/600/R-05/118 (October 2005); found online June 15, 2010 at www.epa.gov/nrmrl/pubs/600R05118/600R05118.pdf.
[20] USDA CCRP Program Riparian Buffers: http://www.google.com/search?hl=en&source=hp&q=Riparian+Buffers+General+Information+on+USDA+-+CCRP+Program+in+Texas+&aq=f&aqi=m1&aql=&oq=&gs_rfai=C65-NJcgeTKrIF4LygwTmx-njDAAAAKoEBU_QYSIM
[21] found online June 19, 2010, at http://www.mt.nrcs.usda.gov/technical/ecs/water/setbacks/riparian.html.

	responds to, requires and survives in abundant water." **"Clue 3: Soils** have been modified by abundant water (as in high water tables), stream or lake processes (like sediment deposition) and lush, productive vegetation."

[22] L. Fitch, & N. Ambrose, Cows and Fish Program; Riparian Areas, A User's Guide to Health; found online at xx (June 15, 2010).

Benefits from a Riparian Zone

Texas Parks and Wildlife publication[23]	These areas "are some of the most productive [habitats] for native wildlife" in Texas."
Austin-Bastrop River Corridor Partnership publication coordinated by the National Park Service RTCA/LCRA[24]	The riparian ecosystem is a buffer between the river and the uplands that provides hydrological, biological and ecological services.
Southeast Watershed Forum[25]	It controls erosion and sedimentation, serves as a filter that prevents water pollution, provides species habitat, absorbs floodwaters and provides shade that reduces temperatures.
NRCS Planning and Design Manual[26]	Its purposes are to reduce pollution and erosion, provide food, habitat and thermal protection for fish and wildlife, slow and filter nutrients and sediments from storm water, stabilize the stream banks, provide species habitat.
Alliance for the Chesapeake Bay[27]	A riparian corridor filters pollution, provides habitat, offers cover and shade, and protects the waterway from erosion and sedimentation.
U.S. Environmental Protection Agency[28]	These vegetated zones or regions adjacent to streams "are thought to be effective at intercepting and controlling nitrogen loads entering water bodies.
U.S. Department of Agriculture[29]	"A healthy riparian buffer will help protect the banks, dissipate the energy of

[23] Wagner, Matt (technical guidance biologist), Texas Parks & Wildlife Department, Managing Riparian Habitats for Wildlife. http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_br_w7000_0306.pdf

[24] Discovering the Colorado: A Vision for the Austin-Bastrop River Corridor, p 23.

[25] Riparian Buffer Zones, publication found online on June 10, 2010 at www.watershed-assistance.net/resources/files/SEWF_WetlandFactsheet_RiparianBuffer.pdf.

[26] Riparian Buffer Preservation, found online June 15, 2010 at www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf.

[27] Riparian Buffer Preservation, found online June 15, 2010 at www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf.

[28] Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. Pg. 1. EPA/600/R-05/118 (October 2005); found online June 15, 2010 at www.epa.gov/nrmrl/pubs/600R05118/600R05118.pdf.

	floodwater, trap sediment, utilize excess nutrients, improve water quality, recharge ground water, sustain base flow and enhance fish and wildlife habitat."
U.S. Department of Agriculture Natural Resource Conservation Service[30]	The importance of riparian areas is mostly due to their spatial relationship to the landscape." It is "long and narrow in relation to other landscape features . . .[and] provides a great many transition zones. The transition zones are the points at which dry and wet ecosystems interface and are the sites of important exchanges of material and energy in the landscape." Riparian areas are valuable because they serve as wildlife habitat, flood water storage, ground water recharge areas, and water quality protection. They are important for flood control and hydrologic function, including water quality, water quantity and timing.
The Red River Resource Conservation and Development (RC&D) Council and the Red River Regional Council (RRRC)	Recent research has established that healthy riparian corridors provide significant benefits to a watershed including: • Filter and store sediment, nutrients, pesticides, and metals from upland surface and groundwater through infiltration, uptake, and transformation. • Control the hydrodynamic interaction of the stream with the adjacent uplands, stabilizing stream

[29] Riparian Buffer Zones, publication found online on June 10, 2010, at www.watershed-assistance.net/resources/files/SEWF_WetlandFactsheet_RiparianBuffer.pdf.
[30] found online June 19, 2010, at http://www.mt.nrcs.usda.gov/technical/ecs/water/setbacks/riparian.html.

	banks, moderating flood discharges, and improving groundwater recharge. • Support high biological diversity and productivity of vegetation, mammals, birds, and fish.
Cows and Fish Program of Lethbridge, Alberta, Canada[31]	"Some examples of these functions include maintenance of biodiversity (building habitat), creation of primary productivity (forage, shelter) and water quality improvement (filtering and buffering water)." **1. Trap & Store Sediment** • Sediment adds to and builds soil in riparian areas. • Sediment aids in the ability of soils to hold and store moisture. • Sediment can carry contaminants and nutrients - trapping it improves water quality. • Excess sediment can harm aquatic animals like fish and insects. **2. Build & Maintain Banks & Shorelines** • Erosion is balanced with bank building - the effects of erosion are reduced by adding bank and shore elsewhere. • Increase stability, resilience and recovery. • Maintain or restore profile of channel - extends width of riparian area through higher water tables. **3. Store Water & Energy** • Watershed safety valve - storage of high water on the floodplain during floods. • Reduce flood damage by slowing water and reducing erosion. • Slow flood water allowing absorption and storage in underground aquifer.

[31] L. Fitch, & N. Ambrose, Cows and Fish Program; Riparian Areas, A User's Guide to Health; found online at http://www.cowsandfish.org/publications/management.html (June 15, 2010).

	4. Recharge Aquifers • Store, hold and slowly release water. • Maintain surface flows in rivers and streams and levels in lakes and wetlands through storage and slow release. • Maintain high water table and extend width of productive riparian area. **5. Filter & Buffer Water** • Reduce amount of contaminants, nutrients and pathogens reaching the water. • Uptake and absorption of nutrients by riparian plants. • Trap sediment, reduce water quality issues and enhance amount of vegetation to perform filtering and buffering function. **6. Reduce & Dissipate Energy** • Reduce water velocity, which slows erosion and sediment transport. • Resist erosion and slow channel and shoreline movement. • Aid in sediment capture. **7. Maintain Biodiversity** • Create and maintain habitats for fish, wildlife, invertebrates and plants. • Connect other habitats to allow corridors for movement and dispersal. • Maintain a high number of individuals and species. **8. Create Primary Productivity** • Vegetation diversity and age-class structure creates links to other riparian functions. • High shelter and forage values. • Enhance soil development. • Capture and recycle nutrients.”

Riparian Area Widths

Jefferson County, Alabama, Five Mile Creek Greenway Management Plan[32]	The Greenway plan calls for a "typical greenway width of 150 feet from each bank" and a three zone buffer plan including.: • Inner Zone – "This streamside zone is particularly sensitive, and should be kept largely undisturbed, the inner zone extends a minimum of 25 feet from the stream bank, but should be expanded to include wetlands and critical habitats." • Middle Zone – "This zone extends at least 50 feet from the outer edge of the inner zone, and includes land in the 100 year flood plain as well as slopes to the point of topographic leveling… Potential uses in the middle zone include walking and biking trails… limited parking and restroom facilities… limited clearing." • Outer Zone – "[extending from the outer edge of the Middle Zone] where an Outer Zone exists it should be used for the provision of parking and trail head areas."
Alliance for the Chesapeake Bay: Riparian Buffer Preservation[33]	**"What is a Riparian Corridor?** A riparian corridor is a perennial or intermittent body of water, its lower and upper banks, and the vegetation that stabilizes its slopes. It includes the channel plus an adjoining strip of the floodplain, usually 100 feet on each side of the channel.
NRCS Planning & Design Manual Riparian Zone[34]	***Definition of buffer boundary –*** Depending on the goals of the buffer, there

[32] Final Master Plan for the Greenways Project (November 16, 1998, revision)
[33] http://www.acb-online.org/pubs/projects/deliverables-145-2-2004.pdf 6/18/10
[34] http://www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf

	are many different approaches to defining buffer width, boundaries and allowable activities. Examples include: • Zoned buffers– designates minimum distances for streamside zones, middle zones and outer zones with the most restrictions placed on the streamside areas; typical width for the streamside zone is 25 feet, 50 to 100 feet for the middle and 20-30 feet for the outer zone; • Designated width based on stream size or order, adjacent land slope, or relationship to floodplain, wetland or easement boundaries, and greenways; • Buffer averaging – allows for variable buffer widths within a development site; allows developers to narrow the buffer width at some points if the average width of the buffer meets the minimum criteria; streamside zones should not be encroached upon."

APPENDIX D: RIPARIAN ORDINANCES

City of Austin Critical Water Quality Zone Ordinance § 25-8-92 & 93[35]

§ 25-8-92 CRITICAL WATER QUALITY ZONES ESTABLISHED

(A) A critical water quality zone is established along each waterway classified under Section 25-8-91 *(Waterway Classifications)*.

(1) The boundaries of a critical water quality zone coincide with the boundaries of the 100 year flood plain, except:

(a) for a minor waterway, the boundaries of the critical water quality zone are located not less than 50 feet and not more than 100 feet from the centerline of the waterway;

(b) for an intermediate waterway, the boundaries of the critical water quality zone are located not less than 100 feet and not more than 200 feet from the centerline of the waterway;

(c) for a major waterway, the boundaries of the critical water quality zone are located not less than 200 feet and not more than 400 feet from the centerline of the waterway; and

(d) for the main channel of Barton Creek, the boundaries of the critical water quality zone are located 400 feet from the centerline of the creek.

(2) Notwithstanding the provisions of Subsections (A)(1)(a), (b), and (c), a critical water quality zone does not extend beyond the crest of a bluff.

(B) Critical water quality zones are established to include the inundated areas that constitute Lake Walter E. Long, Lake Austin, Lady Bird Lake, and the Colorado River downstream of Lady Bird Lake.

(C) Critical water quality zones are established along and parallel to the shorelines of Lake Travis, Lake Austin, and Town Lake.

(1) The shoreline boundary of a critical water quality zone:

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[35] City of Austin Land Development Code § 25-8-92 CRITICAL WATER QUALITY ZONES ESTABLISHED. http://www.amlegal.com/austin_nxt/gateway.dll/?f=templates$fn=altmain-nf.htm$vid=amlegal%3Aaustin_tx$3.0. accessed 4.20.11

(a) for Lake Travis, coincides with the 681.0 foot contour line;

(b) for Lake Austin, coincides with the 492.8 foot contour line; and

(c) for Town Lake, coincides with the 429.0 foot contour line.

(2) The width of a critical water quality zone, measured horizontally inland, is:

(a) 100 feet; or

(b) for a detached single-family residential use, 75 feet.

(D) Critical water quality zones are established along and parallel to the shorelines of the Colorado River downstream of Town Lake.

(1) The shoreline boundary of a critical water quality zone coincides with the river's ordinary high water mark, as defined by Code of Federal Regulations Title 33, Section 328.3 (*Definitions*).

(2) The inland boundary of a critical waterquality zone coincides with the boundary of the 100-year floodplain as delineated by the Federal Emergency Management Agency, except that thewidth of the critical water quality zone, measured horizontally inland, isnot less than 200 feet and not morethan 400 feet.

(E) In an urban watershed, a critical water quality zone is established along each waterway with a drainage area of at least 64acres. This does not apply in the area bounded by IH-35, Riverside Drive, BartonSprings Road, Lamar Boulevard, and 15th Street.

(1) Except as limited by Paragraph (3), for a waterway whose 100 year flood plain has been delineated by the Federal Emergency Management Agency (FEMA):

(a) the boundaries of the critical water quality zone coincide with the boundaries of the flood plain as delineated by FEMA; or

(b) if the applicant has calculated the 100 year flood plain for the waterway and the City has approved the calculations, the boundaries of the critical water quality zone coincide with the boundaries of the calculated flood plain.

(2) Except as limited by Paragraph (3), for a waterway whose 100 year flood plain has not been delineated by FEMA:

(a) the boundaries of a critical water quality zone are located 100 feet from the centerline of the waterway; or

(b) if the applicant has calculated the 100 year flood plain for the waterway and the City has approved the calculations, the boundaries of the critical water quality zone coincide with the boundaries of the calculated floodplain.

(3) The boundaries of a critical water quality zone are located not less than 50 feet and not more than 400 feet from the centerline of the waterway.

Source: Sections 13-7-23(a), (b), (c), (d), (f), and (g); Ord. 990225-70; Ord. 990819-99; Ord. 031211-11; Ord. 20080228-116; Ord. 20101209-075.

§ 25-8-93 WATER QUALITY TRANSITION ZONES ESTABLISHED.

(A) Except for Lake Austin, Lake Travis, and Town Lake, a water quality transition zone is established adjacent and parallel to the outer boundary of each critical water quality zone.

(B) The width of a water quality transition zone is:

(1) for a minor waterway, 100 feet;

(2) for an intermediate waterway, 200 feet; and

(3) for a major waterway, 300 feet.

The City of Napa Riparian Buffer Ordinance[36]

Ordinance on Riparian Habitat Areas
City of Napa, California

17.60.80 Riparian Habitat Areas

The following provisions shall apply to all lots which are contiguous with or directly adjoin an intermittent or perennial stream or river identified in and consistent with the conservation element of the general plan (portions of the Napa River, Napa Creek, Redwood Creek, Browns Valley Creek, Milliken Creek, Sarco Creek, and Tulocay Creek). Lots to which the provisions of this section apply shall be indicated on the zoning map as "CR-6."

A. A protective streamside buffer fifty feet in width measured from the top of a

[36] City of Napa California Riparian Ordinance. http://www.epa.gov/owow/NPS/ordinance/documents/a2c-napa.pdf. Accessed 4.20.11

stream, creek or riverbank landward shall be observed. Top of the bank shall mean the highest elevation of land which confines to their channel waters flowing in an intermittent or perennial stream or river. Except as provided in subsection F of this section, a riparian habitat management plan, prepared by a registered civil engineer or landscape architect shall be required for development including grading, dredging, and filling within the protective streamside buffer. The riparian habitat management plan shall be submitted to the planning director and public works director for review and approval.

B. The protective streamside buffer required by subsection A of this section is a minimum and may be increased if necessary to mitigate the impact of the proposed development on riparian habitat areas.

C. A riparian habitat management plan shall address the following requirements:

1. Site development shall be fitted to the topography and soil so as to create the least potential for vegetation loss and site disturbance;
2. Vegetation removal shall be limited to that amount necessary for the development of the site. Protection of tree crowns and root zones shall be required for all trees planned for retention;
3. Vegetation indigenous to the site or plan community shall be restored in areas affected by construction activities. Temporary vegetation, sufficient to stabilize the soil, may be required on all disturbed areas as needed to prevent soil erosion. New planting shall be given sufficient water, fertilizer and protection to insure reestablishment. Plants which minimized fire hazards should be utilized adjacent to buildings and structures;
4. If proposed development including grading, dredging and filling within the protective streamside buffer would affect the banks of the stream or river, bank stabilization using techniques acceptable to the public works director shall be required to prevent erosion;
5. The riparian habitat management plan shall be developed in consultation with the Department of Fish and Game and/or United States Army Corps of Engineers;
6. A discussion of site design to minimize the disturbance and loss of vegetation.

D. A riparian habitat management plan shall be drawn to scale and shall be of sufficient clarity to indicate the nature and extent to the work, bank stabilization and revegetation efforts proposed. A riparian habitat management plan shall include the following information:

1. Name and address of owner;
2. Name, address, professional status, license number, and phone number of the person who prepared the plan;

3. Location and assessor's parcel number of the proposed site;
4. North arrow, scale, and the name and location of the nearest public road intersection;
5. Existing contours of the site, as well as finished contours to be achieved by grading. Contours shall be sufficiently detailed to define the topography over the entire site (generally at two-foot intervals);
6. Detailed plans of all bank stabilization and erosion control measures
7. Delineation of areas to be cleared during development activities;
8. Restoration vegetation proposed for all surfaces exposed to be exposed during development activities, including any dredged, filled or graded areas;
9. The location and extent of open space buffers and method implementation; any use restrictions and method of implementation.

E. All approved measures to mitigate the loss or impact to riparian habitat shall become conditions or approval of the project. In addition all approved riparian habitat management measures shall be carried out prior to final clearance of the building permit or concurrently with the installation of site improvements in the case of a subdivision map.

F. The planning director may waive the requirement for a riparian habitat management plan for projects which will not result in disturbance to the land or where on-site conditions clearly demonstrate that the site is not now occupied by riparian habitat vegetation and would not effectively respond to riparian revegetation. An applicant requesting such a waiver shall submit sufficient information to substantiate the waiver. Such projects may include, but are not limited to the following:

1. A change of use or status of the property (i.e. rezoning) which will not directly result in construction or land-disturbing activities;
2. An accessory building less than five hundred square feet in size;
3. Construction within an existing structure;
4. A lot line adjustment. (Prior code 30-337).

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