RIPARIAN RESTORATION: AN OPTION FOR VOLUNTARY BUYOUT LANDS IN NEW BRAUNFELS, TX

THESIS

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of APPLIED GEOGRAPHY

by

Jana L. Harter, B.S.

San Marcos, Texas
August 2007

RIPARIAN RESTORATION: AN OPTION FOR VOLUNTARY

BUYOUT LANDS IN NEW BRAUNFELS, TX

Committee Members Approved:

____
Richard A. Earl, Chair

____
Joanna C. Curran

____
Alberto Giordano

Approved:

____
J. Michael Willoughby
Dean of the Graduate College

ACKNOWLEDGEMENTS

Special thanks are extended to Dr. Richard A. Earl for assisting in the development and editing of this thesis. He is a great mentor and teacher whose guidance enabled me to further my educational goals. I would also like to thank my graduate committee members, Dr. Joanna Curran and Dr. Alberto Giordano for their critical review and guidance for this thesis. Dr. Curran was especially helpful with her advice on all the little nuances in research and written scientific expression.

I would like to thank my parents for their support, and my early education in environmental studies. I did not know at the time that the early introduction to the outdoors and respect for nature would be the basis of my later research.

Mike Wallace at Texas Parks and Wildlife spent many hours advising me about plant communities. He also lent his time to some of the site visits and field work for this thesis. David Riskind, also of Texas Parks and Wildlife, provided out-of-print articles describing and explaining plant communities in Texas. Jocelyn Murphy in the New Braunfels City Planning Department provided digital data and her time on researching the buyout properties. Others in the New Braunfels Planning and Engineering Departments also provided their time and expertise for the project. P2 Energy Solutions allowed the use of their aerial photography for the study area. Tom Franke with the City of Austin's Watershed Protection and Development Review Department offered suggestions and help with some of the runoff calculations.

This manuscript was submitted on April 22, 2007.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

CHAPTER I

INTRODUCTION

Property damage from flooding is a persistent problem in Central Texas communities (figure 1). As development increases in the Texas Hill Country, the frequency of and costs related to flooding are projected to increase. Voluntary land buyouts have become popular in many communities to solve the problem of repetitively flooded areas. Since the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (FIRA), there has been a move to require repetitive loss property owners to pay National Flood Insurance Program (NFIP) rates that reflect the actuarial risk associated with their properties. As land buyouts continue, larger areas of land adjacent to rivers will become community property and community leaders will need to make decisions regarding how to use this land. What to do with the voluntary buyout lands is a question of great importance for local communities.

Canyon Dam was completed in 1964 to help with flood control along the Guadalupe River. The dam does not provide complete protection, and major flooding occurred in New Braunfels in 1972 and 1998 when rain fell below the dam and again in 2002 when water came over the spillway. Many residences were flooded, and some more than once because of their locations in the floodway and 100-year floodplain. As Gilbert White said in his 1945 paper (2), “Floods are ‘acts of God,’ but flood losses are largely acts of man.” The objectives of this study were to determine if riparian restoration projects in New Braunfels, Texas were viable options for voluntary buyout lands and to provide guidelines necessary for successful riparian corridor restoration on those lands. Criteria for initiating a successful restoration project for the properties were developed. The restoration projects should provide benefits to communities that have experienced repetitive flood damage.

Fig. 1. Canyon Lake, Comal County, Texas 2002 Flood

CHAPTER II

STUDY AREA

Limits

New Braunfels is located in central Texas between San Antonio and Austin in a region popularly known as the Texas Hill Country (figure 2). The New Braunfels 1998 FEMA buyout project targeted lands in the floodway and 100-year floodplain. It encompassed the riparian zone along the Guadalupe River within the New Braunfels community. Limits for the project have geographic, regulatory, and cultural aspects.

The geomorphology, soil type, and flood regime were used to determine recommended vegetation covers consistent with riparian buffer zone recommendations. Regulations on usage of buyout lands and local land usage plans for the study area properties determine the type of projects that could be implemented on the properties. The properties are located in residential neighborhoods; therefore, projects have to take aesthetics and human interaction into account when choosing vegetation types and placements. The projected maintenance of any project is factored in so as to provide little or no cost for the local community. Restoration is not intended to alter the major hydrologic characteristics of the stream other than bank protection. Canyon Dam, upstream of New Braunfels, has reduced the frequency of large flood events. Therefore, the riparian zone can not be restored to pre-dam conditions, but improvements in plant and wildlife diversity can be made through restorative methods.

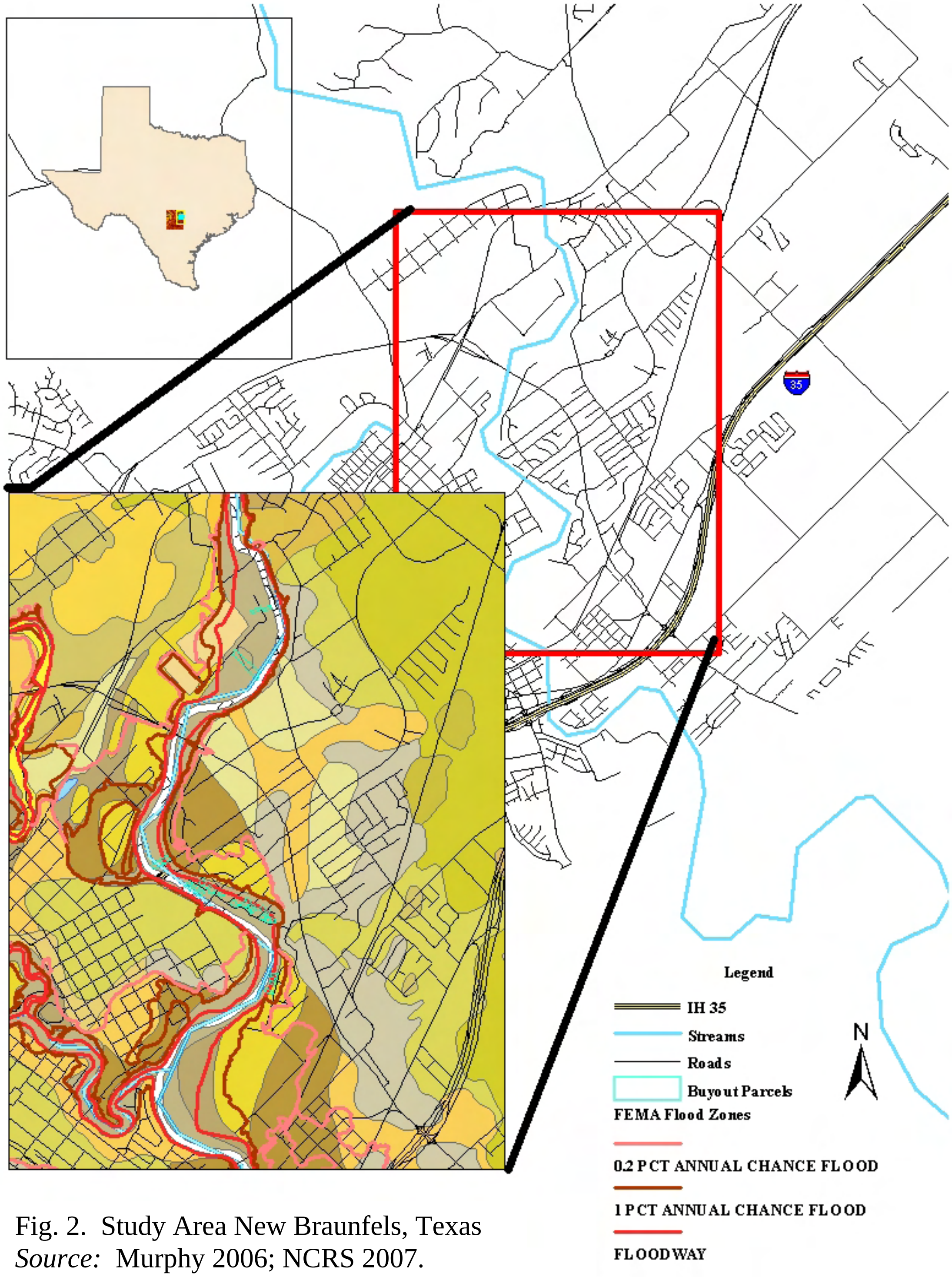


Fig. 2. Study Area New Braunfels, Texas
Source: Murphy 2006; NCRS 2007.

Background of Study Area

Both the climate and land surface conditions make central Texas one of the most flood prone regions in the United States (Leopold, Wolman, and Miller 1964; Baker 1977). Anthropogenic processes, such as increased development, exacerbate this flooding hazard. Most of the region's major rainfall events take place in late spring and late summer-early fall resulting from convective thunderstorms fueled with tropical Gulf moisture (Baker 1977). It is not uncommon for a localized area to receive greater than 10 inches in 24 hours or less. During the early morning hours of June 21, 1997 through the evening of June 22, 1997, 15 to 20 inches of rain fell over parts of south central and central Texas, particularly over the Hill Country (U.S. Department of Commerce 1997). The floods of October 1998 produced nearly 30 inches of rain in a two-day period, and the floods of 2002 produced 35 inches in a seven-day period (see tables 1 and 2)(U.S. Department of Commerce 2003).

Table 1. Largest 24-hr Precipitation Events at New Braunfels Station 416276*

Date	Precip (in)	Date	Precip (in)
10/18/1998	18.35	9/27/1973	6.44
9/9/1921	9.38	6/20/1946	6.25
10/1/1913	7.97	11/24/1974	5.77
10/11/1919	7.82	5/12/1972	5.66
10/4/1959	6.65	7/5/1942	5.45

Source: Williams, C.N., Jr., M.J. Menne, R.S. Vose, and D.R. Easterling. 2006. *United States Historical Climatology Network daily temperature, precipitation, and snow data* ORNL/CDIAC-118, NDP-070. Available from http://cdiac.ornl.gov/epubs/ndp/ushcn/usa.html (accessed 11 May 2007).

* Data corresponding to the 2002 flood is unavailable due to instrument malfunction.

Table 2. Largest Flood Events at New Braunfels USGS 08168500 Guadalupe River above Comal Rv

Water Year	Date	Gage Height (feet)	Streamflow (cfs)
1869		>35.0	>101,000
1913		>35.0	>101,000
1935	6/15/1935	32.95	101,000
1932	7/3/1932	32.48	95,200
1972	5/12/1972	31.65	92,600
1999	10/17/1998	35.57	90,000
2002	7/6/2002	29.44	73,200
1952	9/11/1952	30.7	72,900
1936	9/28/1936	24.85	52,800
1958	5/3/1958	24.44	47,900
1960	10/5/1959	22.33	35,700
1957	4/25/1957	18.13	26,900

Source: U.S. Geological Survey. National Water Information System. 2007. *Peak streamflow for Texas*. Database on-line. Available from http://nwis.waterdata.usgs.gov/tx/nwis/peak?site_no=08168500&agency_cd=USGS&format=html. (accessed 27 April 2007).

The Balcones Escarpment, which forms the eastern boundary of the Hill Country, possibly functions as an orographic trigger to help produce high rainfall intensities (Baker 1977). The Escarpment region also has physiographic characteristics, which contribute to the area's flooding; the drainages have steep sides, thin soils cover limestone rock, low vegetative cover has shallow root systems, and many of the streams flow through canyons with high cliffs (Baker 1977). As a result, there is high run-off of surface water or overland flow, as opposed to interflow or base flow, creating high peak stream discharges and flooding (Baker 1977). Increased development in the area has led to an increase in flooding and frequency; however, the data for the exact amounts are not complete.

Flood hazards may increase in a small watershed as a result of urban growth. With the rapid growth of urban cities, such as Austin and San Antonio, many once small cities, such as New Braunfels, find they are experiencing more severe and frequent flooding problems along small creeks, streams, and other low areas. Urbanization leads to an increase in impervious cover, channel rectification that reduces channel storage, channel obstruction, and floodplain development (Caran and Baker 1986). Impervious cover increases as land is converted from agricultural to urban land use. This, in turn, leads to higher volumes of runoff, which results in increased flooding along riparian corridors and downstream of development (Barnard 1978). The recent rapid urban growth in the Texas Hill Country and nearby areas such as New Braunfels has undoubtedly increased flooding and is a problem that is sure to be exacerbated if certain measures are not undertaken in the very near future. The CH2M Hill study (2002), commissioned by New Braunfels and used by FEMA for the new Digital Flood Insurance Rate Maps (DFIRMs), showed that increased development on the North Guadalupe and South Guadalupe Tributaries led to an increase in runoff. Caran and Baker (1986) claimed that earlier work by W.H.K. Espey et al. (1966) demonstrated that landuse practices alone could increase peak flood discharges in central Texas by as much as 300 percent. These types of urban developmental problems are nothing new to burgeoning cityscapes, but history has shown that there are unique ways to balance growing populations and preserve natural processes. As New Braunfels grows and urbanizes, it will have the opportunity to plan for both population growth and the preservation of natural processes.

One opportunity is to decrease the number of repetitively flooded properties through voluntary buyouts. The city acquired 29 properties from the 1998 voluntary buyout program that were amendable to a riparian restoration project. Restrictions on the voluntary buyout properties require that the land be maintained as open space or allowed to revert back to the natural floodplain (riparian area). Future disaster payments are prohibited and any existing structures must be removed or relocated outside the 100- year floodplain (National Wildlife Federation 1998). In Comal County some buyout properties are leased to neighboring owners or neighborhood associations for tax costs and allowed to lie fallow with little or no maintenance (Ellington 2005). In New Braunfels, the buyout properties are owned by the city and plans for a park in one location were still in the discussion stage after three years. A second city buyout area was supposed to be maintained by a neighborhood association for the use of the land, but there have been complaints about the lack of maintenance (Robbins 2005). Although Martindale is not in the immediate project location area, it is part of the central Texas flood zone. All structures on the buyout properties in Martindale have been removed and the land remains unused. Project and maintenance costs, as well as lack of knowledge on landuse options are the main reason the lands are not being improved or rebuilt (Bagley 2005; Ellington 2005; Robbins 2005).

CHAPTER III

LITERATURE REVIEW

History of Floodplain Buyouts

Flooding damage to is not a new problem unique to central Texas communities. In 1998, the National Wildlife Foundation (NWF) issued a report, *Higher Ground*, which spotlighted voluntary buyouts and relocations as a floodplain management option (NWF 1998). It identified 300 communities that the National Flood Insurance Program (NFIP) classified as repetitive loss communities. A repetitive loss community is any community with at least one repetitive loss property, and a repetitive loss property is any insured property that has sustained two or more flood losses of at least $1000 in any ten-year period. Texas and Louisiana accounted for over half of the properties, and it was estimated that less than 30 percent of the properties located in the floodplains were covered by federally sponsored flood insurance policies. As a result of the Midwest floods of 1993, the Report of the Governor's Task Force on Floodplain Management in 1994 concluded that, "Governments (Federal and State) have decided that in the long run, it is less expensive to purchase flood plain property from willing sellers than to continue repetitively paying insurance claims and/or providing disaster relief" (NWF 1998, 17).

Flood Hazard Management

Floodplains make up about seven percent of all land in the United States (Holway and Burby 1990), and riparian zones probably make up less than five (Committee on

Riparian Zone Functioning and Strategies for Management 2002). The use of floodplains directly affects protection of the environment and public safety. According to the 1989 L.R. Johnston and Associates report, *A Status Report on the Nation's Floodplain Management Activity: An Interim Report*, because of past floodplain development, floods caused approximately 200 deaths and $9 billion in property damage annually in the United States (Holway and Burby 1990). For the past century, people have tried to control floods structurally at great costs and have at times created a false sense of security for landowners (NWF 1998). Over the last 25 years the Army Corps of Engineers has spent more than $25 billion in flood control projects. Flood costs have more than doubled since the early 1900s and from 1993–1998 they exceeded $40 billion. After the 1993 Midwest floods, floodplain buyouts were added to floodplain management practices. Between the 1993 floods and the publishing of the National Wildlife Federation's 1998 report approximately 17,000 homes were bought out in 36 states and one territory (NWF 1998). Although the right to regulate land use is a power the states have traditionally left to local government discretion, critical and hazardous area controls are increasingly being adopted under state or federal mandates.

Riparian Corridor Restoration

Cities and urban sprawl continue to consume formerly rural lands. For the most part, the builders of cities have disregarded this fact, with dangerous and costly consequences: pollution, depletion of resources and increased flooding. In recent years, scientists have documented the character of the urban environment as distinct from the rural, natural environment, which may be the reason for exacerbating problems and the need to control natural annoyances (Harvey and Clark 1965).

Today’s local land-use regulations have considerable influence over urban and rural development. Regulations can be used to control or limit growth, to set standards for new development, and to protect environmentally critical areas, such as riparian zones. These riparian zones play a vital role in natural floodplain processes and should be maintained as undeveloped so that they can function as intended. Yet, because of increased development along geographically appealing areas, these natural flood buffers are in danger of shrinking or being drastically altered with increased flooding as a repercussion.

First described in academic journals nearly a century ago, riparian zones serve as interfaces between the environmental patches where structural or functional systems properties change continuously over space or time (Naiman and Décamps 1997). These interface areas posses specific physical and chemical attributes, biotic properties, and energy that make them a necessary natural part of the geographic landscape and an integral part to the sustainability of river and runoff processes. They are unique in their interactions with adjacent ecological systems in that they allow for the inchoate stages of life for plants and animals alike, which play a vital role in sustaining local ecosystems and biodiversity. The strength of these interactions, which vary over wide temporal and spatial scales, is controlled by the contrast between adjacent resource patches and ecological spaces. Natural riparian zones are some of the most diverse, dynamic, and complex biophysical habitats and have considerable importance to river systems (Décamps 1993).

Riparian corridors encompass the stream channel and the portion of the terrestrial landscape from high watermarks towards the uplands where vegetation may be influenced by elevated water tables or flooding. This is a key characteristic and benefit of the riparian zones as natural flood abatement strategies. Ecological investigations of riparian corridors have described them to be an important landscape feature with substantial controls on environmental vitality (Planty-Tabacchi et al. 1996). Oftentimes, streams are non-equilibrium systems with strong effects on habitat formation and stability, the attributes of riparian vegetation on the local geomorphology and microclimate, and the diversity of ecological functions. The riparian corridor is frequently disturbed by floods and debris flows, creating a mosaic of features over a given spatial scale (Naiman, Décamps, and Pollocka 1993).

Native riparian ecosystems are disappearing or being altered by human activities throughout the United States. Over half of the riparian zones in the lower 48 states have been significantly altered or destroyed (Manci 1989). About three-quarters of the Southwestern United States riparian woodlands have been lost, and many of their plant and animal species are threatened or endangered (Rood et al. 2003). Some species, such as the bonytail chub fish in the Colorado River, have not reproduced in the wild for years (Cohn 2001). Rivers have been dammed and diverted for flood control, hydroelectric power, urban use, agricultural use, recreational, and industrial use (Manci 1989; Molles et al. 1998; Richter and Richter 2000; Cohn 2001; Rood et al. 2003).

Attention is increasingly focused on riparian zones, and current United States policy considers riparian restoration good management practice (Cohn 2001; U.S. EPA 2003; Rood et al. 2003; Sweeney et al. 2004). Restoration projects range in complexity and diversity and encompass many different geographic locations. Restoring riparian zones can lead to improvements in water quality (U.S. EPA 2002, 2003; Klamath Resource Information System 2005). Riparian zones act as buffers that trap sediment and pollutants, provide habitat for birds and animals, control erosion and stream narrowing, control water temperature, and provide nutrients (Cohn 2001; Semlitsch and Bodie 2003; Sweeney et al. 2004). Other benefits of riparian zones include species restoration, ecosystem services re-establishment, and microclimate changes. To what extent riparian restoration influences these activities, is currently being studied (Naiman and Décamps 1997; Cohn 2001; U.S. EPA 2002; Rood et al. 2003; Semlitsch and Bodie 2003; Sweeney et al. 2004; Klamath Resource Information System 2005).

A riparian restoration project in the central Texas area has to take into account the flood aspect, as well as local climatic and physiographic characteristics (Molles et al. 1998; Wissmar and Beschta 1998; Richter and Richter 2000). Floods influence riparian ecosystems and are beneficial in many ways (Molles et al. 1998; Richter and Richter 2000; Cohn 2001; Rood et al. 2003). There is even some evidence to suggest that central Texas stream morphology has adapted to the high magnitude floods (Baker 1977). The middle Guadalupe riparian zone exhibits characteristics of the central Texas escarpment region. It has limestone bedrock with a thin layer of clay-based soil, high cliffs and a narrow river corridor, and the vegetative cover is sparse in places with shallow root systems (Baker 1977). The Guadalupe River itself ranges from a meandering, riffle-pool stream to a braided stream and after it crosses the Balcones Escarpment, to an alluvial type river. As a result, floods on the Guadalupe vary according to the local geomorphology.

Most natural riparian areas are dominated by woody plants, grasses, and emergent herbaceous plants (Committee on Riparian Zone Functioning and Strategies for Management 2002). Types of vegetation chosen for a restoration project would influence the scouring of the landscape, which in turn would affect sediment in the riparian zone (Baker 1977; Committee on Riparian Zone Functioning 2002). The Edwards Plateau riparian regions are characterized by three main plant communities: Bald cypress, sycamore, and black willow; pecan and hackberry; and hackberry, oak, and elm (Riskind and Diamond 1986; Wagner 2004). All three communities are present in the study area.

The U.S. Department of Agriculture (USDA) Forest Service has published a guideline for restoration projects (figure 3) (USDA 1991). Although each riparian area has its own individual characteristics, the USDA plan divides the riparian area into three zones and provides a general outline that can be adapted in part for various situations. Part of the problem in planning a riparian restoration project is that there are so many different definitions and guidelines that it is difficult to adopt a single one as a model (Wissmar and Beschta 1998; U.S. EPA 2003). The USDA plan provides general spatial requirements and functions for each zone (USDA 1991). Modifications on zone width are necessary for Central Texas because the local riparian zones are narrow with exposed limestone in places (Baker 1977).

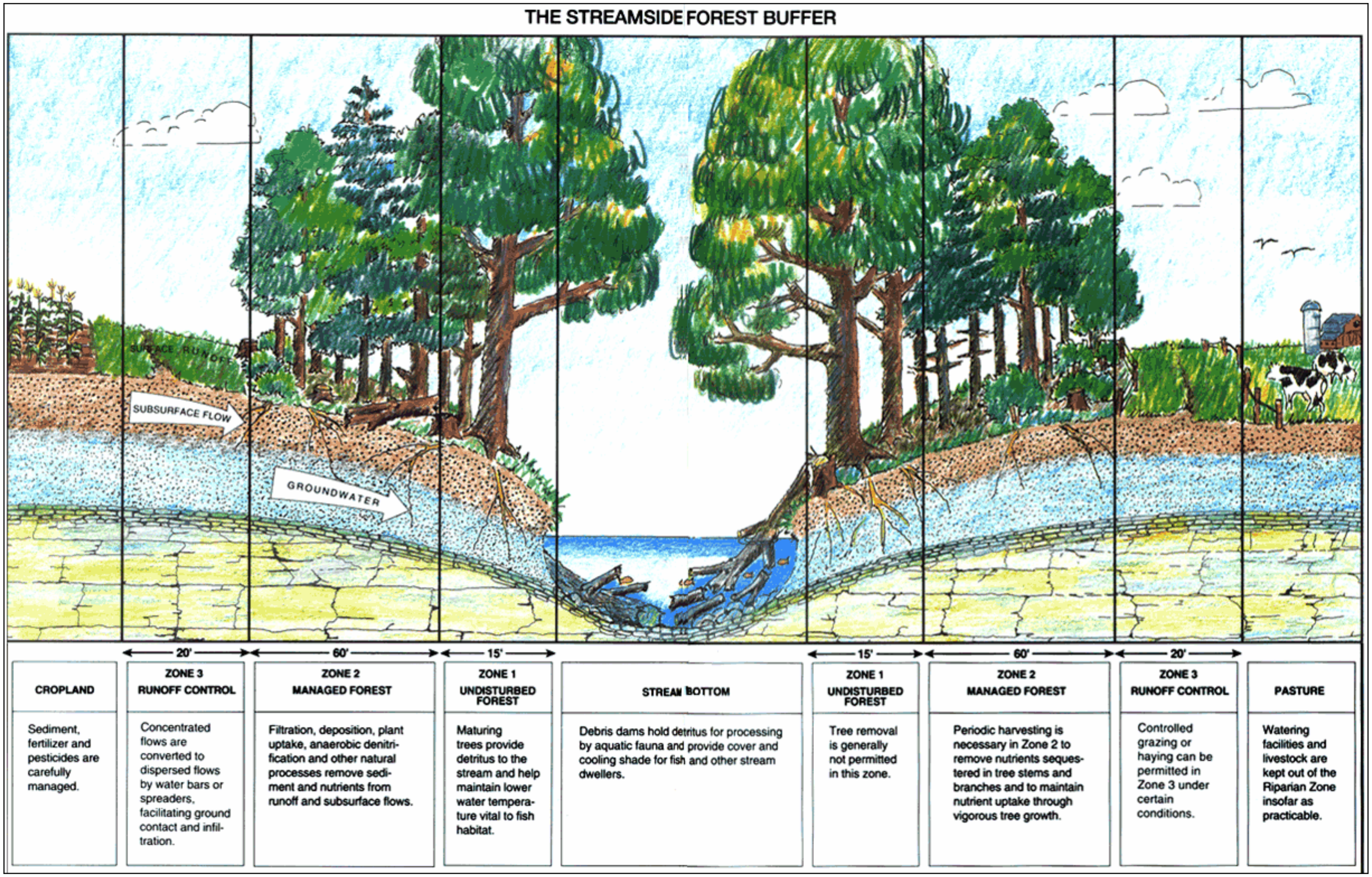


Fig. 3. Streamside Forest Buffer
Source: USDA 1991.

One of the first requirements for a riparian restoration project is the acquisition of the land, whether through landowner permission, purchase, or public right-of way. To date, many of the riparian restoration projects have been through the use of public right-of-ways. The New Braunfels buyouts are considered public properties and are already owned by the local governments. Some are owned by Comal County and some by the city of New Braunfels.

Recently, landowner permission has increased through the use of federal tax incentives, which encourage private landowners voluntarily to restrict land use and development through the donation of conservation easements (McLaughlin 2004). A conservation easement is a legally binding agreement between the landowner and the easement holder, currently a government agency or publicly-supported charity, which becomes part of the land records. It prevents the landowner and successive owners from developing or using the land in ways prohibited by the easement (McLaughlin 2004). Riparian restoration projects are allowed by these easements.

Once the land is acquired a plan for the restoration project must be devised, and there is a wealth of projects and models available. Because there are so many diverse projects and models, some researchers have focused on measuring the success of a project (Palmer et al. 2005). A study by Palmer et al. suggests five criteria for determining the success of a project. First, the project design should be based on a specific goal of a healthier riparian ecosystem at the proposed site. Second, the ecosystem should show measurable improvement. Third, it should be more self-sustaining and resilient to external influences so there is only minimal maintenance.

Fourth, during implementation no lasting harm should be inflicted on the ecosystem, and lastly there should be pre and post assessments that are made public. Riparian areas in the local buyout properties in this study were healthy, although on some properties diversity was limited because of the residential nature of the area. Natural succession should eventually increase diversity, but restoration efforts would hasten this process.

CHAPTER IV

METHODS

The buyout properties were divided into three sections by geographic locations (figures. 4, 5, 6, 7), and secondary data were gathered. The City of New Braunfels volunteered maps and GIS files of the buyout properties. The engineering report by CH2M Hill that was used to draw the new FEMA floodplain maps was accessed, as well as the new FEMA maps. The preliminary plan was to use the 2004 DOQQ imagery that was available from the National Agricultural Imagery Program (NAIP), but more detailed imagery became available through P2 Energy Solutions, a private company. Texas Watch water quality data, at a site on the Guadalupe River near the restoration site, was also available for the past three years. The data included measurements for conductivity, dissolved oxygen (DO), pH, water clarity, and site observations. Vegetation lists for central Texas riparian corridors were compiled from various sources (appendix 2), local landuse was determined from tax records and visual inspection, soil types were obtained from digital soil maps, and plant series were classified according to a scheme developed by David Diamond in 1993 (appendix 1).

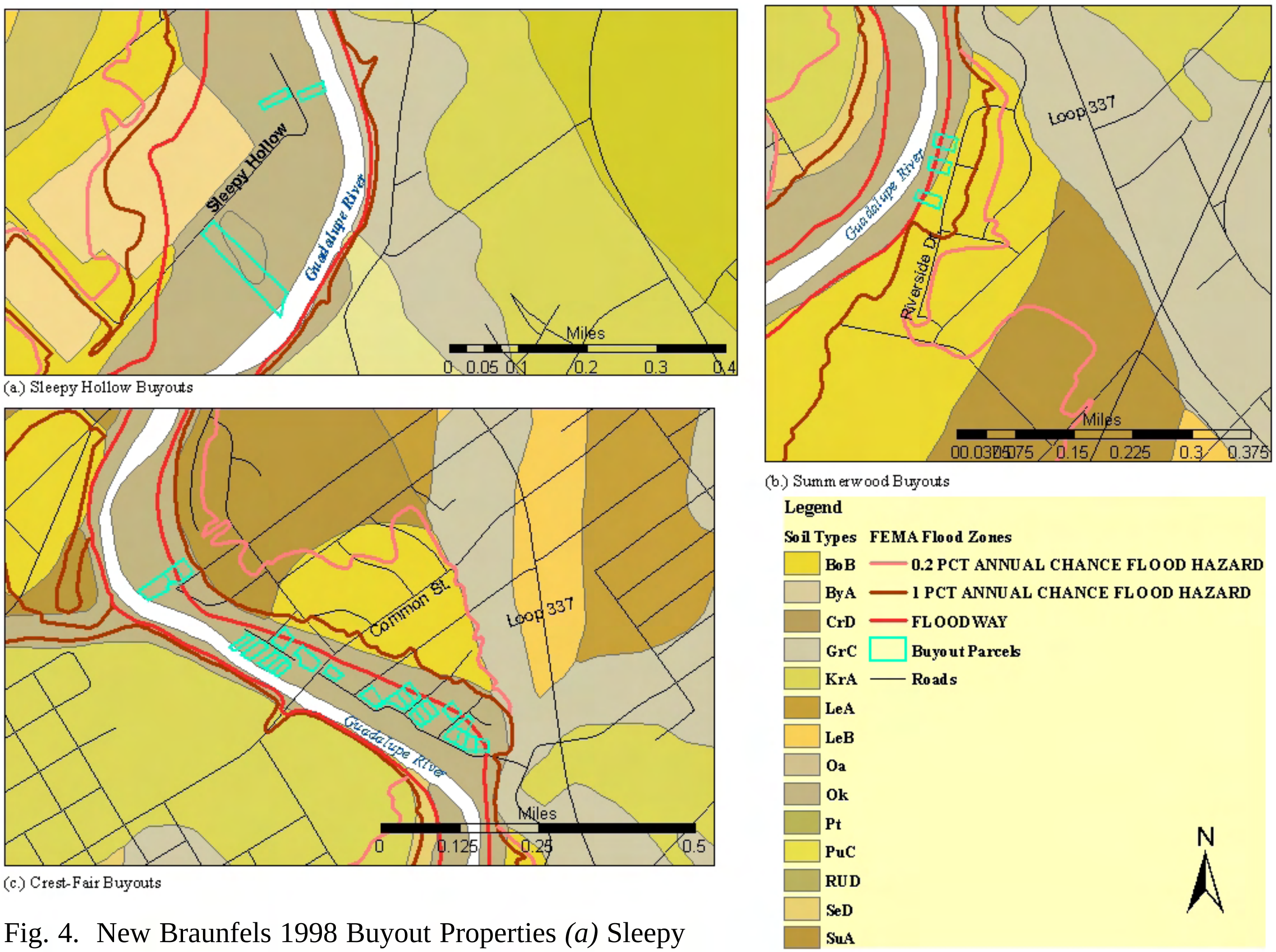


Fig. 4. New Braunfels 1998 Buyout Properties *(a)* Sleepy Hollow Area *(b)* Summerwood *Area (c)* Crest-Fair Area *Source:* Murphy 2006; NCRS 2007.

Fig. 5 Sleepy Hollow Aerial View
Source: Murphy 2006; NCRS 2007; P2 Energy Solutions 2005.

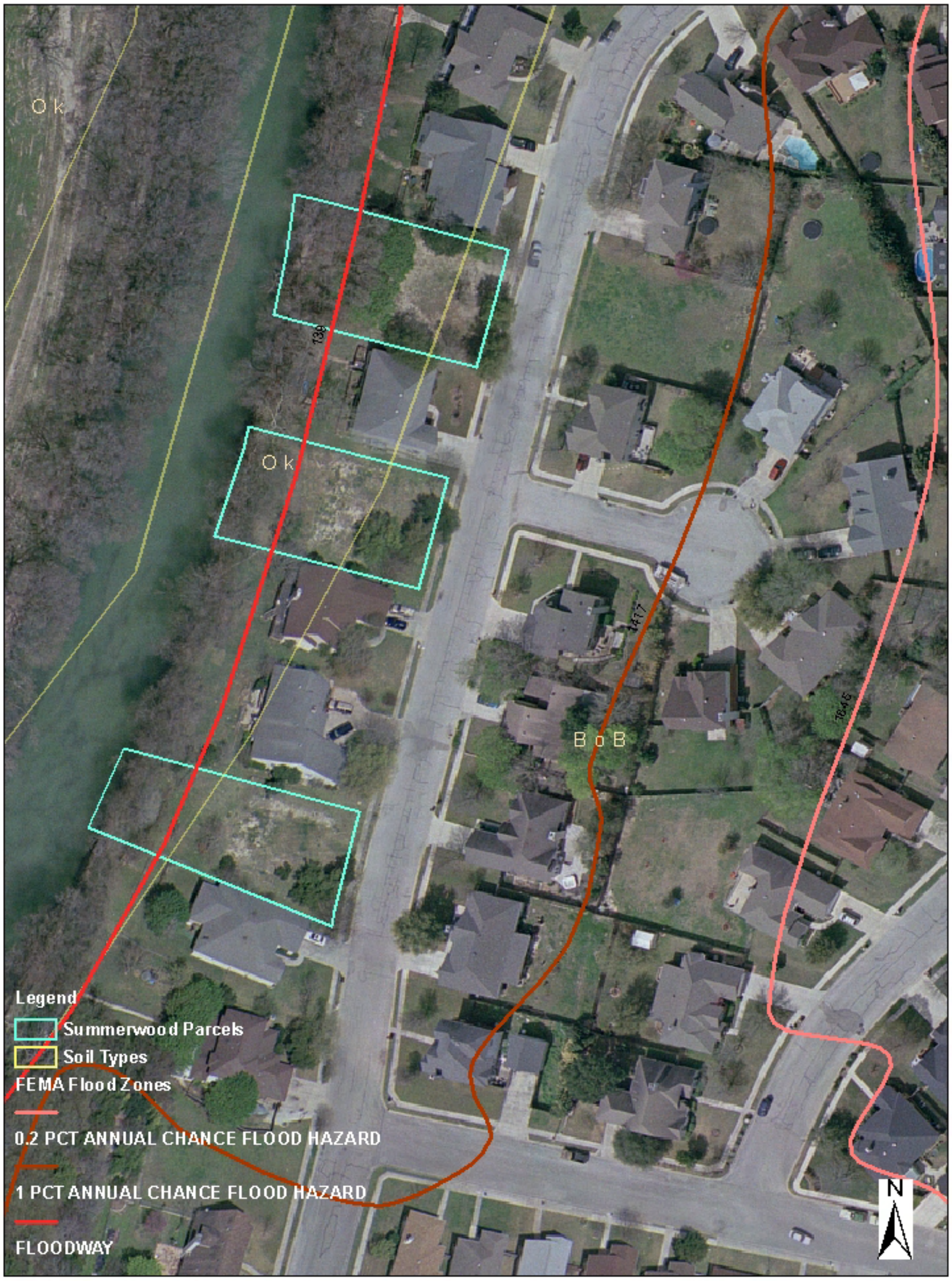


Fig. 6 Summerwood Aerial View
Source: Murphy 2006; NCRS 2007; P2 Energy Solutions 2005.

Fig. 7 Fair-Crest Aerial View
Source: Murphy 2006; NCRS 2007; P2 Energy Solutions 2005.

After the published data collection, on-site visits were conducted and observations recorded for the 29 buyout sites. The sites are the final New Braunfels city buyout sites from the 1998 flood event. For each site the following data were obtained: lot area, current flood plain status, pre-flood land use, soil type, and current vegetative cover. Data from the 29 sites were analyzed employing traditional descriptive statistics. With this data, the properties were classified based upon their suitability for different landuses and revegetation schemes. The properties were then compared to determine the relative significance of each for restoration potential. Individual sites were evaluated to determine which plant communities would occur naturally based on series level classification (Diamond et al. 1987). Plant series are characterized by dominant species or genera. Descriptions of the plant series naturally occurring in the study area are listed in appendix 1. If more than one plant series could occur at the site, preference was given to those with a more at-risk conservation status or of historical occurrence (Diamond 1993). Based upon the analysis, recommendations for vegetation cover, maintenance, possible funding, future contingency plans in case of future buyouts, and possible landuses under the FEMA regulations are proposed.

CHAPTER V

RESULTS

Distribution

A total of 29 sites were evaluated for restoration potential after the 1998 FEMA buy-out project in New Braunfels, Texas (table 3). The sites were divided into three major areas according to their geographic proximity to each other (figure 4). The properties are located in the 100-year flood zone, and all except for the property at 1127 Rivercrest Drive are located in the floodway. All are classified Special Flood Hazard Areas (SFHA) and are in Zone AE according to the Federal Emergency Management Agency's (FEMA) flood maps (FEMA 2006). The properties are located in developed neighborhoods and classified as residential landuse before the buyouts. They range in lot size from 9086 (0.21 acres) to 137,608 square feet (3.16 acres) with the mean being 17,883 (0.41acres) and the median being 12,979 square feet (0.30 acres). Only 17 of the 29 properties are contiguous with another buyout lot. The Fair-Crest aerial map shows an extra lot with a slab on it (figure 7). One of the complications of the buyout was the lack of communication between various departments in the city. From the review of the data, it appeared this particular parcel was part of the original buyout offer but for some reason was not included in the final buyout.

Table 3. 1998 Buyout Properties in New Braunfels, Texas

Street Name	Address	Area Lot (ft²)	Area Lot (ac)	Area Lot (m²)	FEMA Flood Status	Pre-flood Landuse
Candlewood Circle	812	11,475	0.26	1066.06	Zone AE	Residential
Candlewood Circle	819	12,000	0.28	1114.84	Zone AE	Residential
Common Street	1204	9086.4	0.21	844.15	Zone AE	Residential
Crest Lane	606	17,160	0.39	1594.22	Zone AE	Residential
Crest Lane	613	11,276.50	0.26	1047.62	Zone AE	Residential
Crest Lane	617	12,625.50	0.29	1172.95	Zone AE	Residential
Crest Lane	620	16,539	0.38	1536.52	Zone AE	Residential
Crest Lane	625	15,860	0.36	1473.44	Zone AE	Residential
Crest Lane	633	14,222.45	0.33	1321.31	Zone AE	Residential
Fair Lane	312	12,562	0.29	1167.05	Zone AE	Residential
Fair Lane	338	11,520	0.26	1070.24	Zone AE	Residential
Fair Lane	350	10,200	0.23	947.61	Zone AE	Residential
Fair Lane	504	11,024	0.25	1024.16	Zone AE	Residential
River Acres Drive	1208	16,896	0.39	1569.69	Zone AE	Residential
River Enclave	1210	9222	0.21	856.75	Zone AE	Residential
River Enclave	1211	27,258	0.63	2532.35	Zone AE	Residential
River Enclave	1214 (L16)	11,234	0.26	1043.67	Zone AE	Residential
River Enclave	1215 (L9)	10,880	0.25	1010.79	Zone AE	Residential
River Enclave	1218 (L17)	10,988	0.25	1020.82	Zone AE	Residential
River Enclave	1219 (L8)	10,880	0.25	1010.79	Zone AE	Residential
Rivercrest Drive	1103	28,392.50	0.65	2637.75	Zone AE	Residential
Rivercrest Drive	1115	13,300	0.31	1235.61	Zone AE	Residential
Rivercrest Drive	1127	13,300	0.31	1235.61	100 yr, Zone AE	Residential

Table 3-Continued

Street Name	Address	Area Lot (ft²)	Area Lot (ac)	Area Lot (m²)	FEMA Flood Status	Pre-flood Landuse
Riverside Drive	613	12,068.20	0.28	1121.17	Zone AE	Residential
Riverside Drive	625	11,040	0.25	1025.65	Zone AE	Residential
Riverside Drive	633	12,070	0.28	1121.34	Zone AE	Residential
Sleepy Hollow	1310	137,608	3.16	12,784.20	Zone AE	Residential
Sleepy Hollow	1446	12,878	0.30	1196.41	Zone AE	Residential
Sleepy Hollow	1457	15,745	0.36	1462.76	Zone AE	Residential

Soils and Vegetation

Six series level plant communities occur on the buyout properties (table 4). The seventh category, non-natives, was present on all properties. The plant series include other tree types, but are classified by the dominant species (appendix 1). The six categories were Bald Cypress-Sycamore (*Taxodium distichum-Platanus occidentalis*), Pecan-Sugarberry (*Carya illinoensis-Celtis laevigata*), Sugarberry-Elm (*Celtis laevigata-Ulmus* spp)., Plateau Live Oak-Midgrass (*Quercus fusiformis*), Plateau Live Oak-Netleaf Hackberry (*Quercus fusiformis-Celtis reticulata*), and Sycamore-Willow (*Platanus occidentalis-Salix nigra*). The series had conservation ratings of S3, S4, and S5, which depicted their state rankings according to their occurrences. Typically, plant series gradate from one to the next with distance from the stream. The Bald Cypress-Sycamore series was only observed within the first twenty feet of the river's edge on five properties with few Bald Cypress. The series has a S3 conservation status, which means it is uncommon in the state. This could be a result of harvesting by early settlers or human modifications in the water regime resulting in the loss of quick pulse-flooding, which inhibits seed dispersal (Naiman and Décamps 1997). The Pecan-Sugarberry was the predominant plant series occurring on ten of the properties and having a S4 conservation status, which means it has more than 100 occurrences and is secure in the state. Five properties had the Sugarberry-Elm series with a conservation rating of S4. This series includes American and Cedar Elm, but the only one present was the Cedar Elm. The American Elm tends towards a more mesic environment. Farther away from the river, as the soil becomes less mesic and the elevation increases, the Plateau Live Oak-Netleaf Hackberry dominated, with a conservation status of S4. Only one property contained the Plateau Live Oak-Midgrass series, with a conservation status of S3, which is uncommon because of the decreases in native grass coverage. Two properties had the Sycamore-Willow series with a conservation rank of S5, which means it is demonstrably secure in the state. This series is also common in gravelly soils, which are periodically scoured.

Table 4. Buyout Properties Soil and Plant Series

Street Name	Address	Soil	Plant Series	Street Name	Address	Soil	Plant Series
Candlewood Circle	812	Ok	7	River Enclave	1211	Ok	7
Candlewood Circle	819	Ok	2, 7	River Enclave	1214 (L16)	Ok	7
Common Street	1204	Ok	7	River Enclave	1215 (L9)	Ok	7
Crest Lane	606	Ok	7	River Enclave	1218 (L17)	Ok	7
Crest Lane	613	Ok	7	River Enclave	1219 (L8)	Ok	7
Crest Lane	617	Ok	7	Rivercrest Drive	1103	Ok	1, 2, 7
Crest Lane	620	Ok	2, 5, 7	Rivercrest Drive	1115	Ok	2, 7
Crest Lane	625	Ok	7	Rivercrest Drive	1127	Ok	7
Crest Lane	633	Ok	7	Riverside Drive	613	Ok	6, 7
Fair Lane	312	Ok	2, 7	Riverside Drive	625	Ok	1, 5, 7
Fair Lane	338	Ok	2, 7	Riverside Drive	633	Ok	1, 2, 3, 7
Fair Lane	350	Ok	7	Sleepy Hollow	1310	Ok (w)	1, 2, 3, 6, 7
Fair Lane	504	Ok	3, 4, 7	Sleepy Hollow	1446	Ok	1, 2, 3, 7
River Acres Drive	1208	Ok	2, 7	Sleepy Hollow	1457	Ok	3, 5, 7
River Enclave	1210	Ok	7				

Note: Plant series: 1) Bald Cypress-Sycamore 2) Pecan-Sugarberry 3) Sugarberry-Elm 4) Plateau Live Oak-Midgrass 5) Plateau Live Oak-Netleaf Hackberry 6) Sycamore-Willow 7) Other – human alteration, non-natives.
Soil: Ok, Oakalla soils, 0 to 2 percent slopes, frequently flooded, partially hydric.

Current Conditions

The properties were all used for residential purposes prior to the buyout following the flood of 1998. FEMA regulations require the removal of all structures including slabs after a buyout, so all properties have been cleared. Vegetation prior to the flood remains, except for what was scoured by flood and lost during the course of removal of the structures and slabs. Because of the residential landuse, most of the grass was Saint Augustine and there are still domestic shrubs such as ligustrum and red-tipped photinia (figure 8). Succession has occurred because very little has been done to the properties since the removal of the structures (figure 9). Herbaceous plants, vines, and woody plants have started to re-establish in some areas. There is debris consisting of pipes, pieces of concrete and asphalt, and various other materials still located on the properties. From site observations, it is assumed there are still underground pipes present and possibly buried septic tanks in the Sleepy Hollow area.

Fig. 8 633 Summerwood Property

Fig. 9. Summerwood Succession

CHAPTER VI

DISCUSSION

The Guadalupe River meanders through the city of New Braunfels exhibiting a variety of physical characteristics along its banks. The division of the properties into three areas according to their geographic proximity to each other enables the properties to be grouped into similar reaches along the river. Each reach is defined by similar physical characteristics. For example, the properties in the Fair Lane and Crest Lane areas have sloping banks and alluvial type land with more open spaces (figures 10 and 11). The Summerwood area is open, but has a bank drop of about five to ten feet depending on river flow. The Sleepy Hollow area also has a bank drop of about 10 to 15 feet and a combination of open and wooded areas. At one time all areas were one contiguous riparian zone, but development has splintered the area dividing it into many sections. Individual restoration plans must take into account that in the future, the riparian zone might once again be contiguous due to repetitive floods and future buyouts.

Since almost all properties except for one were open with few trees and shrubs, the first step for restoration was to develop a canopy using the plant series that should have occurred naturally. Preference was given for plants with low conservation status. This involved adding Bald Cypress near the river’s edge where there were none. Canopy diversity should include at least four layers, including tall trees, small trees, shrubs and herbaceous cover. Planting in clusters can promote natural re-vegetation by creating "nurseries" where seedlings get protection from herbivores by surrounding plants. The use of cages around new trees or clusters can also provide temporary protection from herbivores. White-tailed deer are the primary herbivore of concern in the study site.

Fig. 10 Crest Lane

Most properties already had Sycamore present due to succession after the last flood. Other trees near the water's edge included Box-elder (*Acer negundo)* and Eastern Cottonwood (*Populus deltoids)*. Box-elder occurred on the property at 1310 Sleepy Hollow and at one time was more prevalent along the riparian zones. The Pecan-Sugarberry and Sugarberry-Elm series were the two dominant occurrences, although several properties lacked the actual trees. Sugarberry is a Hackberry species occurring on the properties. They are quick growing and provide food and habitat for wildlife. Both of these series would provide canopy in a re-vegetation plan, and the Hackberries seemed to be reestablishing on their own. The Plateau Live Oak-Netleaf Hackberry and Plateau Live Oak-Midgrass occurred in the higher elevations of the riparian zone further away from the river. The Hackberry appeared to be re-establishing, but only existing Live Oaks were noted. This could have been a result of mowing by neighbors.

Fig. 11. Fair-Crest Area

Re-establishing the canopy involves removing the invasive non-native species, predominately Ligustrum (*Ligustrum lucidum)*, Chinese Tallow (*Sapium sebiferum)*, and Chinaberry (*Melia azedarach)*. Herbaceous plants had already begun to establish themselves and should continue as the canopy matures. Planting natives would hasten canopy establishment. It is recommended to remove the turf grasses, so native vegetation could become established. However, care should be taken when plowing or disking to not disturb large sections of soil extending to the river bank or erosion could occur. It is best to plow grasses in strips parallel to the river in succession. After one strip has been regrown with other plants, new strips should be plowed. The disturbed soil can be seeded or planted with native clump grasses, shrubs and trees, or allowed to regrow from whatever seeds naturally occur on the site. Seeding or planting native grasses would hasten the establishment process.

The property at 1310 Sleepy Hollow is the largest at 137,608 square feet (3.16 acres) (figure 12). It is the most amendable to restoration because it is already inhabited with native plants, and the size allows for more usage possibilities. It is a sink, a low-lying, poorly drained area where waters collects and sinks into the ground or evaporates, with large trees and plants for wildlife cover and habitat. Site observation supported the idea that gravel may have been extracted from the site and formed the depression. Restoration entails cleanup of construction debris such as chunks of asphalt, pipes, and other materials; removal of non-natives such as Ligustrum, Chinese Tallow, and Chinaberry; and possible removal of an old septic system if present. Trails, picnic areas and wildlife observation sites could be implemented on this site because of the size.

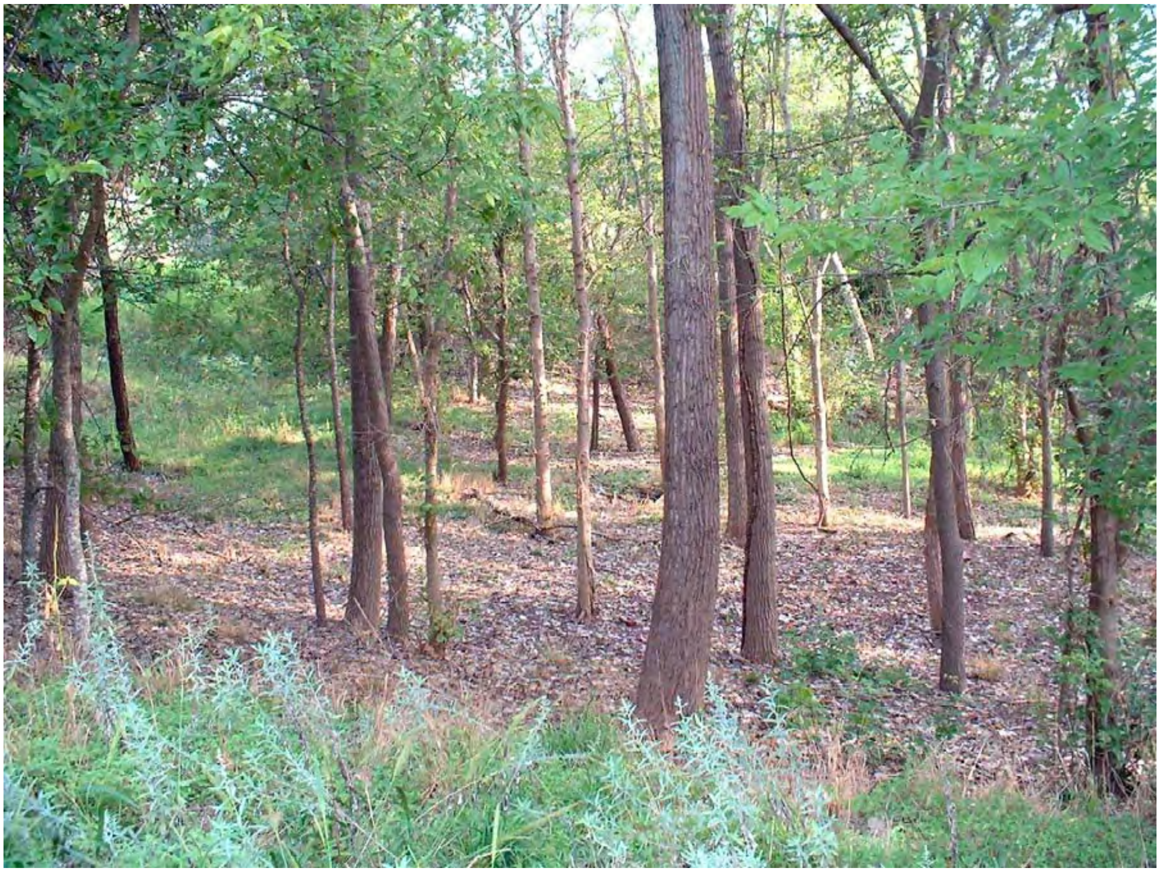


Fig.12. 1310 Sleepy Hollow

Other properties are much smaller. At one time the properties were residential lots and the average size is comparable to a city lot. Restoration plans could be implemented using the planned re-vegetation scheme; however, community involvement is required. Mowing should be discontinued. To alleviate public complaint, native herbaceous plants such as flowering annuals and grasses could be planted for aesthetic as well as restorative purposes. The contiguous properties would also be amendable to other public uses such as picnic areas and wildlife observation areas. They are too open and small for the inclusion of trails. Future buyout additions could change this status.

Any restoration of native vegetation would be advantageous for flood control and water quality. Ideally, woody debris should be left in the river and on the banks after floods to provide habitat for wildlife and flood control. Extensive research shows many advantages of leaving the woody debris (Wallace 1994; Naiman and Décamps 1997). New Braunfels relies on the Guadalupe River for financial income from recreational users, so the river is cleaned after major floods. Public education included in the restoration plan would help to develop support for buyouts of flood prone properties. As buyouts increase, the land area increases, which increases the value of the riparian zone for flood control and as a filter. The Guadalupe River in the New Braunfels area has good water quality, and the increase of restored riparian zones would help maintain that water quality. Canyon Dam helps with flood control, but storms below the dam will occur in the future. Future flooding in this area is inevitable.

CHAPTER VII

SUMMARY

The riparian restorations designed for use in the middle Guadalupe River basin should be applicable to similar basins in the central Texas area because of the corresponding geomorphologic and climatic conditions along central Texas riparian corridors. While a specific project would have to be adapted to the local geographic area, the general template presented here would be a viable option for current and future buyout lands in the central Texas area. This research shows that riparian restoration is a viable landuse option, and local communities could enlist community service oriented organizations to help implement and maintain projects.

This study demonstrates that the most important factors for successful riparian restoration of floodplain buyouts are determination of original plant series based on soil type and flood regimes, re-vegetation with appropriate native plants, establishment of canopy diversity, management for floral species diversity, removal of invasive non-native species, public education, and community involvement. Doing these things will promote a healthy riparian zone and provide habitat for a diversity of fauna. Appendices two and three include suggestions of species for restoration in the study zone. Nuisance plants such as poison ivy (*Toxicodendron radicans)* and giant ragweed (*Ambrosia trifida* var. *texana)* may occur naturally, but are not included in the plant lists.

The most important factors that inhibit successful restoration are lack of knowledge of restoration as an option and information about restoration projects. Most communities do not pursue this course of action because it is never suggested, and they do not think they have the finances to undertake any type of action with the properties. The individual residential lots' small sizes make the project results seem inconsequential. However, increases in development lead to increases in flooding, and government regulations have started restricting coverage of repetitively flooded properties. This will lead to increased buyouts, which will increase the chances for more contiguous properties, thus increasing the size of the riparian zone and the benefits of the restoration projects.

Among the riparian vegetative communities found in Central Texas, the easiest and quickest to reestablish is the Pecan-Sugarberry and Sugarberry-Elm, although individual Sycamore trees were prolific near the water's edge. Herbaceous plants such as Frostweed (*Verbesina baldwinii*) and vines such as Dewberry (*Rubus trivialis)* and Greenbriars (*Smilax bona-nox)* were already reestablishing without specific plantings. As plants return and the canopy increases, more riparian plants will become self-sustaining. The slowest to reestablish is the Bald Cypress and some of the other native trees such as the Box-elder. Part of the reason is that they are already in scarce supply due to man's activities before the floods. Replanting some of the plants with a low conservation status number would increase their occurrence, as well as benefiting the restoration project.

Based upon these observations a successful riparian restoration on buyout lands should follow the following guidelines: 1) conduct site visits to inventory vegetation status and make observations 2) gather data on soils, vegetation, precipitation, and flood regime 3) get community input and identify resources 4) create flexible preliminary plans 5) conduct public education campaign 6) plan and complete installation 7) monitor and make adjustments and 8) perform ongoing evaluation of the project.

APPENDIX 1

PLANT COMMUNITIES OF TEXAS

This appendix includes plant communities at the series level from Diamond 1993.

Bald Cypress-Sycamore Series (*Taxodium distichum-Platanus occidentalis*)
This mainly deciduous forest occurs as gallery forests along narrow floodplains and channels of perennial streams, primarily along the southern and southeastern margins of the Edwards Plateau, but also forms a gallery along streams to the south and east. Texas or Lacey oak (*Quercus buckleyi, Q. laceyi*) deciduous woodlands and evergreen Ashe juniper (*Juniperus ashei*) woodlands often inhabit the same canyons. (G3S3)

Pecan-Sugarberry Series (*Carya illinoensis-Celtis laevigata*)
This deciduous forest or woodland occupies floodplains, primarily within the South Texas Plains, Edwards Plateau, and Blackland Prairie. It is best developed along major rivers, and soils are often heavy textured and calcareous. Important species may include netleaf hackberry (*Celtis reticulata*), cedar elm (*Ulmus crassifolia*), bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), plateau live oak (*Quercus fusiformis*), black walnut (*Juglans nigra*), ash (*Fraxinus* spp.), Texas oak (*Quercus buckleyi*), and box-elder (*Acer negundo*). Drier floodplains of smaller streams may fall within the plateau live oak-hackberry series, while to the east more mesic floodplains support oak-dominated bottomland hardwood communities. Adjacent dry slopes may be Ashe juniper (*Juniperus ashei*) or *Acacia* spp. dominated in the Edwards Plateau and South Texas Plains. (G4S4)

Sugarberry-Elm Series (*Celtis laevigata-Ulmus* spp.)
This broadly-defined deciduous forest occurs on floodplains and mesic slopes, primarily in central and south Texas. American elm (*Ulmus americana*) is common on wetter sites, while cedar elm (*Ulmus crassifolia*) increases to the west and south. Composition varies with flooding regime and geographic location. Pecan (*Carya illinoensis*), ash (*Fraxinus berlandieri, F. pensylvanica, F. texensis*), oaks (*Quercus muhlenbergii, Q. buckleyi, Q. macrocarpa*), and sycamore (*Platanus occidentalis*) are variously important, but geographic differences are poorly documented. The plateau live oak-netleaf hackberry (*Quercus fusiformis-Celtis reticulata*) and pecan-sugarberry series are defined for the Edwards Plateau, South Texas Plains, and Blackland Prairie. Sugarberry- or netleaf hackberry- and cedar elm-dominated communities are a widespread and common disturbance type of uplands and floodplains of central and south Texas. To the east this type grades into typical bottomland hardwoods communities within the water oak-willow oak (*Quercus nigra-Q. phellos*) series. (G4S4)

Plateau Live Oak-Midgrass Series (*Quercus fusiformis*)
This mainly evergreen woodland occupies uplands of the Edwards Plateau where it is often intermixed with midgrass grassland on flats and on gentle slopes. Composition varies with substrate (i.e. between the limestone-derived soils of the Plateau proper and the generally sandier soils of the Llano Uplift) and precipitation. Canopy cover ranges from open to closed, with mottes of monoculture live oak present in some areas. Texas oak (*Quercus buckleyi*), cedar elm (*Ulmus crassifolia*), post oak (*Quercus stellata*), Ashe juniper (*Juniperus ashei*), scalybark oak (*Quercus sinuata* var. *breviloba*), *Quercus* spp., and shrubs such as *Rhus* spp. and *Condalia* spp. are variously present. Shallow soils or

disturbed areas often support Ashe juniper or mesquite (*Prosopis glandulosa*)-dominated woodlands or shrublands, while openings in good condition are midgrass grasslands with species such as little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and curlymesquite (*Hilaria belangeri*). (G3S3)

Plateau Live Oak-Netleaf Hackberry Series (*Quercus fusiformis-Celtis reticulata*)
This evergreen to mainly deciduous woodland or forest occupies floodplains of streams, primarily within the Edwards Plateau, South Texas Plains, and eastern trans-Pecos. Important species may include sugarberry (*Celtis laevigata*), pecan (*Carya illinoensis*), ash (*Fraxinus texensis, F. berlandieri*), cedar elm (*Ulmus crassifolia*), bur oak (*Quercus macrocarpa*), Ashe juniper (*Juniperus ashei*), and Texas persimmon (*Diospyros texana*). More mesic floodplains fall within the pecan-sugarberry or sugarberry-elm series. Adjacent slopes may be Ashe juniper- or *Acacia* spp.-dominated. (G4S4)

Sycamore-Willow Series (*Platanus occidentalis-Salix nigra*)
This broadly-defined mostly deciduous strip forest or woodland occupies moist to wet, often gravelly soils in periodically-scoured creek and river beds across most of the Edwards Plateau and adjacent areas. Sycamore, black willow, and eastern cottonwood (*Populus deltoides*) are usually present, often as scattered small trees representing growth since the most recent catastrophic flood. A poorly-developed shrub layer composed of willow baccharis (*Baccharis neglecta*), buttonbush (*Cephalanthus occidentalis*), creek indigo (*Amorpha fruticosa*) and/or little walnut (*Juglans microcarpa*) may be present, along with a ground layer that varies widely depending on moisture, stratum, disturbance and other factors. (G5S5)

GLOBAL RANK
Each community type has been assigned a code that denotes its conservation status at both the global and state levels. Global rank is denoted by **G** and a number (1–5) or H:

- **G1** = less than 6 occurrences known globally; critically imperiled, especially vulnerable to extinction
- **G2** = 6 to 20 occurrences known globally; imperiled and very vulnerable to extinction throughout its range
- **G3** = 21 to 100 occurrences known globally; either very rare and local throughout its range or found locally (even abundantly at some locations) in a restricted range (e.g., a single state or physiographic region), or because of other factors vulnerable to extinction throughout its range
- **G4** = more than 100 occurrences known, apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery
- **G5** = demonstrably secure globally, though it may be quite rare in parts of its range
- **GH** = of historical occurrence throughout its range, i.e., formerly part of the established biota, with expectation that it may be rediscovered

STATE RANK
State rank is denoted by **S** and a number (1–56) or H:

S1 = less than 6 occurrences known in Texas; critically imperiled in Texas; very vulnerable to extirpation from the state\
S2 = 6 to 20 known occurrences in Texas; imperiled in the state because of rarity; very vulnerable to extirpation from the state
S3 = 21 to 100 known occurrences in Texas; either rare or uncommon in the state
S4 = more than 100 occurrences in Texas; apparently secure in the state, though it may be quite rare in some areas of the state
S5 = demonstrably secure in Texas
SH = historical in Texas, perhaps having not been verified in the last 50 years, but suspected to be extant

APPENDIX 2

VEGETATION LIST FOR CENTRAL TEXAS

This appendix includes native plant suggestions for a Central Texas restoration project.

Trees:

Acer negundo	Box-elder
Carya illinoensis	Pecan
Celtis laevigata	Texas Sugarberry
Celtis laevigata var. *reticulata*	Net-leaf Hackberry
Diospyros virginiana	Common Persimmon
Ehretia anacua	Anaqua
Fraxinus pensylvanica	Green Ash
Fraxinus texensis	Texas Ash
Juglans microcarpa	Texas Black Walnut
Morus rubra	Red Mulberry
Platanus occidentalis	Sycamore
Populus deltoids	Eastern Cottonwood
Prosopis glandulosa	Honey Mesquite
Prunus mexicana	Mexican Plum
Prunus serotina var. *eximia*	Escarpment Black Cherry
Quercus fusiformis	Plateau Live Oak
Salix nigra	Black Willow
Sapindus saponaria	Western Soapberry
Taxodium distichum	Bald Cypress
Ulmus Americana	American Elm
Ulmus crassifolia	Cedar Elm

Shrubs and Small Trees:

Aesculus arguta	Texas Buckeye
Aesculus pavia	Red Buckeye
Aloysia gratissima	White-Brush
Amorpha fruticosa	False Indigo
Berberis trifoliolata	Agarito
Bumelia lanuginosa	Woolybucket Bumelia
Callicarpa americana	American Beautyberry
Cephalanthus occidentalis	Buttonbush
Cercis canadensis var. *texensis*	Texas Redbud
Cornus drummondii	Roughleaf Dogwood
Cotinus obovatus	Texas Smoke Tree
Crataegus sp.	Hawthorn
Diospyros texana	Texas Persimmon
Eysenhardtia texana	Texas Kidneywood
Forestiera pubescens	Elbowbush
Frangula caroliniana	Carolina Buckthorn
Garrya ovata ssp. *Lindheimeri*	Lindheimer Silk Tassel
Ilex decidua	Possumhaw

Lantana urticoides	Texas Lantana
Leucaena retusa	Golden-ball Lead-tree
Lindera benzoin	Spicebush
Mahonia swaseyi	Texas Barberry
Mahonia trifoliolata	Agarita
Parkinsonia aculeate	Retama
Prunus rivularis	Creek Plum
Ptelea trifoliate	Common Hop-Tree
Malus ioensis var. *texana*	Blanco Crabapple
Salvia ballotaeflora	Shrubby Blue Sage
Sambucus canadensis	Elderberry
Saphora affinis	Eve's Necklace
Saphora secundiflora	Texas Mountain-laurel
Senna lindheimeriana	Lindheimer Senna
Styrax platanifolia	Sycamore-Leaf Snow Bell
Styrax texana	Texas Snow-bell (endangered)
Ungnadia speciosa	Mexican-buckeye
Viburnum rufidulum	Rusty Blackhaw
Zanthoxylum hirsutum	Toothache Tree

Vines:

Clematis texensis	Scarlet Leatherflower
Clematis pitcheri	Purple Leatherflower
Cocculus carolinus	Carolina Snailseed
Rubus trivialis	Dewberry
Parthenocissus quinquefolia	Virginia Creeper
Vitis mustangensis	Mustang grape

Grasses and herbaceous vegetation:

Andropogon gerardii	Big Bluestem
Andropogon glomeratus	Bushy Bluestem
Centaurea americana	Basket-Flower
Chasmanthium latifolium	Creek Oats
Conoclinium coelestinum	Blue Mistflower
Cooperia sp.	Rain Lily
Echinacea angustifolia	Purple Coneflower
Eupatorium serotinum	White Boneset
Ipomopsis rubra	Standing Cypress
Liatris mucronata	Gay Feather
Lobelia Cardinalis	Cardinal Flower
Lygodesmia texana	Skeleton-plant
Malvaviscus arboreus	Turk's Cap

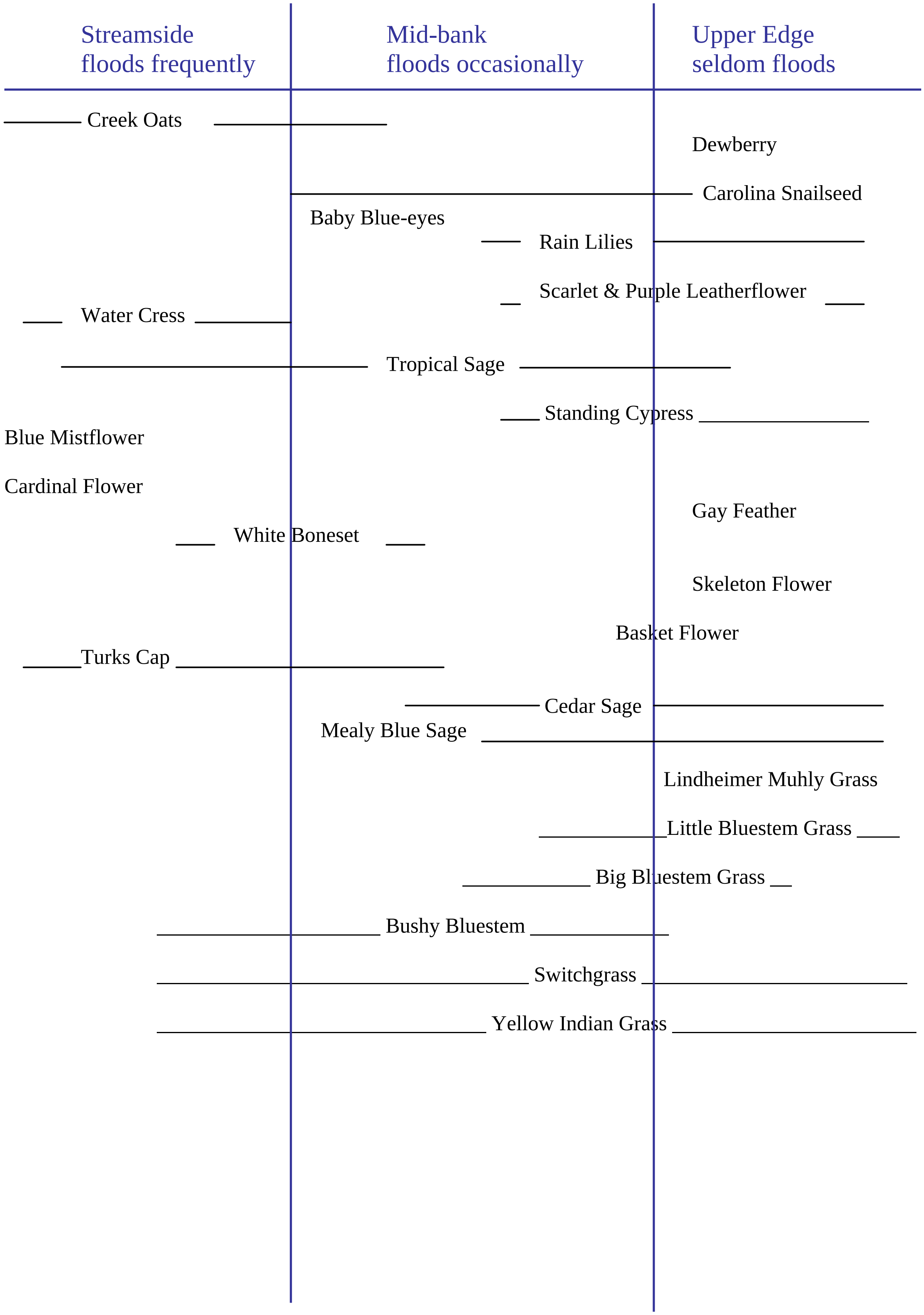
Muhlenbergia lindheimeri	Lindheimer Muhly
Nemophila phacelioides	Baby Blue-eyes
Panicum virgatum	Switchgrass
Salvia coccinea	Tropical Sage
Salvia farinacea	Mealy Blue Sage
Salvia roemeriana	Cedar Sage
Schizachyrium scoparium	Little Bluestem
Sorghastrum nutans	Yellow Indian Grass
Verbesina baldwinii	Frostweed

APPENDIX 3

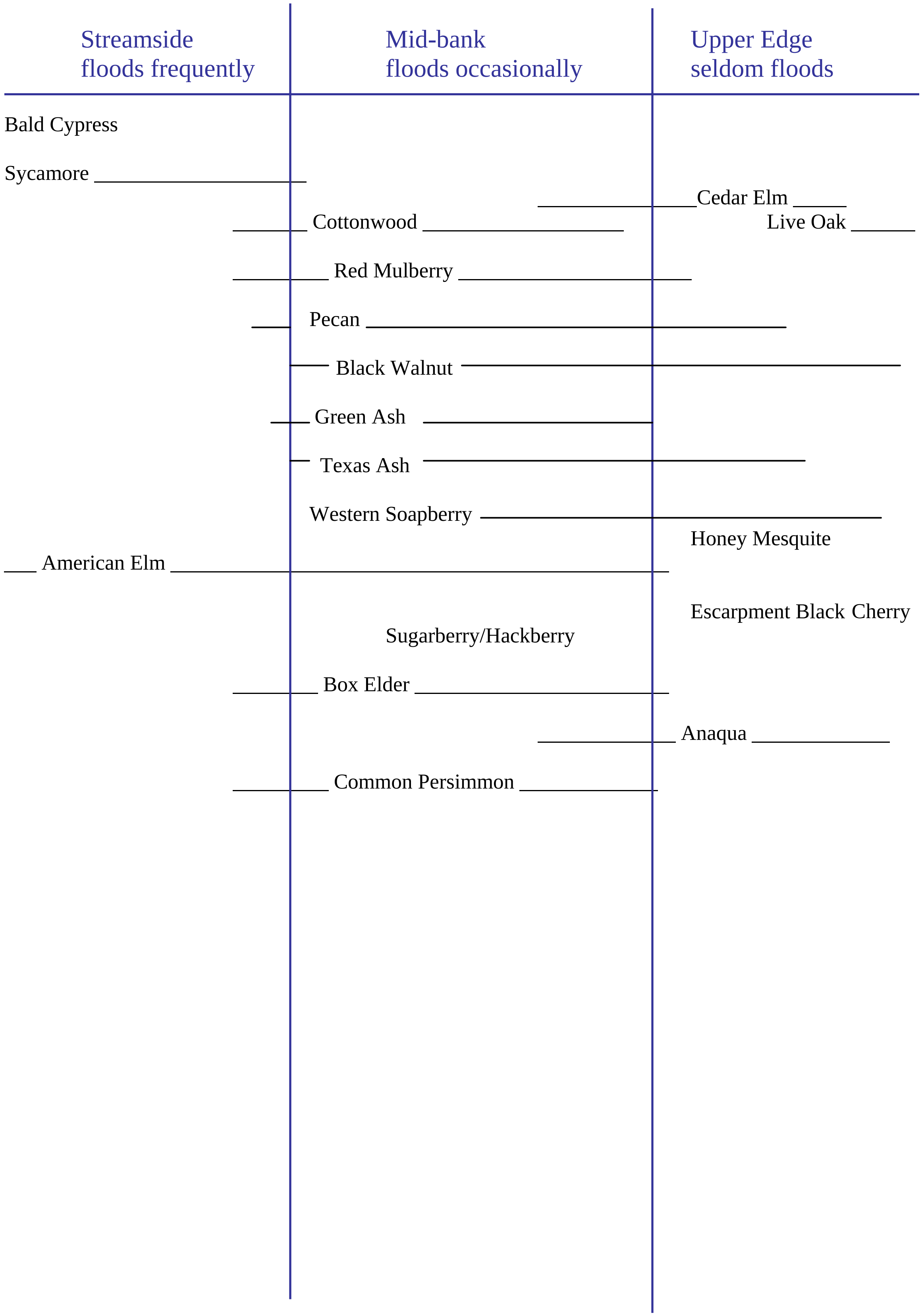
VEGETATION LIST BY RIPARIAN ZONE FOR CENTRAL TEXAS

This appendix includes native plant suggestions for a Central Texas restoration project listed by the part of the riparian zone where they most often occur naturally.

Herbaceous


Streamside
floods frequently
Mid-bank
floods occasionally
Upper Edge
seldom floods
Creek Oats
Dewberry
Carolina Snailseed
Baby Blue-eyes
Rain Lilies
Scarlet & Purple Leatherflower
Water Cress
Tropical Sage
Standing Cypress
Blue Mistflower
Cardinal Flower
Gay Feather
White Boneset
Skeleton Flower
Basket Flower
Turks Cap
Cedar Sage
Mealy Blue Sage
Lindheimer Muhly Grass
Little Bluestem Grass
Big Bluestem Grass
Bushy Bluestem
Switchgrass
Yellow Indian Grass

Trees


Streamside
floods frequently
Mid-bank
floods occasionally
Upper Edge
seldom floods
Bald Cypress
Sycamore
Cedar Elm
Cottonwood
Live Oak
Red Mulberry
Pecan
Black Walnut
Green Ash
Texas Ash
Western Soapberry
Honey Mesquite
American Elm
Escarpment Black Cherry
Sugarberry/Hackberry
Box Elder
Anaqua
Common Persimmon

Shrubs and Small Trees

Streamside floods frequently	Mid-bank floods occasionally	Upper Edge seldom floods

_____ Elbowbush _____

White-Brush __________

______ Texas Kidneywood _____

____________Wafer Ash/Hop-Tree ____

Mountain Laurel-

Spice Bush _____________________________

__________________ Roughleaf Dogwood __________________________________

_______ American Beautyberry ______________________

Texas Barberry

Agarita ________________

Buttonbush

________________ Blanco Crabapple _____

___ False Indigo

___ Sycamore-Leaf Snow Bell

__________ Elderberry ____________

Toothache-Tree/Prickly Ash

___________ Mexican Buckeye ______________________________________

_____ Rusty Blackhaw ________

_____ Carolina Buckthorn _______

____ Hawthorn (sp.) __________________________________

_______________________ Creek Plum ____

Texas Redbud

Lindheimer Senna

Eve's Necklace _______________________________

Golden-ball Lead Tree _______________

Retama

___________ Smoke Tree __________

___________Texas Buckeye _______________

__________ Red Buckeye __________________

Shrubby Blue Sage _______________________________

WORKS CITED

Bagley, Maebeth, former mayor of Martindale. 2005. Interview by author, 25 January, Martindale. Notes. Martindale City Hall, Martindale.

Baker, Victor R. 1977. Stream-channel response to floods with examples from central Texas. *Geological Society of America Bulletin* 88 (August): 1057-1071.

Barnard, Jerald R. 1978. Externalities from urban growth: The case of increased storm runoff and flooding. Land Economics 54, no. 3 (August): 298-315.

Caran, S. Christopher and Victor R. Baker. 1986. Flooding along the Balcones escarpment, central Texas. In *The Balcones Escarpment Geology, Hydrology, Ecology and Social development in Central Texas,* ed. Patrick L. Abbott and C.M.Woodruff, Jr., 1-14. San Antonio: Texas.

CH2M Hill. 2002. *FEMA hydrologic and hydraulic analysis.* New Braunfels, Texas: CH2M Hill.

Cohn, Jeffrey P. 2001. Resurrecting the dammed: A look at Colorado River restoration. *BioScience* 51, no. 12 (December): 998-1003.

Committee on Riparian Zone Functioning and Strategies for Management, Water Science and Technology Board, National Research Council. 2002. *Riparian areas: Functions and strategies for management*. Washington, D.C.: National Academy Press.

Décamps, Henri. 1993. River margins and environmental change. *Ecological Applications* 3, no. 3 (August): 441-445.

Diamond, D. D. 1993. *Classification of the plant communities of Texas (series level)*. Texas Natural Heritage Program. Austin, Texas: Texas Parks and Wildlife Department.

Diamond, David D., David H. Riskind, and Steve L. Orzell. 1987. A framework for plant community classification and conservation in Texas. *Texas Journal of Science*. 39, no.3: 203-221.

Ellington, Janine. 2005. Interview by author, 25 April, Comal County. Notes. Comal County Engineering Department, Comal County.

Espey, W. H. K., C. W. Morgan, and F. D. Masch. 1966. *Study of some effects of urbanization on storm runoff from a small watershed: Austin*. Texas Water Development Board Report 23.

Federal Emergency Management Agency. 2006. *NFIP policy index*. Publication on-line. Available from http://www.fema.gov/NFIPKeywords/description.jsp?varKeywordID=30 (accessed 12 March 2007).

Harvey, Robert O. and W. A. V. Clark. 1965. The nature and economics of urban sprawl. *Land Economics* 41. no. 1 (February): 1-9.

Holway, James M. and Raymond J. Burby. 1990. The effects of floodplain development controls on residential land values. *Land Economics* 66, no. 3 (August): 259-271.

Klamath Resource Information System. *Riparian restoration*. Database on-line. Available from http://www.krisweb.com/restore/riparian.htm (accessed 2 March 2005).

Leopold, Luna B., M. G. Wolman, and J. P. Miller. 1964. *Fluvial processes in geomorphology*. San Francisco: W.H. Freeman and Co.

Manci, Karen M. 1989. *Riparian ecosystem creation and restoration: A literature summary*. U.S. Fish and Wildlife Service Biological Report 89(20): 1-59. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/habitat/ripareco/ripareco.htm (Version 16JUL97) (accessed 14 March 2005).

McLaughlin, Nancy A. 2004. Increasing the tax incentives for conservation easement donations -- A responsible approach. *Ecology Law Quarterly* 31, no. 1: 10-91.

Molles, Manual C. Jr., Clifford S. Crawford, Lisa M. Ellis, H. Maurice Valett, and Clifford N. Dahm. 1998. Managed flooding for riparian ecosystem restoration. *BioScience* 48, no. 9: 749-756.

Murphy, Jocelyn, Planner-City of New Braunfels. 2006. Interview by author, 27 February, New Braunfels. Phone conversation. New Braunfels Municipal Building, New Braunfels.

Naiman, Robert J. and Henri Décamps. 1997. The ecology of interfaces: Riparian zones. *Annual Review of Ecology and Systematics* 28 (November): 621-658.

Naiman, Robert J., Henri Decamps, and Michael Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* 3, no. 2 (May): 209-212.

National Wildlife Federation. 1998. *Higher ground: A report on voluntary property buyouts in the nation's floodplains, a common ground solution serving people at risk, taxpayers and the environment.* Washington D.C.: National Wildlife Federation.

NCRS. 2007. See U.S. Department of Agriculture. 2007.

Palmer, M. A., E. S. Bernhardt, J. D. Allan, P. S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C. N. Dahm, J. Follstad Shah, D. L. Gallat, S. G. Loss, P. Goodwin, D. D. Hart, B. Hassett, R. Jenkinson, G. M. Kondolf, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano, and E. Sudduth. 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology* 42: 208-217.

Planty-Tabacchi, Anne-Marie, Eric Tabacchi, Robert J. Naiman, Collette Deferrari, and Henri Decamps. 1996. Invasibility of species-rich communities in riparian zones. *Conservation Biology* 10, no. 2 (April): 598-607.

P2 Energy Solutions. 2005. Aerial image files from private business to City of New Braunfels, Texas.

Richter, Brian D. and Holly E. Richter. 2000. Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. *Conservation Biology* 14, no. 5 (October): 1467-1478.

Riskind, David H. and David D. Diamond. 1986. Plant communities of the Edwards Plateau of Texas: An overview emphasizing the Balcones Escarpment zone between San Antonio and Austin with special attention to landscape contrasts and natural diversity. In *The Balcones Escarpment: Geology, hydrology, ecology and social development in Central Texas*, ed. Patrick L. Abbott and C.M.Woodruff, Jr., 20-32. Geological Society of America Annual Meeting: San Antonio, Texas.

Robbins, Frank, Director of Planning and Development-City of New Braunfels. 2005. Interview by author, 25 April, New Braunfels. Phone conversation. New Braunfels Municipal Building, New Braunfels.

Rood, Stewart B., Chad R. Gourley, Elisabeth M. Ammon, Lisa G. Heki, Jonathan R. Klotz, Michael L. Morrison, Dan Mosley, G. Gary Scoppettone, Sherman Swanson, and Paul L. Wagner. 2003. Flows for floodplain forests: A successful riparian restoration. *BioScience* 53, no. 7 (July): 647-656.

Semlitsch, Raymond D. and J. Russell Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 17, no. 5 (October): 1219-1228.

Sweeney, Bernard W., Thomas L. Bott, John K. Jackson, Louis A. Kaplan, J. Denis Newbold, Laurel J. Standley, W. Cully Hession, and Richard J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the National Academy of Sciences of the United States of America* 101, no. 39 (September):14132-14137.

U.S. Department of Agriculture. Forest Service. Forest Resources Management. 1991. *Riparian forest buffers - Function and design for protection and enhancement of water resources*, by David J. Welsch. Publication on-line. Available from http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm (accessed 24 March 2005).

U.S. Department of Agriculture. Natural Resources Conservation Service. 2007. *Soil survey geographic (SSURGO) database for Comal and Hays Counties, Texas.* Fort Worth, Texas. Available from http://soildatamart.nrcs.usda.gov/Metadata.aspx?Survey=TX604&UseState=TX (accessed 9 February 2007).

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Weather Service. 1997. *The heavy rain and flood event of June 21-22, 1997 in south central Texas and the Texas hill country*, by Robert Blaha and Bruce Thoren. Technical attachment on-line. Available from http://www.srh.noaa.gov/topics/attach/html/ssd97-55.htm (accessed 17 March 2005).

________. National Oceanic and Atmospheric Administration. National Weather Service. 2003. *Tropical/Middle latitude rain event with an October cold front,* by Robert Blaha. Technical attachment on-line. Available from http://www.srh.noaa.gov/ewx/html/attach/oct/oct94wx.htm (accessed 17 March 2005).

U. S. Environmental Protection Agency. National Risk Management Research Laboratory. 2002. *Number 1: Research needs in riparian buffer restoration,* by Eric E. Jorgensen, Timothy J. Canfield, and Paul M. Mayer. Issue Paper, Advances in Restoration Science. Cincinnati.

________. National Risk Management Research Laboratory. 2003. *Ecosystem restoration to restore water quality; An unrealized opportunity for practitioners and researchers,* by Eric E. Jorgensen and Stephen L. Yarbrough. Research contract to Dynamac Corporation. Ada.

U.S. Geological Survey. National Water Information System. 2007. *Peak streamflow for Texas*. Database on-line. Available from http://nwis.waterdata.usgs.gov/tx/nwis/peak?site_no=08168500&agency_cd=USGS&format=html (accessed 27 April 2007).

Wagner, Matt. 2004. *Managing riparian habitats for wildlife.* Austin, Texas: Texas Parks and Wildlife. PWD BR W7000-306 (6/04). Available from http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_br_w7000_030 pdf (accessed 12 May 2007).

Wallace, Michael W. 1994. Distribution and habitat affinity of the swamp rabbit (*Sylvilagus aquaticus*) on the Edwards Plateau of Texas. Ph.D. diss., Texas State University-San Marcos.

White, Gilbert F. 1945. *Human adjustment to floods: A geographical approach to the flood problem in the United States*. Chicago: University of Chicago, Department of Geography. Research Paper 29.

Williams, C. N., Jr., M. J. Menne, R. S. Vose, and D. R. Easterling. 2006. *United States Historical Climatology Network daily temperature, precipitation, and snow data.* ORNL/CDIAC-118, NDP-070. Available from http://cdiac.ornl.gov/epubs/ndp/ushcn/usa.html (accessed 11 May 2007).

Wissmar, Robert C. and Robert L. Beschta. 1998. Restoration and management of riparian ecosystems: A catchment perspective. *Freshwater Biology* 40: 571-585.

VITA

Jana Lynne Harter was born in Fort Worth, Texas on February 3, 1958 to Charles and Nancy Harter. She received her Bachelor of Science in Education Curriculum and Instruction from Texas A&M in August 1990. She was a classroom teacher for 13 years before entering the Department of Geography's graduate program in the fall of 2004.

Permanent Address: 907 Canyon Edge

Canyon Lake, Texas 78133

This thesis was typed by Jana L. Harter.