THE SPATIAL EVOLUTION OF URBAN FLOOD HAZARD IN SAN ANTONIO, TEXAS

DISSERTATION

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By

Ronald R. Hagelman, III, B.A., M.A.G.

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DEDICATION

This dissertation is dedicated to

Geoffrey Marshall
(1938-2000)

He and his kind words are sorely missed.

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Although the relative scale of this undertaking will surely dwindle with time, any project of this magnitude is never the work of one person. With that in mind, I would like to acknowledge the assistance of a number of people who helped make this possible.

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ABSTRACT

This dissertation investigates the spatial evolution of urban flood hazard in Bexar County and the City of San Antonio, Texas from the period of European settlement to the present. Evidence of the spatial manifestations of human interaction with flood hazard is sought through the investigation of primary and secondary historical resources, cadastral geography data for the period 1820-1998, and census data for the period 1970-1990. Analytical techniques include the development of a historical narrative relating to the evolution of flood control, the statistical analysis of land parcels located in the floodplain versus those outside the floodplain, and cluster and time-change analysis of census tract attributes for population and housing.

Results relating to the evolution of San Antonio's flood control indicate that those efforts have been primarily reactive in response to large flood disasters rather then proactively designed to ward of the long-term impacts of the flood-continuum experienced by the city. Cadastral analysis indicated unique geographies for the urban floodplain. Residential development was characterized by a tendency to develop parcels outside the floodplain first, with subsequent infill proliferating the riskiest locations near flood zones. Commercial development exhibited valuation patterns that indicated that the risk of future flooding, or the aesthetic value of riverine locations, had been capitalized into those properties. Census analysis indicated that structural flood mitigation was associated with white, affluent tracts, while property buyouts were associated with minority, low-income tracts. This indicates that the social geography of the urban area

has influenced, and potentially been influenced by, the geography of flood mitigation in Bexar County.

Keywords: flood hazard, urban historical geography, cadastral geography, and spatial time-change analysis.

CHAPTER 1

INTRODUCTION

The Duality of Floodplains

Floodplains offer opportunity. They provide access to fresh water supplies. They generally offer diverse, but spatially compact, populations of flora and fauna useful to humans in their primary goal of sustenance. Floodplains are often the most fertile lands in the wider areas that they occupy, and therefore offer a well-suited landscape for agricultural development. They provide a system of transportation for people and their goods, and, when necessary, they provide a source of waste disposal for the manufacturing and processing necessary to produce those goods. Riverine environments associated with floodplains are often seen as aesthetically pleasing and therefore offer the opportunity to live among, as well as off of, nature's bounty. In this way, floodplains and the waters that have created them can be seen as cornucopia for human development. Common knowledge, however, tells us that there is not such thing as a "free lunch." If we choose to dine at the water's edge we must pay a price for the preferred seating offered by the location. More often than not this price manifests itself in the form of damage to humans and human structures in periods of extreme water flow. This relationship between human occupation of floodplains and natural hydrologic extremes is commonly referred to as *flood hazard.*

Referring to human use of the natural landscapes of the western United States in 1864, George Perkins Marsh wrote the "ravages committed by man subvert the relations and destroy the balance which nature has established and she avenges herself upon the intruder by letting loose her destructive energies" (Marsh 1864, 43). That statement conjures visions of two combatants: the first thoughtlessly wrecking havoc in a fragile land and the other just awakened for attack. In practice, the interaction of humans with their natural environment is often less dramatic and less sudden. Humans interact with nature and from the interaction derive either benefits (resources) or pay a price for the interaction (hazards). This establishes a relationship of adjustments. We are attracted to those natural landscapes that provide the most for us in the form of resources while at the same time our use of those resources, and our desire to mitigate the hazards embodied by these landscapes, put us in a perpetual state of reflexive modification with nature. Thus is our relationship with floodplains.

Human adjustment to the positive/negative duality of floodplains has occupied much of hazards literature over the last fifty years and much has been learned from the effort. We know that high-probability, low-impact flooding can be greatly controlled through the application of structural engineering in the form of dams and redesigned waterways (see for example any document on flooding published by the United States Army Corps of Engineers). We know that the physical structures we build to ward off the negative impacts of regular flooding have the presumably unanticipated effect of enticing additional floodplain occupancy and therefore increasing the number of people exposed to extreme flooding; or said another way, flood mitigation can increase flood hazard (see for example White 1945, Mileti 1999). We know that the most financially attractive way to provide nonstructural mitigation and relief for an ever-increasing population of floodplain occupants and flood victims is through risk-pooling mechanisms such as flood insurance and disaster relief loans (see for example Borkan and Kunreuther 1979, Kunreuther and Roth 1998). We know that the way in which our governments respond to flood hazard, whether on a local, regional, statewide, or national scale, can greatly modify the outcome of flood disasters (see for example Burby et al. 1988, Platt 1999). We know that the popular perception of natural risk and the economic capitalization of those risks can create unique patterns of mitigation and development (see for example Palm 1981, Tobin and Montz 1994). We know that the process of reconstructing from natural disasters can greatly influence the geography of the places affected by those disasters (see for example Bowden 1982, Rosen 1986). We know that the derivative impacts of flood disaster, and other natural disasters, are greatly impacted by the social, political and economic characteristics of the populations they impact (see for example Varley 1991, Blakie et al. 1994). And finally, despite these advances in the frontiers of our flood hazard knowledge, we know that the economic costs of flood disasters in the United States continues to escalate beyond our wildest expectations (see for example Federal Emergency Management Agency 1999, 2001a).

How can we know more about flooding and flood control, enough in fact to have radically reduced the number of flood-related fatalities in recent years, and yet still have so much of our capital-intensive infrastructure at risk? Why is the attraction to occupy floodplains so strong that we continue to do so at the guaranteed peril of our houses, personal belongings, corporate investments, and tax-supported government structures? Why does urban development continue to be analogous to the moth and the floodplain to the flame? And how does this continued tension between what we know about flood hazard and how we adjust to the risks of flooding mold our urban space? It is the complexities of this last question in particular that this study seeks to unravel. Our relationships with floodplains, and the adjustments we make to flood hazard, have played a substantive role in the use and modification of urban space, and they have done so in different ways over time.

An understanding of the broader topic of how humans have adjusted, and how our urban landscapes reflect those adjustments, will be sought through the examination of one city's experience with urban development and flood hazard management over the last one hundred years. The City of San Antonio, Texas (Bexar County) has been selected as the site for this analysis. San Antonio's relationship with its riverine environment stretches back nearly three hundred years for its European and American inhabitants, and over ten thousand for its indigenous populations. The last one hundred years of the city's flood-hazard adjustment history will be the primary focus of this research. The research will attempt to answer the questions "Does hazard modify space?" and, if so, "How do floodplains, characterized by their natural risk of flooding, develop into distinct geographies within the larger urban fabric of the city?"

Research Hypotheses

The question of how flood hazard has impacted urban form in San Antonio, Texas will be examined by testing three distinct, but related research hypotheses. Each relies on a separate data source and methodology and yet each questions the degree to which developmental trends within San Antonio have been altered over both time and space as a result of the city's interaction with flood risk.

Hypothesis 1 – Reactive, rather than proactive, management will drive substantive advancements in San Antonio's flood-hazard management history. Said differently, floodplain management will in effect be planning mitigation for the *last* event rather then the *next* event. Additionally, it is hypothesized that periods of flood management history will be highly reflective of the urban constituency most at risk within the urban floodplain during these periods and flood management will reflect the geographic nature of floodplain occupants.

Hypothesis 2 – Land development, at the scale of individual parcels, in San Antonio's floodplain will exhibit unique geographies of occupation in comparison to adjacent urbanized areas outside the city's floodplains. These spatio-temporal patterns of development will be modified by human adjustment to both the resource (utility) and the hazard (risk) of the floodplain.

Hypothesis 3 – Mitigation efforts applied to San Antonio's urban landscape will generate and/or reflect unique geographies resultant from human adjustment to flood risk. These unique patterns will be measurable in terms of both contemporary attributes of occupancy as well as change-over-time characteristics.

All three hypotheses have been generated to illuminate the evolution of flood hazard and flood control geography within San Antonio's urban area. This study's results will provide both an analytical exploration and a qualitative chronicle of the patterns of human adjustment to the resource and risk of the riverine environment of the city.

Although San Antonio possesses many unique qualities, both in terms of its historical human development and its natural setting, the results of this study will be presented in the conclusion such that they will inform the wider audience of floodplain managers, inhabitants, and researchers devoted to reducing the damaging impacts of floods and floodplain occupancy in all urban areas.

Structure of Dissertation

This dissertation will be presented in seven chapters following the introduction. Chapter two offers a review of research literature relevant to the analysis conducted. Literature relating to human ecology, flood hazard, floodplain management, and the historical geography of hazards and disasters is reviewed. Chapter three describes the data sources and methodologies applied in the analysis, as well as a discussion of how the distinct methodological approaches relate to the overall goal of this research. Chapter four offers a description of the physical, environmental, and human geography of San Antonio and Bexar County, Texas. This description of site and situation form the backdrop for the three chapters that follow.

Chapters five, six, and seven present the results of the analysis. Chapter five tests hypothesis one and is presented as a historical discussion of the evolution of flood hazard, flood disasters, and flood management from settlement to the present. Discussions of four major flood events from 1913 to 1998 form the core of this section. Chapter six presents the results of testing hypothesis two. Parcel-level patterns of floodplain development, both within (*adjacent development*) and along (*expansion development*) are quantitatively analyzed using non-parametric difference-of-means tests.

Chapter seven provides the results of testing hypotheses three and includes a selection of quantitative measures illustrating the degree to which population and housing geography in San Antonio has been influenced by existing flood control dams. This chapter also explores the degrees to which residential parcels that have been bought by the city and the county in recent years as part of their flood control effort reflects unique geographies within the larger urban fabric. This is accomplished by performing spatial and temporal analysis of census data from 1970, 1980, and 1990. Chapter eight presents conclusions to this research as well as a discussion of recommendations relating to future floodplain development in urban areas.

CHAPTER 2

LITERATURE REVIEW

Overview

This chapter reviews three groups of research literature relevant to the analysis and research goals of this dissertation. These include the lessons of hazards geography generated through the perspective of human ecology, the applied lessons gained through the specific study of flood hazard and floodplain geographies, and the understanding of the antecedents and impacts of past disasters offered through the historical geography of environment and urban development.

Human Ecology and Urban Flood Hazard

By design this research brings the lessons of multiple bodies of literature to bear on the topic of flood hazard evolution, however it finds it impetus in the theoretical contributions of researchers working in the broad field of human ecology. Therefore the implications of human ecology will be discussed first.

Human interaction with the natural environment results in two primary outcomes, resource and hazard (Burton, Kates, and White 1993). Humans adjust to and modify their natural environments in response to resources and hazards presented by the natural environment. This, in turn, can alter the benefits and risks presented by the environment, creating the need for additional adjustments or modifications; and thus generates a perpetual relationship of modification between humans and the natural environments they occupy.

This conceptualization of the human/nature relationship has been described as a closed feedback loop between people and their natural surroundings (Burton, Kates, and White 1993), and is derivative of the human ecological approach to social scientific research. Although John Dewey would later popularize a similar philosophical perspective on the human-nature relationship (Dewey 1938), human ecology, as a basis for social scientific inquiry, was first popularized by Harlan Barrows in his 1923 Association of American Geographers (AAG) Presidential Address (Barrows 1923). Barrows' address was prescriptive and included his belief that "those relationships between man and the earth which result from his efforts to get a living are in general the most direct and intimate; most other relationships are established through these" (Barrows 1923, 13). Even though Carl Sauer, nearly twenty years later in his own AAG presidential address, accused Barrows of pushing geography down a path that led to "a non-genetic description of the human content of areas" and toward an unattainable goal of becoming a "natural science of the human environment" (Sauer 1941, 2), Barrows had acknowledged the temporal nature of a human ecological geography by stating that it "helps us to see that the present adjustments of people to their environments represent only a stage in a ceaseless process of evolution, and it throws some light on the changes that are before us" (Barrows 1923, 12).

The human ecology thesis was incorporated into a number of disciplines within the University of Chicago at the time, especially geography, anthropology and sociology. Initially, however, it found its most ardent popularizers among sociologists, who, under the direction of Robert Park and Ernest Burgess launched a research tradition that has since been referred to as The Chicago School (Johnston et al. 1994). Park described a biotic human community characterized by competition and struggle, but, unlike the non-human biotic world, one modified by superstructures such as culture, economy, and politics. This perspective was applied primarily to urban studies.

> The city, from the point of view of this paper, is something more than a congeries of individual men and of social conveniences...of institutions and administrative devices...The city is, rather a state of mind, a body of customs and traditions, and of the organized attitudes and sentiments that inhere in these customs and are transmitted with this tradition. The city is not, in other words, merely a physical mechanism and an artificial construct. It is involved in the vital process of the people who compose it; it is a product of nature, and particularly of human nature. (Park and Burgess 1925, 1)

Burgess would also articulate a pattern of urban growth, called the concentric zone or the zonal model, which results from this relationship between humans and their urban environments (Park and Burgess 1925).

> The typical processes of the expansion of the city can best be illustrated, perhaps, by a series of concentric circles, which may be numbered to designate both the successive zones of urban extension and the types of areas differentiated in the process of expansion. (50)

The concentric zone model has been criticized for its simplicity and the lack of statistical evidence to support its precise construct (Hoyt 1939, Berry and Rees 1969).

Out of this criticism arose alternative approaches to modeling urban space. One is the sector model promulgated by Hoyt. In Hoyt's model the shape of cities is seen to be "influenced by topography and transportation, and there are no two that have exactly the same form...every city has its buildings arrayed in a pattern that may be somewhat circular, or oblong, or star-shaped" (Hoyt 1939, 12). Both models where later judged to be too dependent on the unwavering dominance of the central business district and are therefore unprepared to explain the emergence of multiple centers of influence within modern cities.

> Both the concentric zone, as a general pattern, and the sector aspect, as applied primarily to residential patterns, assume (although not explicitly) that there is a single urban core around which land use is arranged symmetrically in either concentric or radial patterns. In broad theoretical terms such an assumption may be valid, inasmuch as the handicap of distance alone would favor as much concentration as possible in a small central core. Because of the actual physical impossibility of such a concentration and the existence of separating factors, however, separate nuclei arise. (Harris and Ullman 1945, 17)

Each model has its strengths and weaknesses. Perhaps their greatest power, and therefore the reason for their resonance within the study and analysis of urban structure is their heuristic utility and their ability to prompt further investigation. As this study in part utilizes the general premise of the concentric zone model, it is important to point out that it does not seek to prove one model's preeminence in describing the overall growth patterns of San Antonio, but rather uses the structure of the zonal model to describe the patterns of experience and adjustment that occur along San Antonio's floodplains. This will be discussed in greater detail in subsequent chapters.

In geography, human ecology has had its greatest impact on the study of environmental topics, particularly hazards, both natural and technological, and has spawned numerous examinations of human adjustment to, and management of, environmental risks. The first geographical applications of human ecology can be found in the works of Gilbert White (see for example White 1945, White et. al. 1958, White 1964). Gilbert White's research has focused on flood hazards primarily and has shed light on the decision-making and management issues relating to our nation's floodplain. Subsequent works, such as Kates (1962), Hewitt and Burton (1971) and Burton, Kates and White (1993; first edition 1978) further advanced the idea that the geographic study of hazards should involve inquiry into "how individuals and social groups respond to extreme events in nature" (Burton, Kates, and White 1993, xi). Hewitt (1983) later emphasized the social context of hazard and disaster and has enhanced our awareness of the social and temporal influences on the hazardousness of places and the influence of social context on the outcome of disaster events. These seminal works influenced a new generation of hazards researchers that sought to situate hazards and disasters within the context of place, time, and society.

This study is concerned primarily with the temporal and spatial context of urban flood hazard and floodplain occupancy. In addition to borrowing from historical geography and spatial analysis techniques, it is heavily reliant on past hazards-geography research that has focused on the context of events rather than any one aspect of an event. Hazards-in-context research is based on the idea that most "natural disasters, or most damages in them, are characteristics rather than accidental features of the places and societies where they occur" (Hewitt 1983, 25). Two contextual models, specifically describing hazards within a space/time context, followed Hewitt's (1983) work: the "Hazards in Context" model (Mitchell, Devine, and Jagger 1989) and the "Hazards of Place" model (Cutter and Solecki 1989). Both are derivative of the "hazardousness-of-place" discussions from Hewitt and Burton (1971),

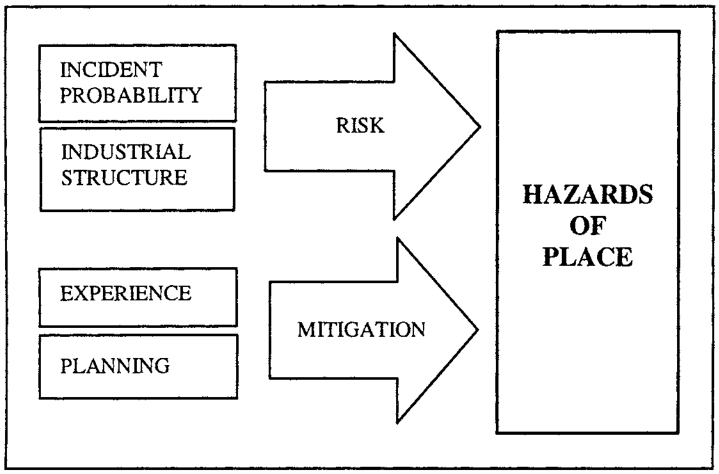
> A natural hazard of any sort is a function both of the physical event itself and of the state of human society, including specifically the adjustments adopted to cope with the hazard and the state of preparedness. The fundamental importance of this point should never be lost sight of. The concept of a flood of a given magnitude or frequency causing a specific amount of damage by itself is misleading. Any volume of damage reported or expected is a function both of the natural event or physical cause and the prevailing or anticipated future state of the society affected. (5-6)

Human society exists within the context of both space and time; therefore, it can be argued that descriptions and analyses of the environmental hazards that plague society, as well as society's complicity in disasters, should be studied within that same context.

Mitchell, Devine, and Jagger (1989) offer a contextual analysis of the relationship between an unusually destructive cyclonic windstorm in England in 1987 and an international stock market crash of the same year. Their discussion, and the resulting model, focus on the temporal confluence of the events but also include the social and economic contexts of the populations addressing the storm's destruction. They conclude "to increase the prospects for successful reduction of disasters it is crucial for analysts and managers to understand the dynamics of hazard contexts, to chart their trends, and to broaden the process of adjusting to include hazard contexts" (Mitchell, Devine, and Jagger 1989, 409). The "Hazards in Context" model, however, is primarily concerned with the temporal context of hazards and as such does not offer a clear conceptualization of the unique contexts of space and place.

The geographic dimensions were conceptualized, and merged with the "all-hazards-in-one-place" idea generated by Hewitt and Burton (1971), in Cutter and Solecki (1989). The resulting model, described as the "Hazards of Place" model (Figure 2.1), describes hazards as being the calculus of the interaction of risks and mitigation efforts specific to a location or region. The result is a description of hazards that is influenced by the unique risk and mitigation characteristics of a particular location. Kirby (1990) echoes this in arguing that in "searching to understand the realm of risks and hazards, we must turn our backs on short-run interpretations of personal behavior and place our research into the evolving study of collective behavior within the locality" (33). Liverman (1990) has added to the literature associated with the contextualization of hazards in her research on the distribution of drought impacts in Mexico. Her research supports the hypothesis that, due to the influence of place-specific social and political structures, there

Figure 2.1. Hazards-of-place model.



Source: Cutter, Susan L. and W. D. Solecki. 1989. The national pattern of airborne toxic releases. *Professional Geographer* 41, no. 2: 149-161.

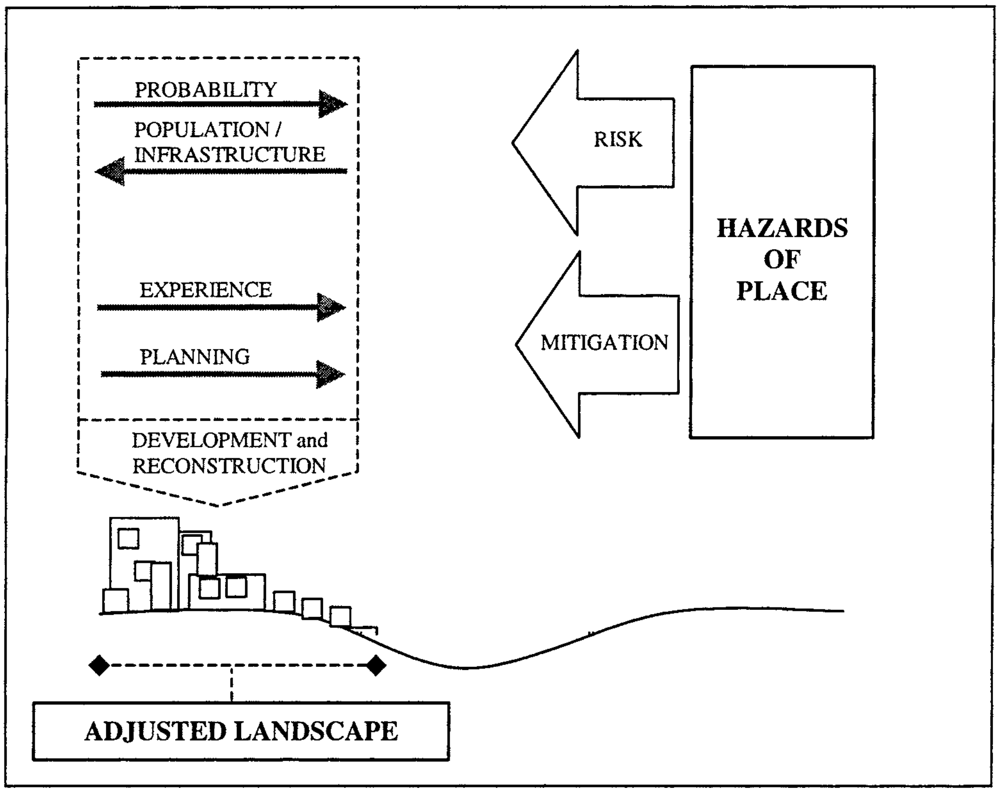
is a "lack of correspondence between precipitation deficits and reported drought losses" (67). In other words, drought disaster is not just the result of a lack of rain. The context within which the disaster occurs has a direct and substantive influence on the severity of the event for the local population.

Research, stemming directly from the Hazards-of-Place model includes Tiefenbacher (1992), Cutter (1996), Cutter and Solecki (1996), Tiefenbacher, Kenopka and Shelley (1997), and Tiefenbacher and Hagelman (1999), and others. These research efforts suggest methodologies to capture the place-specific characteristics affecting environmental risk, hazard, and disaster. This study also seeks to advance these ideas by "animating" the place-specific aspects of urban flood hazard by examining the historical and spatial context of human response to floods in urban areas and by exploring the evidence of adjustments to the environmental risks of the floodplain.

Hazards Geography and the Floodplain

Previous research has examined the possible spatial determinants of the ebb and flow of floodplain development, as well as the perceived efficacy of regulation on the part of managers (see for example White 1945, Gruntfest 1981, Burby and French 1985). This study contends that flood risk, and specifically human relationships to that risk, should modify urban landscapes vis-a-vis the human-environment interaction feedback and the hazards of place (Figure 2.2). Therefore, rather than asking what community and/or management characteristics predict floodplain conditions, I seek to uncover the social and morphological differences in urban geography resulting from the interaction

Figure 2.2. Hazards-of-place and the adjusted landscape.



with flood hazard. Thus the focus is on the genesis and character of spatial outcome rather than on procedural intent or managerial perceptions.

Research previously conducted by hazards scholars can be placed within two broad topics. The first category encompasses analysis of floodplain policy, management and land-use decision-making. The second explores the economic implications of flood hazard on land values and housing stock. These groupings reflect the multidisciplinary nature of hazards research in that economists, public affairs experts, political scientists, psychologists and sociologists often find common ground with geographers on the topic of natural and technological hazards. Because of the prolific data available on flooding and flood disaster, they are often included, along with other natural disasters, in research engaged in exploring the broader implications of natural risk, hazard and disaster. Although these works are pertinent to hazards theory overall, they are not specifically related to this research. Therefore only the two specific bodies of work outlined above will be reviewed here.

Floodplain Policy and Management

Gilbert White is the undisputed "father" of hazards research associated with policy and land use management issues relating to America's floodplains. His 1945 dissertation on human adjustments to flood hazard not only set the stage for his career, it has guided the study of generations of hazards researchers and has informed floodplain management policies we see today. White was critical of the policies, or lack thereof, that dominated the management of our nation's floodplains.

> It cannot be said with confidence that present Federal activities have the net effect of promoting sound land use. Works for protection and abatement minimize the

> flood hazard at public expense for the most part, and in the process provide increments in land value to land owners, some of whom occupy the flood plain on a highly speculative basis. Heavy losses by small property owners are largely subsidized by the government. Further encroachment is thereby tacitly encouraged, and Congress has not yet seen fit to require regulation of encroachment as a condition of Federal participation in flood protection. (White 1945, 211)

It is the issue of the government's role in land use and land management, human adjustments to flood risk, and the idea that floodplain policy should "explore the possibilities of making other adjustments with a view of promoting the most effective use of flood-plain resources" (211) which have occupied much of White's career. One of White's primary concerns, and one that has direct bearing on this research, was that our fixation with structural mitigation in the form of dams and levees would result in more people and structures exposed to flooding, and therefore an increase in the human and economic costs associated with floods.

> History shows a close relationship between flood protection and development in flood-prone areas. From the mid-1930s to the late 1960s federally subsidized flood control projects such as levees and upstream storage were the prevalent form of national response, but nevertheless flood losses continued to rise because of continuing development on floodplains. (Committee on Flood Control Alternatives in the American River Basin 1995, 8)

Although many improvements have been made in our national floodplain policy since his dissertation, White's lament has not changed much over the years. In White et al. (1958), he states

> From investigations of the situation in selected urbanized floodplains in 1957 it is apparent that Federal support of large-scale engineering measures, of improved flood forecasting, and of intensified relief and rehabilitation activity greatly reduced the flood loss hazard in certain areas but increased it in other areas. It also seems evident that the effect of action or inaction by state and local agencies was to encourage further encroachment upon the floodplain in all but a few areas. The net effect of individual decisions by public and private property owners as to the use of flood-plain properties was a substantial invasion of flood-prone areas, even in cities with stable or declining population numbers. (1)

In 1992, White, acting as the chair of a national review committee charged with evaluation of our nation's floodplain policy, declared that private government "programs, however well intentioned, often encourage...adverse development," development that "degrades natural values and increases public expenditure for relief, rehabilitation, and corrective action" (Burby et al. 1992, 3). Following the Mississippi River flood of 1993, which inundated the middle river portion of the valley, Myers and White (1993) continued to warn us those events "like the flood of '93 offer an opportunity to speed the formation of sounder policy. This opportunity should not be squandered" (348). The idea that mitigation, although often reducing risk, increases hazard by spurring encroachment into the floodplain is also explored in the analysis portion of this research.

The policy and management studies that have appeared recently in hazard publications focus primarily on the tangible failings of recent flood-related government management efforts. The primary concern is the "disconnect" between federal policies and the local management of floodplains (Burby and French 1985, Burby et al. 1992). Holway and Burby (1990) "conclude that the NFIP (National Flood Insurance Program) is having an effect on land use in localities across the U.S., but that its effect can be amplified or subverted by local land-use policy decisions" (257). Indeed, "the system needs to become more of a partnership than a top-down system in order to make state and local actors responsible for mitigating risks" (Godschalk et al. 1999). Government "efforts to cope with natural hazards are fragmented horizontally at each level of government, vertically between levels of government, and across different types of hazards" (Burby 1999, 283). Inconsistencies also exist in the provision of information to residents of the hazardousness of their locations and in the local, state and federal regulations associated with their choice to occupy hazardous locales (Borkan and Kunreuther 1979, Palm 1981, Montz 1983, Cross 1985).

The solution to this problem is two-pronged. First, the federal regulations and local management must be "reconnected." Proposals for this range from the creation of sub-state level "Regional Special Districts," which would theoretically better coordinate federal/state to local communication and enforcement (Platt 1986), to the creation of a single governmental entity responsible for all structural and non-structural aspects of flood-risk mitigation (Burby et al. 1992). Second, multiple strategies must be used as experts agree that no single management strategy is adequate to reduce vulnerability and risk in developed floodplains. In 1961, White observed that it "is becoming commonplace to note that neither flood protection nor land-use regulation is a complete or adequate measure when applied alone" (White 1961, 1). Three decades later, Holway and Burby (1993) demonstrated "that elevating buildings to NFIP standards does indeed reduce losses, but that adding additional elevation requirements will have little to no effect on the rate of increase in floodplain development. Instead, these requirements must be supplemented with regulation of floodplain land use" (205). Burby (1999), Godschalk (1999) and Mileti (1999) also support this view. Solutions to the "disconnect" among governmental structures are beyond the immediate scope of this research, however, the lack of consistent application of regulations and management techniques on a local scale are of primary importance. We must gain greater insight into how the disconnect influences the evolution of the urban flood-hazard landscape. It is worth pointing out that a February 2001 report on flood hazard management released by the San Antonio River Authority and the Countywide Citizens Watershed Master Plan Committee, in response to the record breaking flood of October 1998, concludes with the statement "We believe that to make real reductions in the future loss of life and property due to flooding, the responsibility and authority for flood control and drainage improvements must be consolidated and coordinated within our community and between neighboring communities" (43). For San Antonio, like many other urban areas, this disconnect between floodplain managers has been identified as the greatest obstacle to reducing the impact of future flood events (Countywide Citizens Watershed Master Plan Committee 2001).

Floodplain Economy and Differentiation

The second body of hazards literature relating to the floodplain is concerned with the effects that flood-hazard perception, flood-hazard delineation, flood disaster events and local land-use planning have on the economic value of the land and structures within the floodplain (Zimmerman 1979, Babcock and Mitchell 1980, Muckleston 1983, Shilling, Benjamin, and Sirmans 1985, Montz 1987, MacDonald, Murdoch, and White 1987, Montz and Tobin 1988, Tobin and Montz 1988, Montz 1993, Tobin and Montz 1994). The results of the research are mixed. Some find clear differences in the value of properties within the federally designated floodplain and those outside the floodplain (Shilling, Benjamin, and Sirmans 1985) and others conclude "residential real estate sales before and after disclosure suggests that hazard designation and related policies have had no marked impact on property values" (Montz 1993, 225). What stands out, however, is the fact that nearly all of these studies noted differences between the economic value and risk capitalization of floodplain structure and non-floodplain structures, indicating that each zone possesses different geographies. This is attributed to the varying characteristics of an area's flood experience as well as other "local factors" (Tobin and Montz 1994, 683). These spatial differences and local factors, as well as the historical evolution of the "differences," are at the heart of this study. Statistical differences between floodplain properties within and outside the designated floodplain have been explored in past research (Zimmerman 1979, Babcock and Mitchell 1980, Muckleston 1983). Zimmerman (1979) found no differences in the average value per room of owner-occupied dwellings or the average assessed value per square foot of land in the two New Jersey areas studied. The same results were found by Babcock and Mitchell (1980) in their study of residential floodplain property values in Galt, Ontario. Muckleston (1983) did identify differences in the appreciation rates on floodplain properties. Properties within the floodplain appreciated faster in most of the sample groups; the author attributed this to the aesthetic value of the floodplain rather than the risk differences engendered by the landscapes.

Most quantitative studies have been criticized for being dependent on dichotomous variables, limited samples, and limited study periods (Burby et al. 1988). Although the present research utilizes a dichotomous classification of inside/outside the floodplain, it moves past the shortcomings of others, at least those relating to limited parcel samples, by using the complete appraisal record, which includes all years of development for the study area.

At least one other criticism of the above works has been that, like much of hazards research, the focus is on measuring adjustment to the floodplain resulting from the negative feedback of the environment, with no consideration for the positive part of the Burton, Kates and White (1993) model, that of resource. It is entirely possible that the riverine environment may entice both "risk-adjustment" and "utility-adjustment" within the very same floodplain, and moreover these trends may change with time, experience, or capital fluctuations within the same location. Put differently, one region of floodplain occupancy, or even a single occupant, may adjust toward the environmental risk in order to avail themselves of the aesthetic or utilitarian values associated with the riverine environment, while another region, or other individual, may exhibit adjustments away from the floodplain in response to the risk. Finally, changing patterns of commerce and floodplain management may have the effect of reversing one trend or the other over time. These possibilities are explored within the analyses conducted herein.

Historical Geography of Hazards and Disaster

It has been observed that hazards geography traditionally "professes no formal interest in historical questions," however, the chronological perspective remains a tacit premise of the work as the "retrospective viewpoint is essential to explain current conditions and to develop agendas for future resource management" (Colten and Dilsaver 1992, 5-6). It is this very issue of future management that is discussed, with chronological overtones, in the recent "state-of-the-art of hazards" edited volume *Disasters by Design: A Reassessment of Natural Hazards in the United States* (Mileti 1999) which offers a prescriptive discussion for the future of hazards research in the U.S.

> This book calls for and speaks to the specifics required to shift the national culture in ways that would stop at its genesis the ever-increasing spiral of losses from natural and technological hazards and disasters. The task will be to create and install "sustainable hazards mitigation" in the culture of the nation. (viii)

Even Hewitt and Burton (1971), in the study that helped spur much of the *contextualization-of-hazards* research, states that this work stems from "long-run patterns of human response and adjustment" (5) to natural hazards. Much of the work done by hazards geographers is based upon past management and adjustment decisions regarding the hazard being studied. In other words, it is often "past place" which informs hazards theory pertaining to future events.

Geographers have, on occasion, brought the perspectives of geography to bear on past disaster events. Bowden (1982) examined both national and international disaster events in an urban context and concluded that disaster reconstruction "following natural disasters compresses in time and exaggerates in process, but does not basically change the growth and evolution of cities" (p.124). The result of this is an urban landscape that is rapidly expanded and homogenized, in terms of land use, by reconstruction. These trends will be explored in the context of this research as numerous flood events and the subsequent reconstruction will be included in the analysis of both study cities. Rosen's (1986) investigation of urban fires in turn-of-the-century Chicago, Baltimore and Boston illustrates the impact of governmental and social structure on the urban landscape during reconstruction,

> The power to open and widen streets was an especially powerful tool for manipulating land use change. It not only gave officials a way to make certain areas more attractive to new users and out-of-the-way areas more accessible to them, relaxing the demand barriers to spatial change. It also gave officials a means for encouraging the construction of bigger and better structures, because street improvements entailed the demolition of the buildings standing in the way. Thus it also relaxed the structural barriers to spatial change. (83)

The result of this was an altered urban landscape resulting from the reconstruction of fire-damaged areas. Godshalk (1999), Burby (1999) and Platt (1999) have investigated the history and impact of government policy on hazards and disasters more recently. In a statement echoing the lament of all three texts, Platt (1999) concludes that "the federal government is expected to come to the financial rescue of communities and individuals when disaster strikes, but is constrained by political pressure from requiring the latter to restrain unwise building or rebuilding in areas subject to recurrent natural hazards" (294). The result of this paradox is the exponentially rising costs of federal disaster relief and assistance to populations who have historically occupied hazardous areas, but have been unable to generate the local political and economic support necessary, or have simply lacked the desire, to alter their occupancy patterns to less risky locations. As has been stated, there is a "disconnect" between the federal and local approaches to natural hazards management. This disconnect is not just part of the current crisis on floodplain management, but also an important part of the history of their management (Burby et al. 1992, Godshalk 1999, Burby 1999, Platt 1999). This is reflected in Driever and Vaughn's (1988) historical geography of the Kansas City, Missouri, Blue River floodplain, in which they conclude,

> Structural controls and regulations are meaningless without an understanding of a floodplain as a transition zone between two opposing sets of environmental processes, one manmade and the other natural. Many officials view structural controls as a means to reduce the width of a floodplain in reclaiming land for development. This myopic viewpoint persists because it accords with the man-over-nature ethos long held by many Americans. As geographers have stressed, activities on a floodplain must be compatible with periodic flooding, or any reduction in flood frequency will be offset by increased flood damages. (19)

The act of occupying the floodplain creates the hazard, yet we tend to make our adjustments to flood risk only after a disaster has struck, and even then our adjustments are made within the context of ever-changing, multi-scalar influences. Therefore each flood disaster is tied to the floodplain geography and concurrent floodplain regulations, as well as the disaster relief and reconstruction mechanisms available, at the time of the event.

There are numerous examples of historical treatments of past disaster events and hazardous settings, some relating directly to flood events (see for example Bishofberger 1975, Smith 1975, Smith 1977, Van Wormer 1991, Sevcik 1992, Dodgen 1995, Boone 1997a, Schneider 1996, Boone 1997b, Pabis 1998), others addressing the wider pantheon of hazards and disaster events (see for example Rooney 1967, Ellis 1984, Sawislak 1993, Oliver-Smith 1994, Ledesma 1994, Hurley 1994, Snyder 1994, Steinberg 1997, Stephens 1997). Although these studies, and others like them, offer a better understanding of the course of events and the actions of people during past disasters, they provide few direct lessons for future management decisions and remain relatively *aspatial* in their treatment of the events and places. In other words, despite the latent temporal tendencies among hazards researchers and the relatively recent interest in disasters as past "actors" by historians, natural hazards theory and *applied* historical geography seldom intersect. Denecke (1982), in his argument for the use of historical geography in urban planning, wrote "the events of history pass while the cultural landscape and the processes of its change are vivid, present history. In this sense the heritage of the past is an object of modern geography and so of planning" (127). One applied geographical work of particular note here is Colten (1990), which offers a descriptive model of urban hazardous waste accumulation that describes the "geographical patterns of hazardous material disposal ...over the past century within the framework of changing urban form" (154). Colten (1990) reveals an ever-changing pattern of urban technological risk associated with industrial waste disposal, and in so doing offers contemporary waste managers a baseline from which to conduct their current reclamation and management projects. In a similar way, this research proposes that the most effective means to plan for future reduction of flood hazard is through careful examination of the historical and contextual geography of contemporary urban flood hazard. In order to meet this goal, this research will combine the descriptive tools of the historical-geographic traditions with the progressive, regulation-informing perspectives of hazards geography.

Summary

This chapter reviewed three groups of research literature that have informed the conceptualizations, methodologies and/or conclusions of this dissertation. The perspective of human ecology has spawned numerous research agendas in the eighty years since its introduction to the social sciences. The idea that humans and human societies form a reflexive relationship with their natural and built environments, and that this relationship can be studied through its ecological interactions and adjustments, has been integral in advancing our understanding of the myriad influences on urban form, human use of the natural environment, and environmental hazards. Over the last fifty years environmental hazards research, both within and outside the rubric of human ecology, has greatly advanced our understanding of the degree to which perception and awareness affect our relationship with floodplains and flood risk. Hazards research has also illustrated that the presence or absence of environmental risks can influence the spatial patterns of urban areas. Researchers in the field of environmental risks and hazards have also made tremendous strides in advancing the perspective that our managerial approaches to environmental hazards and natural disasters are modified by the social and historical context of the these phenomenon. And lastly, historical geographers working in the sub-fields of urban and environmental studies have illustrated the spatio-temporal ramifications of decisions made in response to environmental hazards and disasters. They have shown, through qualitative and quantitative analysis of the historic record, that natural disasters change the urban places they occur within, and have therefore added additional support to the idea that the contexts of these phenomena are paramount in understanding their impacts on individuals, societies, and the urban forms that we create.

CHAPTER 3

DATA AND METHODOLOGY

Overview

In addition to testing the specific hypotheses outlined in the introduction, this research seeks to advance our understanding of the temporal nature and the spatial influences of floodplain management and floodplain occupancy patterns through the application of a multifaceted methodology. Each hypothesis is tied to a specific quality or quantity of information relevant to this goal. Therefore each will be tested with a specific data set and analytical approach. The following chapter is divided into five sections. The first section discusses the overall approach and purpose of merging multiple methodologies. The second describes the research to be conducted associated with hypothesis one on the historical record relating to flood experience and floodplain management over the last one hundred years. The analysis relating to hypothesis two and three deals with land development patterns both inside and outside the Federal Emergency Management Agency's (FEMA) designated floodplains. Therefore the third section of this chapter will discuss the data and method used to delineation of the floodplain. Sections four and five are tied to hypotheses two and three, respectively.

Hitting a Moving Target

One way in which this research seeks to advance our understanding of flood hazard and floodplain occupancy is through the inclusion of various measures of temporal change. One weakness of past flood-hazard research has been its dependency on limited study periods (Burby et al. 1988). This has minimized our understanding of how different periods of occupancy and management have affected changes in flood hazard. For instance, forming conclusions based on spatial data gathered just prior to a flood event or the introduction of a new management approach runs the risk of not "seeing" the post-event effects on occupancy and hazard. These limitations have resulted primarily from the necessity to convert risk, cadastral and population data for study sites from hardcopy maps and census records to data matrices that can then be subjected to statistical analysis. The funding and human-hours necessary to accomplish this task for one or more floodplain study sites can be formidable. With advancements in computer data maintenance and Geographic Information Systems (GIS) over the last decade, many cities and municipal agencies have converted their data management functions to digital form. The Bexar County Appraisal District, with the assistance of Environmental Research Systems Institute (ESRI), has recently launched an interactive web site that allows individuals to search cadastral records for the entire county. Supporting this web service is a comprehensive GIS of Bexar County's cadastral geography, including spatial and property characteristics data, for the nearly half of a million distinct land parcels in the county. These data was made available by the Bexar County Appraisal District and ESRI, Inc. for this research. The ability to analyze the complete record of San Antonio's land development history offers an opportunity to explore floodplain occupancy patterns at a detailed and comprehensive scale not previously available to hazards researchers.

Despite its comprehensive nature, the cadastral data set does have its limitations. It contains a wealth of information on the characteristics of the land parcels within the county, but provides no information, beyond the surname of each owner, about the current or historical social characteristics of San Antonio's inhabitants. Nor does it provide any direct insight into the flood history and flood-hazard management history of the city. Both are important in understanding the contextual influences on the evolution of floodplain occupancy and flood hazard. Therefore, in addition to the cadastral analysis, population data have been collected, at the census-tract scale, from the U.S. Census Bureau for the census years 1970, 1980, and 1990. The 1990 data are explored in an effort to draw conclusions about the contemporary social patterns of Bexar County and the City of San Antonio. The 1970 and 1980 data were merged with the 1990 data to create various measures of change over the three-decade period. These results have been merged with GIS for the county and the layers compared to patterns of mitigation to understand how the two coincide in both space and time. Additionally, an understanding of the temporal progression of flood experience and flood management efforts has been gathered from government and private engineering reports, city management archives, and popular press reports on flood disasters and mitigation projects.

Each of the three sources of information (cadastral, social, and historical) were subjected to analysis appropriate to their content and the research questions at hand, however, the result is a combined contextual understanding of how floodplain occupancy and flood hazard have evolved over San Antonio's entire history. This approach does not answer all questions associated with San Antonio's flood hazard history. It does however offer substantial insight into how San Antonio has occupied its floodplains and how its flood hazard has been both created, modified, and managed through time. The goal of these methodological efforts is to "hit a moving target," rather than attempt to hold the landscape in temporal stasis while studying one or more spatial characteristics.

Historical Record

The first evidence of San Antonio's floodplain experience, and specifically its interactions and adjustments to the environmental risk engendered by the floodplain, will be presented as a historical narrative on the large-scale flood disasters that have struck the city of San Antonio. As is often the case with historical analysis, the information for this narrative will be gathered from numerous, and diverse sources. Information about each flood disaster will be gleaned from federal, state, local and popular reports on the events and presented in chronological order for review.

Both an attraction to the riverine environment and flood disaster have been part of San Antonio's history for as long as San Antonio has served as an urban settlement. More often than not, flood management efforts result not from foresight, but rather from response to actual events. In this way each flood disaster can be seen as a decision-making point along the evolutionary route of the city's development. In order to fully understand the management decisions and mitigation choices adopted, and related floodplain occupancy patterns, one must necessarily look back to the event that precipitated those choices. In this way disaster reconstruction, or the reaction to realized risk, can be seen as an integral player in the planning decisions for future risks. Moreover, the spatial impacts of each flood event are generally affected by the structural changes to the floodplain that took place prior to the event. Therefore in order to understand the "where" of flood hazard, it is important to understand the "when" of floodplain management.

Information for this portion of the research is taken from five types of historical resources. The first set of resources includes government reports issued by the United States Geological Survey (USGS), National Oceanic & Atmospheric Administration (NOAA), The U.S. Army Corps of Engineers (Army Corps), and state weather services from the period 1950 - 1999. These documents tell the tales of impact, engineering alterations to the floodplain, and the spatial variability of each individual flood event. In many cases these documents are the only source of spatial data relating to past flood damage, including those events prior to 1950. The ACE reports, in particular, offer a wealth of information about past flood disasters. Following flood events, the ACE was often called in to spearhead structural alterations to the floodplain. As part of these efforts copious reports of the event precipitating their alterations were often included in their documentation. Additionally, information relating to the human occupancy patterns for the specific waterway, or portion thereof, is included as well. Again, these documents were generated in response to assessment and alteration projects. They therefore provide direct documentation of structural changes to the floodplain itself. USGS, NOAA, and state weather service reports offer insight into the patterns of precipitation and flooding, as well as other information relating to mitigation and occupancy patterns.

Secondly, there exists a small, but information-rich, selection of private engineering reports commissioned by the City of San Antonio relating to proposed structural projects within the floodplain. The earliest of these dates back to 1920 (Metcalf and Eddy 1920). These reports provide insight into the flood hazard conditions present at the time of each study as well as a record of the impetus for various structural projects. The third collection of documents are municipal engineering, assessment, and policy reports issued by the City of San Antonio, Bexar County, and the San Antonio River Authority. The most recent of these chronicles the impact of the October 1998 flood and makes numerous proposals for structural and administrative changes designed to reduce the impact of future flood events.

These resources are supplemented by newspaper reports surrounding each of the significant flood events in San Antonio's history. These reports provide evidence of the social and political ramifications of each event. They also offer detailed accounts of the spatial impacts of past floods. These records supplement not only the history of flooding, but also the nature of floodplain occupancy patterns offered by the cadastral analysis. Finally, a number of secondary historical and archeological sources have been consulted in an effort to gather information on all significant flood events, including those prior to the generation of formal engineering and municipal reports on more recent events. Although not their primary focus, these documents often mention historical and archeological evidence of flooding, especially within the colonial period of San Antonio's history.

Defining the Floodplain

Digital FEMA Flood Insurance Rating Maps (FIRMs) are used as the spatial measure of the floodplain. FIRMs are the most common indicator of the spatial characteristics of flood risk in urban areas and have been generated for most American urban areas since the passage of the National Flood Insurance Act of 1968. FIRMs describe the areal extent of the 100- and 500-year floodplain, as well as other special risk areas, and are used by local planning and management officials, property owners, and insurance underwriters to indicate the level of risk associated with an individual parcel of land. For the remainder of this study the word "floodplain" will refer to the FEMA risk zones describing the 100- and 500-year floodplain. Although the FIRM GIS includes classifications for a number of additional special risk zones, as well as delineations of areas outside the flood zone, this research is concerned with San Antonio's longitudinal adjustments to flood hazard and therefore focuses on the main delineations of 100-year and 500-years zones.

Floodplain boundaries, as described by FIRMs are changed from time to time as a result of physical changes in the floodplain, flood-damage experience, the implementation of structural mitigation projects, or petition by communities or individuals affected by the designation. This has been the case in San Antonio and, although they are not complete at the time of this research, the FIRM maps are currently undergoing alterations due to the October 1998 flood.

This raises an important point in reference to this research. As a result of this characteristic of FIRMs there is a sizable assumption built into this analysis: the flood zones described by the contemporary FIRMs represent, at least closely, the flood zones of the past. This being said, it is important to note the influence or effect of structural mitigation projects within the floodplain. When these structures take the form of retention dams, as has generally been the case in San Antonio, they can have the affect of reducing the areal extent of flood zones below the dams and, in some cases, increasing them above dams. With the exception of the Olmos Dam, which offers substantial protection to the downtown area, most dams in Bexar County are low-lying retention dams built in intermittent streams. Most of these dams were built prior to the original creation of Bexar County's FIRMs and their spatial impacts should therefore by seen in the contemporary FIRMs. Despite this, the analysis herein explores occupancy patterns prior to both the FIRMs and the dams and therefore interpretations of the earliest years of occupancy should be viewed with this in mind.

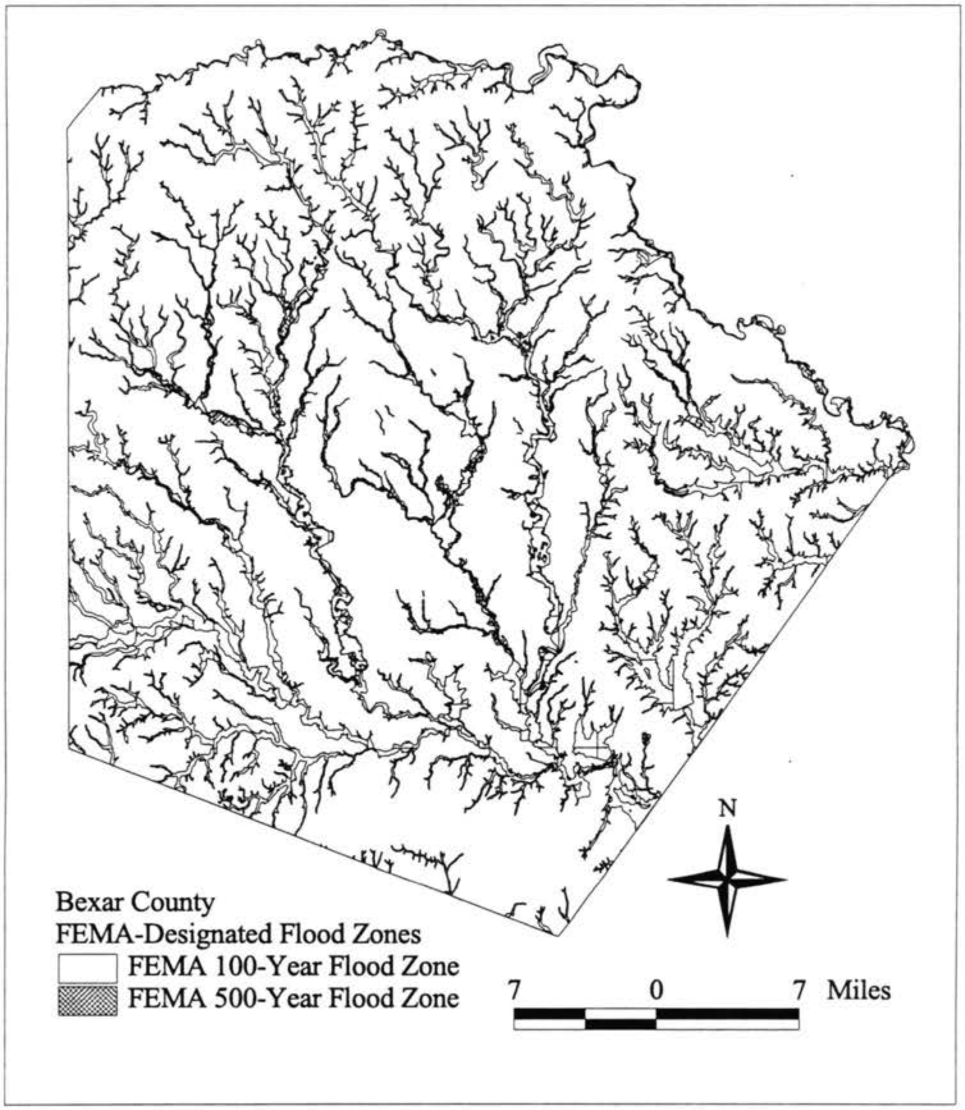
A detailed measurement of the expansion of impermeable land cover and floodwater obstacles is beyond the scope of this research. However, the research results should be viewed with the knowledge that as impermeable land cover increases so does runoff. As floodwater obstacles (e.g. buildings) increase, water is more likely to back up and inundate areas that might not have been affected prior to the placement of the obstacles. These impacts are generally felt on a neighborhood-by-neighborhood (or even block-by-block) scale. Since the statistical analysis of occupancy patterns relating to the floodplain are being conducted at the county, or watershed basin-scale, the assumption that these localized impacts will be mitigated by the larger data set is therefore built into the discussion of the results.

Cadastral Analysis

Cadastral data for Bexar County are used to test the hypothesis that floodplains represent distinct geographies within the larger urban fabric. The importance to this study of the cadastral data made available by the Bexar County Appraisal District and ESRI cannot be overemphasized. Although the historical narrative and the census geography analysis are helpful for understanding the spatial evolution of San Antonio's flood hazard, the cadastral data forms the backbone of this study. The reason behind this is simple: these data contain a spatial record at the scale of individual parcels. Parcel is the cadastral term for an individual property owner's spatial land holding. These units become the building blocks for other databases such as the census that aggregate urban attributes in larger spatial units. No other database of urban geographical attributes is available at this scale. Although census geography uses units as small as block groups (unit based primarily on local neighborhood boundaries), these sub-county delineations are only available as of the 1980 census and reliable census tract data (the next larger spatial unit) for Bexar County is only available as of the 1970 census. For comparison, Bexar County's 1990 census contained 5,786 block groups and 225 census tract units, while the 2000 appraisal database contains 448,646 parcels. With the dispersed nature of San Antonio's floodplains (Figure 3.1), it is difficult, if not impossible, to analyze differences between inside and outside floodplain occupancy using the courser census units. However, with the cadastral records for the entire county, one can easily delineate those parcels inside the floodplain, and establish comparative sets of parcels within distinct regions outside the floodplain.

The appraisal database includes a number of useful attributes for each parcel. The first useful attribute of each parcel is obviously location. Centroids for each parcel were calculated using an Arcview program extension provided by ESRI and these centroids then became the locational values used in the analysis. To test the distinct nature of the urban floodplain, four of the database attributes were selected. The first is "land value," which records the current value of the land parcels excepting any structural improvements. The second is "improvement value," which represents the value

Figure 3.1. Bexar County FEMA designated flood zones.



of any structural improvements to the land parcel. The third is "year built," which provides the year in which the improvements were made to the land parcels. This attribute can then be converted to "age of improvements" as a measure of when the parcel was originally developed for use or occupancy. Lastly, the attribute file contains information on the type and use of the structures located within the parcel. From these descriptions the classification of commercial, residential or rural/farm will be included in the analysis. This database is constantly modified as land development in Bexar County continues daily. Therefore, in addition to the parcel records that contain this information, there exist 95,522 parcels that have been platted for future development but have no date or improvement values as of the year 2000. These parcels, referred to as "no date" parcels herein, are treated as a separate group within the analysis and serve as a strong indication of patterns of current development within the county.

The idea being explored in this portion of the research is that the urban geography of floodplains is unique because of the nature of their environments. This hypothesis can be conceptualized as a difference-of-means among the cadastral values outlined above for parcels within the floodplain versus those outside the floodplain. But how should those differences be examined? Hazards geography literature has observed that in "a perfectly functioning market, the risk of flooding would be considered, and the expected present value of flooding costs would be capitalized into property values" lowering property values in the floodplain (Burby et al. 1988, 155). As was discussed in the literature review, others have studied this and reached a variety of conclusions. This research moves beyond those studies by recognizing the use of the natural riverine environment renders both hazard and resource (Burton, Kates and White 1993). Therefore just as locations understood to be risky should have lower values, locations understood to be utilitarian should inversely have higher values than areas outside the floodplain. Both possibilities represent an adjustment to the natural setting of the floodplain. Additionally, flood control projects and land development trends within the region can have the effect of "flipping the switch" between the two possible outcomes.

San Antonio's land development has been basically concentric over the last 100 years, starting with the original settlement of the Alamo and its accompanying structures and moving out across the county. One indication of this is that if one calculates the centroid of Bexar County and the centroid of the 1990 urbanized area of the City of San Antonio, both fall within less than four miles of the Alamo itself. By thinking of San Antonio's urban growth in this way, the floodplains of Bexar County can be seen as radial spokes within the concentric rings of San Antonio's development. This allows measurement of floodplain occupancy in two directions. The first direction is lateral (or adjacent) occupancy, and the second is radial (or expansion occupancy) (Figure 3.2).

Adjacent occupancy is tested by comparing those parcels within the floodplain to a sample of those outside the floodplain. The outside sample was generated by selecting all parcels within a 100-meter buffer around the floodplain (Figure 3.3). The three cadastral values (land value, improvement value, and age of structure) were tested for differences in their means as a measurement of their unique nature. Three outcomes are possible for this portion of the analysis (Figure 3.4). If there has been no adjustment to the risk/resource of the riverine environment then there should be no significant difference in the means of any of the three attributes (Figure 3.4a); the floodplain poses no barrier or attraction to occupancy. However, occupying the floodplain may be deemed

Figure 3.2. Floodplain occupancy as expansion/adjacent growth.

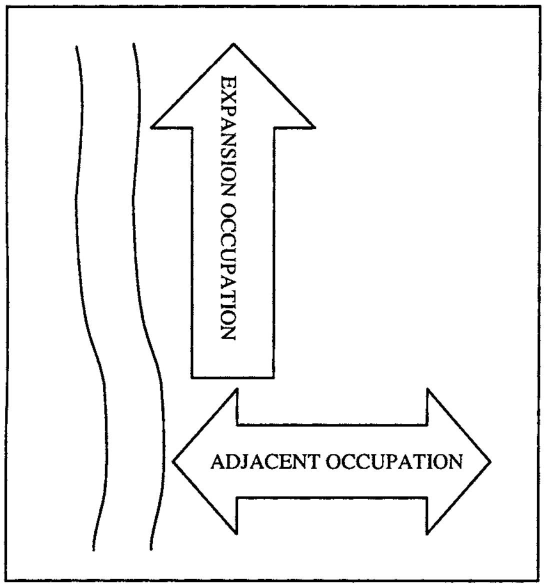


Figure 3.3. Parcel selection within 100-year flood zone, 500-year flood zone, and 100 meter sample buffer.

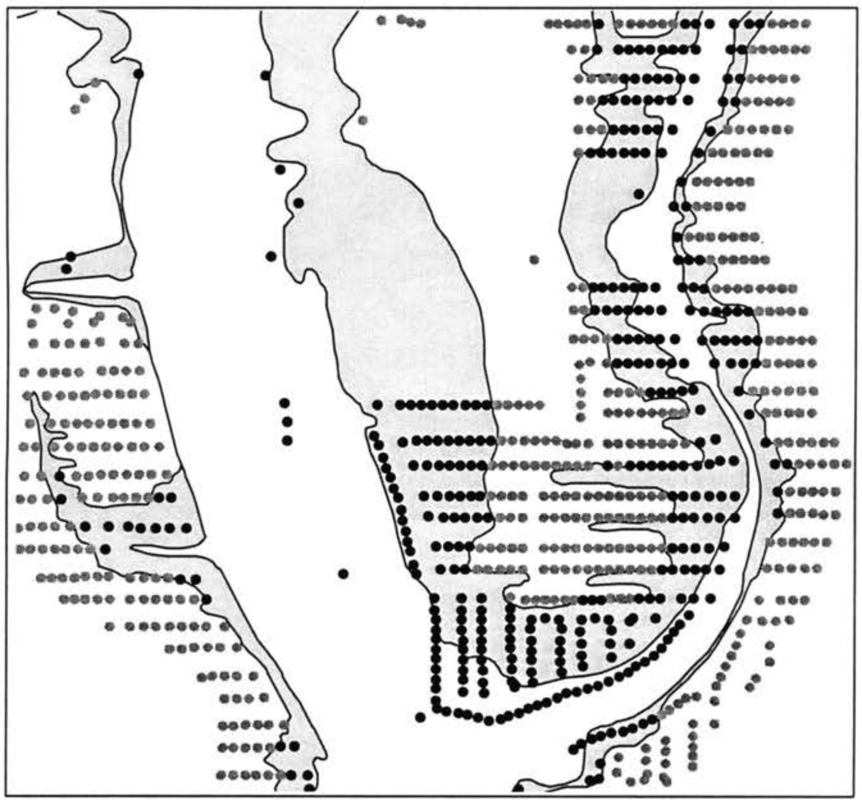
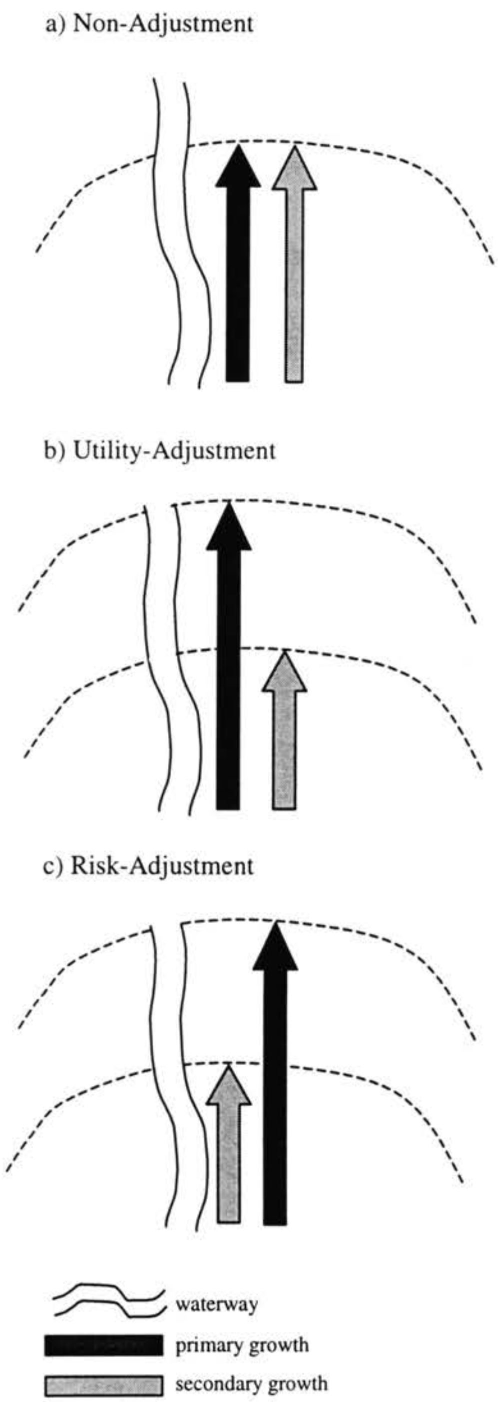


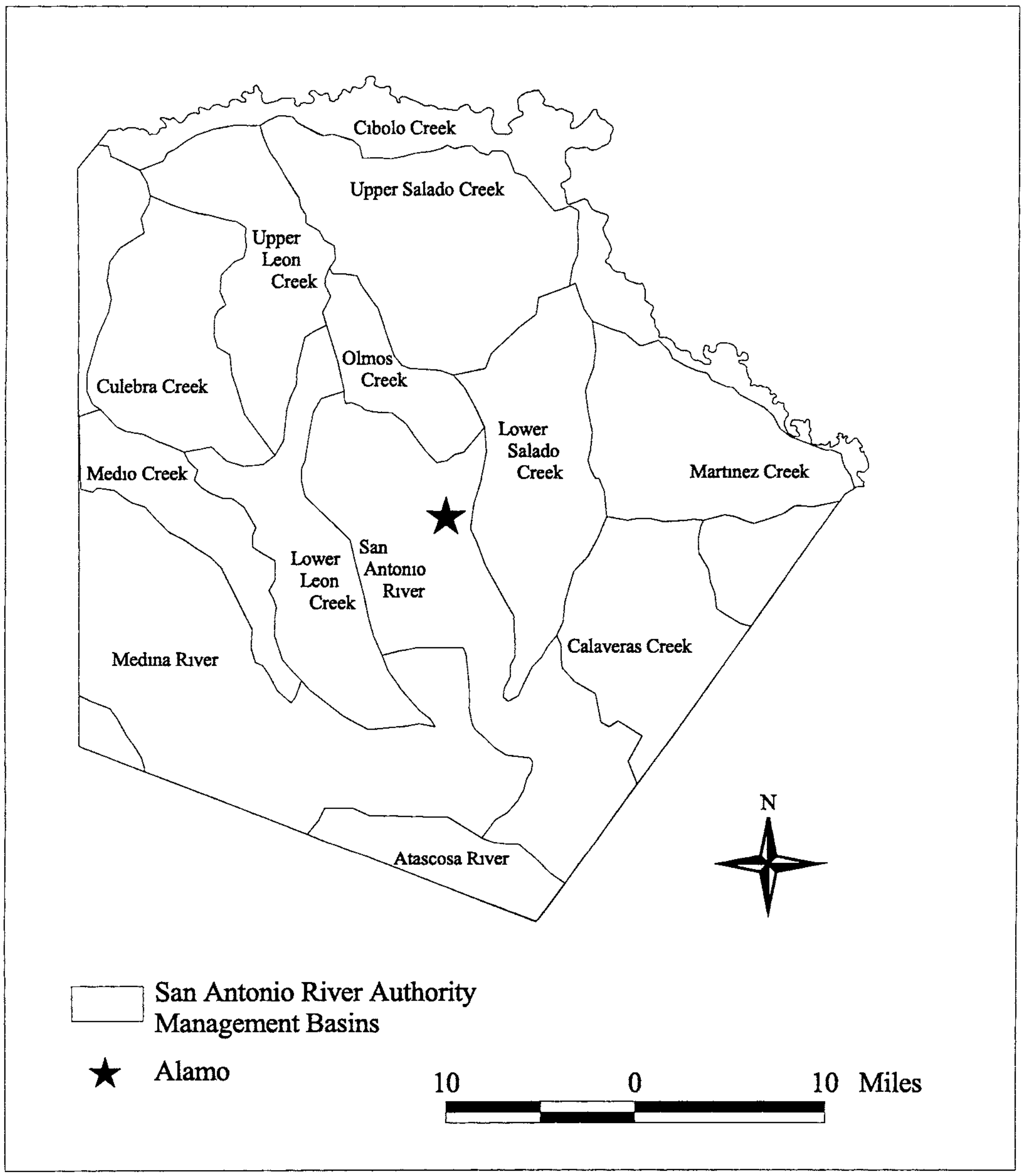
Figure 3.4. Hypothetical *expansion* floodplain adjustments.



preferable, because of its utility, aesthetic, or the ability of the occupant to successfully offset the financial risks of potential flooding. If this is the case then a "utility-adjustment" should be observed in the difference-of-means tests of the parcel attributes. One would then expect to see higher land and improvement values and older structures within the floodplain (Figure 3.4b). Older structures would be found in the floodplain because it would have attracted first settlements because of its apparent utility. Inversely, if the floodplain were perceived as a hazard, and therefore less preferable to occupy, one would expect to observe lower land and improvement values and newer structures in the floodplain. The floodplain would be occupied as a "second choice" and therefore would be populated by structures built after those occupying non-floodplain regions. This scenario can be described as generating a "risk-adjustment" landscape (Figure 3.4c).

The San Antonio River Authority (SARA), which has primary responsibilities within Bexar County for flood control management, manages the county's floodplains based on thirteen distinct watersheds, or basins, within the county (Figure 3.5). It has been recently observed that flood control measures within each of the basins have historically received varying amounts of financial support (Countywide Citizens Watershed Master Plan Committee 2001). Additionally, the historical occupancy of each basin is impacted by its location within the county, with those farther away from the point of original settlement receiving the bulk of their development in more recent years. For this reason this analysis is conducted not only for the county as a whole, but also on a basin-by-basin basis. The results can then illuminate the spatial, and to some degree the temporal, variability of the risk/utility-adjustments described. One of the main topographical characteristics of Bexar County and the City of San Antonio is its location

Figure 3.5. Bexar County: San Antonio River Authority Management Basins.



relative to the Balcones fault line and the Edwards Aquifer recharge zone. The landscapes above and below the fault line are undoubtedly quite different, and therefore produce different flood hazard settings. For this reason, this portion of the analysis includes difference-of-means tests for parcels above and below the fault line. This too allows for greater insight into the spatial variability of floodplain occupancy within the county. Lastly, this portion of the analysis also utilizes the commercial/residential classifications provided by the appraisal records. The assumption is that the two different types of land uses, and the capital structures that support them, may render different relationships with the floodplain.

Testing the influence of the floodplain on radial or expansion occupancy patterns was accomplished in the following manner. First, distance to the Alamo for each of the parcels centroids was calculated. Using the dates for structural improvements on each parcel, these values serve as a measurement of San Antonio's temporal expansion (Figure 3.6), and were further classified by their locational relationship to the floodplain (inside or outside). Using the Alamo as the centroid for all development within Bexar County, mean distances of centroids by decade were compared for parcels inside verse those outside. Again three possible outcomes to this portion of the analysis were hypothesized (Figure 3.7). The first is a non-adjustment scenario, whereby there are no significant differences in the floodplain verses non-floodplain mean distances (Figure 3.7a). In the event that floodplain occupancy is preferable, an expansion utility-adjustment pattern would be characterized by larger mean distances by decade inside the floodplain compared to the mean distance of those outside. Areas outside the floodplain would be the second choice for occupancy and would follow "behind" the inside occupancy pattern

Figure 3.6. City of San Antonio historical concentric growth rings.

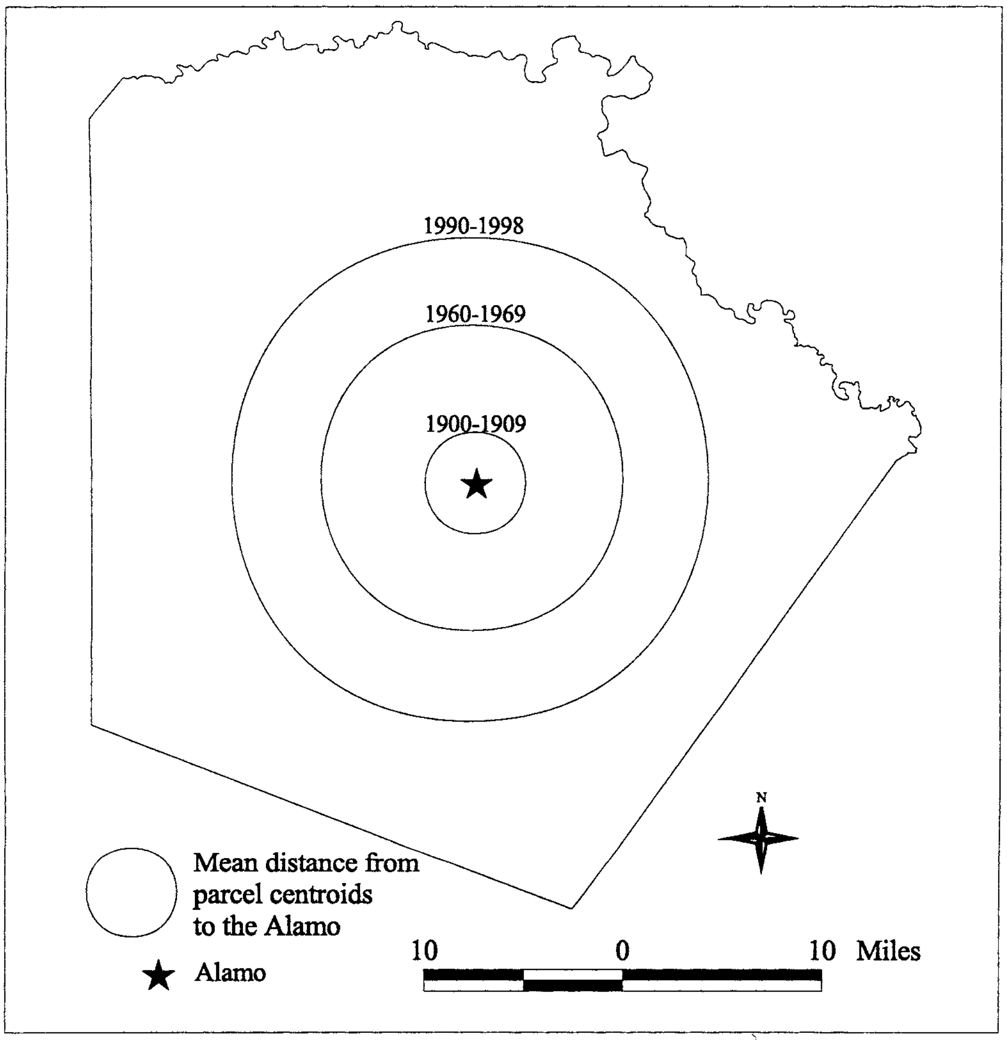
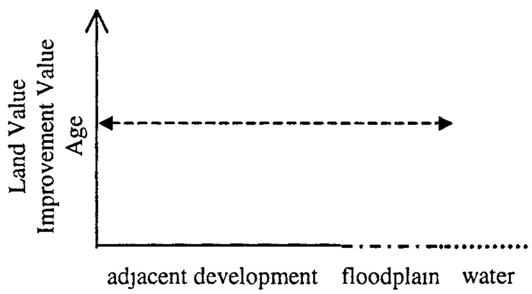
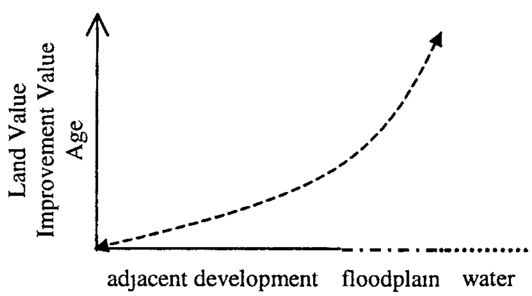


Figure 3.7. Hypothetical *adjacent* floodplain adjustments.

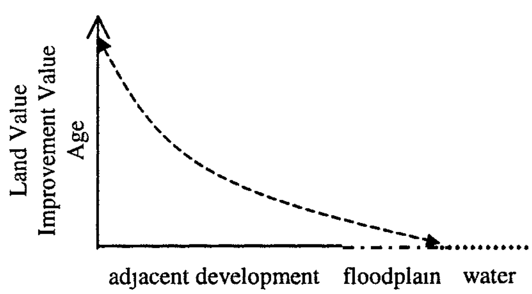
a) Non-Adjustment



b) Utility-Adjustment



c) Risk-Adjustment



(Figure 3.7b). Inversely, if the floodplain where perceived as less desirable, presumably due to the risk of flooding, then the expansion occupancy pattern would be reversed and the mean distances of those parcels outside the floodplain would be significantly greater by decade than those inside (Figure 3.7c.). In this scenario, the floodplain is occupied as a second choice and occupancy inside therefore follows behind that outside. The possibility that these relationships may change over time is also explored.

In preparing the various data sets described above it became clear that the assumption of a normal distribution of observations would not be met for all sets. Therfore a Mann-Whitney U test was selected to test the difference-of-means rather than the more commonly used Student's t-Test. "The Mann-Whitney U test is a fairly simple test of whether there is a significant difference between two [non-parametric] sample sets of data...the null hypothesis being that the two samples are taken from a common population" (Ebdon 1997). The procedure produces a U value and an accompanying significance test (in this analysis a two-tailed test is used). From these results the null hypothesis can be accepted or rejected. Even in the event that the null hypothesis is rejected though, the results do not provide a measurement of how the two groups differ. In order to determine how they differ one must examine the actual mean values of each sample set. For this reason, both the Mann-Whitney U test results and the mean values for those comparisons that exhibit statistically significant differences are discussed.

Population, Dams and Buyouts

The final hypothesis being tested in this research relates to the possible relationships between flood hazard management and the population geography of San

Antonio and Bexar County. This portion of the analysis first focuses on the influence of structural mitigation projects (retention dams) on the character and rate-of-change of the census tracts in which they are located, and then on the nature of those census tracts which have received one the newest manifestations of structural flood control, namely property buyouts, to assess the degree to which they may be unique within the larger urban fabric of San Antonio. The first assessment is based on hazards literature relating specifically to flood management. The second has been conceptualized in response to the contemporary body of research relating to environmental equity. The premise is that the burdens, or negative externalities, of environmental hazards are often borne by more vulnerable populations.

One of the groundbreaking observations made by Gilbert White and his associates in the early years of hazards research was associated with the interaction between flood control measures and human encroachment into the floodplain. He observed that control measures often had the unfortunate affect of enticing development. If encroachment into the floodplain is spurred by structural alterations reducing the risk of flooding within the floodplain, then the human geography of those locations should exhibit unique characteristics, at least in terms of their growth rates. It may be further hypothesized that if these "points of enticement" represent artificial influences on urban development at specific moments in the development of San Antonio, then the areas surrounding these points in a sense capture a type of development idiosyncratic to the time of occupancy in the "resin" of their landscapes. When measured at a census-tract scale, it can be said that those census tracts where structural mitigation projects have occurred should be in some way different from those where no mitigation has taken place.

Environmental equity research has generally focused on technological risks that permeate our urban landscapes. I suggest that the same analysis can be appropriate for examining natural risks, particularly those that are spatially embedded in the landscape (e.g., flooding, earthquake, coastal hurricane impacts). Additionally, environmental equity research has traditionally focused on two types of potential inequity, outcome and procedural (Cutter 1995). Outcome inequity relates to social conditions surrounding areas of hazard (e.g. neighborhoods in which landfills or toxic waste dumps are located). Investigations into procedural inequities have focused on the governmental and/or social processes that ultimately locate these hazards on the landscape. The question examined in this research is loosely based on both perspectives. Over 400 homes have been bought out by the City of San Antonio or Bexar County since the October 1998 flood (San Antonio River Authority 1999). Whether these homes will be adversely affected by future flooding is obviously no longer in question. One can say that owners of these homes have benefited from the procedural application of this form of environmental hazard mitigation. However, it can also be said that these homes once represented distinct patches in the urban/social fabric of San Antonio. Given that parcels continue to be developed within San Antonio's floodplain, a fact that is clear from examining the "no date" parcels discussed above, are there any clear differences between the social characteristics of those areas being bought out and those areas being allowed to develop? And if so, do the characteristics of both types of areas offer any insight into why one is being systematically removed from the floodplain while another is being allowed to progress into the floodplain?

In order to assess the impact of structural mitigation projects and the nature of urban areas undergoing buyouts, three main data sets are used. First, information on structural mitigation projects in the form of retention dams has been taken from ACE records (United States Army Corps of Engineers 2000). These data contain a number of attributes associated with dams in Bexar County (Table 3.1). Only those dams intended for flood control or storm-water management will be included. The second data set includes a list of properties that have been purchased for the purposes of flood control by the City of San Antonio and Bexar County. These have been provided by their respective entities and have been mapped at the parcel level. The third set of data, the population characteristics in areas surrounding these points of mitigation, is taken from the census.

The location of these phenomena will be compared to census geography in an effort to examine the social patterns associated with each. These data were collected, at the census tract scale, for 1970, 1980 and 1990 from private and government databases (United States Census Bureau 1970, United States Census Bureau 1980, United States Census Bureau 1990, GeoLytics, Inc. 1999, GeoLytics, Inc. 2000). Attributes describing population, economic, and housing characteristics for each year will be included in this analysis (Table 3.2). The goal is not to calculate which combination of these attributes best serves to predict tracts with structural mitigation, but rather to understand the overall place and place-change character of those tracts. The first technique employed to this end will be to run a K-means cluster analysis of the 1990 census tract data in order to produce a place-character map of San Antonio. Cluster analysis offers an "efficient way of displaying complex relationships among many objects," (Davis 1986, 507) and, in Q-mode, allows clusters to be generated as a function of inter-object (in this case tracts),

Table 3.1. Bexar County dam characteristics.

Purpose	N	%	Description	
C	26	43%	Flood Control and Storm Water Management	
R	17	28%	Recreation	
P	4	6%	Fire Protection, Stock or Small Pond	
S	4	6%	Water Supply	
I	7	12%	Irrigation	
O	2	3%	Other	
Hazard			**Result of Failure**	
High	31	52%	Probable Loss of Human Life	
Significant	1	2%	No Probable Loss of Life; Significant Economic or Environmental impacts	
Low	28	47%	No Loss of Life; Low Economic or Environmental impact	
Basin Name			**Hazard (N)**	**Purpose (N)**
Atascosa River	1	2%	Significant	S
Calaveras Creek	10	17%	High (6), Low (4)	C (6), S (2), R (1), O (1)
Cibolo Creek	2	3%	Low (2)	P (1), R (1)
Culebra Creek	2	3%	High (1), Low (1)	R (1), S (1)
Lower Leon Creek	1	2%	Low	R
Lower Salado Creek	2	3%	High (1), Low (1)	R (2)
Martinez Creek	6	10%	High (6)	C (6)
Medina River	13	22%	Low (13)	R (8), I (3), P (1), S (1)
Medio Creek	2	3%	Low (2)	R (1), I (1)
San Antonio River	7	12%	High (4), Low (3)	I (3), R (3), C (1), O (1)
Upper Leon Creek	1	2%	Low	P
Upper Salado Creek	13	22%	High (13)	C (13)

Source: United States Army Corps of Engineers. 2000. *Water Control Infrastructure, National Inventory of Dams.* CD-Rom. Washington, DC: U.S. Army Corps.

Table 3.2. 1970, 1980, and 1990 census tract attributes.

Variable
Population Characteristics:
total population
population density
percentage population white
percentage population black
percentage population Hispanic (% Spanish Language for 1970)
percentage population other race
percentage of population 14 or younger
percentage of population 60 or older
Economic Characteristics:
median family income
percentage of total population employed
Housing Characteristics:
median value of housing
median age of housing
percentage of housing occupied

rather then inter-variable, covariance (563). Tracts are mapped based on their cluster assignments and then the two mitigation phenomena described above are tallied for each type of cluster to assess their social geographic distributions.

The final stage of this analysis describes the change that has occurred within census-tract attributes over the period 1970-1990. The first step renders each census year into a common set of spatial units. As Bexar County and the City of San Antonio have grown over that time period, new census tracts have been delineated with each decennial census period. The 1970 census included 166 census tracts for Bexar County, the 1980 census included 178, and the 1990 census included 224. This makes it difficult to make comparisons to determine change over time, as what was a single tract in 1970 may be two, three or more tracts in 1990. In order to overcome this, the 1990 and 1980 census tract files, and their accompanying attributes, have been collapsed into 1970 spatial units. Thus three layers of census geography, with consistent spatial units, can be subjected to time-change analysis. Characteristics of change over time are most often described as a percentage of increase from period one to period two. This is a useful measure. However, we can logically assume that there are more nuances to change than simply a bulk increase or decrease. In other words, simply expressing the net change runs the risk of obscuring otherwise useful information about the spatial variability of change. In order to coax these nuances of change out of the comparison of census period the values of velocity (or rate of change) and acceleration (the rate of the rate of change) are calculated for each attribute in each tract. This technique has been described by Eyton (1991).

> Differentiating...variables with respect to time produces estimates of change for phenomena that can also be interpreted in terms of velocity and acceleration. Velocity is the measure of the rate of change for the variables and the acceleration indicates whether the rate of change is increasing, decreasing, or remaining

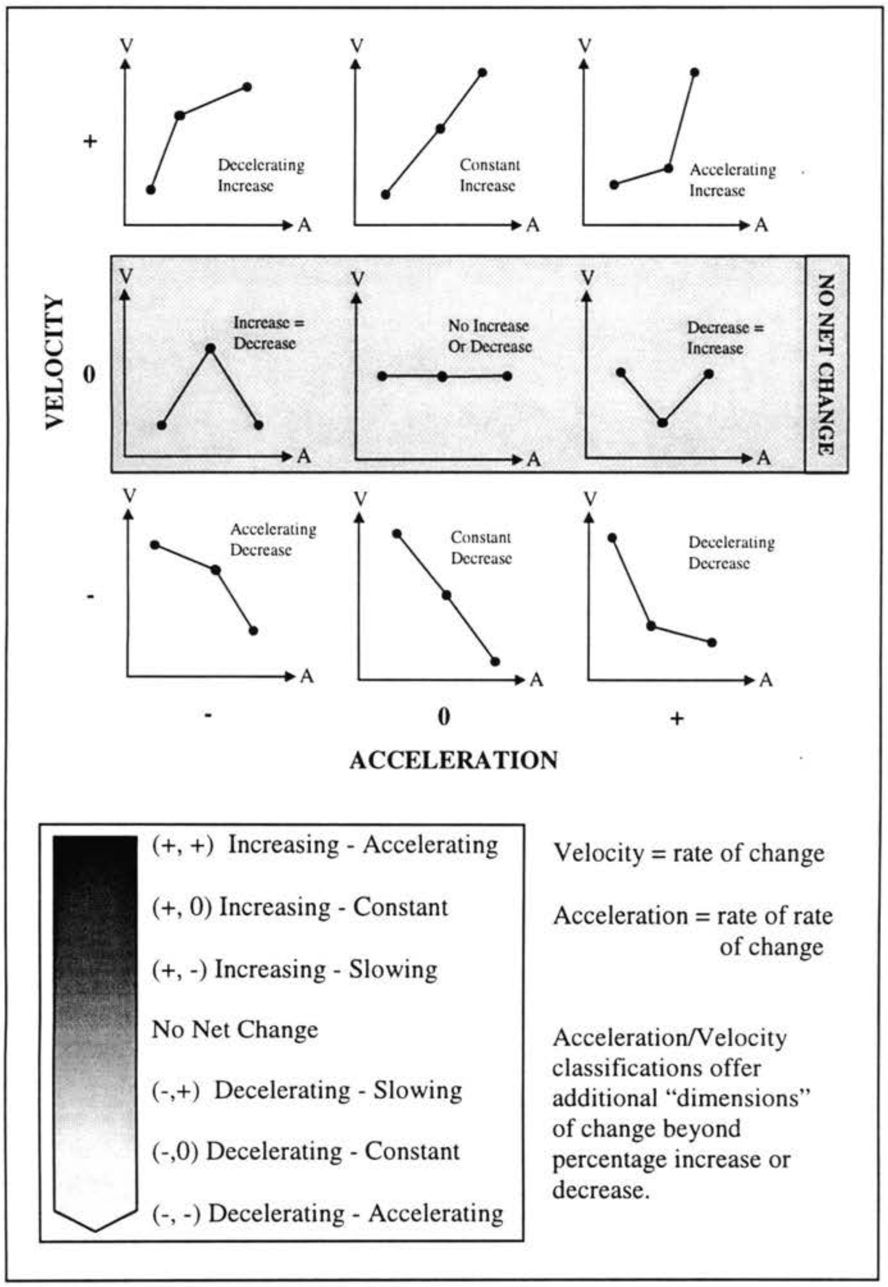
> constant. When these measures are spatially distributed, a velocity and acceleration map of the changes can be constructed (98).

The measurement of velocity, in particular, becomes a useful measure of the differences between tracts' rates of change. When expressed on a bivariate scale with the acceleration values, these measures can be used to classify each census tract according to its velocity and acceleration characteristics (Figure 3.8). This renders a richer understanding of how each tract has changed over time, and a more comprehensive understanding of the coincidence of change and mitigation efforts is enabled.

Summary

In addition to describing the overall goals of the analysis of the research, this chapter described the data sources and methodologies that are used to test the three research hypotheses for this study. Hypothesis one, relating to the history of flood hazard, flood disaster, and flood management in San Antonio is tested using a variety of qualitative sources, including federal, state, and municipal engineering reports, newspaper accounts surrounding specific flood events or flood control projects, and other primary and secondary documents relating the historical development of San Antonio and its flood control measures. Data issues relating to the delineation of floodplains by FEMA were discussed in order to illustrate the strengths and weaknesses of these delineations. The cadastral data for Bexar County, which is used to test hypothesis two, is described and the conceptualization of expansion floodplain occupancy was outlined. Lastly, the contemporary and change-over-time measures of population and housing census geography associated with testing hypothesis three are described. This portion of the

Figure 3.8. Velocity/acceleration classification legend.



Source: Modified from Eyton, J. Ronald. 1991. Rate-of-change maps. *Cartography and Geographic Information Systems* 18, no. 2: 87-103.

analysis is designed to offer insight into the degree to which the geographies surrounding these phenomena are unique within the larger urban fabric of the City of San Antonio and Bexar County. A description of the physical, human, and historical geography of San Antonio is provided in the following chapter.

CHAPTER 4

STUDY SITE AND SITUATION

Overview

This chapter provides a brief overview of the physical and human geography of the City of San Antonio and Bexar County. It is not meant to be an exhaustive treatment. Rather it describes those physiographic and human attributes that bear directly on the region's flood hazard characteristics and the city's urban geographical development.

Environmental Setting

Human occupation of the area that is now Bexar County and the City of San Antonio has long been premised on the diverse natural resource base offered by the site. Natural springs flow from the base of the Balcones Fault uplift that runs southwest to northeast across the region and drain the karst aquifer north of the area. These waters and the resulting riverine environments that stretch down to the Gulf of Mexico, approximately one hundred miles to the southeast, have provided humans with a consistent, albeit finite, water source for thousands of years. Savannah cedar and live oak forests stand to the northwest of the area. These provided ample game, shelter, fuel, and, in more recent years, prime lands for the development of a vast ranching industry. This area, part of the Central Texas region known as the Hill Country, has also been the focus of intense residential land development in the last fifty years. Below the Balcones Fault, spreading out to the south and southeast lays the Gulf Coastal Plain. This flat, sparsely wooded grassland, carved by rivers and streams originating in the Hill Country and along the Balcones Fault has proven to be one of the most agriculturally rich areas in North America. Once ranged by indigenous Indian tribes, it is now dotted with small towns and vast commercial farms supported by irrigation from the San Antonio, The Colorado, and the Guadalupe rivers that cross its open plains. Just west of Bexar County the landscape transitions into an semi-arid region that stretches from Texas to California, making this location a final way station for westward movement before entering the dry steppe environments of the southwest. The city of San Antonio sits at the nexus of these distinct, but complementary natural regions. Its histories, and its hazards, are inextricably tied to those features.

Physical Geography

The most dramatic physiographic characteristic of the San Antonio site is by far the harsh line of natural demarcation generated by the Balcones Fault. The fault itself corresponds approximately with the contour line of 750 feet above sea level (Figure 4.1). The geologic formations above the fault are from the Mesozoic era, ending approximately sixty-six million years ago, while those below are from the more recent Cenozoic. The fault zone itself runs from Del Rio, along the U.S.-Mexico border, northeast to San Antonio, New Braunfels, and northeastern Texas. The fault resulted from subsidence of the southeastern portion of the state at the close of the Mesozoic era. The section above the fault was once a broad high plateau standing over one thousand feet above the coastal plain at its highest points, creating an average change in elevation within Bexar County of approximately 300 feet (Figure 4.2). Over time it has been

Figure 4.1. Bexar County elevation contours.

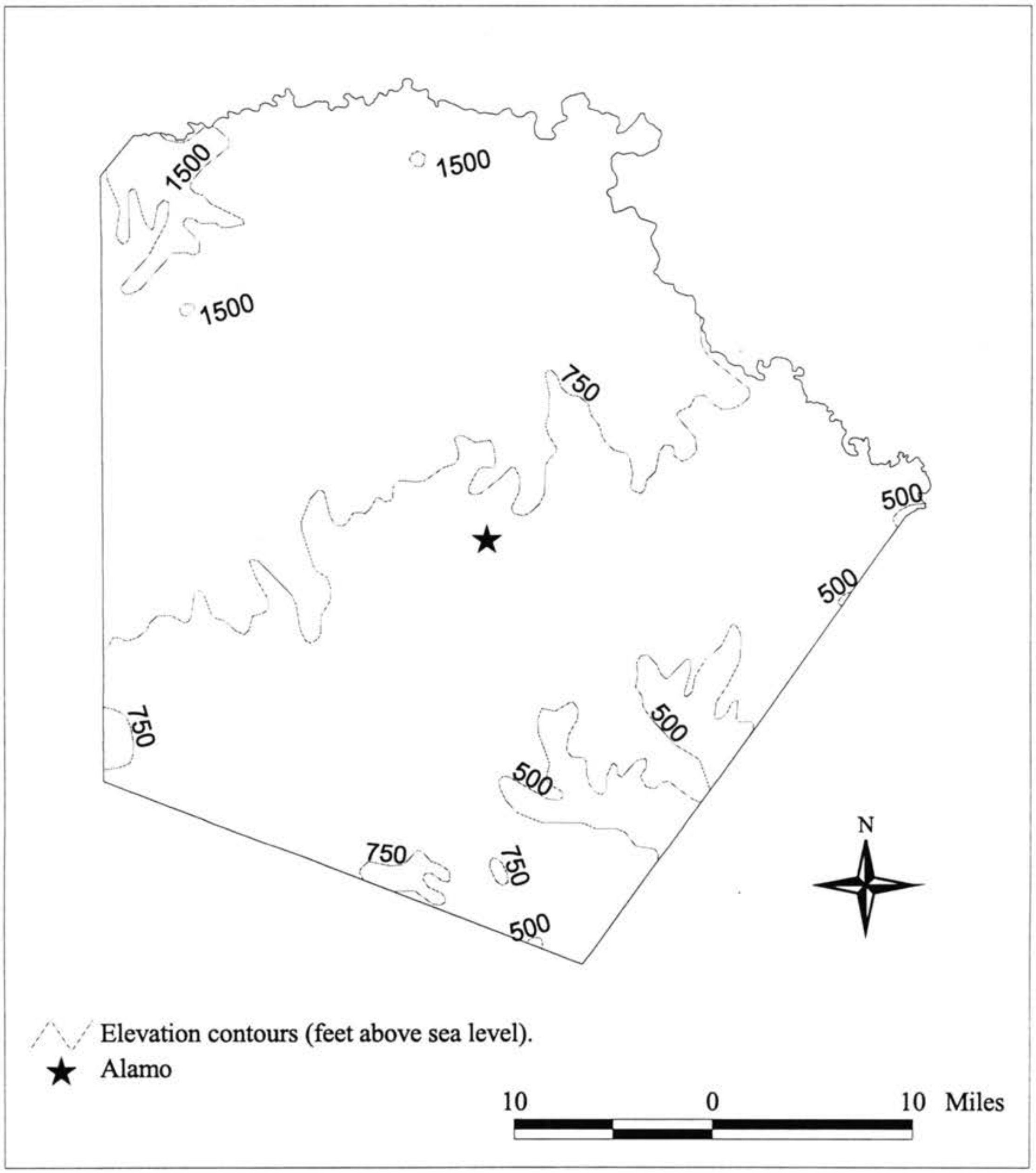
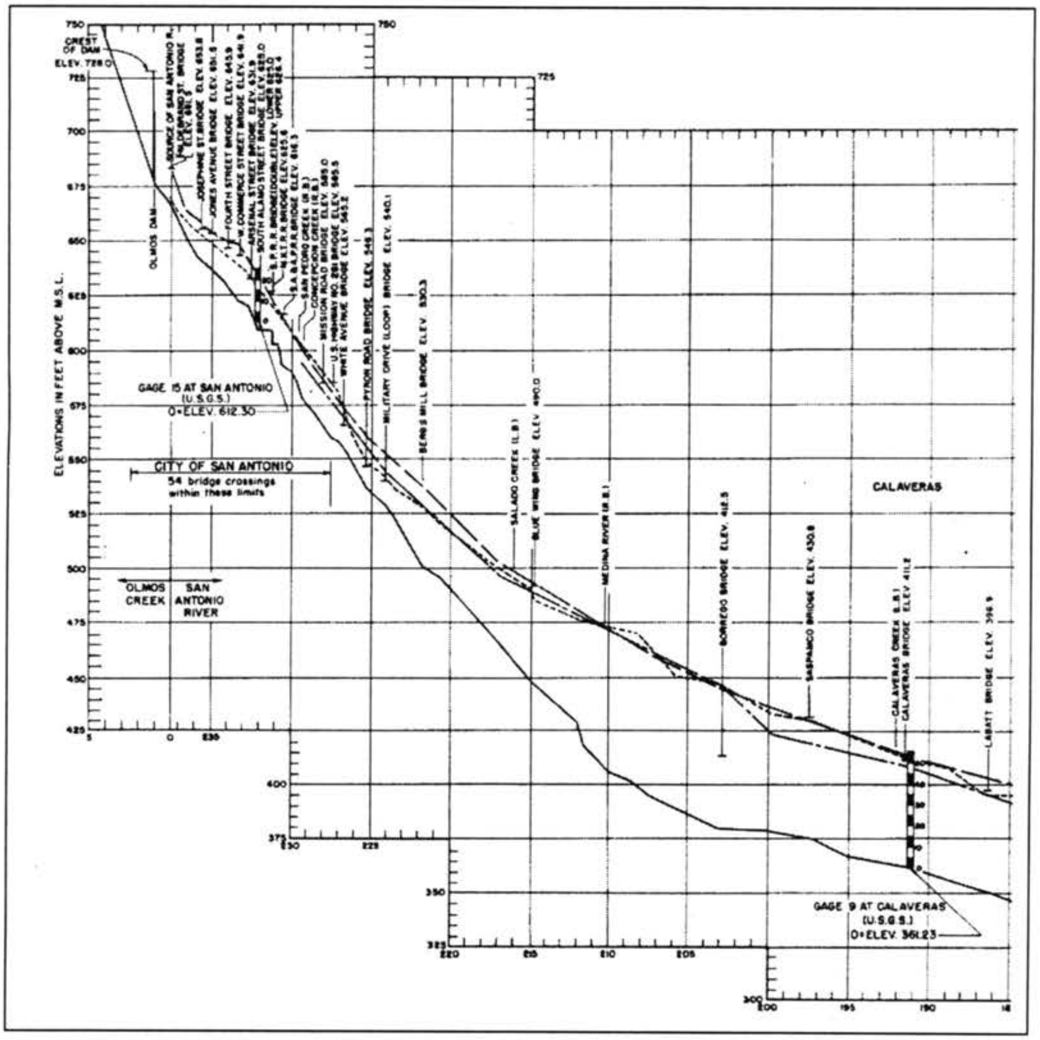


Figure 4.2. San Antonio River elevation profile: Olmos Basin to Calaveras, Texas.

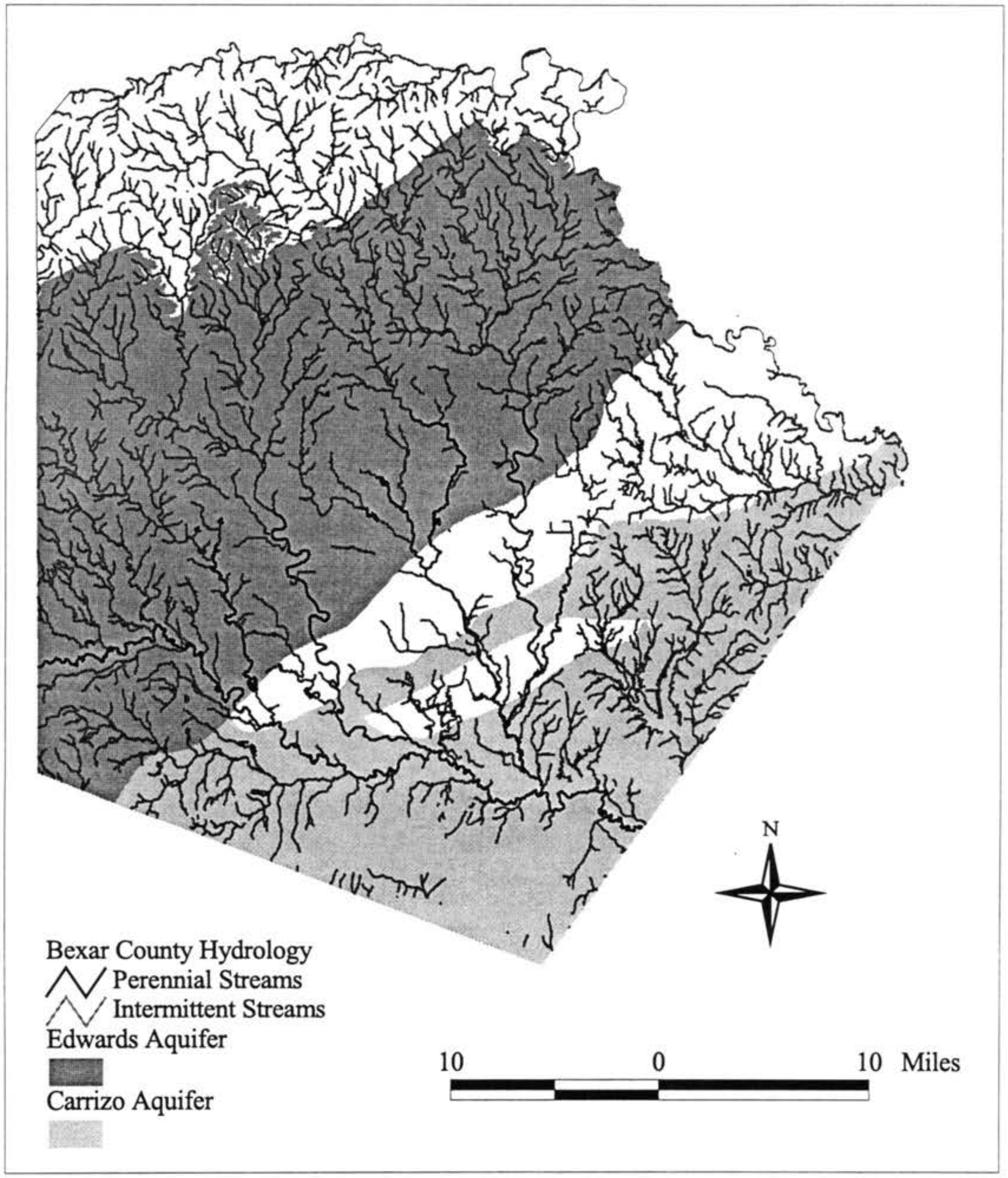


Source: United States Army Corps of Engineers. 1950d. *Report on survey of Guadalupe and SanAntonio Rivers and tributaries,Texas for flood control and allied purposes, vol. 5*. Fort Worth, TX: Corps of Engineers, US. Army.

deeply dissected by rivers, intermittent streams, and periodic large-scale flood events. The erosion of the soft limestone uplift has created a karst aquifer peppered with subterranean waterways and cavern systems that often stretch for miles underground. Cedar, juniper, and live oak forests spotted with prairie-grass clearings dominate the vegetation above the fault (United States Army Corps of Engineers 1950a, United States Department of Agriculture 1960). In recent years fire suppression from ranchers and residential land developers have allowed ash juniper trees to proliferate across many of the areas previously kept clear by the occasional wildfire. Below the fault line is the Gulf Coastal Plain directly to the south and the Blackland Prairie to the southeast. These grassland prairies are nearly level with poorly defined and broadly meandering drainage ways, except for the main valley of the San Antonio River. Soils are deep with slow percolation rates and are often highly fertile loams and clays that have been heavily utilized for commercial agricultural production (United States Department of Agriculture 1960).

This sharp geological contrast has been woven together by the dendritic drainage patterns that carve deeply into the Edwards Plateau and spill out into the Coastal Plain. These waterways form a two-tiered system of perennial streams, fed predominately by springs along the Balcones Fault, and numerous intermittent streams carved by seasonal rainfall in the region (Figure 4.3). As the rivers and streams cross the Coastal Plain immediately to the south of San Antonio they contribute to the shallow, sandy Carrizo Aquifer before meandering south to the Gulf of Mexico. According to the San Antonio River Authority's classification (San Antonio River Authority 1999) the larger of these waterways form thirteen distinct basins, with the San Antonio River basin as the central

Figure 4.3. Bexar County hydrology.

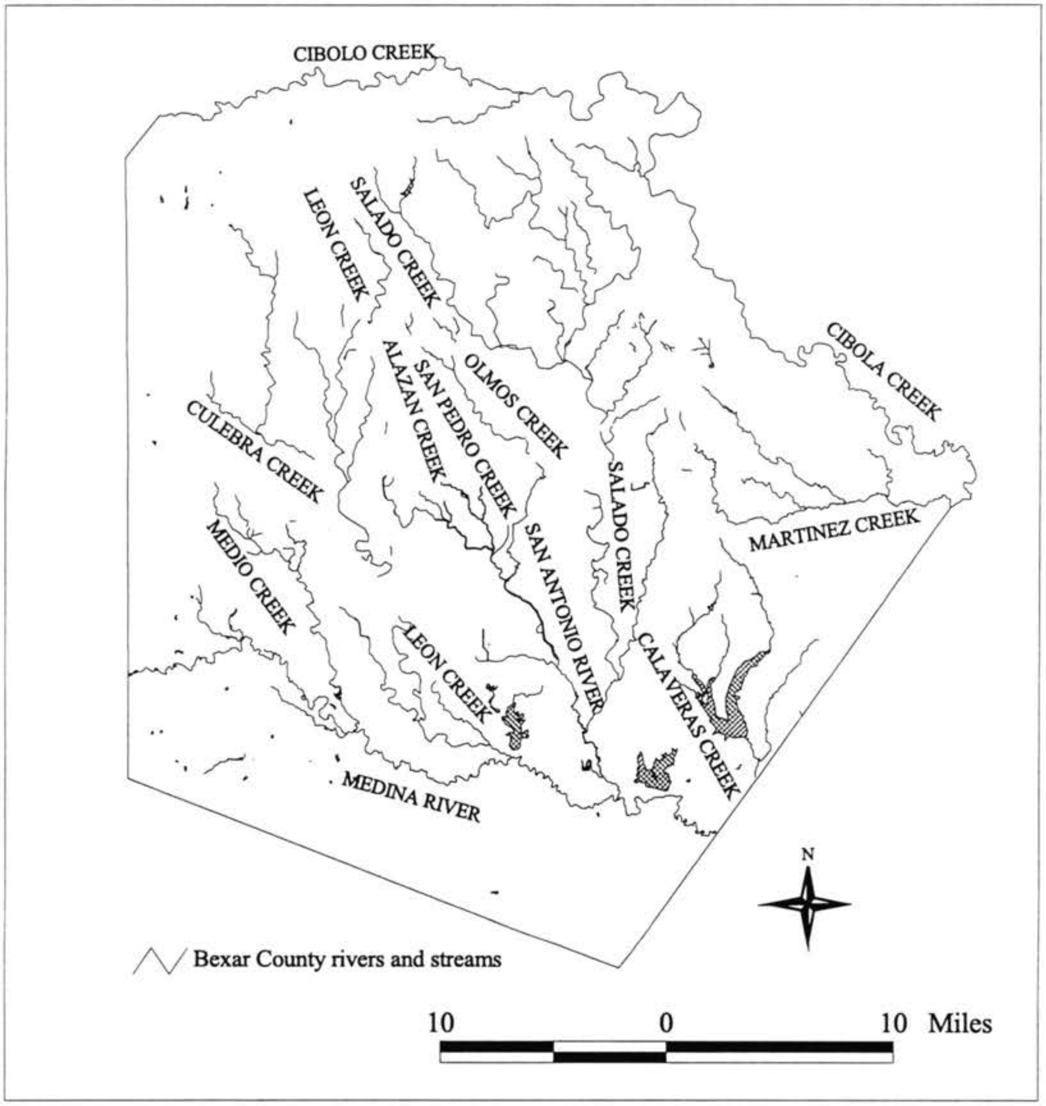


stem of the drainage system (Figure 3.5, 4.4). The entire drainage system, including both aquifers, is fed exclusively by local rainfall. On average the heaviest rains fall in May and September, while the driest months, on average, tend to be December through March and July, although late summer and fall can produce heavy sporadic rain events resulting from remnants of Gulf and Pacific tropical storms and stalled cold fronts moving down from the northwest. Normal annual rainfall is about 30 inches, with extremes ranging from 10.11 inches in 1917 to 52.28 in 1973 (NOAA 2000). Flooding generated by intense rainfall either from the collision of fronts or by remnant hurricane and tropical storms moving inland over the region can be intensified by the orographic effects of the Edwards Plateau (Caran and Baker 1986). A discussion of flood events within the region's human history, as well as their implications to the subject of flood control and development within Bexar County can be found in chapter four.

Human Geography

Various indigenous Native American groups originally settled the area that is now the City of San Antonio and Bexar County ten to twelve thousand years ago (Newcomb 1961). The first Europeans to explore the area, beginning in the early 1600s, were from Spain and France. Spain eventually established a series of mission-based colonial settlements and claimed exclusive dominion over the region throughout the 1700s and into the early 1800s. It was during this period, specifically in 1718, that Spain established a settlement, based on a string of five missions along the San Antonio River, which would eventually become the city of San Antonio. By the 1820s, initially under the invitation of the Spanish-led government in Mexico, American and Western European settlers began to occupy the area. Tensions between these first "Anglo" settlers and their

Figure 4.4. Bexar County rivers and streams.



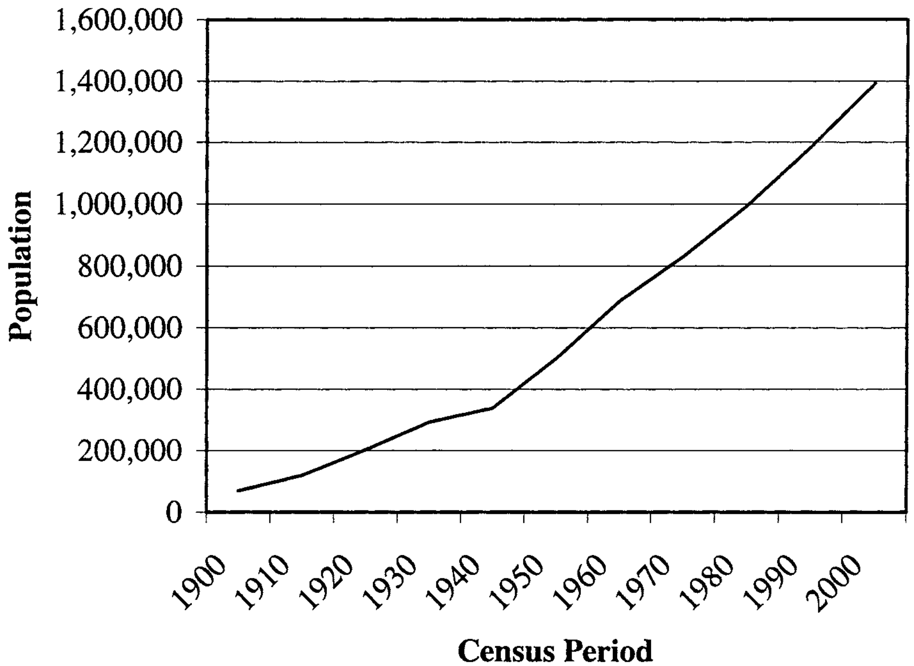
Mexican hosts soon rose and led to a series of battles ending with the establishment of an independent Republic of Texas in 1836. In 1845 Texas joined the Union only to secede in 1861 at the onset of the Civil War along with numerous other southern states dependant on slave labor for their large-scale commercial agricultural economies. Following the defeat of the south in the Civil War, Texas again became a state in 1870.

San Antonio's importance as a commercial center for the burgeoning agricultural production of the region, as well as a primary way station for travel to Mexico and the west coast, solidified during the years leading to the turn of the century (Miller and Johnson 1990, Johnson 1990). Bexar County population records from 1850 indicate a population of 6,052 (Ramos 1999). Population increased steadily in the county until the end of World War II, when growth rates experienced a substantial increase (Figure 4.5). In the fifty years since that time the population of Bexar County has grown to 1,392,931 according to preliminary figures from the 2000 census (United States Census Bureau 2001). Current Texas State Data Center estimates rank the City of San Antonio as the second largest in Texas (Ramos 1999). Census data from the 2000 census indicate that over half (54.3%) of the county's population is "Hispanic or Latino" in origin, with white and black (both non-Hispanic) accounting for most of the remaining population (35.6% and 7.2% respectively). With a median household income of $32, 374 and a total population poverty rate of 18.5%, the county is quite close to the state average for both values (United States Census Bureau 2001).

Urban Morphology and Flood Hazard

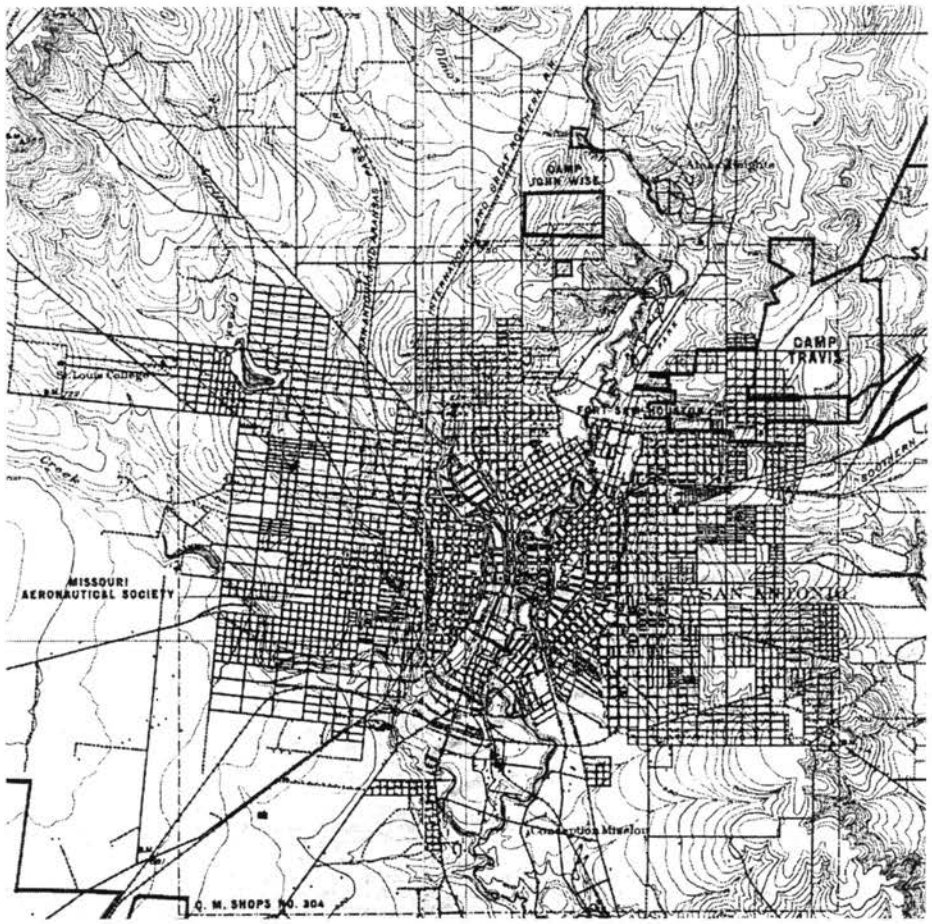
Contemporary and historical maps of the urbanized area of San Antonio illustrate the city's growth in recent decades (Figure 4.6, 4.7, 4.8, and 4.9). The city's growth

Figure 4.5. Bexar County historical census of population.



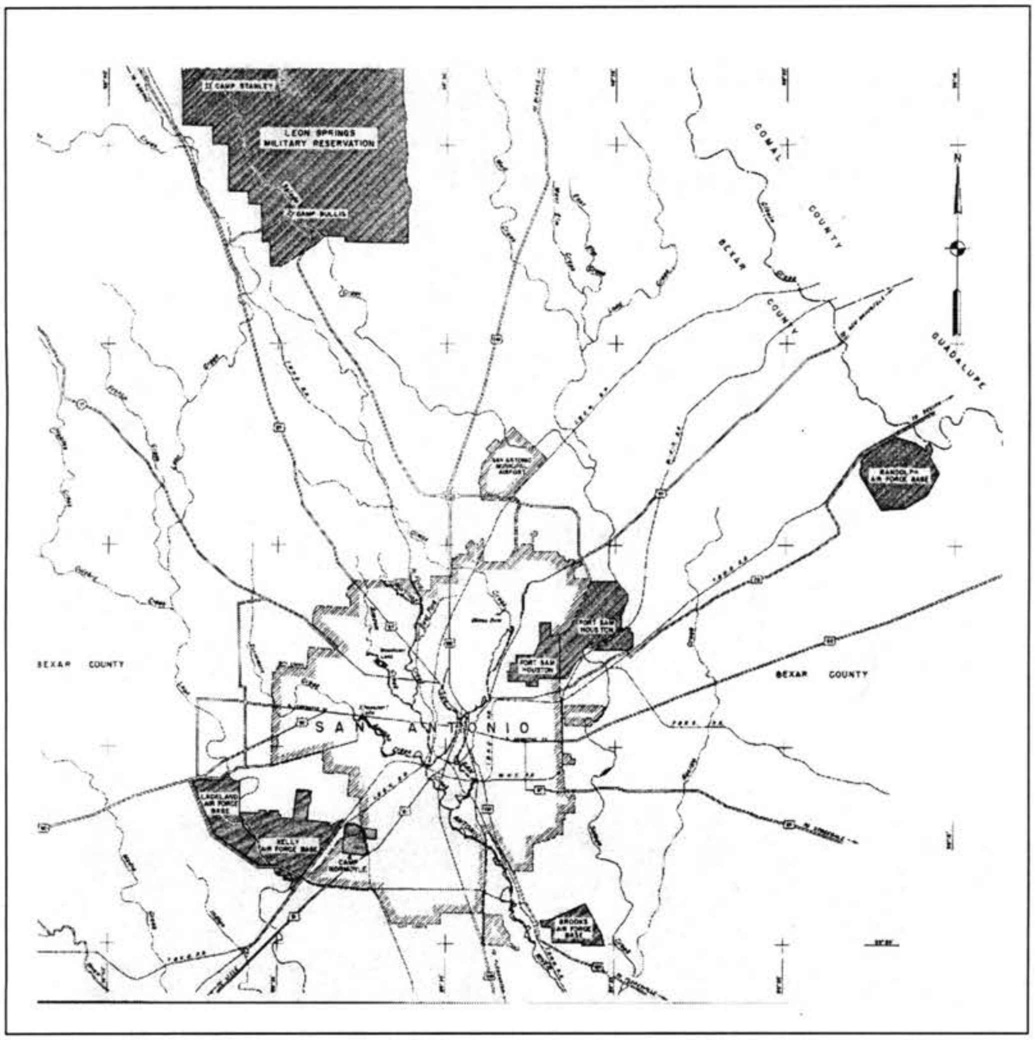
Source: Texas Comptroller of Public Accounts. 2001. *Population and Economic Detail for Cities, Counties, MSAs, and States*. Online source; accessed June 30, 2001; available from http://www.window.state.tx.us/ecodata/popdata/popfiles.html.

Figure 4.6. City of San Antonio, 1918.



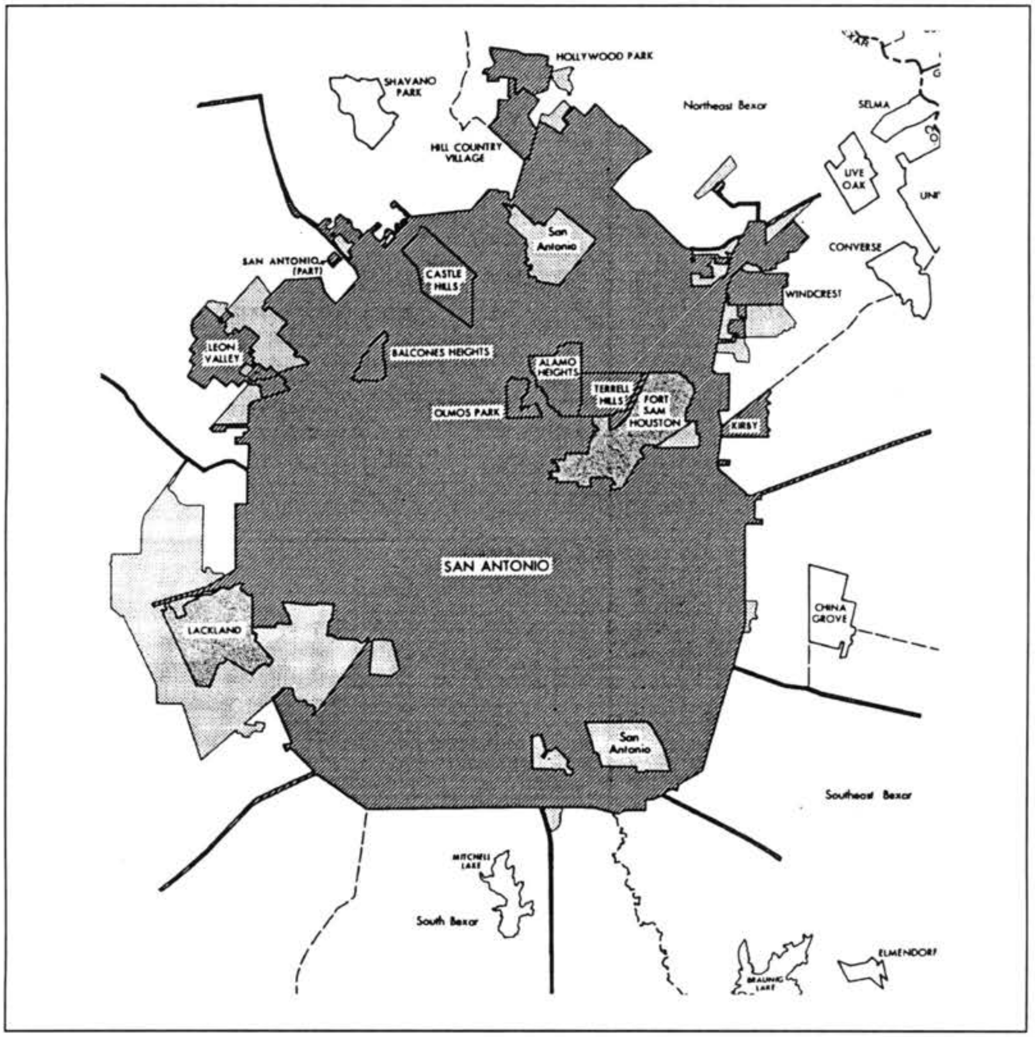
Source: (University of Texas Library Online 2001)

Figure 4.7. City of San Antonio, 1950.



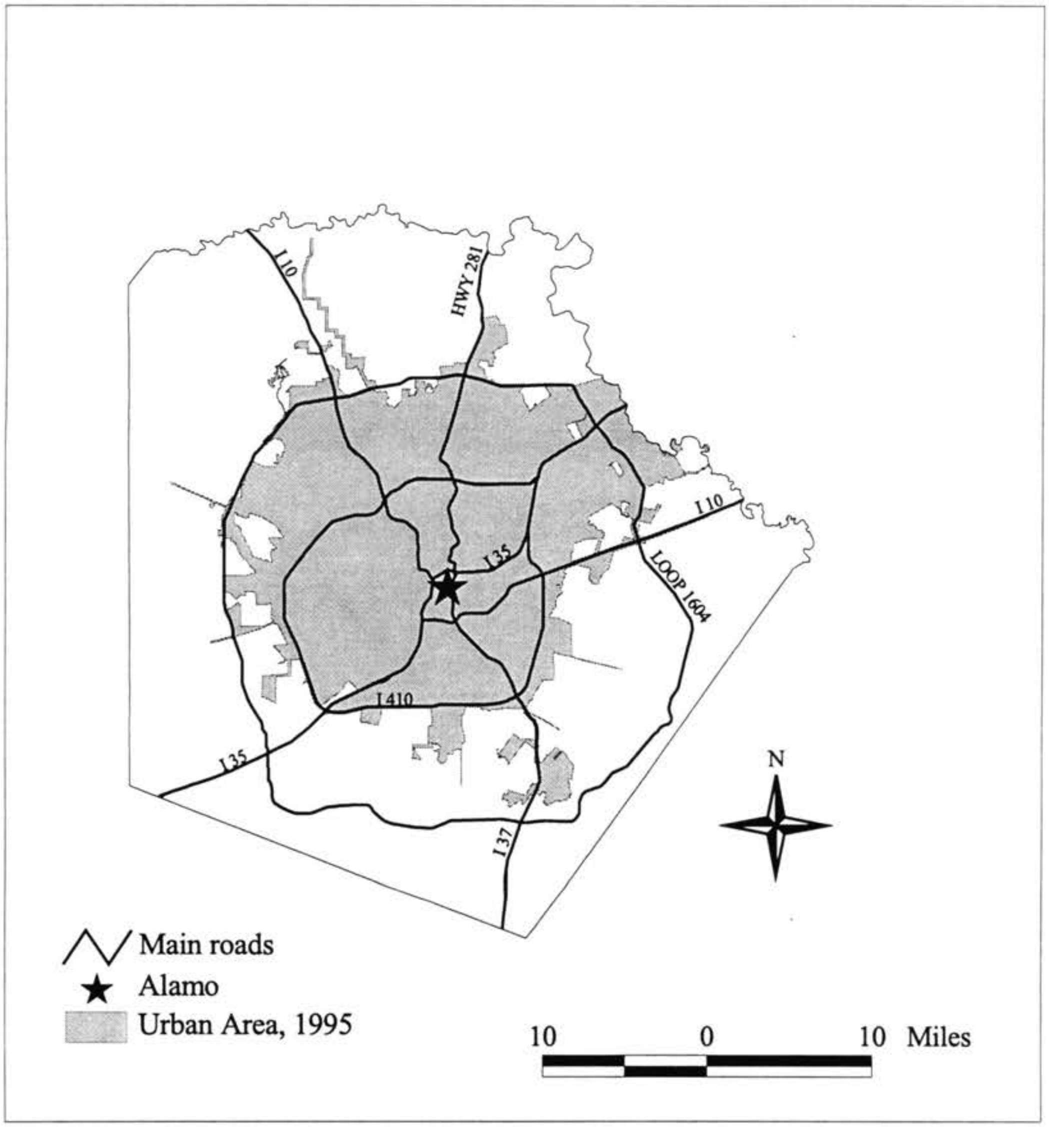
Source: United States Army Corps of Engineers. 1950c. *Report on survey of Guadalupe and San Antonio Rivers and tributaries, Texas for flood control and allied purposes, vol. 4*. Fort Worth, TX: Corps of Engineers, US. Army.

Figure 4.8. San Antonio urbanized area, 1970.



Source: United States Census Bureau. 1970. *Census of Population and Housing*. Washington, DC: United States Department of Commerce, Census Bureau.

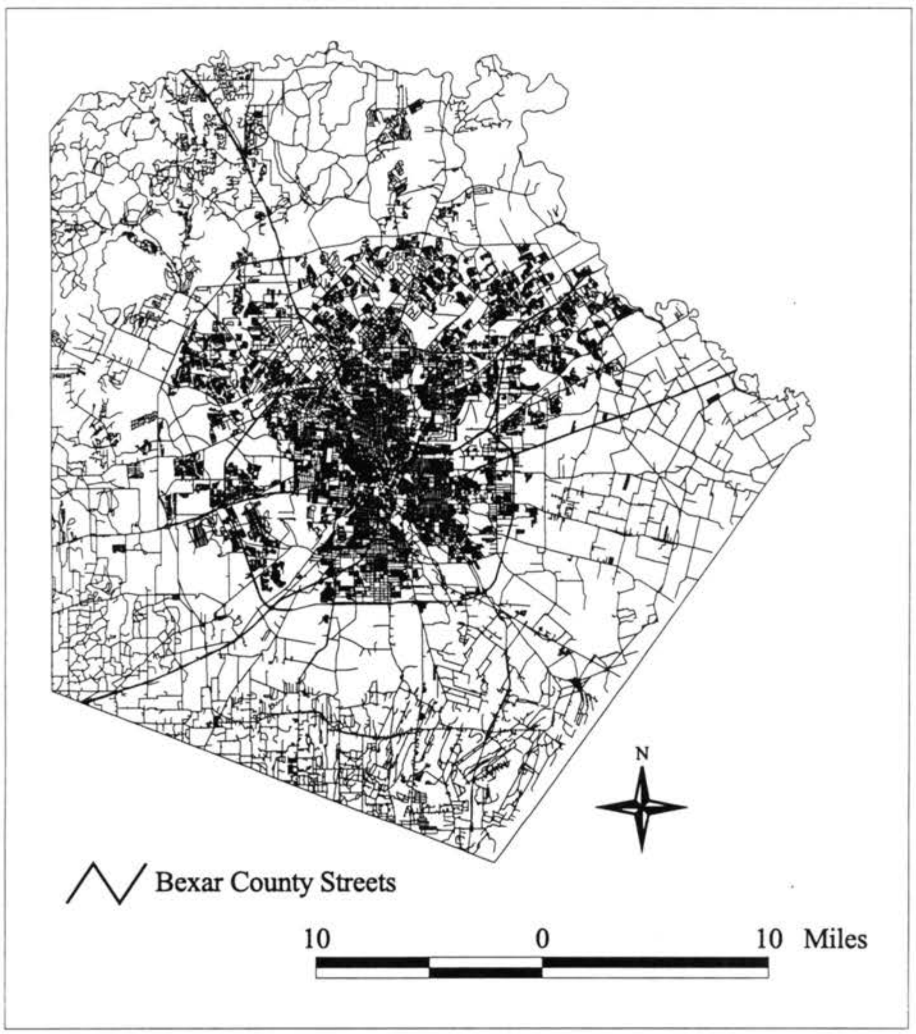
Figure 4.9. San Antonio urbanized area, 1995.



pattern has been primarily concentric in nature, with a strong pull to the north and east into the aesthetically attractive, but environmentally sensitive, regions of the Edwards Plateau. Using the Alamo as a centroid one can calculate the average distance of parcel-level development for periods of urban growth in San Antonio (this approach is discussed in detail within the methodology chapter).

Figure 4.10, showing street-level data for Bexar County, support this concentric/northeastern pattern of land development. As the urbanized area of Bexar County has expanded it has spread out across, along, and into the varied natural landscapes described in this chapter. The Balcones Fault has proven to be both a hindrance and an attraction to land development over the years. It is costly to build on top of the aquifer for both construction and environmental management reasons, but it is an area that is coveted by landowners for its aesthetic value. The fertile land to the south of the city has been almost entirely cultivated at this point, and as a result has been less densely developed for residential use. As the city has grown it has occupied more and more of the areas adjacent to the dense dendritic stream patterns described above. It is in these areas that San Antonians have, consciously or unconsciously, drawn battle lines with nature. As urbanization has encroached into the floodplains of these perennial and intermittent streams, runoff rates and flood-stage levels have increased, creating the effect of two armies rushing headlong into disaster. This "battle" has been fought on many fronts: political, economic, and geographic. The remainder of this study is devoted to understanding the historical development of flood control within Bexar County, the spatial patterns of urbanization within the floodplain, and the impact flood hazard mitigation has had on the patterns of urbanization within the county. More generally, it

Figure 4.10. Bexar County streets.



seeks to explore the relationship that has emerged between nature and humans within the confines of this diverse and dynamic natural environment.

This process begins with an analysis of the historical record aimed at examining the history of San Antonio's flood control and flood disaster experience. The urban morphology described above evolved over more than one hundred years of development. Numerous flood events have been experienced within the San Antonio area during that time, however a select few have had the greatest influence on flood control projects and, therefore, the urban geography of San Antonio's floodplain. The following chapter will focus primarily on those events that have had the greatest impact on urban form or which most clearly reflect the changing geography of flood hazard with Bexar County.

CHAPTER 5

A HISTORY OF FLOODING AND FLOOD HAZARD IN SAN ANTONIO, TEXAS

Overview

The *prima facie* intent of human occupation of natural settings is the utilization of the resources of the location. Once utilized, the dynamic characteristics of the natural setting become both resource and hazard to its human occupants. It then becomes the task of the occupants to choose from an array of "adjustments" meant to maximize the use of the natural resource and minimize, or mitigate, the impacts of future extreme natural events. These choices range from physically altering the natural setting - with engineered structures intended to ward off the impacts of future events - to the simple, but often undesireable, act of abandoning the location all together (Burton, Kates, and White 1993). These adjustment decisions are made even more complicated by the temporal nature of their influences. George Marsh's "ravages of man" and "destructive energies of nature" seldom manifest immediately. They, or knowledge of them, emerge over time. "Adjustments" therefore are cumulative. They pile up over time, built one upon the other. With each new decision being affected by past experience, the magnitude of the event prompting the decision, the state of contemporary knowledge relating to adjustment options, and the ideology of environmental management most prevalent at the time of adjustment. Thus has been the relationship of San Antonio's inhabitants with the natural riverine environment they have elected to occupy. Therefore to understand modern flood control in San Antonio, or any other location for that matter, one must be aware of the evolution of the historical management-strata accumulated within the urban landscape.

This chapter tests the first hypothesis presented in the introduction. It posits that the history of flood hazard management in San Antonio and Bexar County will be marked by reactive approaches to extreme flood events more so than proactive solutions to future threats. Therefore the county's flood hazards history will be punctuated by extreme flood events and the approaches adopted will reflect the urban floodplain constituency at the time of each event. With this in mind, the purpose of this chapter is not so much to provide a complete chronicle of every flood event in Bexar County and the City of San Antonio, but rather to identify those flood events, and the management decisions surrounding them, that have served as major turning points in San Antonio's use and management of its floodplains. Four flood events have been identified for this purpose. They occurred in the years 1913, 1921, 1946, and 1998. Each prompted a series of floodplain management decisions and the lessons of each resonate throughout the urban landscape of contemporary San Antonio.

Europeans first settled San Antonio in 1718, two hundred years before the first flood event discussed here. Certainly these early populations experienced a number of flood events, big and small, during this time. Records are meager for this time period, especially regarding nature's extremes. There do exist, however, a number of resources that hint at the interaction these earliest settlers had with both the tremendous resource of the San Antonio River and the infrequent, but destructive, hazards posed by the riverine environment. Although they are on a much smaller urban scale, these reports provide insight into some of the adjustments made by European and American settlers. In many ways they were faced with the same choices that managers face today: mitigate or move. It is worth exploring these reports to see how San Antonio's first floodplain managers, reluctant thought they may have been, set the stage for future management decisions.

Setting the Stage

Indigenous populations are known to have "concentrated along the streams and rivers of central Texas" for well over ten thousand years before the first Spanish explorers would arrive (Newcomb 1961, 135). As early as 8000 B.C. hunter-gatherer tribes occupied the headwaters of the San Antonio River (Fisher 1997). By the time the Spanish arrived, San Pedro Springs had been serving as a "focal point of three or more affiliated Coahuiltecan bands known as the Payayas" for many years (Newcomb 1961). Their village was called Yanaguana (Chabot 1931), a name that many Spanish colonists used to describe all the tribes of the Coahuiltecan in the region. One can assume that these inhabitants had knowledge, and therefore made some form of adjustments, to the river's flood hazard. However, any evidence of this has been long washed away by the wave of Spanish, French, and American colonialism that swept over the region. The riverine environments that began with a series of natural springs flowing out of the base of the Balcones Escarpment, offered these early colonists a natural largess that would be described in 1716 by Captain Domingo Ramon.

> On the 14th of May the expedition reached "a spring, level with the ground, which they called *San Pedro*. It was large enough to supply a city. They entered a beautiful spot on the San Antonio River, where there were walnuts, vines, willows, elms, and other kinds of trees. They crossed the river which was of good size, the water being up to the stirrups but no deeper. They went up the river to hunt a good place and found a fine one where there was a beautiful little open place with wood and pasturage. They explored the head of the river and found hemp three varas high and flax four spans high...Fish enough for everybody was

> caught and it was seen that water could be easily taken from the river for irrigation. (Chabot 1929, 22-23)

Two years later in 1718 a group of families, under the direction of Don Martin de Alcon, Governor of Coahuila and Texas, arrived on the eastern edge of the San Antonio River, with the intention of crossing it and joining the few people left from prior Spanish occupations, only to find the river swollen out beyond its banks (Chabot 1929). The fort that the Spanish army had been sent to build would be washed downstream in May of 1722 (Chabot 1929). "In 1724 a furious hurricane destroyed" the Mission San Antonio de Valero, and as a result "a more convenient site was chosen about two gun shots away" (Chabot 1931, SARA 1999, San Antonio Conservation Society 2001). This location corresponds with the current site of Alamo Plaza. Records of flood events fall off for a period as the settlement of San Antonio waxed and waned in response to changes in Spain's ability, and ultimately its responsibility, to support its New World colonies during and after the American Revolution. During this period San Antonio remained an outpost deep in the heart of Comanche country.

The 1800s brought renewed interests from Mexico to re-establish its claims to Texas, from the United States to seal its border with Mexico, and from Europeans to open up new points of immigration beyond the eastern seaboard. With this came a new prosperity and a new base of European knowledge, technology, culture, and interest in making the most of San Antonio's unique natural setting.

On July 5th, 1819 a cloudburst over the Olmos Creek basin forced floodwaters down both the San Pedro Creek and the San Antonio River covering "the city of the Alamo from one end to the other" (*San Antonio Express* 1913f, 2). The storm waters washed away adobe houses and filled the downtown plaza area with water reported to be nine feet deep, although this depth has been called into question by subsequent engineering reports (Metcalf and Eddy 1920, 12). As a result of the flood damage, many residents, and the entire army-barracks complex, were relocated to what is now *La Villita* due to its higher elevation (Chabot 1931, Hunter 1941, Fisher 1997). This location, just south of the Alamo along the southern edge of the river's "Great Bend," was formed "by rich alluvium from overbank flooding" and "would have had abundant water supply from the two nearby" irrigation canals (Labadie 1986). Santa Anna's Mexican Army would use the very same site as a cannon embattlement during the siege of the Alamo due to its superior elevation (Labadie 1986).

By the time of the next recorded flood events, Texas would have had won its independence from Mexico in 1836, passed through its nine-year period as a republic, and became a U.S. state in 1845. In that same year San Antonio was hit by a severe flood that "caused the city council to urge that the city be moved to higher ground" and the mayor to suggest building a dam on Olmos Creek (Fisher 1997), a proposal that would prove prophetic in coming years. Floods of some consequence were reported in 1852, 1865, 1866, 1868, and 1880 (Metcalf and Eddy 1920), however poor meteorological and public records for the time, owing partially to the interruptions of the Civil War and Reconstruction during this period, offer few details of the events. In retrospective accounts, flood damage in 1865 was blamed on the numerous dams associated with the then crumbling irrigation structures passing through downtown (*San Antonio Express* 1913a). Archeological digs of the Acequia Madre (the first in a series of irrigation channels dug by the Spanish in the area) indicate that flood events following the channels' abandonment in the mid-1800s mixed Spanish colonial period artifacts with debris from the 1890s (Schuetz 1970). With the end of the Civil War and reintegration of the south during Reconstruction, the foundation for San Antonio's growth as a center for trade and commerce, serving Texas' growing agricultural economy, was set with the arrival of its first rail line in 1876 (Chabot 1931). By 1900 the Census Bureau would report a total population of 69, 422 for Bexar County (Texas Comptroller of Public Accounts 2001).

During the waning years of the nineteenth century the San Antonio River gained a reputation as an idyllic water recreation spot hosting weekend carriage washing parties, floating bath houses, and state-of-the-art steel bridges imported from Germany spanning its downtown reaches (Fisher 1997). By 1850, the river also served more municipal purposes, including providing the main drinking-water supply, providing water and power to a few industrial plants and a growing number of breweries and tanneries, and serving as the city's main sewage removal outlet (McLemore 1980). In an 1857 visit to the city Frederick Olmsted would remark that the "San Antonio Spring may be classed as the first water among the gems of the natural world" (Olmsted 1978, 117). However, late in the 1800s it became apparent to citizens that the natural flow of the river was drying up. A 1896 geologic report (Hill and Vaughn) was the first to document the effect local artesian wells were having on the perennial flow of the river, and by 1911 underground water was being pumped from the aquifer in order to supplement the river channel flow (Eckhart 2001). In the same year the San Antonio River Improvement Association was formed to manage the conversion of the downtown riverbed into a public showcase for the city (Fisher 1997). By 1913 River Commissioner George Surkey, supported by numerous San Antonio elites, was spearheading the first in a series of large-scale river beautification projects, including the construction of cement barriers, know as "Surkey's Sea Walls," lining the downtown portion of the river (Fisher 1997). These plans would be put on hold, however, when, in the first few days of October of that same year San Antonio would be hit with its largest flood disaster since 1819 (*San Antonio Express* 1913a, Lanning-Rush 1998). The flood of 1913 struck a city long committed to its riparian site, and one that would not be quick to pull up stakes and move to higher ground. As a result, flood disaster would be met with flood control rather than flood avoidance.

The Flood of 1913

October rainfall records for San Antonio showed a deficit of 2.24 inches despite the four-inch excess that fell in September (*San Antonio Express* 1913a). On the morning of October 1, 7.54 inches fell in northeast San Antonio (Crecelius 1924). Up to 14 inches from the remnant of the tropical depression that moved up from Mexico and stalled against a descending cool front fell to the north and east of San Antonio causing much worse flooding across the Guadalupe, San Marcos, Colorado and Brazos River valleys (United States Army Corps of Engineers 1950a). Despite the fact that the heaviest rains fell outside the city, floodwaters inundated the downtown area, killed four people, and caused at least $250,000 of damage (*San Antonio Express* 1913b). Estimates were later revised to $500,000 (Metcalf and Eddy 1920). A 1950 report by the Army Corps of Engineers stated that the "flood of October 1913 caused flooding throughout the entire length of the San Antonio River and produced maximum known stages along the San Antonio River between the mouth of Cibolo Creek and the mouth of the San Antonio

River and on Cibolo Creek" (United States Army Corps of Engineers 1950a, 25). Most of the damage was incurred by commercial buildings in the downtown area and bridges in the surrounding area (*San Antonio Express*, 1913d). Reports noted a "downpour" that rushed down "St. Mary's Street at a rapid speed from a crevasse the torrent found in the embankment" and inundated the Gunter Hotel (*San Antonio Express* 1913c, 10). This alerted the city to the vulnerability of the commercial landscape mushrooming along the downtown reaches of the San Antonio River. Inundation maps from the 1920 Metcalf and Eddy report indicate the flooding from this storm was concentrated directly on the commercial downtown area (342, plate XXXV). Or at least these were the only areas where the impacts were documented. This was the match that, once put to the tender of the growing sentiment among San Antonio leaders that more, and bigger, flood control solutions should be sought, would start a wildfire of interest in proposals for river improvement.

Calls for structural flood control measures would emerge almost instantly. The real estate section of the Express News, usually devoted to such pedestrian topics as the rate of building permits that week, would bear the headline "Tame the River, Say Realty Men" (*San Antonio Express* 1913e, 10). The newspaper would be peppered with articles describing the need for structural improvements, including a day-by-day description of the City of San Antonio Mayor's quick conversion to the idea of a dam across Olmos Creek.

> "I haven't fully investigated the details of the Olmos plan," said he, "but I am convinced there is merit to the suggestion. My attention has been called to this on several occasions, and now that I see it is imperative that the city do something to prevent such a flood in the future, I shall have City Engineer Helland make a thorough investigation of the suggestion and see just what can be done. I have no idea what the cost would be to construct this dam, but if the cost is not prohibitive

> its benefits would more than repay the cost of the investment. (*San Antonio Express* 1913g, 4)

Mayor Brown was already part of the way there in terms of the costs, as a $300,000 bond had been passed to improve the storm and sewer drains downtown (*San Antonio Express* 1913d). All that was needed was an extra incentive to local taxpayers and an engineering report that warned of dire consequences for inaction. The former came in the form of a second, less devastating, flood in December of that year and another in October of the following year. The latter came a few years after from the Boston-based engineering consulting firm of Metcalf and Eddy, hired to investigate the possible solutions to San Antonio's flooding problem (Metcalf and Eddy 1920).

Although other piecemeal efforts had been made in years prior to the 1913 flood, the Metcalf and Eddy (1920) report was the first comprehensive flood engineering study conducted in San Antonio. Steeped in the technocratic perspective of the day, it recommended extensive work be done on the river channels themselves as well as the construction of the, by then, much talked-about Olmos Creek Dam (Metcalf and Eddy 1920). Their proposal included deepening the channel, fortifying the banks with angled cement walls, carving cutoffs for many of the natural bends in the downtown reaches of the San Antonio River, and finally removing most, if not all, of the trees that might block future floodwaters. The latter proposal angered local citizens more focused on the rivers festive and commercial potential during "normal" periods than its destructive potential during extremes (Fisher 1997). The engineers pulled no punches though in describing the necessity of such dramatic changes.

> We are deeply impressed by the fact...that the city is constantly facing the menace of disastrous floods. We doubt if the citizens realize the ruinous loss

> which would result today with the present condition of the river channels, from such a flood as that of a century ago (1819). When such a flood will recur, no man can say. But that it will occur is certain. Therefore, with rapid growth in value of property in the city, particularly in the congested value and commercial districts, it is imperative that this danger be recognized and that the work necessary to prevent serious injury from flooding be undertaken and carried to completion as rapidly as the financial resources of the city shall permit, lest when the flood comes it shall find the city unprepared and do ruinous damage. (Metcalf and Eddy 1920, ii)

These prophecies were issued in the waning months of 1920. With over seven years elapsed since the 1913 flood, there was no immediate effort to implement the engineers' proposal. Metcalf and Eddy (1920) had ended their report with a final warning, "We urge that your citizens shall remember that this disastrous flood is just as likely to come next year as at any other time" (iv). In retrospect this statement seems eerily prophetic. On September 9 and 10 the following year the remnants of a hurricane moved inland from the southern tip of the Gulf Coast dumping heavy rains over much of south Texas. The "flood of September 9 and 10, 1921 put 12 feet of water through downtown San Antonio; drowned 51 persons in San Antonio; drowned 87 people near Taylor; and 93 in Williamson County. The 231 total fatalities made this the deadliest flood in Texas history" (SARA 1999, 3-3). Like so many disasters before and after, it marked a turning point is San Antonio's approach to floodplain management.

The Flood of 1921

The difference between a flood-event and a flood-disaster can be measured by the impact the event has on the human systems it interacts with. On this scale, the1921 flood earned a primary role in the pantheon of the region's flood history. However, with the "axis of maximum rain-fall following closely the Balcones Escarpment" (Crecelius 1924,

8) its impacts were widespread. Meteorological reports on the event are quick to point out that things could have been much worse.

> The total rain-fall and the run-off per square mile of drainage area were much less in the basin of San Antonio River than in the basins of many other streams in the path of the storm. If rain-fall in the basin of San Antonio River has been as heavy as it was in much of basin of Little River, in Bell, Milam and Williamson Counties, the destruction at San Antonio would have been so great as to make that actually suffered there seem insignificant. (Crecelius 1924, 11)

Total rainfall in the upper Olmos Creek watershed for the September 9-10 flood event ranged from 17 inches in the upper watershed to about 11 inches near San Pedro Avenue and produced the maximum known flood stages seen at that time (United States Army Corps of Engineers 1950a, 1972). It is important to note that this rain fell on an Olmos Creek basin "two thirds of which [was] wooded hills and one third cultivated land" (Crecelius 1924, 4). A stark contrast to the Army Corps of Engineer's description of the watershed fifty years later, in which they state about "20% of the upper reaches of the watershed has experienced some urban development and the remainder is almost 100% developed" (United States Army Corps of Engineers 1972). Development has continued in the thirty years since that report. Had the basin been in its current state of residential and commercial development the flood would have undoubtedly been far more destructive.

The most dramatic impacts of the flood were to be found in the highly urbanized downtown where structural alterations to the floodplain's morphology proved highly destructive. "The encroachments on the river channel in the business district…reduced its capacity to such an extent that floods that would formally have passed without doing damage now over-flow the banks and store vast quantities of water in the heart of the business district" (Crecelius 1924, 7). *The San Antonio Express* described the flood's impact on downtown as being the most destructive in the city's history with San Pedro Creek "forced far beyond its banks by back water" and the channels of the San Antonio River, Alazan Creek, and Martinez Creek being "swift torrents which swept through homes and business places at such velocity that few which were caught in the swirling waters were able to escape." (*San Antonio Express* 1921a, 1).

The newspaper was also quick to report that, in terms of property loss, the greatest losers were the business community and the city itself.

> With five of the 27 bridges spanning the San Antonio River almost totally destroyed, eight partially wrecked, and miles of the city's wood block paved streets ripped open and totally wrecked, as well as numerous smaller bridges over the various creeks taken out, it is impossible to estimate the damage to downtown streets…it is thought that at least two thirds of the wood block paving is utterly destroyed. (*San Antonio Express* 1921b, 3)

Headlines such as " Property Loss is Heaviest in Downtown Business District" (*San Antonio Express* 1921a, 3) and "City is Among Largest Losers from Big Flood" (*San Antonio Express* 1921b, 3) served a dual purpose. They not only informed local citizens of the floods impact, they forewarned of the need for the costly, large-scale engineering projects that would follow the event. By Monday September 12th, in a story titled "Engineer Favors Big Dam Across Olmos Creek," the newspaper would quote the former City Commissioner, "and one of the best known engineers in the city" as saying "a dam on the Olmos above the river with openings permitting only enough water through to fill the channel of the river would have saved the city" (*San Antonio Express* 1921b, 4). Belying a faith in structural measures, the paper would report that the privately-built, low lying West End Dam on the upper reaches of Alazan Creek had performed near miracles in holding back flood waters and saving the residential structures in its immediate surroundings (*San Antonio Express* 1921c, 7). The next day's follow-up story, "145 Homes Swept Away Along Creek," however described the awesome reality of the devastation along Alazan Creek (*San Antonio Express* 1921d, 12). That report was much smaller and located near the end of that day's edition. In hindsight it seems as if, even before the floodwaters receded, the Olmos Dam became inevitable.

According to Army Corps of Engineers' records, there had only been two dams of any size or consequence built in Bexar County prior to the 1921 floods (Army Corps of Engineers 2000). Both were located in the south central portion of the county and, despite the fact that more recent reports have indicated that the reservoirs produced by these structures have "reduced all flood flows immediately below the dams to non-damaging proportions," (United States Department of Agriculture 1952) both were designed for irrigation purposes rather then for flood control. It is safe to say that undertaking a project the size of Olmos Creek Dam would require a leap of fiscal faith by San Antonio's taxpayers. But with the damage of the 1921 flood still fresh in the memories of local citizens, the city began the process of garnering funds for the project.

> On December 4th, 1923 the City of San Antonio voted bonds for flood prevention in the amount of two million eight hundred thousand ($2,800,000.00) dollars. Of this amount two million two hundred thousand ($2,200,000.00) dollars were allotted for the construction of a detention dam on Olmos Creek and six hundred thousand ($600,000.00) dollars for channel improvement. On September 1st, 1924, after nine months of delay due to legal complications, office and field forces were organized. Additional surveys, foundation test borings and the collection of all available data were begun. (Crecelius 1924, 2)

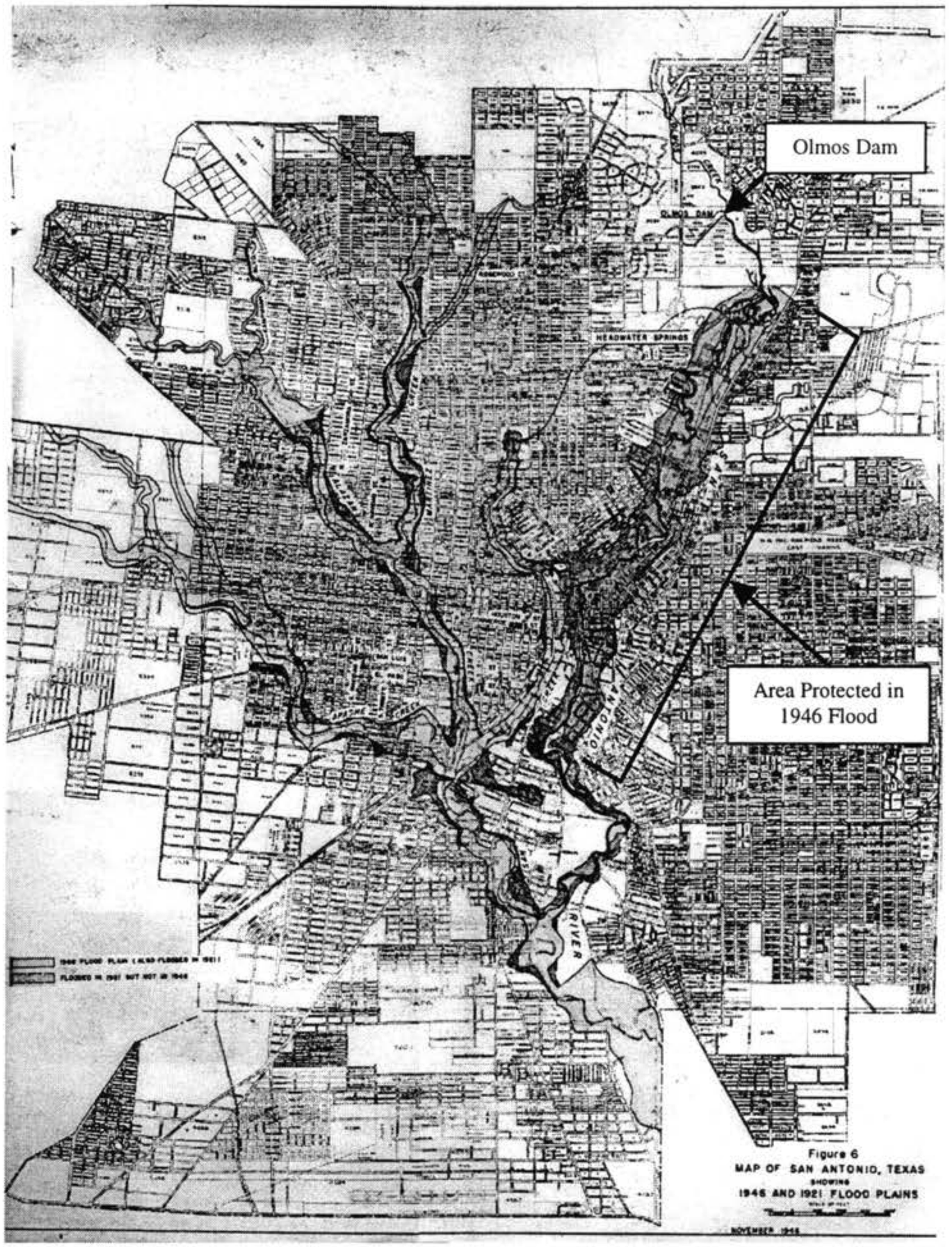
The dam was completed in 1927 at a final cost of $1.5 million. At the time, the dam was the first if its kind in Texas. "The 1, 941 foot long concrete structure was founded on a limestone formation with a height of 54 feet and includes six sluice gates to control flood water releases" (San Antonio River Authority 1999, 3-11). It has since undergone only minor modifications including the addition of a 1,152-foot spillway to avoid it being overtopped in the most extreme events (San Antonio River Authority 1999). The impact the dam has had on flooding patterns in the downtown area of San Antonio is immense. Areas that had been completely inundated in the 1921 flood remain largely flood free to this day. A map generated by a 1948 United States Geological Survey (USGS) in response to the 1946 flood, clearly illustrates the level of protection afforded by the dam (Figure 5.1). The reductions in flood damages offered by the dams are inarguable, however it is important to note that they are extremely localized.

> The Olmos Reservoir has materially reduced the frequency of occurrence of a flood year along the San Antonio River above the mouth of San Pedro Creek, but it has had no effect on floods along San Pedro, Apache, Alazan, and Martinez Creeks, which are located in the western section of the city… (United States Army Corps of Engineers 1950b, 27)

The fact that the dam, although apparently necessary, would be an inadequate solution for the entire city was clear even during its planning stages. S.F. Crecelius, Flood Prevention Engineer for the City of San Antonio Flood Prevention Department, would end his 1924 *Report of Investigations Preliminary to the Design of the Olmos Creek Detention Dam* with the statement "We must bear in mind that the dam alone can not protect the City against floods resulting from heavy rain-fall in other water-sheds and below the dam…eventually the City will be compelled to improve the channels of San Antonio River and its tributaries within the City limits in order to effect complete regulation of floods" (Crecelius 1924, 4).

Ultimately the dam would be only a part of the overall flood-control expenditures in the years following the 1921 flood. The San Antonio River and its surrounding

Figure 5.1. Extent of 1921, 1946 urban flood inundation.



Source: Breeding, Seth D. 1948. *Flood of September 1946 at San Antonio, Texas.* Circular 32, United States Department of the Interior, United States Geological Survey. Washington, DC: United States Department of the Interior.

tributaries would undergo vast alterations in the two decades following the flood.

> Flood control construction on the San Antonio River tributaries included work on San Pedro Creek, consisting of the construction of a channel 20 to 22 feet wide on the bottom with a concrete floor and masonry and concrete retaining walls for a distance of 3,600 feet through the business district, and enlarging the channel to a bottom width of about 138 feet for a distance of 1.5 miles below the junction with Alazan and Apache Creeks. Channel rectification also was accomplished on Alazan and Martinez Creeks for a distance of 2.5 miles and on Apache Creek for a distance of 0.75 miles. The channel of Alazan Creek at its junction with San Pedro Creek was relocated to join Apache Creek near its confluence with San Pedro Creek. (San Antonio River Authority 1970, 2)

In addition, the main stem of the San Antonio River would undergo similar adjustments. The first buildings, including the Alamo, to be located by Europeans along the San Antonio River had been placed along the banks of a large meander, the loop of which stretched directly east from the river's otherwise linear course. Over time, this area had grown and become the core of San Antonio's Central Business District. Structures in and along this part of the river had borne the brunt of the river's blow in the 1921 flood. To avoid this in future floods, a straight channel was carved in 1929 from the top of the first bend of the meander to its lower end, about a tenth of a mile downstream (San Antonio River Authority 1999). Named the Great Bend Cutoff, this channel and its accompanying flood gates would allow flood managers to close off the meander and direct flood waters directly downstream, effectively missing the bulk of the downtown area. Additionally, the Works Progress Administration (WPA) would be convinced to "contribute $40,000 in channel rectification and $355,000 to channel beautification" (San Antonio River Authority 1970). These improvements, both structural and aesthetic, along with the Olmos Dam would bolster confidence and spur development in San Antonio's downtown area for years to come. In total $4, 555,000 were spent on the flood control improvement prompted by the 1921 flood (San Antonio River Authority 1970).

With the increased investment in flood control, there arose a need for a management agency to oversee current and future control projects. By 1937, local management of the ever more manipulated reaches of Bexar County's floodplains would be transferred from various city agencies to a political subdivision of the State of Texas, first known as the San Antonio River Canal and Conservancy District, but later to be named the San Antonio River Authority. "The agency's original purpose was to seek development of a barge canal from the Gulf Coast to the city of San Antonio, but its functions were expanded in 1939 to include the promotion of flood control" (Texas State Historical Association 2001, 1). The agency continues to be the vanguard for flood control in San Antonio and Bexar County.

Within a few years following the flood, the landscape of San Antonio's downtown had been altered by the comforting presence of the Olmos Dam, standing watch on the northern skyline, and the sleek, landscaped channel-walls carved into the CBD. The river had been recaptured, put back in its place and held there by extensive structural engineering. If ever there was a time when retreating from the banks of the river to avoid flood damages had been considered as an adjustment choice it was now no longer an option. Millions had been spent to control future floods, local government agencies had emerged as managers of the structures and the apparent preeminence of structural control methods had been illustrated to the people of San Antonio. Apparently shielded from the horrors of flood disaster, San Antonians fell back in love with their river. Plans were proposed by Robert Hugman in 1929, and initially endorsed by local politicians and businessmen, to redesign the entire downtown area around the river into a park-like retail paradise (Fisher 1997). Although Hugman's plans would eventually be implemented, in spirit at least if not in precise design, at the time they were quickly swallowed by the political mastication of another trend within the city, the desire by many residents to establish a city plan that extended beyond the downtown and into the growing residential and commercial perimeter of San Antonio (Fisher 1997). This foreshadowed the future of San Antonio's flood problems as well. As urbanization spread out from the CBD, so did flood hazard. "In spite of the flood control work accomplished following the 1921 flood, the work did not prove to be adequate to meet the requirements of the rapidly urbanizing City. This was demonstrated to one and all during the 1946 flood" (San Antonio River Authority 1970, 3).

The Flood of 1946

Between 1921 and 1946 San Antonio would experience six flood events (United States Army Corps of Engineers 1954), but none would be as damaging as or as extensive as the 1921 flood and none would truly test the capabilities of the various flood control structures that had been constructed, none that is, until the flood of 1946. As a result of the "Rivers and Harbors Act approved on June 1938, which authorized a preliminary examination and survey of San Antonio River, Tex., to determine the advisability of improvement for navigation, flood control, power, and for the prevention of erosion" (United States Army Corps of Engineers 1954, VII), San Antonio received support and Congressional authorization to study comprehensively Bexar County's flood problems (San Antonio River Authority 1970). World War II would interrupt these plans for nearly a decade, however. If the distractions of international conflict had resulted in citizens of San Antonio losing their focus on local flood problems, the "cold front stalling over the

City, colliding with warm air from the Gulf, and producing rainfall of 10 inches at Olmos Dam and six inches in upper reaches of the watershed" would be a harsh reminder of their on-going battles at home (Rust Lichter/Jameson 1996).

On September 25^{th}, 1946 San Antonio received approximately three inches of rain. "This rain produced little runoff but did saturate the ground enough to increase the rate of runoff of the subsequent heavy rains" (Breeding 1948, 1). The "subsequent rains" began to fall late in the evening on September 26^{th}.

> Heavy rainfall began about 8 p.m. September 26, and within a short time San Pedro Creek and its tributaries (Alazan, Martinez, and Apache Creeks) were in flood and all reached peak stages about 1 to 2 a.m. September 27. The floods from these streams caused the greater part of the damage in San Antonio. (Breeding 1948, 1)

Friday's headline " Flood Claims Four Lives, Hundreds of Homes, Stores Under Water" (*San Antonio Express* 1946a, 1) would reveal, or foreshadow, that the focus of San Antonio's flood control problem had shifted from the CBD to the growing suburban areas surrounding the city. Despite the fact that numerous businesses were damaged along E. Commerce, Travis and N. St. Mary's streets due to overwhelmed storm sewers, Olmos Dam had protected the bulk of the downtown area. (*San Antonio Express* 1946a, Breeding 1948)

The flood of 1946 was Olmos Dam's first real test, and it performed brilliantly. The dam was quickly credited with "saving hundreds of lives and preventing millions of dollars in property damage" by holding over thirty-five feet of flood waters behind its walls until, by the afternoon of the 28^{th}, they could be released safely into the newly cemented and straightened channels of the San Antonio River (*San Antonio Express* 1946b, 1).

> The fact that the San Antonio River did little damage through the city can be attributed to the presence of Olmos Dam on Olmos Creek, the main tributary to the river, which held back the waters that otherwise might have caused a major flood on the stream. (Breeding 1948, 1)

The success of the dam downtown (Figure 5.1) was somewhat overshadowed, however, by the widespread impacts beyond the downtown. For the first time news reports about the flood focused on suburban impacts downstream in the south and southeastern portions of Bexar County. In the suburban settlement of Elmendorf, near Calaveras Creek, "occupants of homes were forced to chop holes in the roofs through which they could climb to safety and prevent being trapped inside the houses" (*San Antonio Express* 1946c, 1). These impacts outside of the CBD heralded a new era for San Antonio's flood management. The problem was becoming bigger, both spatially and monetarily. In the years between the 1921 flood and the 1946 flood San Antonio's population had grown from under 200,000 to nearly 400,000, and few of these people now benefited directly from Olmos Dam. Of the nearly $3 million dollars worth of damage caused by the 1946 flood, most of that had been to residential and commercial structures outside the CBD (San Antonio River Authority 1970). In one sense the 1946 flood proved San Antonio's monument to engineering and local, self-funded, cooperation (Olmos Dam). In another, it issued a warning that the city, in its entire growing expanse, would need a "pocket" much deeper than that of local taxpayers and commercial interests to remain protected from future floods.

It has been observed that twentieth century environmental management in the United States can be characterized by "an attitude shift facilitated by a displacement of liability from the individual to the government" (Meyer-Arendt 1992, 217). Federally funded social programs, started in the late 1930s as emergency relief measures for a nation plagued by an ailing economy, cross-pollinated with the a robust post-war economy in the late 1940s, and blossomed into a seemingly endless harvest of federally funded support mechanisms for many aspects of social and environmental management in the United States.

> Congress began, hesitantly at first, to devise a new set of programs and policies that collectively would transfer much of the financial costs of disasters from individuals and communities to the nation as a whole (in other words to the federal taxpayer). In the process, an implicit new social compact was gradually forged between government and citizenry in which the former assumed a large share of disaster losses arising from the bad luck or bad judgment of the latter. (Platt 1999, 11)

Although the federal government had played a key role in natural disaster mitigation and relief throughout the nation, it had been primarily ad hoc prior to the late 1940s. Congressional funding had been handed out on a regional or disaster-by-disaster basis. Platt (1999) indicates that this approach changed permanently with the Disaster Relief Act of 1950, marking a "Transitional Period" whereby the federal government became, albeit on a limited basis in comparison to today, more intricately involved in local hazard management. This limited role ultimately evolved to a much larger one. "After 1950, and more emphatically after the Federal Disaster Relief Act of 1970, the federal government assumed a permanent role as the primary source of funds and expertise to deal with major and some not-so-major disasters" (Platt 1999, 15). Thus was the experience of the City of San Antonio in the years following the 1946 flood.

A call for increased federal participation had been issued in a series of public hearings held on the San Antonio and Guadalupe rivers in 1938. These calls were reissued, and ultimately approved, following the flood of 1946.

> As a result of the flood the U.S Army Corps of Engineers (COE) resumed their comprehensive study of the flood problems in Bexar County originally authorized

> by United States Congress under the Rivers and Harbor Act of 1938. The preliminary flood control examination was completed in 1946 and the survey if the river completed in 1950. The entire study went before Congress in 1954 for consideration and approval. The COE study, titled the "San Antonio Channel Improvement Project" (SACIP) was approved by Congress in September 1954. The project called for deepening, widening and straightening 31 miles of the San Antonio River and its tributaries within the San Antonio metropolitan area. (San Antonio River Authority 1999, 2-1)

Army Corps documents of this period are rich with justifications for these expenditures. Texas' role as a major agricultural and industrial region, primarily its petroleum and petrochemical industries, are oft-sited reasons for major flood control in Texas cities and coastal regions (United States Army Corps of Engineers 1950a, 1950c, 1954, 1972). Other reasons cited in the 1950 study include the $111,953,109 worth of developed property located in the floodplain along with the calculation that another flood of record would damage at least $9 million worth of those existing structures (United States Army Corps of Engineers 1950a). It was further estimated at the time of the report that "during the life of the proposed project, it [was] reasonable to assume that development within the flood plain area [would] increase at least 50 percent," thus rendering the improvements even more valuable to all interested parties (United States Army Corps of Engineers 1950c, 113). Additional arguments for continued federal support came following a flood in 1957 that affected many central and north Texas' water basins.

> The San Antonio Channel Improvement Project is currently under construction and has this project been in operation during the 1957 floods the experienced damages of about $3,700,000 would have been eliminated. (United States Army Corps of Engineers 1959, 8-3)

From1955 to 1960 a series of agreements between the City of San Antonio, the Army Corps of Engineers, and the San Antonio River Authority established the responsibilities of each organization in implementing the San Antonio Channel Improvement Project

(SACIP). The federal government would bear the bulk of the costs of construction, while city and county taxpayers would share right-of-way and maintenance costs (San Antonio River Authority 1970).

In addition to the structural improvements being made on the San Antonio River itself, smaller, but more wide-scale projects were implemented on it tributaries. Starting in the late 1950s the Soil Conservation Service (now the Natural Resource Conservation Service) built thirteen flood retention dams on the Salado Creek watershed, six flood retention dams in the Martinez Creek watershed and seven dams in the Calaveras Creek watershed (Vickery and Associates 1997, San Antonio River Authority 1999). Olmos Dam also underwent structural improvements to compensate for the increased potential runoff from upstream urbanization (San Antonio River Authority 1999). These were in addition to a number of small-scale alterations to the streambeds of each of these tributaries that would continue to the present day.

At the same time that Bexar County's floodplains were undergoing structural alterations through the SACIP, another paradigm shift in floodplain management was underway at a national level. When viewed at a national level, it was becoming clear to many that "despite the installation of preventative and protective works and the adoption of other public programs designed to reduce losses caused by flood damage, these methods [had] not been sufficient to protect adequately against growing exposure to future flood losses" (Office of the General Council 1997, 2). Rapid rates of suburbanization were quickly outstripping the ability of many protective structures to ward off the negative impacts of flooding. Into the mid-1960s, researchers (such as Gilbert White) began to demonstrate the mixed efficacies of structural mitigation projects, flood disaster costs continued to rise despite these efforts, and, maybe most importantly, the chorus of floodplain "managers" began to expand well beyond the CBD and older residential areas in most cities. In short, the "structural approach" which had been codified by the Flood Control Act of 1936, would no longer be enough to manage the nation's growing flood hazard.

"In 1968, Congress created the National Flood Insurance Program (NFIP) in response to the rising cost of taxpayer funded disaster relief for flood victims and the increasing amount of damage caused by floods" (Federal Emergency Management Agency 2001a, 1). The passage of the National Flood Insurance Act ushered in a new era of floodplain management. It embraced, or at least acknowledged, that a one-size-fits-all approach to managing floodplains was no longer going to suffice. It also acknowledged that a nonstructural approach to hazard mitigation, based on pooling the economic risk of disaster among those most likely to experience loss was a viable route for communities. Lastly, the legislation, including its various updates throughout the last three decades, acknowledged that a compromise had to be struck between complete local control and complete federal control of floodplain management. The federal government could provide money and expertise, but could not reasonably provide comprehensive policing of all floodplain development at a local scale. That would still have to be done by local and state managers. In order to satisfy this need, the National Flood Insurance Act of 1968, and later in the Flood Disaster Protection Act of 1973, would establish a relationship with local floodplain management entities whereby the federally backed flood insurance would only be offered to residents if the community established an official (and federally approved) floodplain management plan describing the ways in which development within their floodplain jurisdictions would be curtailed, controlled, or at least adequately monitored. These plans could include anything from additional locally funded structural improvements to special floodplain zoning. In San Antonio, the responsibility for generating and managing these plans fell on the City of San Antonio, Bexar County, and the San Antonio River Authority.

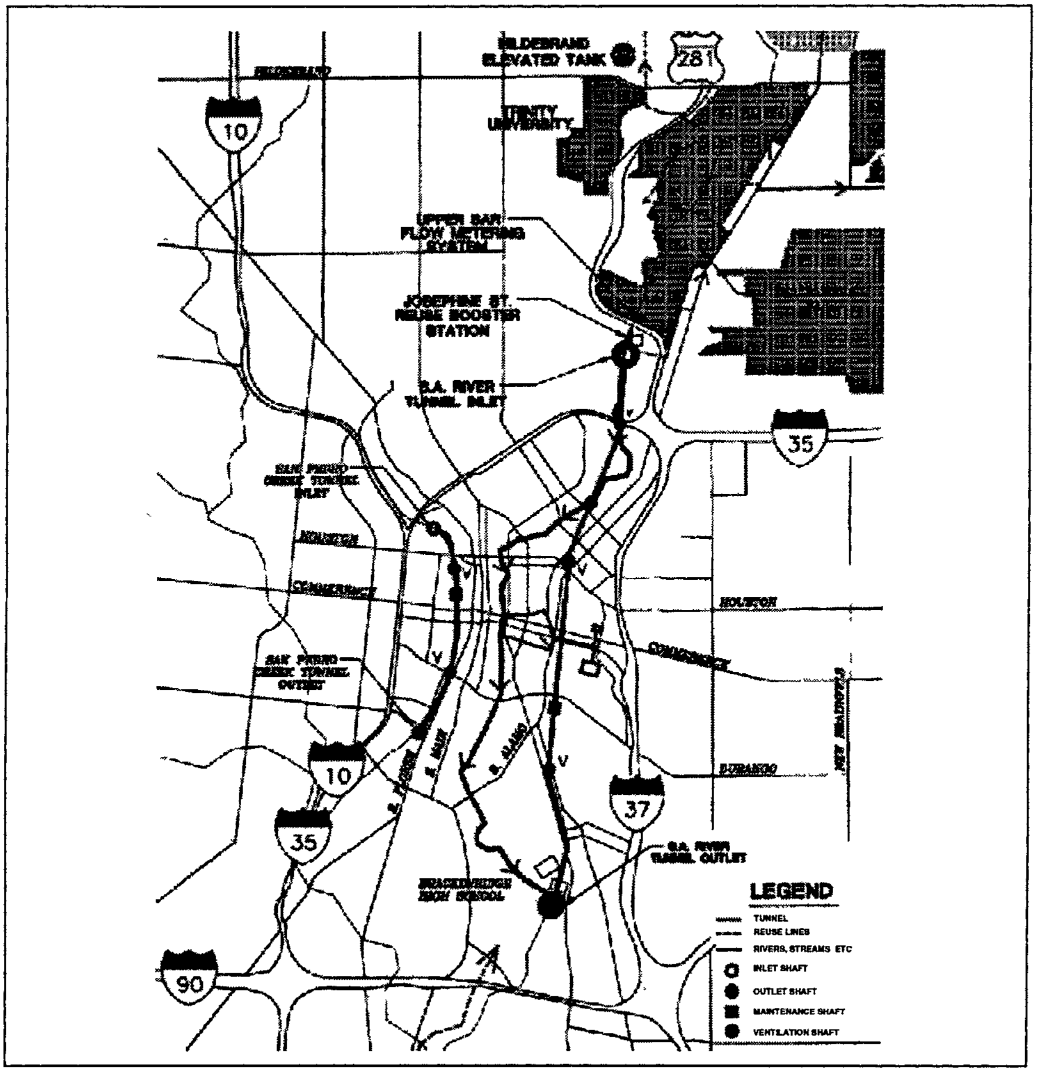
Although none were as significant as the flood of 1946, there were a number of flood events in Bexar County from that flood of record to the next in 1998. Lives were lost and property was destroyed in each of these smaller events, but they did little to perturb the course of floodplain development. Olmos Dam continued to offer the CBD exceptional protection, the rural/suburban retention dams being constructed throughout this period offered partial protection to residential areas outside the CBD and, slowly at first, flood insurance became a permanent part of flood disaster relief for residents caught in the spatially dispersed inundations. A 1986 Army Corps of Engineers study states "there have been 859 flood insurance policies issued in San Antonio on which 93 claims have been paid to a total of $407,000" (United States Army Corps of Engineers 1986). Creating comprehensive Flood Insurance Rating Maps (FIRMs) for every urbanized area in the Untied States was, and remains, a mammoth and time-consuming task. The timing of their completion and updates can impact the degree to which residents in flood-prone areas adopt flood insurance coverage. Furthermore, although coverage is now mandatory when a homeowner chooses any of the federally related mortgage loans, if a homeowner purchased their home prior to the completion of their community's FIRM or purchased their land through some other financing mechanism, they may bypass this requirement – or in some cases even are unaware of the coverage itself.

> Although the City of San Antonio is a participant in the National Flood Insurance Program, many homes subjected to flooding along Olmos Creek were built prior to the publication of the Flood Insurance Rate Maps for San Antonio in 1983 and their owners are therefore unaware of or are not required to by National Flood Insurance. As a result, most of the homes flooded in the recent 1991 and 1993 storm events were not insured for their damages. (Rust Lichliter/Jameson 1996, 2-6)

The most recent reports issued by the National Flood Insurance Program on policies in force indicate that, as of December 31, 2000 there were 2,275 policyholders in the City of San Antonio and 995 in Bexar County (Federal Emergency Management Agency 2001a). Although better than the numbers cited in the 1986 report, this can hardly be thought of as complete participation.

Despite the growing utilization of nonstructural mitigation in the form of flood insurance within the San Antonio area and the proliferation of structural modifications within its suburban fringe, the city has by no means turned its back on its structural commitment to flood control in its CBD. The greatest testaments to this fact are the San Antonio River Tunnel and the San Pedro Creek Tunnel, which run from the northern edge of downtown to the southern edge of downtown, entirely within Loop 410 (Figure 5.2). "The original plan for the SACIP included channelization through the downtown area upstream from Nueva Street. Detailed investigations revealed that this channel would be very costly and disruptive to urban activities along and near the river" (San Antonio River Authority 1993). Instead, two tunnels, both approximately 20 feet in diameter, running over one hundred feet below ground would become the solution to

Figure 5.2. San Antonio River Tunnel / San Pedro Creek Tunnel locations.



Source: City of San Antonio. 2001. *Flood control history of San Antonio.* Public Works Department, Streets and Drainage Division. Online source; accessed August 15 2001; available from http://www.ci.sat.tx.us/pubwrks/streets.htm.

augmenting Olmos Dam and the Great Bend Cutoff (San Antonio River Authority 1999, Ekhart 2001). The San Pedro Creek Tunnel (SPCT) was completed in 1991, at a total cost of $39.8 million and the San Antonio River Tunnel (SART) was completed in late 1997 and operational in early 1998 at a cost of approximately $70 million dollars (San Antonio River Authority 1999, City of San Antonio 2001). The performance of the tunnels in the 1998 flood will be discussed below, but their place in the pantheon of San Antonio flood control can be traced directly back to the 1954 authorization for the Army Corps improvement projects mentioned above. That the idea of building two tunnels large enough to drive a large truck through under the entire city was not envisioned in the original plans is clear from examining the first engineering proposals. Therefore the tunnels can be interpreted in two distinct ways, in terms of the role they play in the history of adjustments made by the city. First they can be seen as testaments to the ingenuity and creativity of the engineers, city leaders, and floodplain mangers that have played a role in their creation. Faced with dramatic obstacles to flood water control, they came up with an equally dramatic (and effective) solution. In this way, they are the logical extension of the engineering paradigm that has dominated flood control in San Antonio since the flood of 1921. Alternatively though, the tunnels can be seen as representative of the continued reliance on structural projects to protect the occupation of risky locations. They were necessitated by the increased risk of flooding due to upstream floodplain development, and the increasing value of downtown structures subject to flooding. Rather then seeking more permanent solutions, such as the, albeit costly, removal of commercial and residential structures along the downtown reaches of both waterways, the city has created yet another massive structural mitigation project which will require continued monetary inputs. Despite the tunnels' superior performance during the 1998 flood, one can easily imagine a time in the not too distant future when the tunnels will have to be expanded, extended, or reproduced in other parts of the city.

Floodplain management in San Antonio and across Bexar County, in the years following the flood of 1946, must be seen as an amalgamation of both structural and nonstructural approaches. In one sense, this can be seen as a success story in that the community has achieved the multi-faceted approach to floodplain management that has long been supported by researchers, the Army Corps, and FEMA. In another sense though, all of these efforts can be seen as offering protection, support, and even enticement to land owners to locate their structures in risky locations. It is safe to say that this was not the goal of San Antonio's floodplain managers throughout the years, it is however the net effect of their efforts. The most recent program instituted by FEMA and the NFIP offers federal assistance to communities that are able to coordinate the purchase of land parcels and removal of structures within their most risk-prone areas (these are referred to as "buyouts" or "buy-backs"). In 1996 the City of San Antonio contracted with two private engineering firms to develop proposals for future floodplain management in the Upper Olmos Creek watershed and Leon Creek Basin. Both reports included the suggestion of ambitious buyout programs along with existing channel improvements in both watersheds (Rust Lichliter/ Jameson 1996, San Antonio River Authority 1999). Although the city, the county, and SARA would begin to move in this direction, it would be the next, and most damaging, flood event in 1998 that would not only underscore the need to remove structures from the floodplain, but would also generate the relief- and assistance-funding necessary to accomplish that goal.

The Flood of 1998

In many ways the impacts on flood control and flood management generated by the "Great Flood of October 1998," as it is often referred to, have not entirely manifested themselves upon the landscape of San Antonio. The characteristics of the storm, the devastation, and the immediate municipal and community responses to both, however have been well documented. On October 16th the remnants of Hurricane Madeleine made their way out of the Pacific Ocean, across northern Mexico and collided with another low-pressure cell around the four-corners region of the southwestern United States. This collision, made stationary by slow-moving pressure cells to the south and east "sent very deep water vapor across Mexico through Texas into the Central/Northern Plains to the Great Lakes region" (San Antonio River Authority 1999, 3-3). This formation coupled with a strong low-level jet stream across central Texas spawned a band of precipitation running approximately along the Balcones fault line on the morning of October 17. San Antonio "tallied 18.07 inches of rain in October, its wettest month ever, including 11.26 inches on the 17th, its wettest day ever" (National Oceanic and Atmospheric Administration 1999, 1). "By the time the water receded, 29 people were dead, thousands homeless and more than $1 billion in property lost. The government has since spent more then $208 million to help homeowners recover from the flood and to improve flood control in the region." (*San Antonio Express-News* 2000a, 1B).

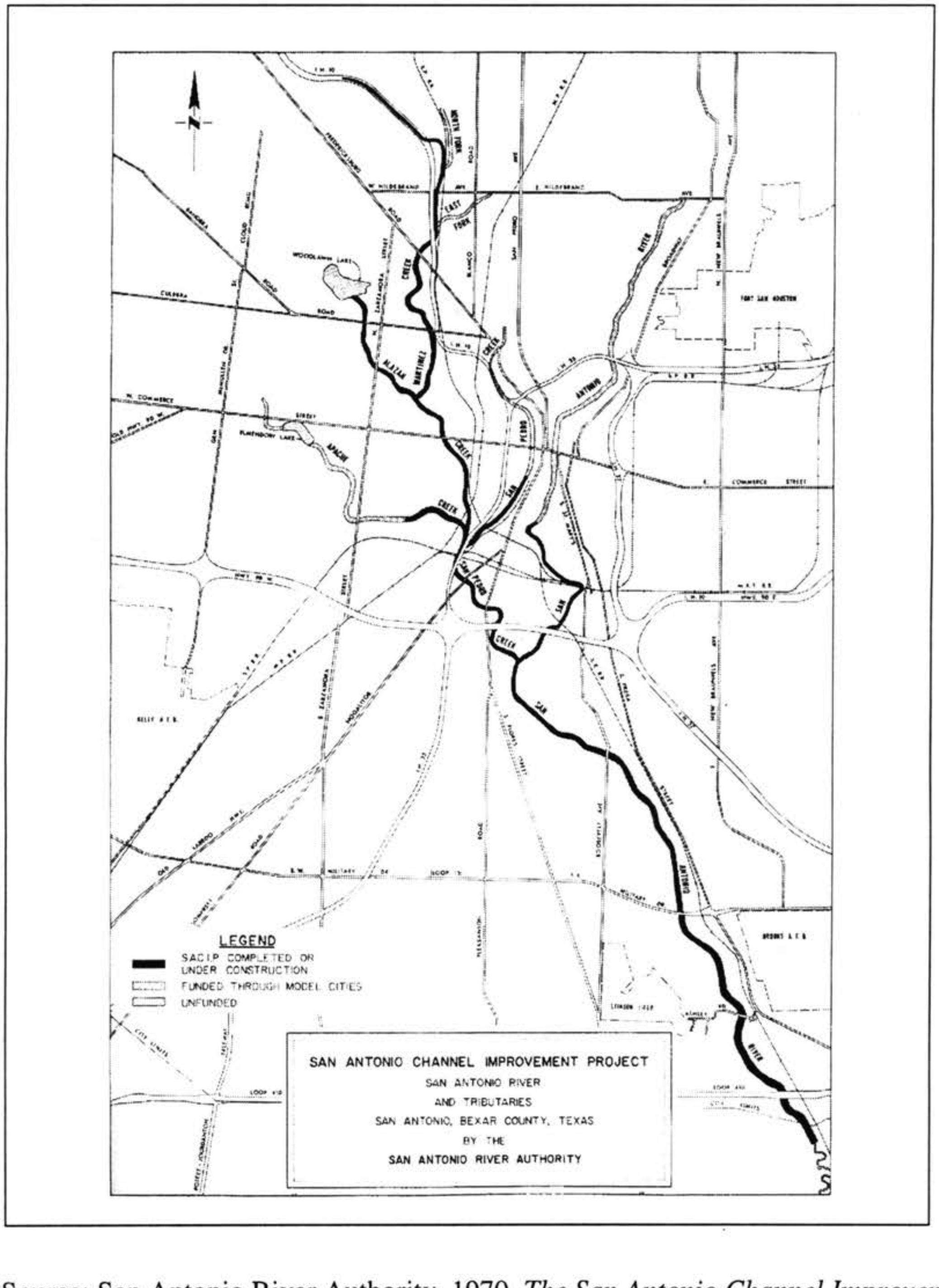
Within Bexar County flood-height measurements place the event at anywhere from a 25-year storm to a 500-year storm depending on the location. Post event flood-stage analysis performed by the city, the county, SARA, and contracted engineering firms revealed the varied geography of the flooding.

> This produced a return frequency value of approximately 33-years on the Upper Leon Creek and a value of 296-years for the total storm pattern. The flood stage in Leon Creek was six (6) feet higher than the previously recorded high water mark. This mark also exceeded a 100-year flood level in sections of the Leon Creek south of Kelly Air Force Base...The Flood of 1998 produced flows in excess of a 40-year event over multiple surges along the San Antonio River and flows estimated near a 500-year event along Salado Creek. In the western potion of Bexar County the flood was less significant and may have been in the order of a 25-year event because of reduced rainfall amounts spread out over a 24-hour period of time. (San Antonio River Authority 1999, 3-9, 3-10)

Neighborhoods along Salado Creek, particularly Wheatley Heights in its south-central reaches, were especially devastated by floodwaters. Despite that fact that floodwaters rose to unprecedented heights behind Olmos Dam (only 4.39 feet from the top), and water backed up behind the dam temporarily closing Highway 281, the dam performed its duties perfectly (San Antonio River Authority 1999). Early reports that the dam contributed to flooding along Salado Creek, due to back-flow, have since been proven incorrect. In short, Olmos Dam, now the oldest of San Antonio's flood control structures proved invaluable once again. It is important, however, to note that without the SACIP channel improvements and the availability of the two underground tunnels the CBD would have been impacted to a much greater extent. In the 1921 flood it was estimated that the dam would have nearly erased the flood's impact on the CBD. In the 1946 flood it greatly reduced but did not eliminate the flood's impacts on the downtown area. In the 1998 flood it would have been wholly inadequate without the additional structural improvements made in the interim years.

Many of the areas within and outside downtown were protected by the channel improvements instituted by the SACIP (Figure 5.3). One exception was along "Martinez Creek from Huisache Street to Perez Street" where flooding was "aggravated by the fact that the SACIP design was based on flood flows of the 1946 flood of record which are lower than the 100-year flood" (San Antonio River Authority, 1999, 3-18). Despite extensive damage from erosion, channel improvements made under the various stages of the SACIP held up favorably during the 1998 flood, although it can be said that at many points their limits were tested. Older sections gave way under intense water pressure and most of the system ran at "bank full" levels throughout the flood event. Should the next flood of record strike San Antonio prior to additional improvements, the report may not be as favorable. The various flood retention and water conservation dams spread out around the city also preformed favorably in the 1998 flood. Although it is difficult to offer precise estimations of their impact on flood reduction SARA (1999) and the USDA (1998) estimate that had these structures not been in place damages from the flood would have been increased by millions of dollars.

Figure 5.3. San Antonio Channel Improvement Project, 1970.



Source: San Antonio River Authority. 1970. *The San Antonio Channel Improvement Project, An Intergovernmental effort to reduce flooding in the San Antonio metropolitan area*. San Antonio, TX: San Antonio River Authority.

The most dramatic success story among the structural improvements was certainly the two underground SACIP tunnels.

> The watersheds upstream of the tunnel inlet structures received from 14 to 16 inches of rain. During the flood event, floodwaters were contained within the channels of the San Pedro Creek and the San Antonio River in the immediate downtown area...in addition to protecting the downtown area form flooding the SART also prevented flooding along the river from the Interstate Highway 35 area to Lexington Avenue north of downtown and in the King William Neighborhood area from Nueva Street to South Alamo Street as also protected by the SART. South of downtown, in the area from South Alamo Street to Lone Star Boulevard, floodwaters were confined to the river channel. (San Antonio River Authority 1999, 3-13)

One of the areas most devastated by the 1946 floods was the then-new residential neighborhood just of west of downtown (adjacent to IH 35 today). The San Pedro Tunnel runs directly through this section of town; it received relatively little flood damage as a result of the tunnel's floodwater diversion. In comparison "just north of the tunnel inlet the Finesilver Art Complex did receive flood damage" and areas just north of the San Antonio River tunnel inlet also received flood damages (San Antonio River Authority 1999, 3-17). The tunnels themselves received some damage, but it was mainly limited to the inlet and outlet structures rather then the tunnels themselves (San Antonio River Authority 1999, City of San Antonio 2001). Like Olmos Dam and the Great Bend Cutoff before them, these flood control structures proved invaluable to the primarily commercial occupants of the downtown floodplain. Flood hazard has definitely been reduced as result of their construction, even if floodplain occupancy and the value of floodplain structures have not.

There are at least three obvious trends in flood hazard management highlighted by the October 1998 flood event that stand to alter the urban geography of San Antonio. The first is the increased role of federal assistance. There was an immediate response on the part of Governor George W. Bush to bring federal funding to the disaster site with as much speed as possible. Within days, newspaper headlines in San Antonio were focusing on the governor's call for a Presidential Disaster Declaration and the promise of copious funds that follow these declarations. During the Los Angeles riots in the late 1980s and Hurricane Iniki and Andrew in the early 1990s, President George Bush received a great deal of criticism for what was considered a slow federal reaction to the disasters. No doubt aware of his father's troubles and eager to appear supportive of local concerns, Governor George W. Bush was quick and firm in his demands for a declaration. President William Clinton issued the declaration almost immediately, unleashing a tremendous influx of federal funds to aid disaster victims across the state. Over $320 million flowed into the state in the form of direct disaster assistance, Small Business Administration loans, unemployment relief, and temporary housing relief (Federal Emergency Management Agency 1999). This was not unique to this flood event, but rather indicative of a national trend that began in the 1930s, grew throughout the post-WWII/Cold War period, and was institutionalized with the passage of the Stafford Disaster Relief and Emergency Assistance Act of 1988 (Platt 1999). This massive influx of federal funds has provided the assistance necessary to implement a number of improvements to the existing flood control structures in San Antonio and Bexar County, as well as priming the local tax-pumps for aesthetic enhancements relating to the historical preservation and tourism potential of the San Antonio River beyond the CBD. Enhancements to the Water Resources Development Act, signed by President Bill Clinton in December 2000, provided federal funds for, among other national projects, channel improvements in the San Antonio area. This money, merged with various bonds and tax-increase funds generated by Bexar County and the City of San Antonio since the 1998 flood, are being poured into both flood control improvements along the San Antonio River (the continued maintenance and expansion of the SACIP) and its tributaries as well as sizable investments in the aesthetic conditions along the San Antonio River between the existing downtown River Walk and Mission Espada (the southernmost of the five Spanish missions). Aesthetic improvements will include increasing the extent and size of the hike-and-bike trails, redesigning parts of the existing "V-shaped channel…considered a visual blight by many," and replanting trees and ground cover in areas destroyed by the 1998 flood (*San Antonio Express-News* 2000b, 7B). It is reasonable to assume that the result of this effort will be a river environment more attuned to its potential as a local, regional, and national tourist destination than as a river less likely to release its destructive energies on adjacent development. Taken as a whole, these efforts underscore a philosophy that has been part of San Antonio's relationship with its river environment since first settled by Europeans: mitigate the risk of the river, but always do so with an eye for maximizing its utility.

At least within the main stem of the San Antonio River, retreat appears not to be an option. Once outside of the historic main stem of the river, however, retreat, or specifically removal of structures, is developing into the preferred approach. The second post-1998 flood trend, which has clear spatial impacts on the urban form of San Antonio, is the city and county's property buyout efforts instituted under FEMA's Hazard Mitigation Grant Program (HMGP). Launched in 1993, the HMGP allows FEMA to provide 75% of the costs (up to 20% of the total assistance provided for the flood event) to local agencies to support the purchase of high-risk residential property within the floodplain. Over 20,000 properties have been purchased nation-wide through this program since 1993 (Federal Emergency Management Agency 2001b). This program is being managed locally, by the City of San Antonio and the San Antonio River Authority (on behalf of Bexar County). In all, over 600 homes have been identified for purchase. A description of the areas in which buyouts have been enacted or proposed is included in the analysis portion of the research, however it is worth pointing out in this discussion that the majority of the buyout properties are located in inner-urban, low-income neighborhoods, below the Balcones Fault. For San Antonio this represents a full circle return to the adjustments made by their first occupants. In other words in 1724, when flooding first damaged the Alamo, the response of the Spanish colonists was to move their structures to higher ground. Now, two hundred and eighty years later, San Antonio floodplain managers have been prompted to adopt the same approach in response to the spatially expanding and economically increasing impacts of flood disasters within their community.

Lastly, the wide-spread impacts of the 1998 flood, and the millions of dollars being spent on a wide range of floodplain-related projects has breathed new life into proposals to consolidate flood control responsibilities within Bexar County and the City of San Antonio. The diffused nature of floodplain management responsibilities has not passed San Antonio by in recent years. Like many large cities, flood control responsibilities are split between numerous city, county, state, and federal agencies. As discussed in the literature review, the research and planning community has offered numerous proposals for remedying this situation (see for example Platt 1986, Burby et al. 1992, Committee on Flood Control Alternatives in the American River Basin 1995). The

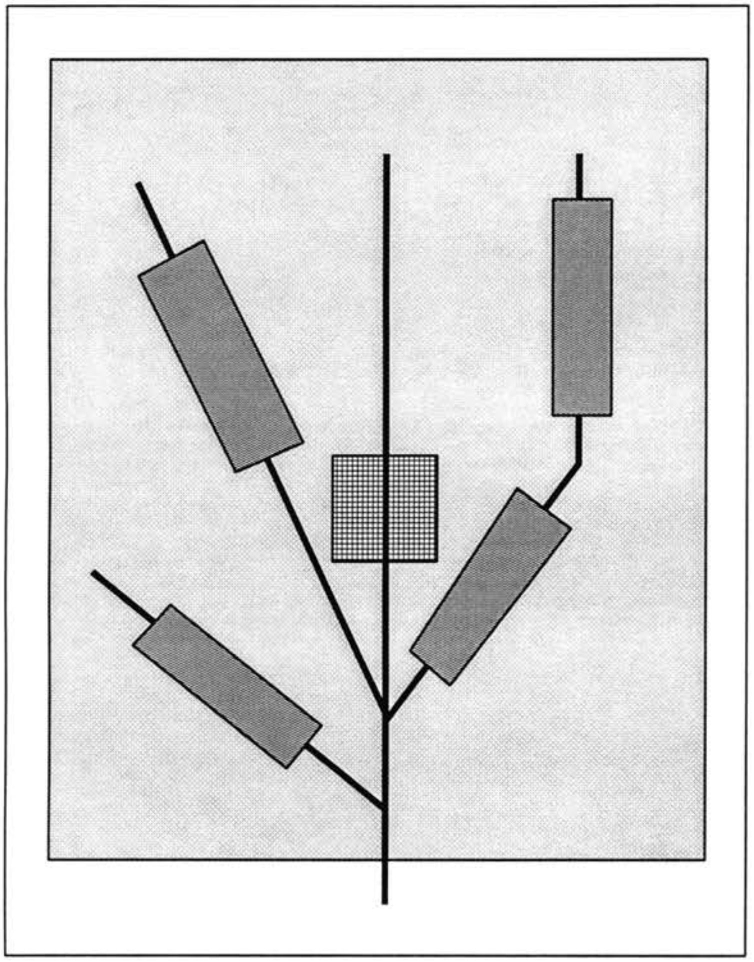
Final Report of the County Wide Citizens Watershed Master Plan Committee (2001) issued in conjunction with the City of San Antonio, Bexar County, and the San Antonio River Authority concludes with a number of recommendations to the Bexar County Commissioners Court and the San Antonio City Council. Most of the recommendations involve the improvement of procedures for community involvement in future flood control planning (a measure of the expanding geography of flood control in San Antonio in and of itself) and specific efforts to improve the channel conditions of the San Antonio River and its tributaries. However, the final recommendation, and potentially the most politically volatile, states the "jurisdiction-by-jurisdiction, project-by-project approach of today is inefficient and, as proven in the October 1998 flood, not as effective as it should be for a community of our size" (Countywide Citizens Watershed Master Plan Committee 2001, 43). Although much has transpired in flood control since the 1998 flood, a consolidation of responsibilities, and incidentally the management of flood control funds, has not occurred. Although difficult to measure, it is not hard to imagine how this territoriality within the flood management community can have not only the economic effect of potentially wasting flood control funds through administrative redundancies, but also the geographic effect of promoting the inequitable distribution of funds based on the jurisdictions of the many agencies involved. The San Antonio River Authority, a state agency, has jurisdiction in Bexar, Karnes, Wilson, and Goliad Counties. The City of San Antonio's jurisdiction is clearly defined by the city limits. And, where flood control responsibilities have not been given over to SARA, Bexar County has jurisdiction across the entire county, with primary responsibilities in those areas outside the city limits. Although this research has not focused on the cross-jurisdictional impacts of flood control, it is clear that the geography of those jurisdictions, or the central coordination thereof, has the potential to play a meaningful role in the future of flood control efforts across the San Antonio/Bexar County area.

The Expanding Constituencies of Flood Hazard

In offering a working definition of *natural hazard*, Tobin and Montz (1997) state that "hazard exists because humans or their activities are constantly exposed to natural forces," which, on occasion, can overwhelm human complexes and cause a *natural disaster* (6). Boiling this down, it can be said that in order for hazard and disaster to be of concern, there must be both a dynamic physical location and a human group that has formed a spatial relationship with that location. This being said, a cursory examination of the historical geography of San Antonio's flood hazard might yield the simple answer that as San Antonio's population, and its occupancy of the surrounding floodplains, expanded so did its flood hazard. This statement is essentially true, but it oversimplifies the complexities of changing population patterns and the evolving knowledge, awareness, and management philosophies that have characterized San Antonio's flood-hazard experience over the last century. The historical geography of San Antonio's flood hazard has been characterized by two primary trends. The first is an areal expansion of management from a downtown, central core to the broader agglomerative landscape of a mega-city. The second is an increasing complexity in the risk and relief management techniques necessary to serve a growing population invested both politically and economically in the expense and outcome of flood control. Seen together, these trends have generated distinct periods of flood control in San Antonio, each characterized by both the spatial extent of the urban area and the scale of relief available to its populations (Figure 5.4).

The Centralized Period (1900-1930) is marked by a spatial and economic focus on the emerging CBD. Flood events prior to 1913, as well as the devastating flood from that year, impacted a spatially compact, mixed residential/commercial landscape centered on the original site of the Alamo and the reaches of the San Antonio River immediately north and south of the CBD. The San Antonio River played both a commercial and recreational role in the development of San Antonio during this period. The importance of the river to the commerce and self-image of San Antonio can be seen through early efforts to keep water flowing through its reaches by supplementing its dwindling spring-fed flow with water pumped from deeper in the Edwards Aquifer. Although heavy industrialization of the floodplain has not been a ubiquitous component of San Antonio's development, a handful of manufacturing and processing plants serving the agricultural areas of the region did occupy parts of the river. Breweries, tanneries, and grain processing plants made up the bulk of these businesses. In addition, a thriving banking and commercial trade industry took root in San Antonio's downtown commercial district existed off of the local agricultural base, the growing trade and travel to western portions of the American continent, and the emerging military presence necessary to defend a newly established border to the immediate south. Despite the fact the risk of downtown flooding had been identified during the period, it took the demonstrative realization of the risk, in the form of the 1921 flood, to galvanize the commercial and municipal populations to the task of protecting the fledgling city. Structural solutions to

Figure 5.4. Idealized historical geography of flood hazard in Bexar County, Texas.



River

Centralized Period (1900-1950)
Hazard Constituency: CBD concentration

Expansion Period (1950-1970)
Hazard Constituency: CBD and emerging suburban concentrations

Complex Period (1970-Present)
Hazard Constituency: CBD, urban residential, and suburban fringe

the flood problem, primarily in the form of Olmos Dam, were seen as tangible and permanent solutions to the flood hazard of the San Antonio River. The one-time fee of building a dam was also attractive to local business concerns, the dominant player in San Antonio's urban development (Miller 1990, Johnson 1990) and the primary constituency that would bear the brunt of the costs through local taxation. Heartened by the protection offered by the dam, the city, with limited assistance from the federal government, began a series of river beautification and channel improvement projects in the late 1920s and early 1930s. This trend coincided with a burst of urban development initiatives launched by the city in the 1920s and 1930s (Sanders 1990). The role of the federal government, specifically the Army Corps of Engineers, was just beginning to expand in the late 1930s only to be interrupted by World War II. Despite the apparent simplicity of the Olmos Dam solution and the growing comfort afforded by federally-funded channelization projects started anew following the flood of 1946, the city's spatial extent and population growth was quickly surpassing the protective measures afforded by the downtown projects.

This urban expansion into the tributaries of the San Antonio River and the flood control efforts prompted by the growth can be characterized as the Expansion Period (1950-1970). Buoyed by regional agriculture and spurred on by an increasing amount of space devoted to military land use and the national economic importance of the burgeoning Texas Gulf Coast petroleum industry, this period saw an exponential increase in the involvement, and investment, of the state and federal government. Various stages of disaster relief legislation, especially the Disaster Relief Act of 1950, and a growing role on the part of the federal government in the development of urban infrastructure nation-wide were felt in San Antonio. Throughout the 1950s and 1960s copious structural improvements were made to the San Antonio River's main stem as well as along many of its tributaries. These came in the form of channel improvements, generally performed and financed by the Army Corps of Engineers, and the construction of numerous small retention dams in the developing urban fringe, generally financed by state and federal agencies responsible for flood control and soil conservation. Although the protection afforded by these flood control measures was immense, they coincided with, and potentially encouraged, the expansion of the urban area and an increasing density of residential occupation within the area's floodplain. This growth would require that San Antonio avail itself of more than dams and straightened channels to provide protection to its floodplain occupants.

The National Flood Insurance Act of 1968 ushered in a new era of flood management to the nation and to San Antonio alike. The legislation marked a national recognition that structural mitigation alone would not be sufficient for the growing American population. Although structural projects continued to be employed in most cities, an emphasis on floodplain zoning and risk pooling (flood insurance) began to emerge. This period in San Antonio's flood hazard evolution can be characterized as the Complex Period (1970-present). Gone were the days when downtown commercial concerns dominated conversations about flood control. Gone also was the approach of stepping aside and allowing the federal government to engineer solutions to flood control on behalf of the urban population. Flood control projects during this period range from a continued investment in large- and small-scale physical flood control structures to encouraging, or requiring, the participation of local residents in national flood insurance.

The emerging importance of residential communities along the urban fringe pulled attention, and funding, away from the aging urban residential areas to the growing suburban populations, who began demanding equal investment in their reaches of the San Antonio River tributaries. Flood hazard management became a complex of structural, nonstructural, and regulatory remedies designed to serve a more diffused and diverse urban population. The flood of 1998 illustrated that although the continued investment in structural projects was of value, the nonstructural approaches of insurance, disaster relief loans, and, most recently, post-disaster funding for property buyouts are clearly the most important strands in the safety net of flood control planning. This multi-faceted approach has created the necessity for centralized management of the region's floodplains, and although this may not be realized prior to the next "great" flood, the idea's inertia can be felt in nearly all of the documents promulgated following the 1998 flood. The next geographical evolution in San Antonio flood control will be in the scale of jurisdiction. By all appearances the San Antonio River Authority, or some offshoot thereof, will ultimately emerge as a regional, but centralized, manager for the area's floodplains. This idea is based on creating a more efficient flood management approach. Whether efficiency translates to proactive control policies rather than reactive projects, as has been the city's history, remains to be seen. What is certain is that the constituency of such an entity will be more complex, more diverse, and more diffused across Bexar County's floodplain when the next flood arrives.

Summary

This chapter examines the history of flood hazard and flood control in San Antonio and Bexar County, Texas. The historical record supports this chapter's hypothesis in that it is clear from the material discussed above that San Antonio's flood hazard history is punctuated by the extreme events and the managerial reactions to those events rather than period of proactive management in preparation for future disasters. The chapter further illustrated the expanding nature of the San Antonio's floodplain constituency. It is the spatially expanding and demographically diversifying nature of San Antonio's floodplain occupants that has prompted floodplain managers to invest in ever-greater structural modification, to seek ever larger economic remedies to flood disasters, and to expand the political machinery necessary to support the ever-more complicated array of flood hazard solutions.

Underpinning these changing periods of flood control are evolving patterns of floodplain occupation. The following two chapters are devoted to exploring the specific patterns of occupation that have characterized the last one hundred years of floodplain occupancy within Bexar County as well as to analyzing the degree to which the ever-evolving flood hazard mitigation techniques applied to San Antonio's floodplain have altered the human geography of the city.

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CHAPTER 6

CADASTRAL GEOGRAPHY AND EVIDENCE OF FLOODPLAIN ADJUSTMENT

Overview

This chapter presents the analysis of Bexar County's cadastral data addressing the second hypothesis presented in the introduction. This hypothesis poses the question of whether floodplains (described here as the 100- and 500-year FEMA designated flood zones) represent unique geographies within the larger urban fabric of San Antonio. Much of the literature on the influence of risk and economic damage associated with flooding in urban floodplains indicates that floodplains should have distinct geographies. Additionally, the theoretical implications of human ecology are that there should be patterns of adjustment in regions where human interaction with natural processes present the potential for loss. These ideas will be explored in three ways. First, a discussion of the overall trends, by historic period and floodplain location, of parcel development is presented. Second, the concentric growth patterns of parcel development along the "radial spokes" of San Antonio's floodplains are analyzed, focusing here on the temporal occupancy patterns. As San Antonio's urban area has expanded, has the tendency been to occupy the floodplain first and then move into adjacent areas outside the floodplain, or has the tendency been to occupy the less risky, non-floodplain regions first with later development extending into the floodplain? The former pattern would indicate that occupying the floodplain presents a degree of utility that exceeds the risk of loss associated with flooding. The latter would indicate that although risk adjustment is present in the initial development of the urban space, subsequent development is either marginalized into the floodplain or enabled by the increased value of land occupied in already developed areas.

Third, the final section of this chapter will focus on the differences between parcels within the floodplain and those outside yet adjacent to the floodplain. The premise is that parcels within the floodplain should exhibit land values, improvement values, and/or age values that are significantly different than a sample of parcels within a one hundred meter buffer adjacent to the floodplain. The parcel data are first analyzed as an entire group, but are also broken into subgroups based on whether they are commercial or residential parcels, whether they are above or below the Balcones Fault, and by their location within SARA's thirteen designated management basins. To reiterate, when the floodplain exhibits significantly higher land values, improvement values, and are older properties, it is assumed that the aesthetic or utilitarian attraction of the floodplain has exceeded potential losses or perceived losses associated with flooding. When floodplain parcels have lower values and structures are newer, it is assumed that a risk adjustment has been made through a preference for the less risky areas beyond the floodplain.

Parcels by Decade and Floodplain Status

Table 6.1 provides a description of all parcels in Bexar County by type and status inside and outside the floodplain beginning with those parcels dated 1820-1899 and then by decade until the period 1990-1998. "No date" parcels are also categorized by type and location

Table 6.1. Parcels by decade and floodplain location.

Decade	1820-1899	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949
All Parcels						
Total	407.00	1563.00	3751.00	14222.00	14144.00	35910.00
In	56.00	106.00	129 00	486.00	538.00	1397 00
%	14%	7%	3%	3%	4%	4%
Out	351.00	1457.00	3622.00	13736.00	13606.00	34513.00
%	86%	93%	97%	97%	96%	96%
Residential						
Total	309.00	1401.00	3544.00	13612.00	12993.00	33504.00
In	30.00	68.00	86 00	385.00	398.00	1192.00
%	10%	5%	2%	3%	3%	4%
Out	279.00	1333 00	3458.00	13227.00	12595.00	32312.00
%	90%	95%	98%	97%	97%	96%
Commercial						
Total	40.00	96 00	118.00	348.00	527.00	1156.00
In	13.00	26.00	23.00	60.00	71 00	109 00
%	33%	27%	19%	17%	13%	9%
Out	27 00	70.00	95 00	288.00	456 00	1047.00
%	68%	73%	81%	83%	87%	91%
Rural and Farm						
Total	58.00	67.00	89.00	262.00	624.00	1250.00
In	13.00	12.00	20.00	41.00	69.00	96.00
%	22%	18%	22%	16%	11%	8%
Out	45.00	54.00	69.00	221.00	555.00	1154.00
%	78%	81%	78%	84%	89%	92%

Decade	1950-1959	1960-1969	1970-1979	1980-1989	1990-1998	No Date
All Parcels						
Total	55405.00	50984.00	63707.00	68881.00	44153.00	95512.00
In	1653.00	2366.00	2690.00	4000.00	2157.00	8518.00
%	3%	5%	4%	6%	5%	9%
Out	53752.00	48618.00	60017.00	64881.00	41996.00	86994.00
%	97%	95%	94%	94%	95%	91%
Residential						
Total	51540 00	45567.00	58385 00	62254.00	40246.00	51156.00
In	1292.00	1955.00	2321.00	3525.00	1921.00	3866.00
%	3%	4%	4%	6%	5%	8%
Out	50248.00	43612.00	55064.00	58729.00	38325.00	47290.00
%	97%	96%	94%	94%	95%	92%
Commercial						
Total	2208.00	3348.00	3574.00	4426.00	2199.00	17704.00
In	194.00	273.00	259.00	329.00	140.00	2137.00
%	9%	8%	7%	7%	6%	12%
Out	2014.00	3075.00	3315.00	4097.00	2059 00	15567.00
%	91%	92%	93%	93%	94%	88%
Rural and Farm						
Total	1657.00	2069.00	1748.00	2201.00	1708.00	26652.00
In	167.00	138.00	110.00	146.00	96.00	2515.00
%	10%	7%	6%	7%	6%	9%
Out	1490.00	1931.00	1638 00	2055.00	1612 00	24137.00
%	90%	93%	94%	93%	94%	91%

within or outside of the floodplain. It is important to note that as structures have been destroyed or torn down and replaced with newer structures the dates attributed to that parcel would reflect the newer construction rather than the older, original date of development. In other words, the age value associated with each parcel describes the structures rather than the date the parcel was platted. This means that parcels dated, for instance, during the 1900-1909 period are those parcels where a structure was built during that period and the structure has withstood the tests of time and development to remain on the parcel. Therefore, despite the comprehensive nature of these data, each period should be seen as a sample of structures built rather than a complete cataloging of all structures developed during the time frame. Nevertheless these data offer a uniquely comprehensive set of measurements associated with the temporal expansion of land development within Bexar County.

A number of interesting trends associated with the role of floodplain occupancy in San Antonio's land development history can be discerned (Table 6.1). Overall, the relationship between the percentages of parcels developed within the floodplain versus those developed outside the floodplain has remained relatively static throughout the years. The period 1820-1899 shows the development of a higher percentage of parcels within the floodplain (14%) than in subsequent periods, however this is most likely attributable to the preservation of historical structures, primarily in the downtown area, that were established near the river's edge in San Antonio's early years of development. The percentage of parcels located in the floodplain drops to seven percent in the period 1900-1909 and then levels out to range between three and six percent for all subsequent periods. This indicates that, with the exception of the earliest years of development, there are no distinct periods when large-scale occupancy of the floodplain, or inversely avoidance of the floodplain, dominated San Antonio's development patterns. To some degree this can be explained by considering the geography of the floodplain itself. Because of the diffuse nature of flood-prone areas, the spatial opportunity to occupy the floodplain within Bexar County remained rather consistent across the county (Figure 3.1). However, this also indicates that since the beginning the 1900s San Antonio has not experienced a period of wholesale avoidance of its most flood-prone areas, despite the historical accumulation of awareness about flood hazard. Similarly, other than the early settlement period, the "Total Parcels" data do not indicate that there was a time when occupying the floodplain was seen as particularly attractive, or "safe" due to mitigation measures. It may be that at this temporal scale the finer nuances of the ebb and flow of floodplain occupancy are muted. However, it can be said that as the city has expanded, development in the floodplain has not been thwarted by awareness and repetitive loss, or, if it has, the net effect of measures taken to enable continued development has had the effect of holding the percentage of total parcels located within the floodplain basically static.

When examined by commercial and residential groups, the floodplain occupancy data exhibit a bit more variation between periods. The residential data exhibit a similar decline, from a high of ten percent, in the percentage of parcels within the floodplain following the 1820-1899 period. Although the range among all subsequent decades is from a low of two percent in 1910-1919 to a high of six percent in 1980-1989, the general trend with residential parcels is a gradual increase from the 1910s to the present. This is potentially the result of an accumulation of both structural and non-structural mitigation options over that period of time having the effect of enticing, or at least enabling, further floodplain development. It may also be attributed to the gradual secondary-development infilling of the floodplain. This idea is discussed in greater detail below. The commercial-parcel data exhibit a pattern of general decline following their peek during the initial early settlement period. One possible explanation for this trend is the fact that those areas of San Antonio's floodplain that remain commercial today are centered primarily on the CBD. Commercial development in more recent periods has followed other "developmental forces," primarily those associated with rail and interstate highway patterns. As the necessity to locate commercial activities near the main stem of the San Antonio River faded with the advent of municipal water and sewage technology and as the transportation technology shifted away from the river (which never transitioned into a main mode for commercial transportation despite early attempts to make it so), so has the location of commercial activities along the river. In a sense, this left the floodplain, which was generally avoided by rail and highway construction, to be used for residential development. Rural and farm parcels located in the floodplain also exhibit a general decline over the 178-year study period. This can probably best be explained by advances in irrigation technology that reduced the need to locate cropland adjacent to surface-water sources. Altogether, the data indicate that both commercial and farm and rural land use has been gradually, albeit in small increments, replaced by residential land uses.

If it is assumed that the no-date parcel subset represents parcels that will undergo structural improvements in the next few years, an interesting pattern emerges. All categories show an increased percentage of parcels in the floodplain. Additionally, many of the commercial parcels in this group are large tracts of land that have been purchased for future subdivision. In other words, they were originally platted by a commercial land development firm, but it can be assumed that their intention is to subdivide the tract into parcels and pass ownership on to individual private owners for residential purposes. Should all of the existing no-date residential parcels be developed in addition to the subdivision of a number of the commercial tracts, there will be a trend toward a higher percentage of residential parcels within the floodplain in future years. Changes in floodplain regulation could have the effect of stemming this advance into the floodplain. However current trends, particularly in the northern section of the county where many of these no date parcels are located, are toward developing the floodplain and offsetting the costs through non-structural mitigation. It can be said then that future floodplain residents will be able to offset the risk of the floodplain (through risk-pooling) such that the utility of locating in these often more attractive Hill Country settings will become an increasingly likely choice. This guarantees at least two things: growing tax revenues for the municipal districts with jurisdiction over these floodplains and increases in the economic damages suffered in the next "great flood."

These are the broad trends in the data. But does the attraction or repulsion of the natural risk and resource of the floodplain create distinct geographies? This question will be analyzed in greater detail, and at a refined spatial scale, in the two following sections.

Occupancy and Growth Along the Floodplain

The Data and Methodology chapter presented two types of hypothetical urban growth patterns in relation to the floodplain (Figure 3.2). This section discusses the statistical analysis of expansion (or radial) growth along the San Antonio River's floodplains. First, the average distances of all parcel centroids, within the same decadal periods presented in Table 6.1, to the spatial center of San Antonio historical urban development (the Alamo) was calculated. The difference between the mean distance to the Alamo of parcel centroids inside the floodplain versus those outside were then subjected to a difference-of-means test to assess whether the observed differences were statistically significant. This was done for all residential and commercial parcels together and for both residential and commercial parcels separately. The results are presented in Tables 6.2, 6.3, and 6.4 respectively.

In all three sets of analysis the parcels outside the floodplain exhibit a statistically significant tendency to "lead" parcels inside the floodplain. This is representative of a *risk adjustment* pattern (Figure 3.4). In other words, on average, development of both residential and commercial parcels have tended to locate outside of the floodplain first, theoretically in deference to the environmental risk and increased cost of occupancy engendered by the floodplain, and then infill toward the floodplain. Only the first, early settlement period (1820-1899) and the period 1910-1919 (residential only) do not produce significant difference between the two groups. In order to illustrate this graphically, six example sites were selected and maps were generated illustrating the progression of parcel development (Figure 6.1). The selected areas are predominately residential and were chosen because they provide particularly dramatic examples of the spatial tendency described above. As this tendency is an average, there exist areas of development where the floodplain is occupied first and subsequent development emerges outside of the floodplain. However, the patterns illustrated in the example sites represent the overall geographic patterns of floodplain occupation when viewed as concentric development.

Table 6.2. Inside/outside floodplain difference-of-means results, distance of residential/commercial parcel centroids to the Alamo.

	N	Mean, Entire Set (meters)	Mean Inside Floodplain (meters)	Mean Outside Floodplain (meters)	Difference (Inside – Outside) (meters)	Mann-Whitney Sig. (2-tailed)
1820-1899	347	2425	1606	2541	(-935)	.002
1900-1909	1497	3059	1931	3135	(-1204)	.000
1910-1919	3662	3543	2825	3565	(-740)	.000
1920-1929	13960	4281	3732	4299	(-567)	.000
1930-1939	13520	4984	4239	5011	(-772)	.000
1940-1941	34660	6143	5491	6168	(-677)	.000
1950-1959	53748	8315	7212	8346	(-1134)	.000
1960-1969	48914	11863	10288	11938	(-1650)	.000
1970-1979	61959	15625	14640	15668	(-1028)	.000
1980-1989	66681	17529	16857	17570	(-713)	.000
1990-1998	42455	19088	18175	19135	(-960)	.000
No Date	47736*	18214	15985	18423	(-2343)	.000
No Date Residential	51039	16383	13933	16583	(-2650)	.000
No Date Commercial	17704	11777	10782	11913	(-1131)	.000
No Date Rural & Farm	26652	26053	23896	26277	(-2383)	.000

* N represents a 50% random sample of "No Date" parcels, excluding "exempt" parcels.

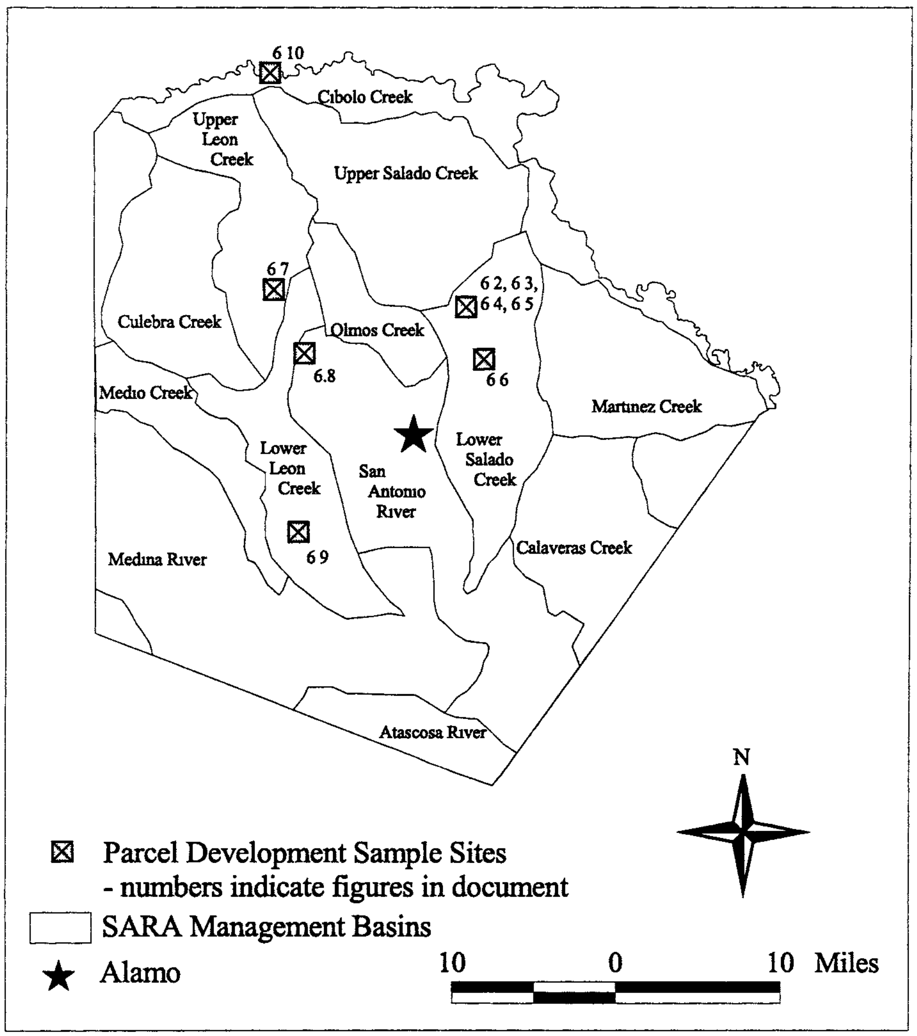
Table 6.3. Inside/outside floodplain difference-of-means results, distance of residential parcel centroids to the Alamo.

	N	Mean of Residential Parcels (meters)	Mean Inside Floodplain (meters)	Mean Outside Floodplain (meters)	Difference (Inside – Outside (meters)	Mann-Whitney Sig. (2-tailed)
1820-1899	308	2421	1848	2483	(-653)	.214
1900-1909	1401	3103	2135	3152	(-1017)	.000
1910-1919	3544	3567	3237	3576	(-339)	.026
1920-1929	13612	4303	3953	4314	(-361)	.000
1930-1939	12994	5006	4570	5019	(-449)	.000
1940-1941	33504	6166	5625	6186	(-561)	.000
1950-1959	51540	8392	7622	8412	(-790)	.000
1960-1969	45568	12130	10810	12190	(-380)	.000
1970-1979	58385	15898	15190	15928	(-738)	.000
1980-1989	62256	17831	17345	17860	(-515)	.001
1990-1998	40246	19343	18624	19379	(-755)	.000

Table 6.4. Inside/outside floodplain difference-of-means results, distance of commercial parcel centroids to the Alamo.

	N	Mean for Entire Set (meters)	Mean Inside Floodplain (meters)	Mean Outside Floodplain (meters	Difference (Inside – Outside) (meters)	Mann-Whitney Sig. (2-tailed)
1820-1899	39	2460	1048	3166	(-2118)	.089
1900-1909	96	2424	1400	2804	(-1404)	.001
1910-1919	117	2830	1282	3208	(-1926)	.000
1920-1929	349	3381	2311	3603	(-1292)	.000
1930-1939	526	4460	2386	4783	(-2397)	.000
1940-1941	1156	5467	4028	5617	(-1589)	.000
1950-1959	2208	6504	4478	6699	(-2221)	.000
1960-1969	3346	8220	6555	8367	(-1812)	.000
1970-1979	3574	11164	9720	11276	(-1556)	.000
1980-1989	4425	13278	11631	13411	(-1780)	.000
1990-1998	2199	14428	12012	14593	(-2581)	.000

Figure 6.1. Parcel development sample sites.



Figures 6.2, 6.3, 6.4, and 6.5 illustrate the decadal progression of parcels into a portion of the Lower Salado Creek floodplain (located between Wetmore Rd. and Nacogdoches Rd.) for the period 1960-1999. Parcels developed prior to 1960, progressing out from the CBD, appear on the lower left of the map (Figure 6.2). Parcels developed during the decade of 1960-1969 clearly extend land development up to, but only slightly within, the perimeter of the floodplain (Figure 6.3). Parcels added from 1970-1979 include a number of areas where growth has emerged adjacent to existing parcels and well in the floodplain (Figures 6.4). Additional infill proliferated within the undeveloped areas of the floodplain from 1980-1999 (Figure 6.5). Clearly the floodplain was avoided in the early period of development in this location, but occupied by infill as the area underwent the economic and infrastructure changes that accompany residential development over the last three decades. A second site on Lower Salado Creek (Figure 6.6), located just north of Rittiman Road, illustrates a similar pattern of developmental progression deeper into the floodplain over the period 1960 to 1979. Most of the land development prior to 1960 stops short of encroaching on the floodplain. However, those parcels added during the 1960s clearly move into riskier areas in between the main stem of Lower Salado Creek (to the west) and its smaller tributary (to the east), as well as infilling along the perimeter of both. Parcels added in the 1970s encroach beyond the current 500-year flood zone and well into the 100-year flood zone. Again the pattern is outside development leading to inside development.

Figure 6.2. Lower Salado Creek example site 1: Development prior to 1960.

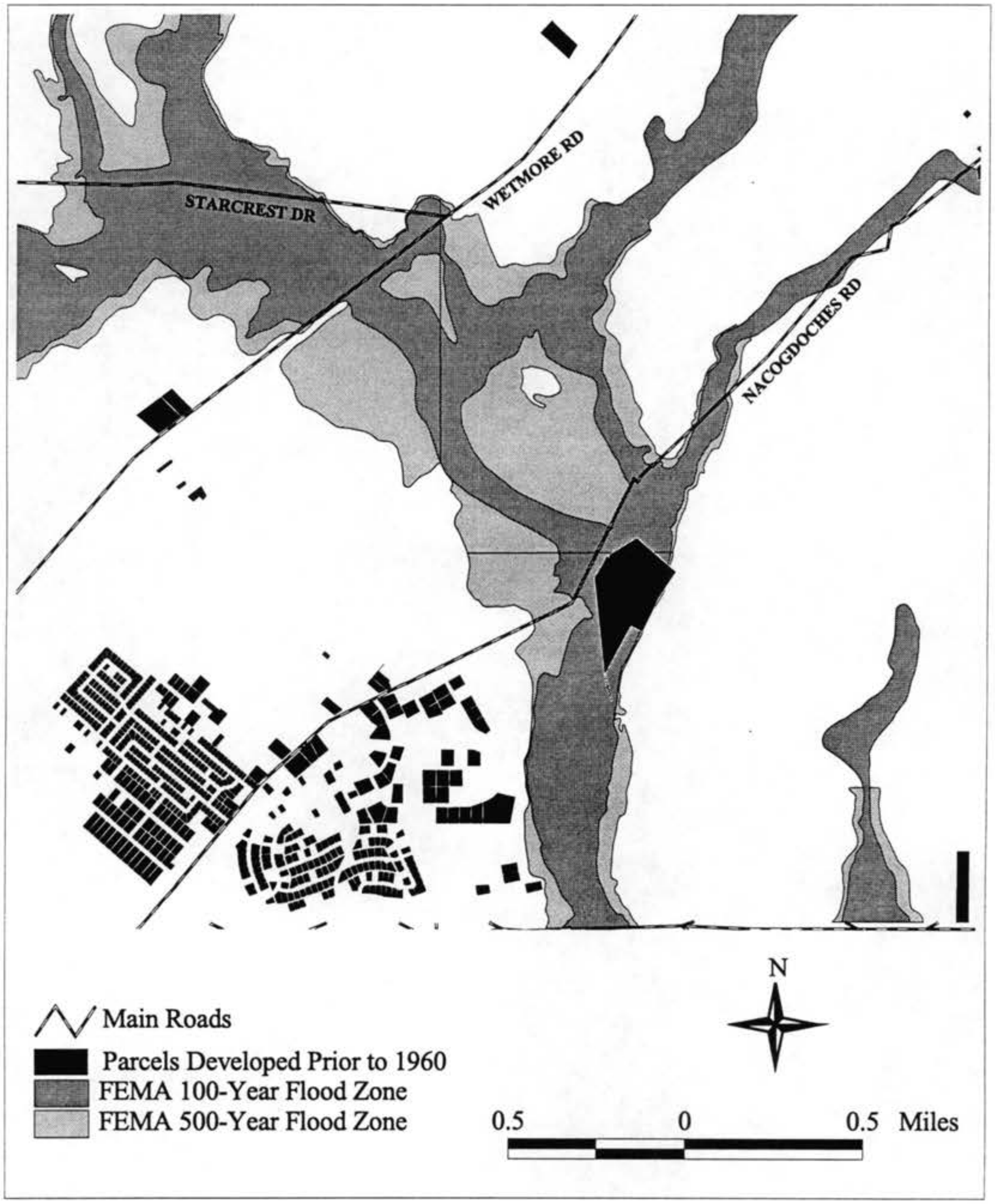


Figure 6.3. Lower Salado Creek example site 1: 1960s development.

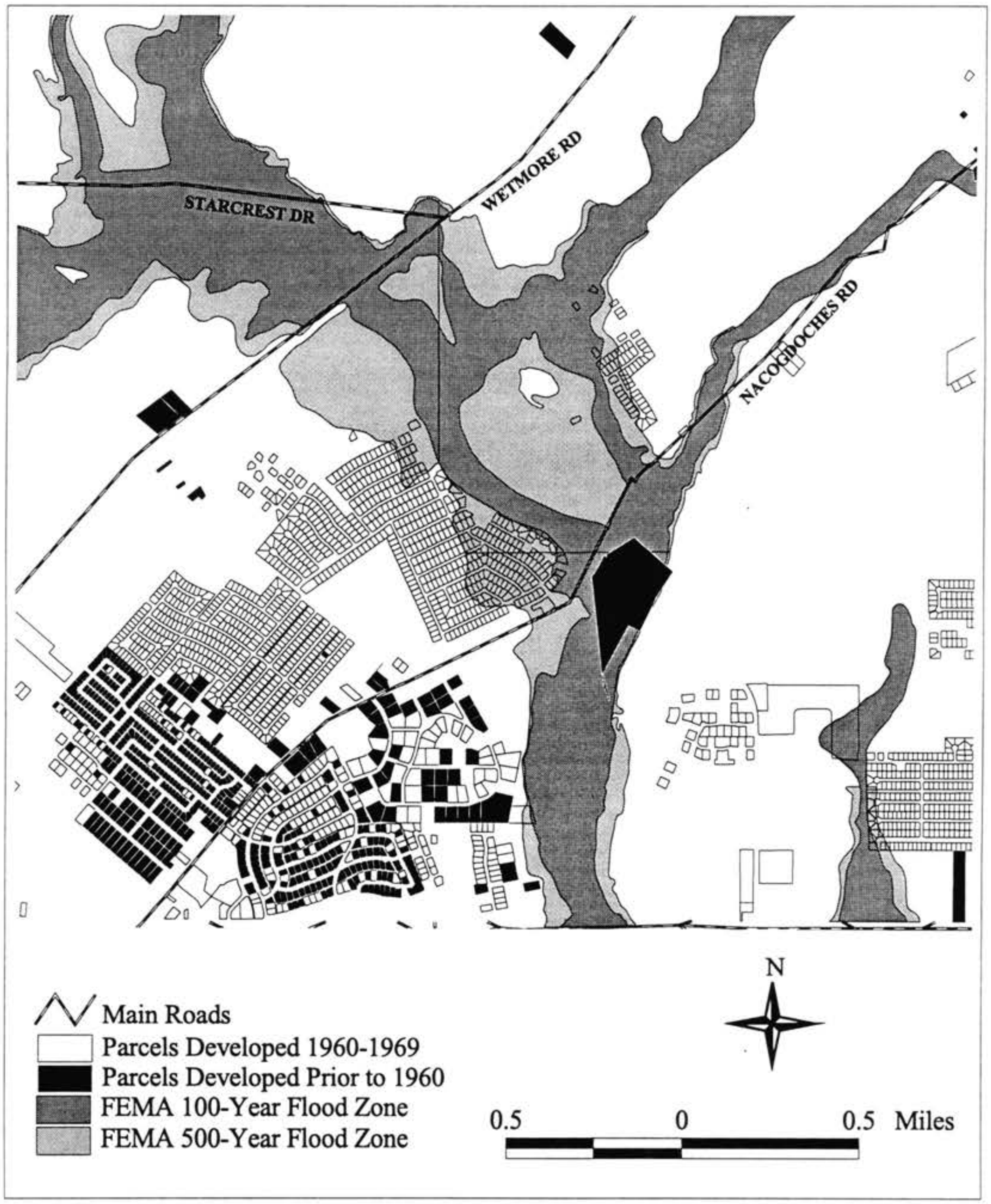


Figure 6.4. Lower Salado Creek example site 1: 1970s development.

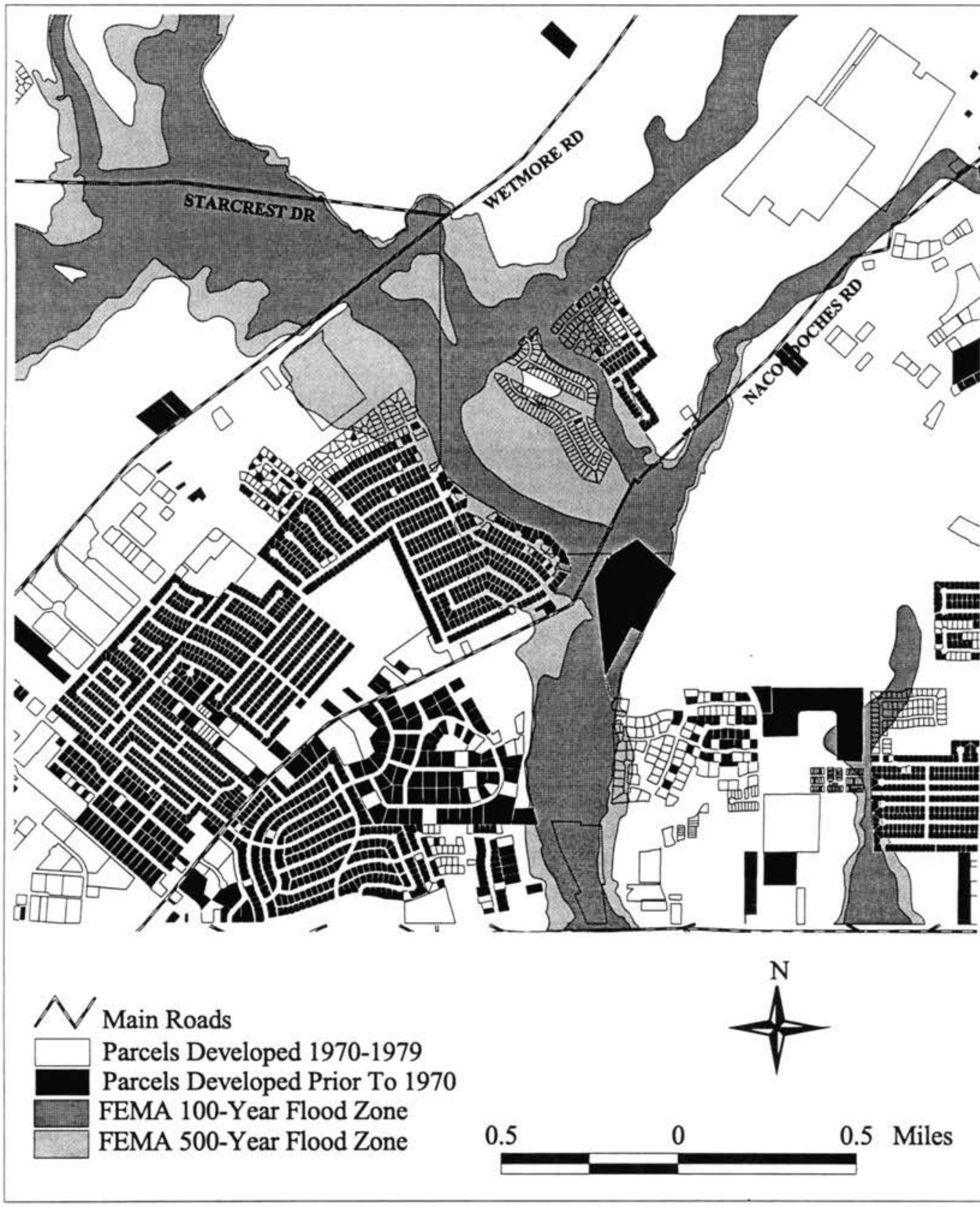


Figure 6.5. Lower Salado Creek example site 1: 1980 - 1999 development.

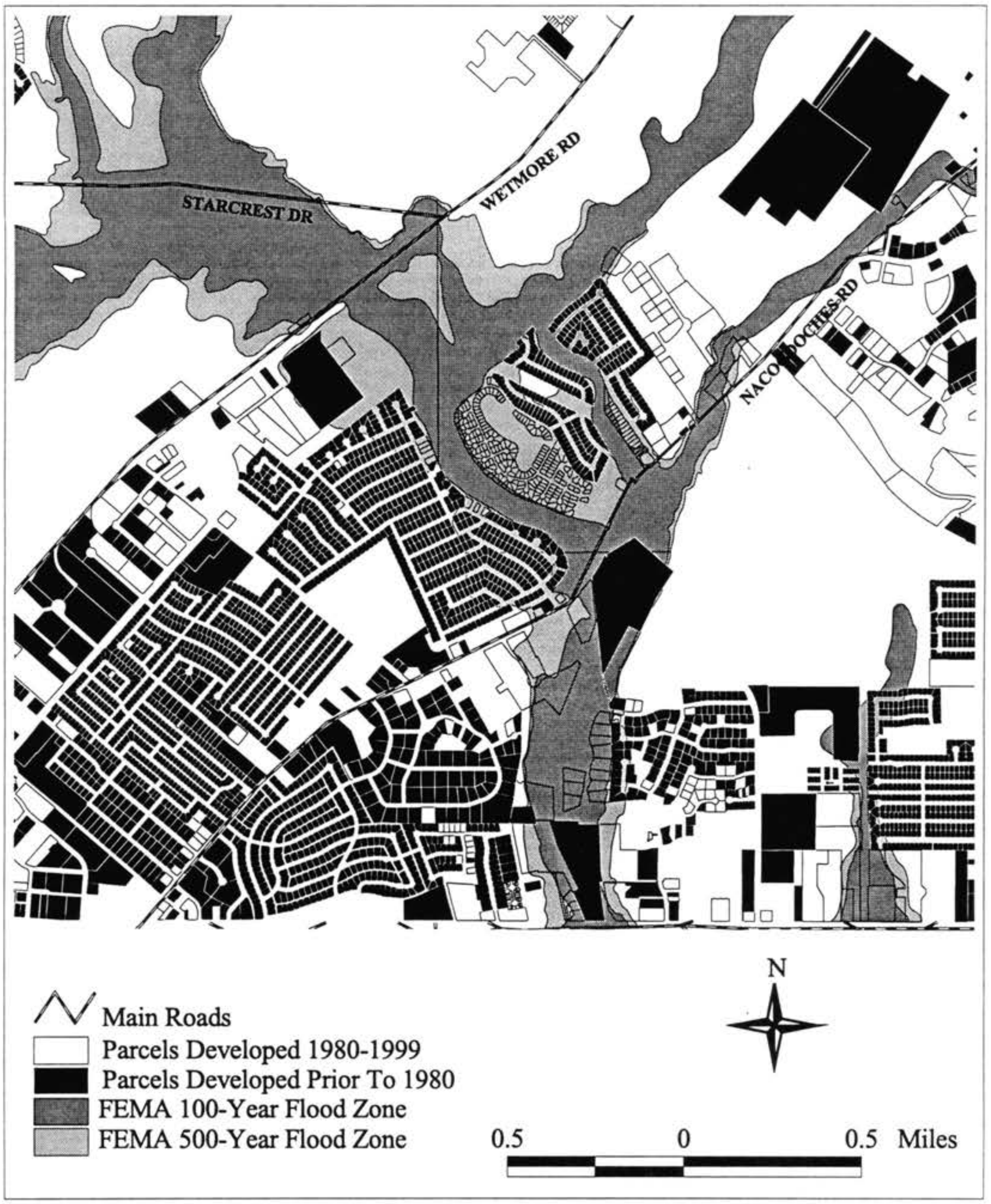
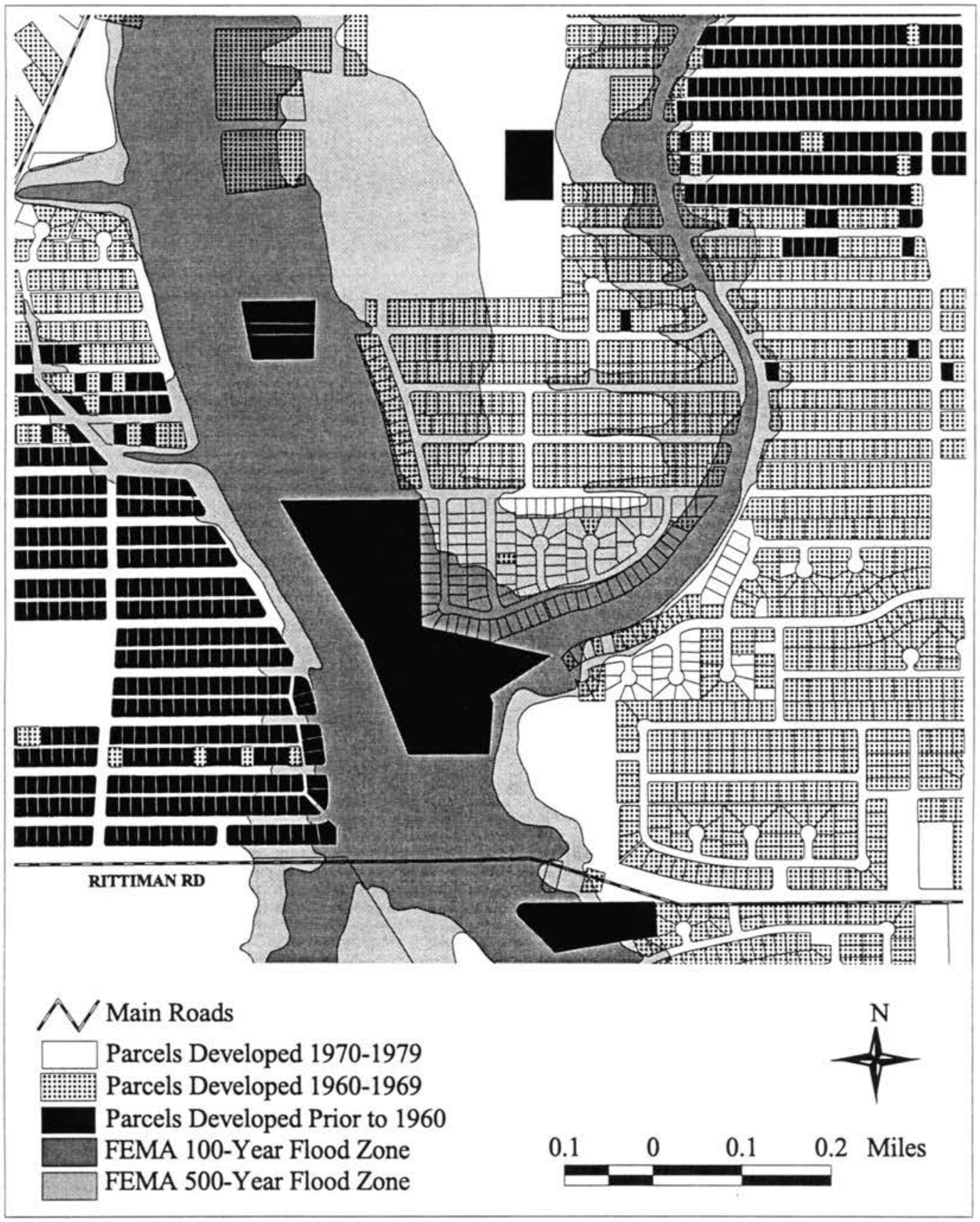


Figure 6.6. Lower Salado Creek Basin example site 2.



Parcel development during the 1980s and 1990s were mapped for a third site south of Babcock Road on Upper Leon Creek (Figure 6.7). In this case, parcels developed prior to 1980 are located both outside and inside (within the 500-year flood zone) the floodplain. Parcels developed in the 1990s and 1980s completely fill in the remainder of the undeveloped 500-year flood zone and push parcel development into the 100-year flood zone portions of the floodplain. A fourth site on Cibolo Creek, near FM 3351, shows a similar pattern for parcel development in the last decade (Figure 6.8). Parcels developed prior to 1990 have yet to extend as far north as Cibolo Creek's flood zones. However parcels developed in the 1990s and no-date parcels, which have been platted but not yet improved, have both in-filled prior development and extend newer development well into the floodplain.

To illustrate the degree to which this pattern extends to intra-decadal development, two additional sites have been selected. A site in southeast San Antonio experienced the bulk of its land development in the 1970s (Figure 6.9). Parcel centroids are illustrated in graduated size based on the year they were improved; larger centroids represent more recent development. Although the pattern is not as dramatic, the overall tendency is the same. The earlier parcels, located outside the floodplain, are improved first with subsequent development exhibiting a tendency to extend toward and into the 100-year flood zone. An area near where Wurzbach Road crosses one of the northernmost tributaries of the San Antonio River is mapped in the same manner for development during the 1960s (Figure 6.10). Here the tendency was to improve parcels outside the floodplain first, with subsequent development spreading into as well as outside the floodplain.

Figure 6.7. Upper Leon Creek Basin example site.

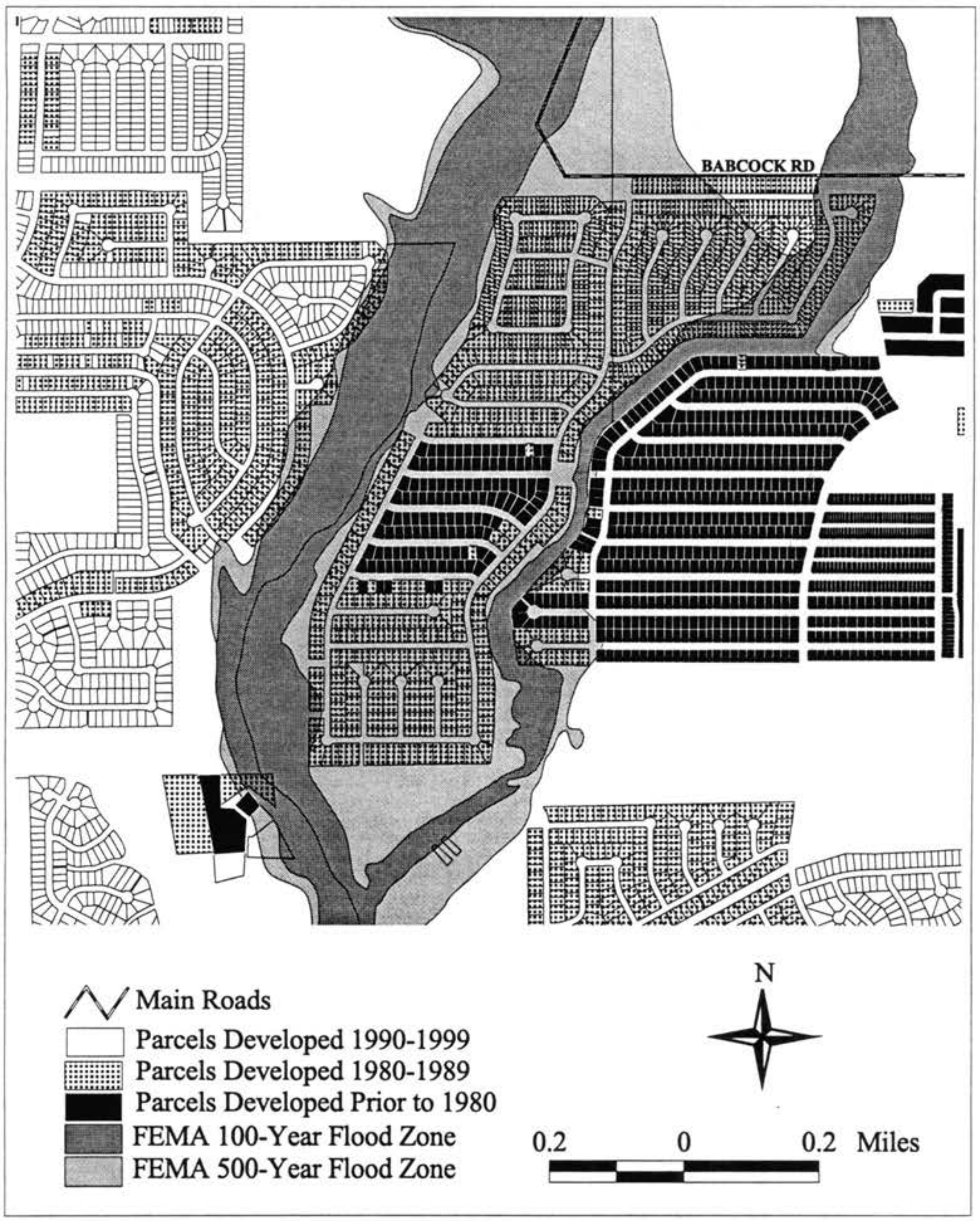


Figure 6.8. Cibolo Creek example site.

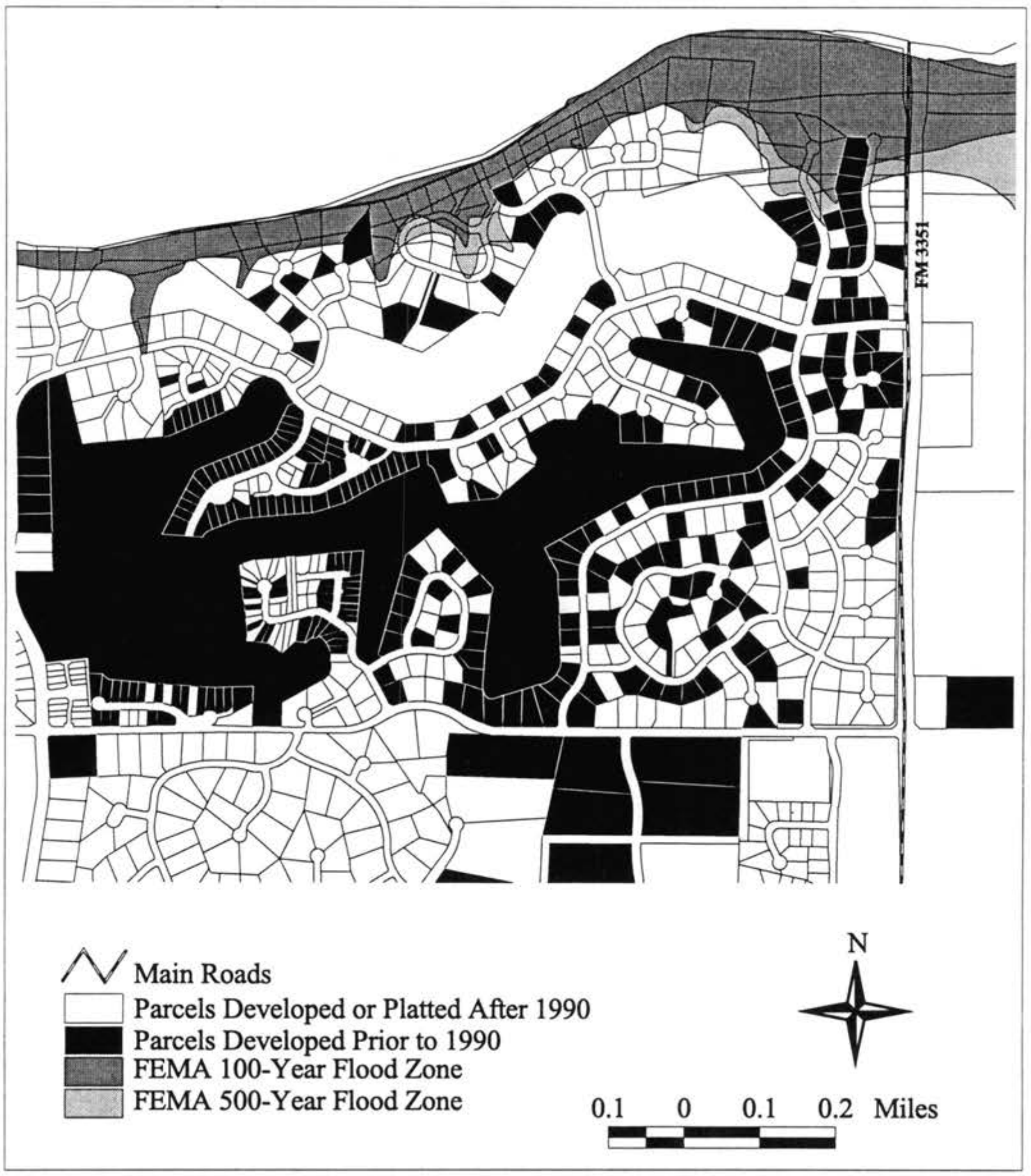


Figure 6.9. Lower Leon Creek Basin example site.

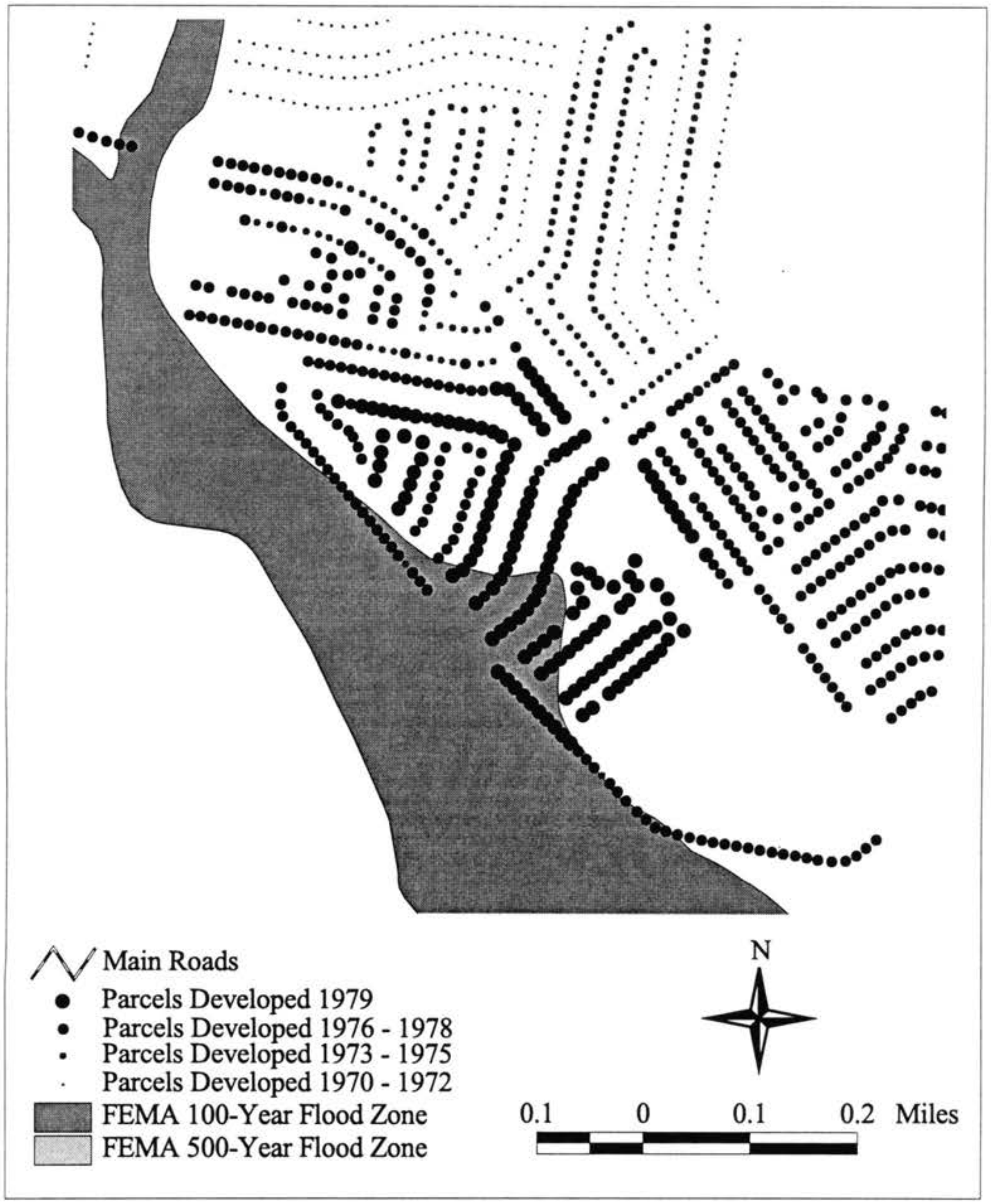
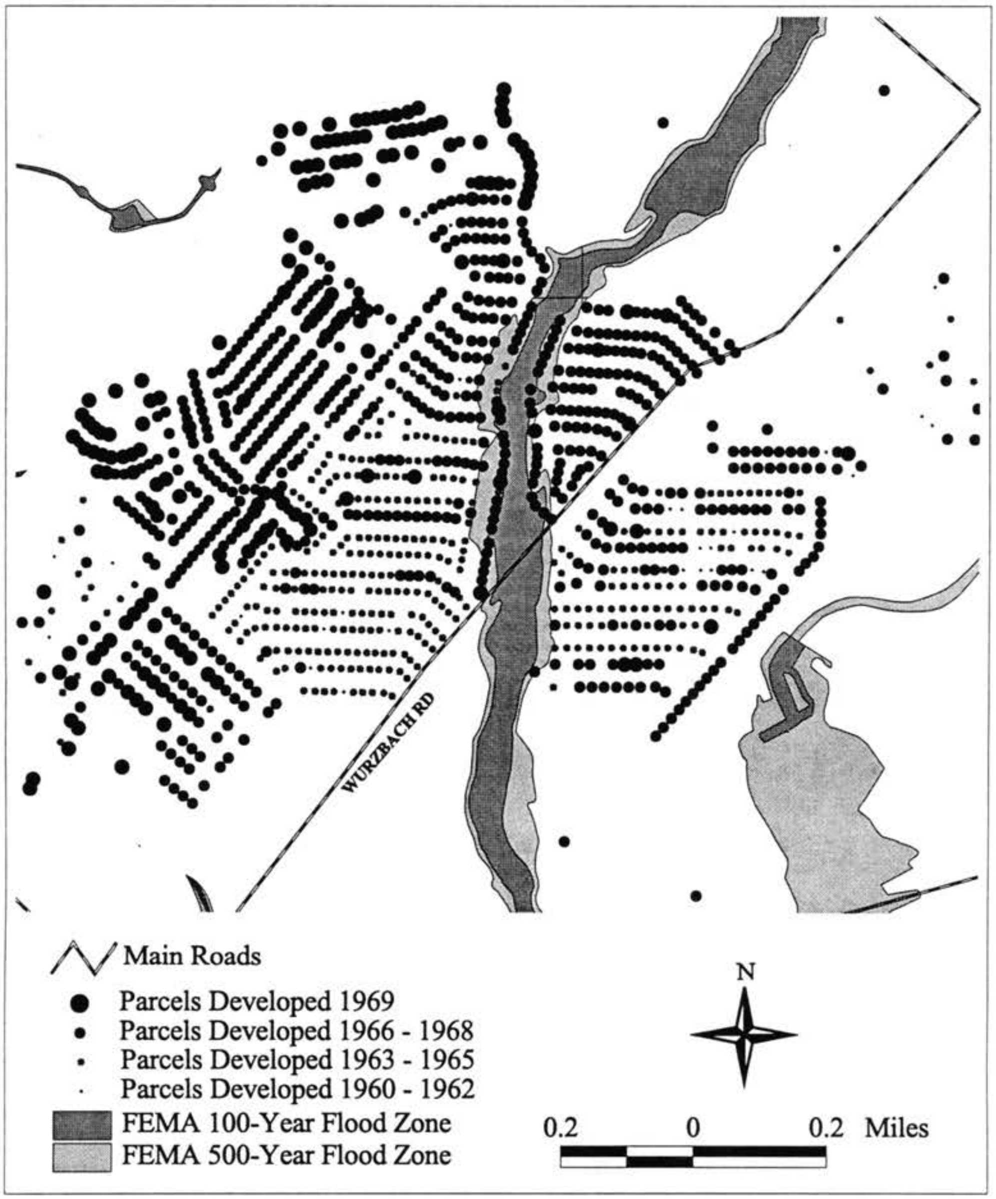


Figure 6.10. San Antonio River Basin example site.



The fact that the overall trend for expansion development is the same for all years indicates that although experience, mitigation, and regulation associated with flood hazard have increased over time, their impacts on the pattern of floodplain development have been negligible when viewed over the entire period of San Antonio's development. Furthermore, that these patterns hold up both among different decades and within particular decades of development offers further evidence for their preeminence. The explanation for this pattern of occupancy is most likely related to the economics of land development.

As undeveloped land is subdivided and converted to residential use with structural improvements, it increases the development potential of adjacent undeveloped land. Additionally, the extension and improvement of municipal services in developing areas also raises land values. Together this increases both the actual value and the investment value of undeveloped adjacent areas of urban land. Given that it is more costly to locate structures in the floodplain, either due to the recognition of risk on the part of individual landowners, or due to the zoning and regulation of the floodplain in anticipation of future flooding impacts, it stands to reason that these areas would be avoided in the initial stages of development. Why capitalize the risk of the floodplain in the initial stages of development when those costs can be avoided? Once property values reach a critical point, it becomes feasible to develop the more costly floodplain parcels. By taking advantage of existing infrastructure it is potentially more cost-effective for land developers to develop the floodplain parcels avoided in the initial stages of development, than it is to carve out new development on the urban fringe.

Based on these results it can be said that humans are *adjusting* to the risk of flooding in the human-ecological sense, but those adjustments are then modified by the further adjustment of the evolving economic utility of the risky locations. Seen through the Burton, Kates and White (1993) rubric, it is clear that the initial interaction with the natural risk of the floodplain results in avoidance. However, as the ability to control (structural mitigation) or offset (non-structural mitigation and economic utility) the natural risk of flooding has emerged, the interaction has shifted to one of occupancy. Our first impulse is to avoid the proliferation of the flood hazard, but the economic pressure of land development patterns ultimately overrides that impulse and pushes development into the riskier locations, thus increasing the overall flood hazard of the area. The fact that this has been a primarily residential phenomenon is important as well. Commercial land developers seem willing to plat the floodplain, but are not so quick to invest in improving those parcels. It is not until the non-floodplain parcels have been purchased and improved that we see individual landowners willing to incur the additional "costs" of locating in the floodplain. In other words, the fact that the risk, and costs (real or potential) associated with the risk, are being dispersed across a greater number of "managers" becomes key to the encroachment process.

The patterns above are apparent when floodplain development is observed in this expansion growth perspective. Clearly the floodplain represents a unique geography, in the sense that it is the location of second choice, and humans, in the course of developing their urban space, interact with it in unique ways. The next section of this chapter approaches this issue from the perspective of adjacent land development. In other words, once developed, do land parcels within the floodplain exhibit unique attributes?

Evidence of Adjustment Within the Floodplain

In order to test the degree to which parcels within the floodplain are unique in comparison to non-floodplain development, the means for land value, improvement value, and age of structures are compared to the means of the same values for a sample of parcels taken from a 100-meter buffer created around the cumulative 100- and 500-year FEMA flood zones. The values for both groups are subjected to a difference-of-means test. The analysis was run for all parcels together and then for residential and commercial parcels separately. In all three cases the statistical tests are run for three geographic divisions: all of Bexar County, above and below the Balcones Fault, and by SARA management basin. The results of the tests are presented in Tables 6.5, 6.7, and 6.9. Following each respective table is another table listing the actual means for groupings exhibiting a statistically significant relationship and a classification of *risk adjustment* or *utility adjustment* for that relationship (Tables 6.6, 6.8, and 6.10). The results of this analysis are not as uniform as those discussed above. Rather they illustrate an adjustment landscape that is highly varied across the county and among different types of parcels.

Tables 6.5 and 6.6 show results for all parcels (commercial and residential). These tables include all parcels with dates classified as commercial, residential, or farm and rural parcels. A number of significant relationships emerge for the analysis, however the results of the statistical tests are somewhat confounded by including all three types of parcels together. This becomes clear when the farm and rural parcels are dropped and commercial and residential parcels are analyzed separately in Tables 6.7-6.10. Table 6.5 and 6.6 do however provide as useful an illustration of the distribution of total parcels

Table 6.5. Inside vs. outside* floodplain, difference-of-means results for all parcels.

Unit		Land Value		Improvement Value		Age	
	N	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0
Full Set	52,206	.000	R**	.000	R	.000	R
Balcones Escarpment							
Above	31,046 (60%)	.000	R	.000	R	.136	A
Below	21,160 (40%)	.002	R	.000	R	.000	R
Basins							
Atascosa River	39 (.07%)	.822	A	.685	A	.869	A
Calaveras Creek	377 (.7%)	.001	R	.582	A	1.00	A
Cibolo Creek	818 (2%)	.007	R	.000	R	.000	R
Culebra Creek	3,362 (6%)	.000	R	.028	A	.000	R
Lower Leon Creek	3,738 (7%)	.574	A	.025	A	.000	R
Upper Leon Creek	4,083 (9%)	.000	R	.000	R	.000	R
Lower Salado Creek	9,073 (17%)	.000	R	.000	R	.024	A
Upper Salado Creek	6,070 (12%)	.127	A	.614	A	.478	A
Martinez Creek	4,225 (8%)	.000	R	.000	R	.029	A
Medina Creek	825 (2%)	.000	R	.243	A	.040	A
Medio Creek	1,453 (3%)	.003	R	.006	R	.000	R
Olmos Creek	4,068 (8%)	.007	R	.000	R	.835	A
San Antonio River	13,356 (26%)	.000	R	.719	A	.000	R

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100-meter buffer around current FEMA digital FIRMs.

** "R" indicates null hypothesis rejected (H_0 = parcels are drawn from the same population). "A" indicates H_0 accepted (there is no statistically significant difference between the mean ranks of the two groups).

Table 6.6. Inside vs. outside* floodplain, means for significant difference-of-means results for all parcels.

Unit	N	Land Value Mean (In/Out Floodplain)	RA/ UA**	Improvement Value Mean (In/Out Floodplain)	RA/ UA	Age Mean (In/Out Floodplain)	RA/ UA
Full Set	52,206	In – $32,347 Out – $24,833	UA	In – $98,273 Out – $87,311	UA	In – 32 Out – 30	UA
Balcones Escarpment							
Above	31,046 (60%)	In – $28,732 Out - $27,274	UA	In – $96,552 Out - $104,106	RA		
Below	21,160 (40%)	In – $37,493 Out - $21,205	UA	In – $100,722 Out - $62,349	UA	In – 44 Out – 40	UA
Basins							
Atascosa River	39 (.07%)						
Calaveras Creek	377 (.7%)	In - $22,873 Out - $23,779	RA				
Cibolo Creek	818 (2%)	In - $34,659 Out - $26,670	UA	In – $81,021 Out – $118,660	RA	In - 34 Out – 20	UA
Culebra Creek	3,362 (6%)	In - $17,239 Out - $14,366	UA			In – 13 Out - 19	RA
Lower Leon Creek	3,738 (7%)					In – 26 Out – 24	UA
Upper Leon Creek	4,803 (9%)	In - $16,070 Out - $22,145	RA	In – $63,729 Out – $97,080	RA	In - 19 Out – 16	UA
Lower Salado Creek	9,073 (17%)	In – $23,028 Out – $20,310	UA	In – $82,307 Out – $77,021	UA		
Upper Salado Creek	6,070 (12%)						
Martinez Creek	4,225 (8%)	In - $11,916 Out - $12,649	RA	In – $54,286 Out – $61,712	RA		
Medina Creek	825 (2%)	In - $32,985 Out - $20,559	UA				
Medio Creek	1,453 (3%)	In - $11,408 Out - $15,121	RA	In – $59,999 Out – $62,353	RA	In - 15 Out – 18	RA
Olmos Creek	4,068 (8%)	In - $52,394 Out - $51,307	RA	In – $183,935 Out – $151,342	UA		
San Antonio River	13,356 (26%)	In - $49,599 Out - $26,048	RA			In – 51 Out – 50	UA

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100-meter buffer around current FEMA digital FIRMs.

** RA = "risk-adjustment," UA = "utility-adjustment." See Figure 3.7 for explanation.

Table 6.7. Inside vs. outside* floodplain, difference-of-means results for residential parcels.

Unit		Land Value		Improvement Value		Age	
	N	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0
Full Set: Residential	46,224	.000	R**	.000	R	.000	R
Balcones Escarpment							
Above	28,832 (62%)	.000	R	.000	R	.003	R
Below	17,392 (38%)	.000	R	.000	R	.000	R
Basins							
Atascosa River	4 (.01%)	N/A	N/A	N/A	N/A	N/A	N/A
Calaveras Creek	16 (.03%)	N/A	N/A	N/A	N/A	N/A	N/A
Cibolo Creek	505 (1%)	.000	R	.000	R	.190	A
Culebra Creek	2,974 (6%)	.000	R	.066	A	.000	R
Lower Leon Creek	3,495 (8%)	.118	A	.018	A	.000	R
Upper Leon Creek	4,595 (10%)	.000	R	.000	R	.000	R
Lower Salado Creek	8,432 (18%)	.000	R	.000	R	.002	R
Upper Salado Creek	5,736 (12%)	.000	R	.0.38	A	.015	A
Martinez Creek	4,040 (9%)	.000	R	.000	R	.008	A
Medina Creek	25 (.05%)	.115	A	.338	A	.461	A
Medio Creek	1,399 (3%)	.003	R	.005	R	.000	R
Olmos Creek	3,748 (8%)	.000	R	.000	R	.247	A
San Antonio River	11,259 (24%)	.477	A	.000	R	.000	R

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100 meter buffer around current FEMA digital FIRMs.

** "R" indicates null hypothesis rejected (H_0 = parcels are drawn from the same population). "A" indicates H_0 accepted (there is no statistically significant difference between the mean ranks of the two groups).

Table 6.8. Inside vs. outside* floodplain, means for significant difference-of-means results for residential parcels.

Unit		Land Value		Improvement Value		Age	
	N	Mean (In/Out Floodplain)	RA/ UA**	Mean (In/Out Floodplain)	RA/ UA	Mean (In/Out Floodplain)	RA/ UA
Full Set: Residential	46,224	In – $12,620 Out – $15,419	RA	In – $56,826 Out – $68,669	RA	In – 31 Out – 30	UA
Balcones Escarpment							
Above	28,832 (62%)	In – $14,555 Out – $18,023	RA	In – $69,348 Out – $83,800	RA	In – 23 Out – 24	RA
Below	17,392 (38%)	In - $9,279 Out - $11,168	RA	In – $35,213 Out – $43,983	RA	In – 44 Out – 40	UA
Basins							
Atascosa River	4 (.01%)						
Calaveras Creek	16 (.03%)						
Cibolo Creek	505 (1%)	In – $36,259 Out - $23,076	UA	In – $191,001 Out - $133,627	UA		
Culebra Creek	2,974 (6%)	In – $11,985 Out - $11,408	UA			In – 11 Out – 17	RA
Lower Leon Creek	3,495 (8%)					In – 26 Out – 24	UA
Upper Leon Creek	4,595 (10%)	In – $11,787 Out - $18,090	RA	In – $61,848 Out - $94,129	RA	In – 19 Out – 16	UA
Lower Salado Creek	8,432 (18%)	In - $12,073 Out – $12,324	RA	In - $55,201 Out – $56,235	RA	In – 32 Out – 33	RA
Upper Salado Creek	5,736 (12%)	In – $23,840 Out - $25,690	RA				
Martinez Creek	4,040 (9%)	In – $9,123 Out - $10,623	RA	In – $53,232 Out - $58737	RA		
Medina Creek	25 (.05%)						
Medio Creek	1,399 (3%)	In – $9,577 Out - $10,331	RA	In – $59,090 Out - $57,686	UA	In – 14 Out – 18	RA
Olmos Creek	3,748 (8%)	In – $ 24,061 Out - $31,962	RA	In – $84,672 Out - $107,086	RA		
San Antonio River	11,259 (24%)			In – $31,246 Out - $32,700	RA	In – 53 Out – 51	UA

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100 meter buffer around current FEMA digital FIRMs.

** RA = "risk-adjustment," UA = "utility-adjustment." See Figure 3.7.

Table 6.9. Inside vs. outside* floodplain, difference-of-means results for commercial parcels.

Unit		Land Value		Improvement Value		Age	
	N	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0	Sig. (2-tailed)	H_0
Full Set: Commercial	3,524	.000	R**	.062	A	.000	R
Balcones Escarpment							
Above	1,452 (41%)	.001	R	.616	A	.008	A
Below	2,072 (59%)	.000	R	.525	A	.000	R
Basins							
Atascosa River	4 (.1%)	N/A	N/A	N/A	N/A	N/A	N/A
Calaveras Creek	12 (.3%)	N/A	N/A	N/A	N/A	N/A	N/A
Cibolo Creek	37 (1%)	.486	A	.429	A	.567	A
Culebra Creek	88 (3%)	.143	A	.308	A	.673	A
Lower Leon Creek	166 (5%)	.996	A	.923	A	.334	A
Upper Leon Creek	100 (3%)	.451	A	.103	A	.002	R
Lower Salado Creek	537 (15%)	.833	A	.058	A	.136	A
Upper Salado Creek	279 (8%)	.000	R	.002	R	.000	R
Martinez Creek	72 (2%)	.432	A	.119	A	.867	A
Medina Creek	39 (1%)	.696	A	.828	A	.553	A
Medio Creek	22 (.6%)	.837	A	.652	A	.026	A
Olmos Creek	304 (9%)	.014	A	.644	A	.256	A
San Antonio River	1863 (53%)	.000	R	.704	A	.000	R

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100-meter buffer around current FEMA digital FIRMs.

** "R" indicates null hypothesis rejected (H_0 = parcels are drawn from the same population). "A" indicates H_0 accepted (there is no statistically significant difference between the mean ranks of the two groups).

Table 6.10. Inside vs. outside* floodplain, means for significant difference-of-means results for commercial parcels.

Unit		Land Value		Improvement Value		Age	
	N	Mean (In/Out Floodplain)	RA/ UA**	Mean (In/Out Floodplain)	RA/ UA	Mean (In/Out Floodplain)	RA/ UA
Full Set: Commercial	3,524	In – $204,910 Out – $176,182	UA			In – 37 Out – 31	UA
Balcones Escarpment							
Above	1,452 (41%)	In – $247,031 Out – $220,824	UA				
Below	2,072 (59%)	In – $183,381 Out – $137,152	UA			In – 44 Out – 40	UA
Basins							
Atascosa River	4 (.1%)						
Calaveras Creek	12 (.3%)						
Cibolo Creek	37 (1%)						
Culebra Creek	88 (3%)						
Lower Leon Creek	166 (5%)						
Upper Leon Creek	100 (3%)					In – 23 Out – 17	UA
Lower Salado Creek	537 (15%)						
Upper Salado Creek	279 (8%)	In – $347,314 Out – $176,847	UA	In – $744,393 Out – $503,931	UA	In – 20 Out – 14	UA
Martinez Creek	72 (2%)						
Medina Creek	39 (1%)						
Medio Creek	22 (.6%)						
Olmos Creek	304 (9%)						
San Antonio River	1863 (53%)	In – $203,654 Out – $162,939	UA			In – 46 Out – 41	UA

* "Inside" includes all parcels within the 100-year and 500-year zones on current FEMA digital FIRMs. "Outside" includes all parcels located within a 100 meter buffer around current FEMA digital FIRMs.

** RA = "risk-adjustment," UA = "utility-adjustment." See Figure 3.7.

within Bexar County. In these tables there is a definite bias toward development above the Balcones Fault line (60% above, 40% below). When disaggregated into residential and commercial groups however, it becomes clear that this bias is being supported primarily by residential and farm and rural parcels, as the relationship for commercial development alone is the exact opposite (41% above, 59% below). This makes sense as early commercial development in San Antonio was focused on the CBD and adjacent areas below the headwaters of the San Antonio River. This is also an artifact of the ranch to residence transition that is occurring to much of the Hill Country land use in this region. These tables also support the overall concentric development patterns of Bexar County as the bulk of developed parcels can be found in the San Antonio River basin and its immediate tributary basins to the east and west, Salado Creek basin and Leon Creek basin respectively. These areas have undergone the most extensive development historically, with the perimeter basins being the most recent recipients of land development. The risk/utility adjustment results are varied across the entire county and among spatial units in these tables. The underlying trends supporting this variability become clearer when the parcels are analyzed by commercial/residential type.

Tables 6.9 and 6.10 show results for the commercial parcel analysis. For all statistically significant results the relationship is one of utility adjustment. When compared to the results for the residential parcels, it is obvious that the strong utility adjustment trends of the commercial parcels were skewing the residential relationships. When analyzed as the full set and above/below the Balcones Fault, commercial land values within the floodplain are significantly higher than those in areas adjacent to the floodplain. Overall commercial land values are higher above the fault than below. To some degree this can probably be attributed to the higher costs of construction in the karst topography and the preferred access to the higher value residential regions above the fault. However it can be said that commercial landowners appear willing to pay a premium for locating within the floodplain. When viewed at a basin-by-basin scale, this relationship does not hold up across the entire county. It does, however, in the San Antonio River basin and the Upper Salado Creek basin. The significant relationship in the San Antonio River basin can be explained by the dominance of the CBD. Early commercial development in San Antonio definitely focused on river access and, as is underscored by the fact that today the Riverwalk tourist development winds throughout the CBD, these patterns have persisted even as land development has expanded across the county.

The Upper Salado Creek basin hosts an area of development that could be labeled as San Antonio's first "edge city." This basin contains the intersection of IH 35 with Loop 410 and part of the intersections of IH 35 with Loop 1604. As development as been pulled up the IH 35 corridor toward towns like Sealy, New Braunfels and Schertz, this area has emerged as a new commercial residential hub within Bexar County and Guadalupe County to the northeast. The most dramatic example of this may be Universal City that has been all but swallowed by San Antonio expansion up the IH 35 corridor in recent years. One interesting possibility here is that as residential areas have sprung up in this area in recent years, the secondary stage of occupation that was seen in the concentric development analysis is being engaged in by the commercial services that inevitably follow successful residential development. Stated differently, the first impulse of residential development is to located outside the floodplain, while the secondary development of commercial interests are left to occupy the more risky locations, at least in this newer area of development. Interestingly only the Upper Salado Creek results indicate a significant relationship for improvement value. Whether this is the result of the type of commercial businesses (retail/service) that tend to locate in this area or the result of flood-risk capitalization is not clear from this analysis. However the difference in the mean value of inside ($744, 393) versus outside ($501, 931) is substantial, indicating that commercial developers are not only willing to pay a premium for land in Salado Creek basin, but also have the tendency to invest more extensively in the structures they place there.

The results for both the commercial and residential analysis relating to age of structure are problematic. Although some residential areas exhibit a risk adjustment (older structure outside the floodplain) both data sets host a number of significant relationships indicating a utility adjustment (older ages in the floodplain). On the surface this contradicts the results of the expansion development analysis discussed earlier, whereby the first stage of development tended to be outside the floodplain and the second inside. Two possible explanations for this are offered. The first is simply that the concentric analysis is run on average centroid-to-Alamo distances. It may be that although the overall trend is to locate outside the floodplain first, the adjacent results are accurate for those specific basins where the relationship indicates a tendency for older development in the floodplain and these spatial nuances are not being picked up in the concentric analysis. Secondly, it is proposed that it may be an artifact of the total land space available for development inside versus outside the floodplain. Although the first impulse of development may be to build outside the floodplain, with the subsequent stages being extended into the floodplain, the total land area outside the floodplain is much greater. Therefore as infill continues in both regions, the opportunity to build in the floodplain is reduced faster than outside (land once occupied in the floodplain is no longer available for infilling). Thus the overall effect of recent infill has been to lower the mean age of parcel development in the outside data set, even though the initial patterns of occupation may well have matched the patterns of the concentric analysis. Even with these caveats in mind, it can be said that the results of the full commercial parcel tests indicate a slight tendency for older structures to be in the floodplain. This relationship remains statistically significant for the below the fault subgroup. Further it holds up for three of the basin subgroups. These are the San Antonio River basin (hosting San Antonio's original river-focused development), the Upper Salado Creek basin (the focus of the IH 35 edge city discussed above), and the Upper Leon Creek basin that has also undergone heavy development. In the case of the latter two, these results are most likely tied to the infill process described above.

For those instances where older residential parcels exhibit a tendency to be in the floodplain, it is proposed that they too are artifacts of the shear bulk of infilling that has taken place in areas outside the floodplain. The one exception to this may again be the San Antonio River basin where settlement patterns for the early period of urban development still persist. It is also worth noting that the highlighted age differences, although statistically significant, are very slight. Focusing on the attributes of land and improvement value for the residential data set, a number of significant and varied relationships emerge. For the full set, both the land value and improvement values are significantly different for those values to represent a risk adjustment (higher values outside the floodplain). This is the opposite trend from the commercial parcel analysis, indicating that the risk and utility pressures of the floodplain manifest differently for the two types of landowners. When disaggregated into the above- and below-the-fault groups, the relationship holds for both values in both locations. It is interesting that overall the land values above the fault are higher and the improvement values are substantially higher. This underscores the previous discussion of the residential landowners' preference for the Hill Country landscape over the coastal plain area. In other words, regardless of being inside or outside the floodplain residential landowners are clearly willing to pay a premium to live "on the hill."

Residential parcels exhibit statistically significant differences in land and improvement values for many of the basin subgroups. The majority of these are indicative of a risk adjustment, with those locations outside the floodplain being more valued among the available parcels. There are at least two possible explanations for this. First, this relationship matches the concentric analysis results with the older more established areas outside the floodplain exhibiting higher values. In other words, parcels in the floodplain are most likely in areas still undergoing earlier stages of development and infilling, thus they do not yet exhibit their highest potential values. The other possible explanation for this is the simple fact that land outside the floodplain is more valued because it is theoretically beyond the reach of future flooding. In either case, the premise posed by past research in this topic that the economic risk of locating in the floodplain should be capitalized in land and improvement values (Montz 1987, Montz 1993, Montz and Tobin 1988) is not being illustrated on this landscape.

This premise may however be emerging in the areas of Bexar County undergoing more recent development. The few exceptions to the risk adjustment trend among the residential basin subgroups can be found in the Cibolo Creek, Culebra Creek, and Medio Creek basins. It may be that in these more recently developed areas the risk, and the awareness of the risk, of locating in the floodplain is finally appearing in the cost of the structures located in the floodplain. Whether these higher costs are the results of the requirement to purchase additional insurance, the necessity to engage in small-scale structural mitigation in the form of raising structures above FEMA's Base Flood Elevation (BFE), or just the market's response to the privilege of having a house within the riverine environment is not clear from this analysis. However, these results bode well for the future of floodplain development in that there may at least be an emerging trend to make locating in the floodplain costlier.

The counterpoint to this argument is twofold. First, there are obviously many developed parcels well within the existing floodplain and overall they are currently less expensive to own. This means that, economically speaking, they remain an attractive option for many future San Antonio residents. Also, there exist many "no date" parcels in all of the management basins; infilling in the more established areas of development may very likely continue to support the trend of pushing additional development into the floodplain. This trend can obviously be countered through city- and county-wide zoning efforts, but with few exceptions, this is not currently the policy. There are some areas that have been designated by FEMA as "floodways," meaning that no new development is to be allowed. And there is the new buyout program that is being applied in certain portions of the city. However conversations with Bexar County Appraisal representatives have yielded at least anecdotal evidence that, despite these disincentives, it remains relatively easy for land developers to qualify for both city and county approval by making less than heroic efforts to modify the landscape and meet BFE requirements.

The second counter to the idea that things are getting better has to do with the relationship between land development and runoff rates. If land development is currently crowding in on the floodplain but not encroaching completely into the existing flood zones (again because of perceived risk of doing so), the end result will be to increase runoff rates in future flood events because of the increase in impermeable ground cover. Thus making a risk adjustment decision by locating *adjacent* to the flood zone today may equate to *being* in the flood zone tomorrow. In either case it is clear that the overall trend in residential development has been, at least historically, to value outside floodplain development more than inside development. For commercial development the trend is just the opposite, or at least the trend toward capitalizing the risk of floodplain locations is just the opposite. In both cases it can be said that based on these results the floodplain again exhibits a unique geography within the larger urban area.

Summary

This chapter has presented the results of various difference-of-means tests relating to the hypothesis that floodplains represent unique geographies within the larger urban fabric of San Antonio and Bexar County. The first section discussed the data matrix of all parcels within Bexar County grouped by decade, date of development, floodplain location, and type of parcel use. These results indicated that although there is some evidence of floodplain adjustment in the earliest years of settlement, there are no distinct periods in which there occurred a dramatic shift away from or toward the floodplain, at least at this scale. There was however a slight trend for the percentage of commercial parcels within the floodplain to decrease and the percentage of residential parcels to increase in recent years.

The second section presented results of the analysis of the expansion of San Antonio's urban area by decade. Difference-of-means tests were applied to the mean distance to the Alamo of each centroid within each decade for parcels grouped within and outside the floodplain. These tests indicated a strong overall tendency to develop parcels outside the floodplain first, with secondary development following into the floodplain. It is proposed that this is the result of a combination of risk avoidance in the first instance that is overwhelmed by the economics of land development in the second.

The third section of this chapter presented results of analysis of the adjacent development patterns of parcels inside the floodplain versus those in a 100-meter buffer around the floodplain. Difference-of-means tests were run for three cadastral attributes: land value, improvement value, and age of structure. Data sets included all residential and commercial parcels, as well as the geographic subdivisions of above and below the Balcones Fault line and among the thirteen SARA management basins. Overall the tendency was for commercial parcels to exhibit a utility adjustment (higher values in the floodplain) and for residential parcels to exhibit a risk adjustment (higher values outside the floodplain), indicating that the risk of locating in the floodplain is internalized differently depending on the intended use of the parcel. Lastly, explanations were offered for those instances where statistically significant results did not match the overall trends.

The final analytical chapter which follows will expand the search for unique geographies resulting from the influence of flood hazard by examining the degree to which tract-level census geography for Bexar County reflects unique spatial patterns for areas where certain structural and non-structural flood control measures have been applied. The goal is to illustrate not only the contemporary patterns, but also the degree to which change-over-time attributes reflect statistically significant differences among "managed" census tracts versus "unmanaged" tracts.

CHAPTER 7

THE GEOGRAPHY OF BEXAR COUNTY FLOOD MITIGATION PROJECTS

Overview

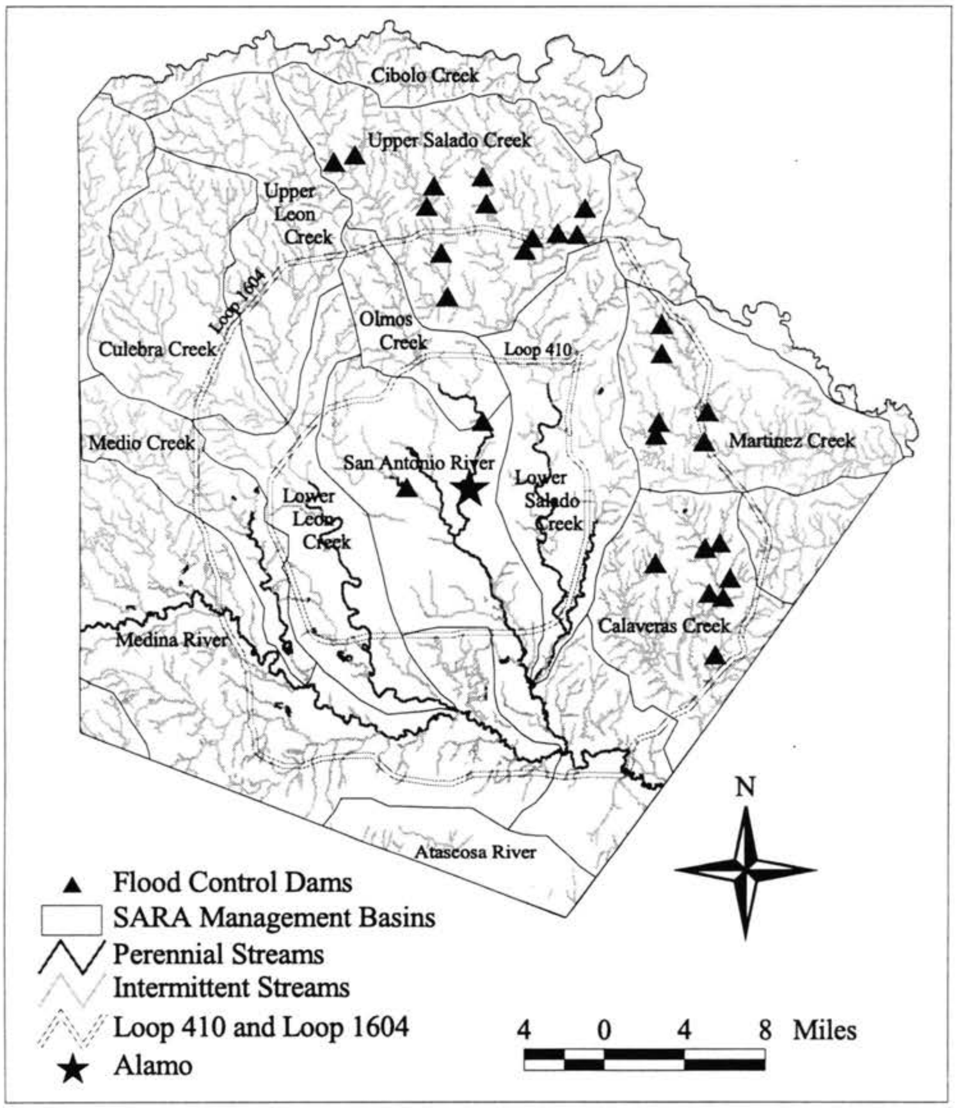
Prior chapters have explored the history of floodplain management and the quantitative evidence of floodplain adjustment on the part of urban land development. This chapter extends the search for unique urban geographies associated with flood hazard beyond the immediate sway of the floodplain. This is accomplished by examining urban census geography at the census-tract scale. Census data from 1970, 1980, and 1990 are used to produce three distinct discussions of San Antonio's urban geography. The occurrence of two forms of flood hazard mitigation, flood control dams and property buyouts, are then compared to these urban geographies to illustrate the degree to which each influences, or at least coincides spatially with, unique social-spatial patterns.

Following a discussion of the geography of flood control dams and property buyouts in Bexar County, the results of each analysis are presented in three subsections. First a cluster technique is employed to generate an agglomerative social landscape that illustrates the general social and economic geography of San Antonio. Second, difference-of-means analysis of 1990 census data compares those tracts with these mitigation techniques employed to those without them. The third subsection presents the results of time-change analysis using measurements of velocity and acceleration in addition to net change. These measurements are also subjected to a difference-of-means analysis for tracts with the two forms of mitigation versus those without.

The Geography of Dams and Buyouts

Two forms of flood hazard mitigation have been selected for this analysis. The first, a structural mitigation option, is the flood-control dam. According to the United States Army Corps of Engineers there are sixty-two dams in Bexar County as of 2000 (Table 3.1) (United States Army Corps of Engineers 2000). Of these, twenty-six are considered to be exclusively for the purpose of flood control, with two additional dams being used for a combination of flood control, recreation, and water supply. These twenty-eight dams are included in this analysis (Figure 7.1). These dams are also classified as “High Hazard” dams, indicating that if they failed, there would likely be a loss of life in areas below the dam. This in and of itself illustrates the degree to which dam building and land development co-occupy Bexar County’s urban landscape. It does not however provide any measurement of the degree to which these developed areas surrounding these structures may be unique when compared to other developed areas of the county. As Table 3.1 and Figure 7.1 illustrate, these structures are located primarily in the east and northeast sections of the county, within the Upper Salado Creek, Martinez Creek, and Calaveras Creek basins. The majority (20) of the dams were built from 1960-1979; during the same time period that residential and commercial developments were extended into these outer reaches of the county. Which of these two phenomena constitute the “chicken” and which the “egg” is not being directly analyzed here. However, it is clear the two are spatially symbiotic. What is being examined is the degree

Figure 7.1. Bexar County flood control dams.



to which those census tracts that have been the beneficiary of flood control dams possess distinct census geographies.

The second type of flood hazard mitigation employed in this chapter, euphemistically referred to as non-structural, is the property buyout program, which has become popular in recent years. This program is supported by FEMA and is designed to enable cities and other municipal subdivisions to purchase property and structures that experience repeated damage from flooding. As much as 75% of the costs of purchasing these properties is funded by FEMA (with federal dollars), although the local municipal entity manages the purchase negotiation and the property selection. Geographic data acquired from the City of San Antonio and Bexar County reveal locations of residential properties purchased through this program following the 1998 flood. These data, acquired in early 2001, represent only those properties that had been purchased at that time. For the City of San Antonio data set included only properties purchased under the buyout program. The Bexar County data included residential properties that the county has purchased since the 1998 flood. Whether they were bought with FEMA's help or exclusively with county funds is not clear for each site. Nonetheless, they represent a good sample of the application of this flood hazard mitigation technique employed by the county.

Figure 7.2 shows the spatial distribution of the property buyouts for both Bexar County and the City of San Antonio. This mitigation technique is obviously primarily applied in the older urbanized areas of the city, as well as in select areas outside the city. Table 7.1 provides a comparison of the buyout parcels with all Bexar County parcels, all residential parcels, and all undeveloped (no date) parcels as well as a breakdown of

Figure 7.2. City of San Antonio and Bexar County buyout parcels.

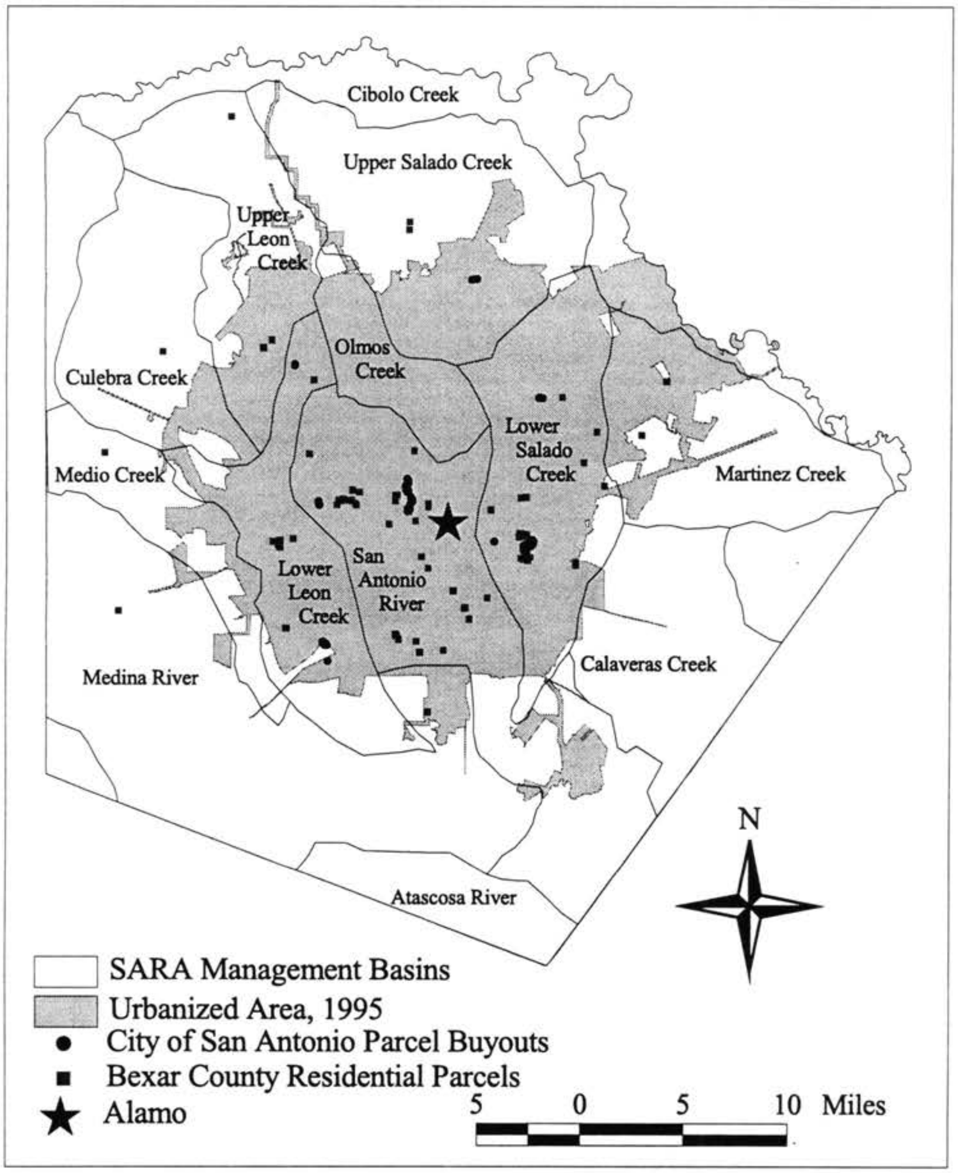


Table 7.1. All parcels and buyout parcels comparison.

	All Parcels With Dates		Residential Parcels With Dates		City of San Antonio Buyout Parcels		Bexar County Residential Parcels		Undeveloped Residential Parcels in Floodplain	
N	353,124		323,327		257		103		3,858	
Mean Age of Improvements	35 yrs		35 yrs		48 yrs		52yrs		N/A	
Mean Land Value	$21,337		$13,487		$7,179		N/A*		$8,827	
Mean Improvement Value	$77,646		$59,914		$17,044		N/A*		N/A	
Basin	N	%	N		N	%	N	%	N	%
Atascosa River	992	.3%	0							
Calaveras Creek	2,343	.7%	263	08%					4	1%
Cibolo Creek	5,576	2%	4232	1%					53	1%
Culebra Creek	17,366	5%	16428	5%			1	1%	454	12%
Martinez Creek	20,196	6%	19082	6%			2	2%	95	2%
Medina River	5,129	2%	1711	5%			2	2%	37	1%
Medio Creek	12,485	4%	12222	4%			1	1%	58	2%
Olmos Creek	29,227	8%	27450	9%					128	3%
San Antonio River	115,445	33%	105845	33%	87	34%	35	34%	1052	27%
Lower Leon Creek	27,642	8%	26236	8%	22	9%	11	11%	278	7%
Upper Leon Creek	19,562	6%	18615	6%			4	4%	387	10%
Lower Salado Creek	63,049	18%	59579	18%	145	56%	45	44%	809	21%
Upper Salado Creek	33,330	9%	31696	10%	3	1%	2	2%	503	13%
Outside Basins	782	.2%	1							

* Only sixteen of the Bexar County parcels have retained their age, and only three have retained land and improvement values, as of the August 2000 Bexar County appraisal records.

buyout parcels by SARA basin. A simple comparison of the means for land value, improvement value, and age of structure for these groups shows that buyout parcels are generally in older neighborhoods with substantially lower land and improvement values. The programmatic criterion for which parcels are purchased is that they should be parcels that have experienced repeated flooding in recent years.

The local criteria applied beyond this were not made available in any of the documentation received along with the data, nor did representatives from either entity readily offer them. However, from the data in Table 7.1 it can be assumed that one of two approaches is being taken. An altruistic interpretation is that the cheapest parcels are being purchased in order to maximize the number of residents being removed from the floodplain. A more pessimistic interpretation is that these parcels provide the least amount of revenue for the municipal entities that manage them. In other words, it is clear from Table 7.1 and from previous discussions in chapter seven that undeveloped parcels in the floodplain are located primarily in the higher land value area of the county. The mean land value of the undeveloped parcels is nearly nine thousand dollars for parcels that are, at best, in emerging neighborhoods, yet the mean land value for City of San Antonio buyout parcels in established residential areas, is just over seven thousand. Whether there is a conscious effort to discriminate is not at all clear. However it cannot be ignored that the trend of buying out older, cheaper homes while leaving "pre-developed" space for newer, ostensibly more expensive, homes has the effect of leaving the option open for higher taxed homes to be built in the newly developed, suburban flood zones at the same time that lower taxed homes are being removed from the "inner urban" flood zones. The next sections offer further illustrations of the extent to which the spatial occurrence of both dams and buyouts are coincident with specific socioeconomic patterns.

Census Clusters

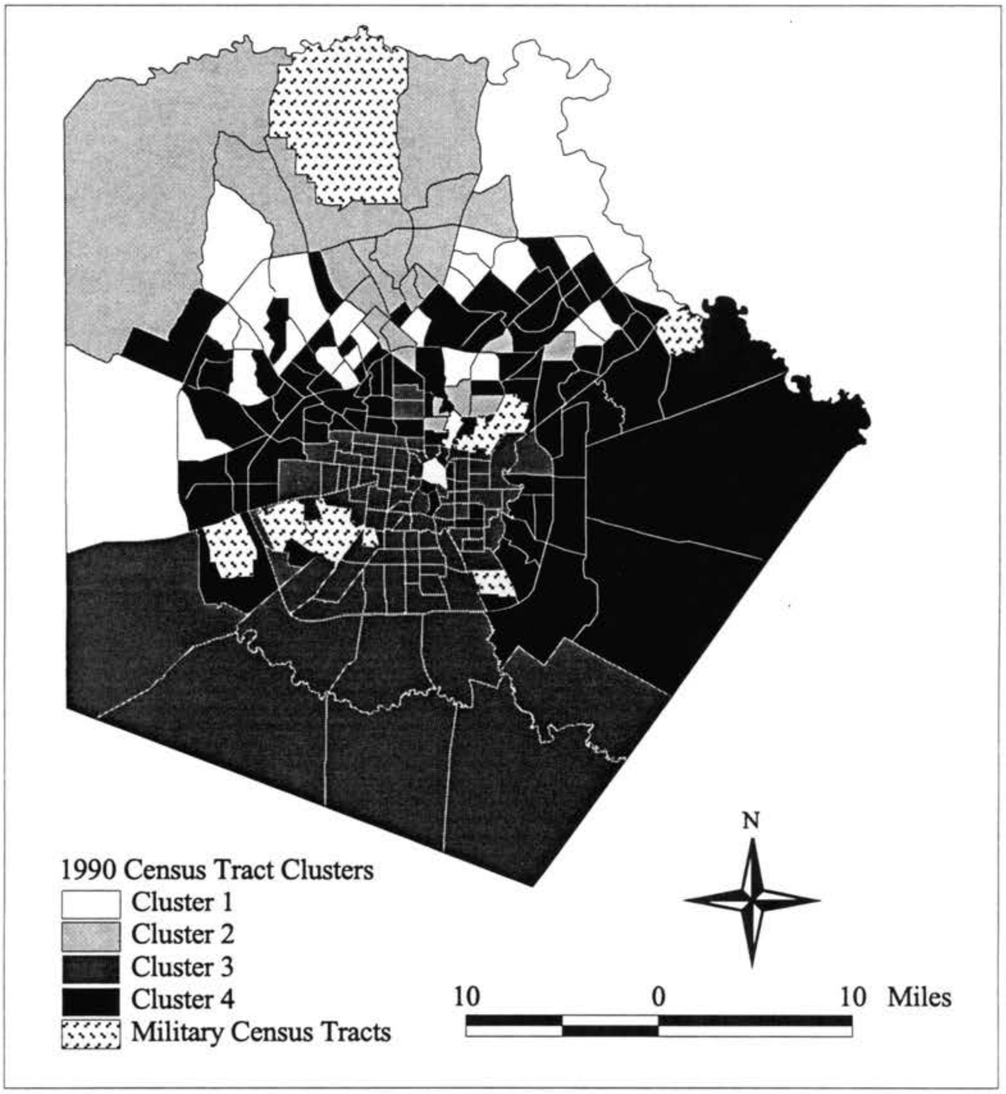
One approach to exploring the socioeconomic geography of mitigation in Bexar County is to provide a generalized illustration of the human landscape, upon which these mitigation techniques are applied. In other words, although numerous statistical attributes can be acquired from the census, it is how these attributes agglomerate, or cluster, in space that best describes that overall socioeconomic geography of the urban area. To this end a K-means cluster analysis was conducted on the census attributes described in Table 3.2. This is a "Q-mode" technique, which is to say that it is used when one seeks to explore how cases (in this situation census tracts), rather then attributes, cluster based on their characteristics. Four clusters were identified from this analysis. Descriptions of each, as well as indications of the distribution of each census attribute within each cluster, are provided in Table 7.2. The terms high, median, and low relate to the distribution of standardized values of the attributes within that cluster group. In other words, an indication of "high" means that the z-score values for that census attribute tended to be above the mean for that group, "median" means they tended to be centered on the mean, and "low" means they tended to be below the mean. It is through the examination of the tendencies of these standardized values that the description of the distinct clusters is generated.

Figure 7.3 is a map of 1990 Bexar County census tracts classed by their corresponding cluster in Table 7.2. It is clear from this illustration that there is a distinct

Table 7.2. 1990 Bexar County census tract cluster descriptions.

1		2		3		4	
N=28		N=22		N=85		N=82	
Description:		Description:		Description:		Description:	
White, higher-income singles/couples living in newer homes. Area has undergone recent suburban development.		White, higher-income population undergoing rural/ranch depopulation in transition to suburban development.		Hispanic and African-American, lower-income families in ageing urban/suburban neighborhoods.		White with Black and Other, middle-income, working families. Living in established suburban neighborhoods experiencing in-fill.	
Attributes.		Attributes:		Attributes:		Attributes	
Low	Density	Low	Density	High	Density	Median	Density
Median	Population	Low	Population	Median	Population	Median	Population
High	% White	High	% White	Low	% White	High	% White
Low	% Black	Low	% Black	Median	% Black	Median	% Black
Median	% Other	Median	% Other	Low	% Other	High	% Other
Low	% Hispanic	Low	% Hispanic	High	% Hispanic	Low	% Hispanic
High	Family $	High	Family $	Low	Family $	Median	Family $
Low	Over 60	High	Over 60	Median	Over 60	Low	Over 60
Low	Under 14	Low	Under 14	High	Under 14	Median	Under 14
High	% Employed	High	% Employed	Low	% Employed	High	% Employed
Median	% Occ Hs	High	% Occ Hs	Median	% Occ Hs	Median	% Occ Hs
High	Ave Hs $	High	Ave Hs $	Low	Ave Hs $	High	Ave Hs $
Low	Ave Age	Low	Ave Age	High	Ave Age	Median	Ave Age

Figure 7.3. Bexar County 1990 census tract clusters.



geography to the socioeconomic characteristics of Bexar County residents. Cluster one includes tracts that are predominately white, with middle-aged populations and newer homes. These form a northeast to southwest line of suburban transition in the northern section of the county. This area has been heavily suburbanized with low-density housing, but only in recent years, and therefore tends to host wealthier populations with higher value housing. Cluster two includes tracts in the same general region of the county, many of which are in earlier stages of ranch-to-suburban transition. They therefore exhibit slightly older populations, but a similar racial/ethnic and economic demographic. Cluster four includes the predominately minority sections of the county and the inner urban area. Higher percentages of San Antonio's Black and Hispanic populations, lower housing and income values, and a higher percentage of children characterize this cluster. Cluster four encompasses the eastern central section of the county and the inner-suburban ring of slightly older residential development that is spatially coincident with Loop 410. This area represents the more thoroughly developed, middle-class residential area of town and includes the edge-city along the IH35 corridor reaching into Guadalupe County to the northeast. The demographic of this cluster is middle-income, generally white, but with slightly higher percentages of Black and other minority populations. The age distributions are indicative of middle-aged adults with children, or families, as well.

Table 7.3 shows the distribution of flood control dams and buyout parcels by cluster. Cluster four hosts the largest contingency of dams (14%), although most of these were built in the earlier stages of dam building in the county. Clusters one and two, the younger, higher property value region the county has been the beneficiary of more recent dam building. This further underscores the spatial and temporal coincidence of dams and

Table 7.3. Flood control dams and property buyouts by 1990 census clusters.

Census Cluster	Dams N=28 (%)	Dams by Year Completed: Prior to 1936	1948-1959	1960-1969	1970-1979	1980-1989	1990-1999	City of San Antonio Buyouts N=258 (%)	Bexar County Residential Floodplain Parcels N=103 (%)
1	4 (14%)				3		1	5 (8%)	1 (1%)
2	7 (25%)				6	1		0	5 (5%)
3	1 (4%)			1				226 (88%)	79 (77%)
4	14 (50%)	1	7	6				27 (10%)	18 (17%)
Military Census Tracts	2 (3%)				2				

residential development as the general suburbanization trend in the county has shifted from cluster four to clusters one and two over the last few decades. This is also characteristic of the suburbanization trend from below and along the Balcones Fault line to well above it over recent years.

Buyout parcels exhibit a much different geography. The vast majority of buyouts can be found in cluster three, or the high minority, low-income region of the county. Cluster three, which again represents an urban developmental middle ground between cluster four and clusters one and two, hosts nearly all of the remaining buyout parcels. Again, the trend is for flood hazard mitigation funds to be spent on supporting residential development of the floodplain in newer, higher income (and predominately white) areas of the county, while mitigation funds expended on the lower-income, minority sections of the county are being spent, at least in very recent years, on tearing down houses and clearing the floodplain. It is worth pointing out that a portion of cluster four in the San Antonio River floodplain has, in the past, received structural flood mitigation through the San Antonio Channel Improvement Project. However, those areas are rather limited in comparison to the total floodplain acreage within the cluster. Again, these data do not shed light directly on the procedural intent of the various mitigation projects employed across the county. They do however indicate a distinct geographic difference in the areas receiving the two different techniques.

Difference-of-Means for 1990 Attributes

The next step was to provide some statistical evidence for the geographic differences observed above. To this end a difference-of-means test was applied to census tract attributes comparing tracts with and without flood control dams and with and without buyout parcels. Only four of the census tract attributes from Table 3.2 indicated a statistically significant difference among tracts with dams versus those without dams. These results are presented in Table 7.4 and maps of each significant census attribute are presented in Figures 7.4, 7.5, 7.6, and 7.7. Tracts with dams exhibit a much higher percentage of white population and a much lower percentage of Hispanic population. Additionally, families in tracts with dams had a substantially higher income, by almost 60% percent, as of the 1990 census, and median housing values in tracts with dams were over twice the median of those without.

No census tracts, with City of San Antonio buyouts parcels, exhibited statistically significant differences among the selected census attributes when compared to tracts without City of San Antonio buyouts. However, Bexar County buyouts did produce significant difference among three of the census attributes. These are presented in Table 7.5. Tracts with Bexar County buyouts tended to have much lower percentages of white population, slightly lower median family incomes, and a lower median value of housing. These tests once again, provide evidence to support the premise that there are unique urban geographies to the occurrence of flood hazard mitigation within Bexar County.

Time-Change Geography

Further examination of the unique geographies of flood hazard mitigation within Bexar County were sought by examining time-change characteristics of census attributes from 1970, 1980, and 1990 at the tract level. In order to measure change over time within census tracts from the three periods consistent spatial units had to be created. This was

Table 7.4. Flood control dams: Significant difference-of-means among census tract attributes.

N=217	Mean With Dams N=16	Mean Without Dams N=201	Mann-Whitney Sig. (2-tailed)
% of Population White	72%	39%	.000
% of Population Hispanic	23%	52%	.000
Median Family Income	$46,089.63	$29,059.26	.000
Median Value of Housing	$121,843.75	$60,643.28	.001

Figure 7.4. Percent population white, 1990.

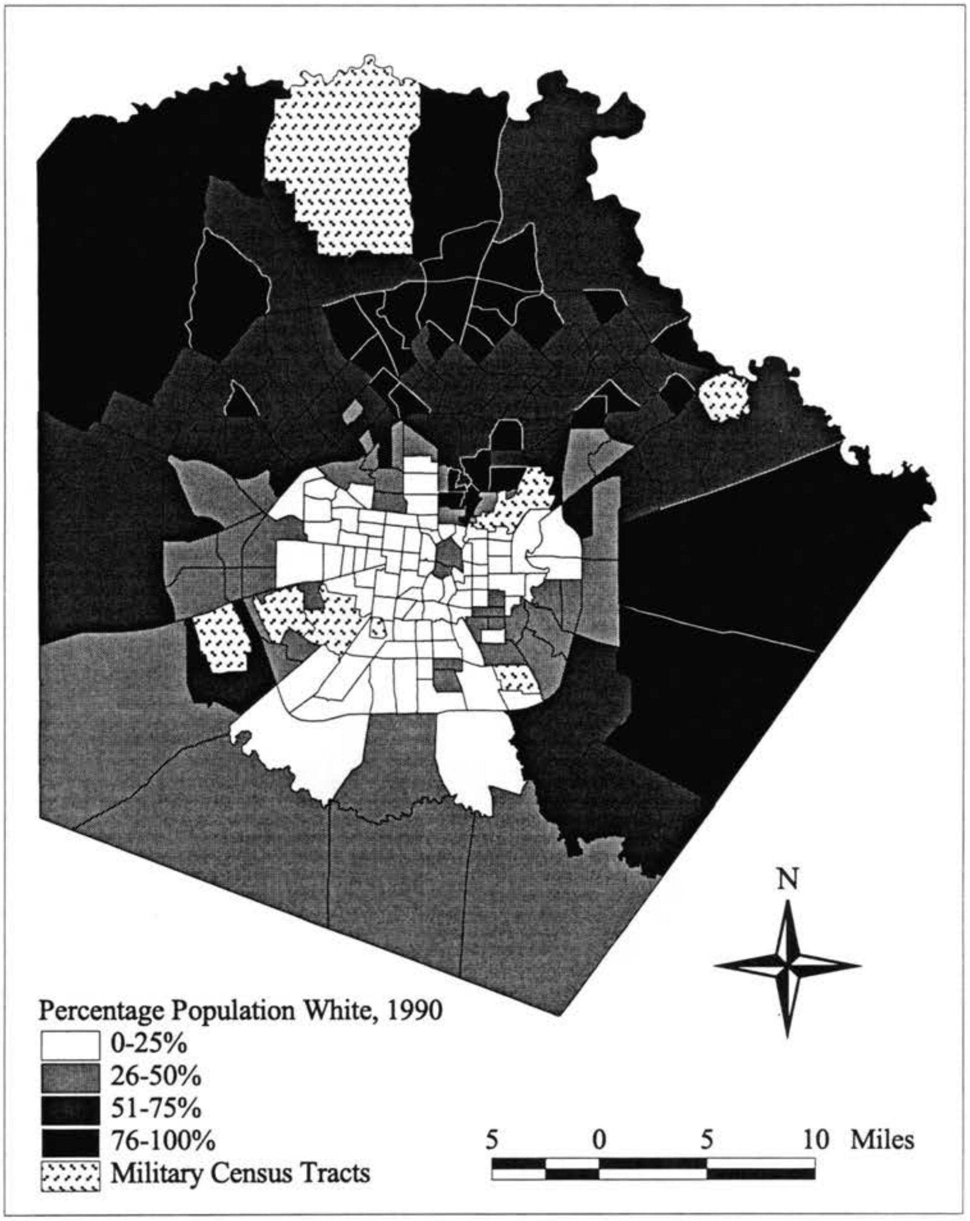


Figure 7.5. Percent population Hispanic, 1990.

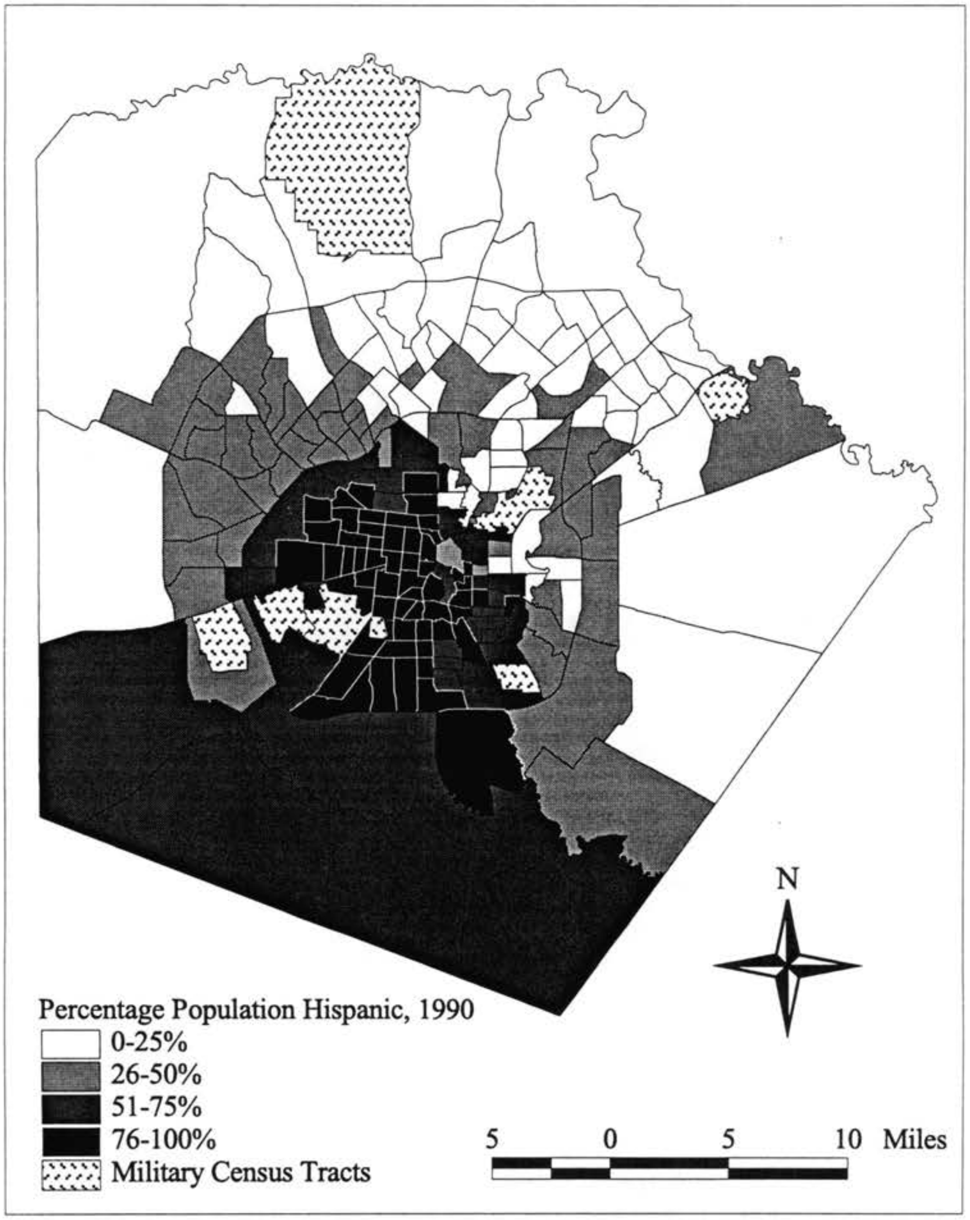


Figure 7.6. Median family income, 1990.

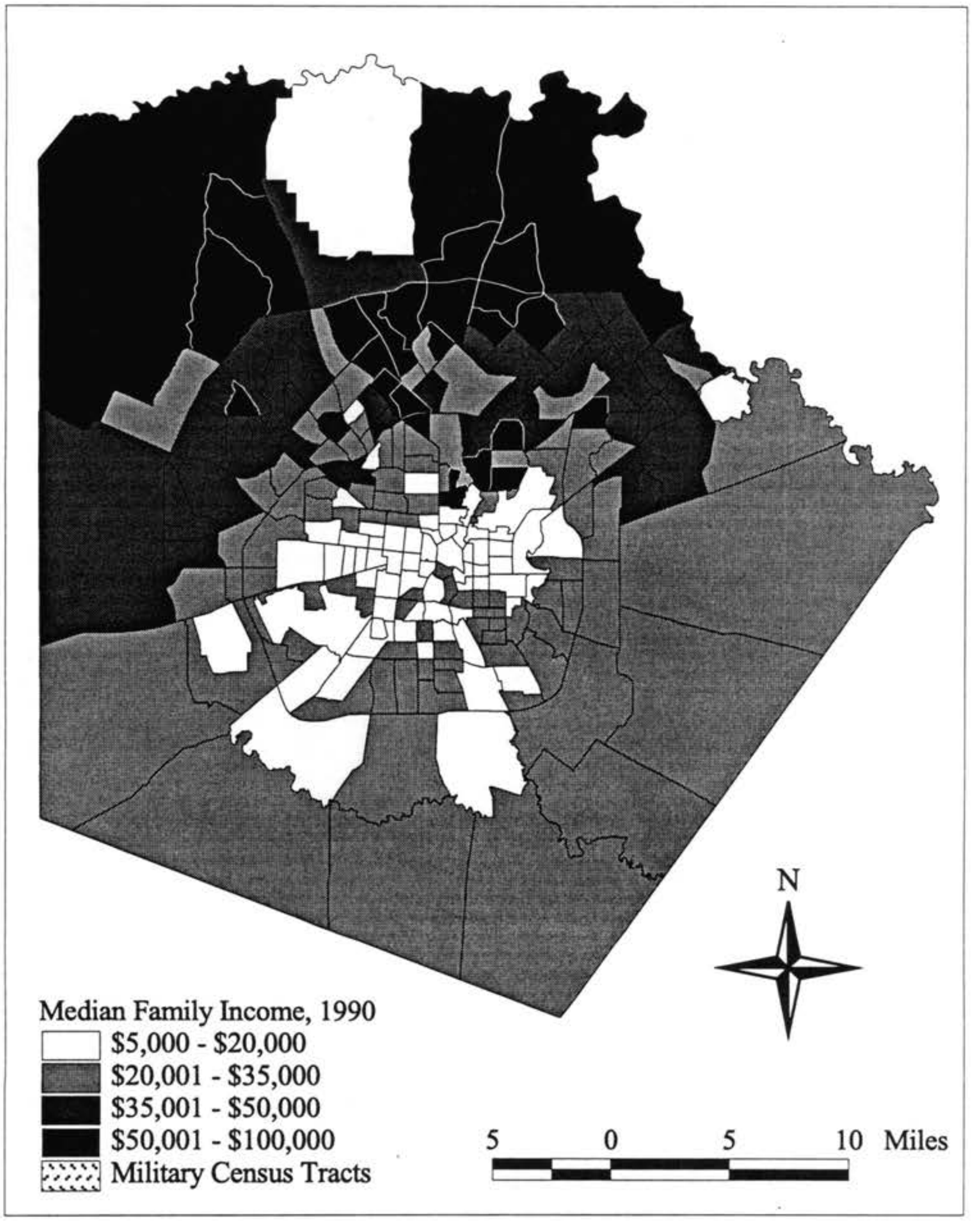


Figure 7.7. Median value of housing, 1990.

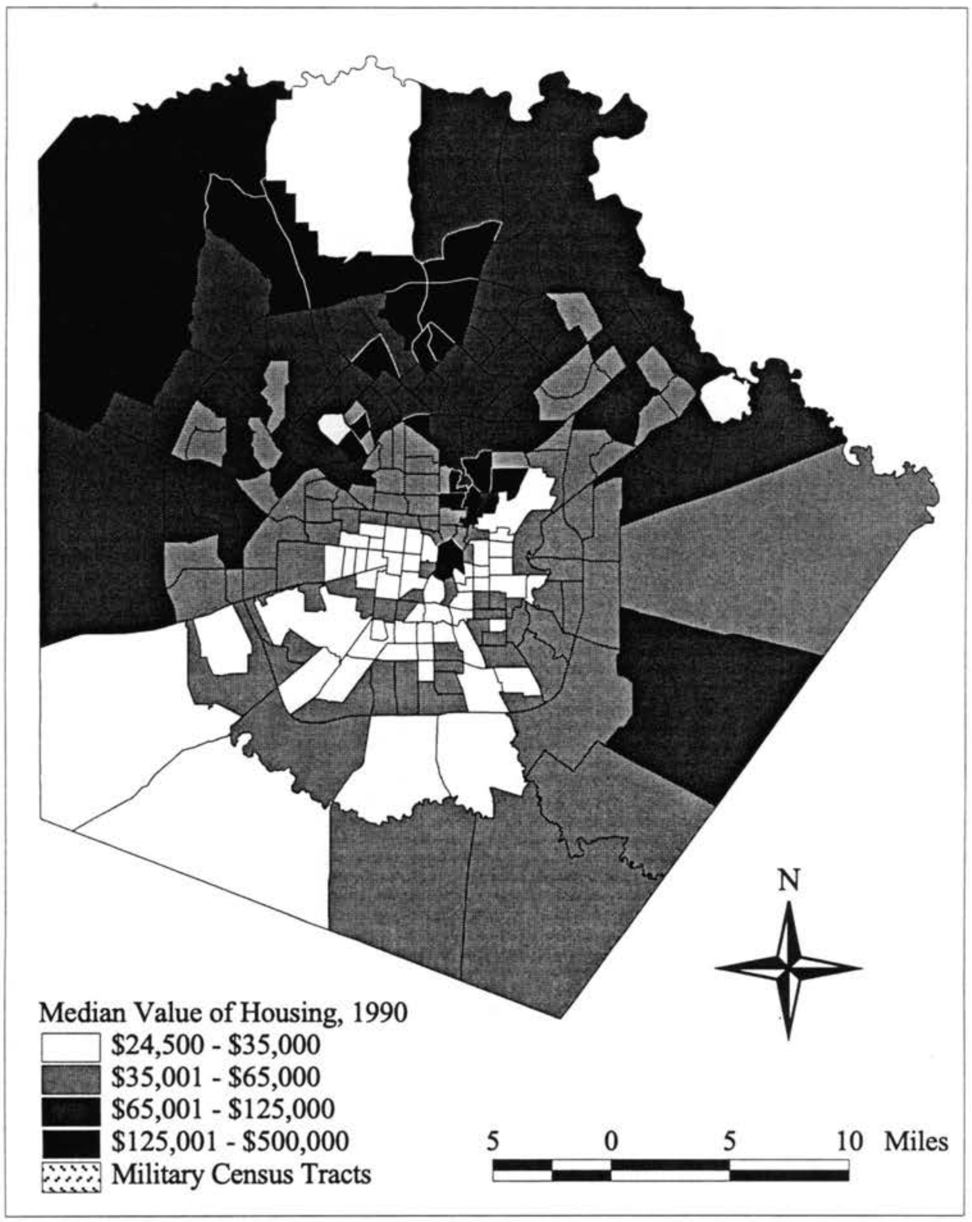


Table 7.5. Bexar County buyouts: Significant difference-of-means among census tract attributes.

N=217	Mean With Bexar Buyout Parcels N=37	Mean Without Bexar Buyout Parcels N=180	Mann-Whitney Sig. (2-tailed)
% of Population White	28%	45%	.001
Median Family Income	$24,412.25	$31,528.71	.003
Median Value of Housing	$48,533.14	$68,572.22	.001

accomplished by collapsing the attributes for 1980 tracts and the 1990 tracts into 1970 tract units. Measures of net change, velocity and acceleration were then calculated for each attribute and each tract. These data are presented in two formats herein. First, a difference of means test was applied to the change-values comparing tracts with to those without dams and those with to those without buyout parcels. No significant differences were observed among buyout parcels. However four change attributes did exhibit significant differences among tracts with and without dams (Table 7.6). This analysis indicates that populations in tracts with dams have enjoyed a greater and more rapid increase in family income and housing values over the 1970 to 1990 period. Additionally, tracts with dams have experienced a greater net change in population and have changed at a substantially higher rate than tracts without dams.

Following Eyton (1991) velocity and acceleration classifications were developed for two of the change attributes (population and all housing units) (see Figure 3.8 for description of velocity/acceleration classifications). Each census tract experiencing the two types of mitigation discussed here was classified by their characteristics of velocity and acceleration for the two census change attributes. This provides a more detailed description of the change that has occurred within these tracts as well as an expanded scale upon which to compare the tracts relative change experience. These results are presented in Tables 7.7 and 7.8. Table 7.7 provides velocity/acceleration characteristics for tracts hosting flood control dams. It is clear that not only have these tracts enjoyed high rates of growth in both values, their growth can be characterized as increasing at an accelerating pace. Meaning not only have they grown, but also the rate at which they are growing is increasing over time. This is especially true for housing, with nearly seventy

Table 7.6. Flood control dams: Significant difference-of-means variables among time-change census attributes.

N=159 (1990, 1980 tract boundaries collapsed to 1970 units)	Mean With Dams N=11	Mean Without Dams N=148	Mann-Whitney Sig. (2-tailed)
Population - % Change 1970-1990	16.31	1.14	.002
Population – Velocity 1970-1990	588.04	81.90	.004
Median Family Income - %Change 1970-1990	79.21	3.65	.000
Median Family Income - Velocity 1970-1990	5,957.14	1,303.77	.000
All Housing Units - % Change 1970-1990	17.94	1.66	.001
All Housing Units - Velocity 1970-1990	261.26	50.51	.001
Median Value of Housing - % Change 1970-1990	11.96	4.12	.004
Median Value of Housing - Velocity 1970-1990	18,783.63	2,987.87	.000

Table 7.7. Velocity and acceleration classifications for dammed tracts.

Velocity / Acceleration Change Attributes	Dams	Dams by Year Completed					
	N=28 (%)	Prior to 1936	1948-1959	1960-1969	1970-1979	1980-1989	1990-1999
Military Census Tracts	2 (7%)				2		
Population							
(+, +) Increasing - Accelerating	12 (43%)		2	4	4	1	1
(+, 0) Increasing - Constant							
(+, -) Increasing - Slowing	12 (43%)		5	2	5		
No Net Change							
(-, +) Decreasing - Slowing	2 (7%)	2		1			
(-, 0) Decreasing - Constant							
(-, -) Decreasing - Accelerating							
All Housing							
(+, +) Increasing - Accelerating	19 (68%)	1	2	5	9	1	1
(+, 0) Increasing - Constant							
(+, -) Increasing - Slowing	6 (21%)		5	1			
No Net Change							
(-, +) Decreasing – Slowing	1 (4%)			1			
(-, 0) Decreasing – Constant							
(-, -) Decreasing - Accelerating							

Table 7.8. Velocity and acceleration classifications for buyout and undeveloped residential parcels.

Velocity / Acceleration Change Attributes	City of San Antonio Buyouts	Bexar County Residential Floodplain Parcels	Undeveloped Residential Parcels in Floodplain
	N=258 (%)	N=103 (%)	N=3858 (%)
Military Census Tracts			2 (.07%)
Population			
(+, +) Increasing - Accelerating	32 (12%)	18 (17%)	1790 (46%)
(+, 0) Increasing - Constant			
(+, -) Increasing - Slowing	1 (.4%)	24 (23%)	710 (18%)
No Net Change		3 (3%)	92 (2%)
(-, +) Decreasing - Slowing	12 (5%)	13 (13%)	434 (11%)
(-, 0) Decreasing - Constant	153 (59%)	36 (35%)	622 (16%)
(-, -) Decreasing - Accelerating	60 (23%)	9 (9%)	216 (6%)
All Housing			
(+, +) Increasing - Accelerating	32 (12%)	21 (20%)	2036 (53%)
(+, 0) Increasing - Constant			1 (.02%)
(+, -) Increasing - Slowing	134 (52%)	57 (55%)	1213 (31%)
No Net Change		1 (1%)	29 (.8%)
(-, +) Decreasing - Slowing	1 (.4%)	5 (5%)	220 (6%)
(-, 0) Decreasing - Constant	45 (17%)		23 (.6%)
(-, -) Decreasing - Accelerating	46 (18%)	19 (18%)	333 (9%)

of the dammed tracts falling into the "Increasing-Accelerating" category.

Table 7.8 shows the same classification scheme for all buyout parcels as well as for the undeveloped residential (no-date) parcels. Once again, there is a clear pattern to the distribution of both. The bulk of City of San Antonio buyout parcels are in the constant or accelerating decrease classification for both census change attributes. Bexar County buyout parcels are a bit more dispersed across the classifications. For population change the trend is still for buyouts to be in those tracts that have experienced decreasing rates of change over the time period, however for housing, the majority of tracts can be found in the "increasing-slowing" classification. Again, this indicates that there has been an increase in population, but the rate at which it is increasing has been slowing over the time period. Referring back to Figure 7.2, it can be seen that Bexar County parcels are more dispersed and therefore the time-change classifications are being influenced by the handful of tracts that lie in the outer suburbanizing rings of the city. This also indicates that Bexar County's buyout criteria may be more about simply removing houses in the floodplain rather than removing the lowest valued houses in the floodplain.

It is also interesting to note that the vast majority of undeveloped parcels are classified in the increasing rates of change categories. To some degree the relationship here is obvious. Undeveloped residential parcels represent the vanguard of land development. The fact that they tend to be in those tracts experiencing the highest rates of change is therefore not surprising. However, the fact that many of them are in the tracts experiencing the highest rates of increasing acceleration is troublesome, when you consider the fact that many of these parcels are in the floodplain. This trend is analogous to a driver hitting the accelerator in a car that is heading into a sharp curve. The fact that these are undeveloped parcels at least holds out the opportunity for the driver, in this case the city, floodplain mangers, and land developers, to put on the brakes before careening off the highway.

Summary

This chapter provided quantitative evidence for the degree to which Bexar County census tracts that have experienced flood hazard mitigation, in the form of dams and property buyouts, are unique when compared to tracts that have not had similar mitigation techniques applied to them. This was accomplished using a selection of census attributes from the 1970, 1980, and 1990 census of housing and population. Census-tract clusters for the entire county served to illustrate the agglomerative patterns of census geography in Bexar County as the spatial tendencies for damaged tracts to be located in more affluent, white, urbanizing areas of the county. Inversely, buyout tracts tended to be located in low- to middle-income, racially mixed regions with a higher percentage of families – presumably lower- to middle-class working neighborhoods. Difference-of-means tests supported this trend to some extent by illustrating that dammed tracts had a significant tendency to exhibit higher income, white populations living in higher valued housing, while buyout tracts exhibited significant tendencies to be in higher minority, lower income areas with lower valued housing. Lastly, time-change analysis showed that that dammed tracts tend to be those experiencing the highest rates of growth for both population and housing from 1970 to 1990, while buyout tracts tended to be in areas experiencing lower rates of growth over the same time period.

These results can be summed up in two ways. First, census tracts that have experienced the bulk of flood-hazard mitigation, at least these two types of mitigation, do in fact exhibit unique geographies. The degree to which the mitigation efforts have directly caused these unique landscapes is not clear form this analysis, but the fact remains they are unique when compared to all tracts within Bexar County. Secondly, it is clear that in the most literal sense, there has been an inequitable application of mitigation techniques overall. Populations that have benefited, or effectively demanded, flood control dams be placed within their floodplains exhibit a more economically affluent, low minority character. Populations that have been the recipients of the more recent buyout program exhibit opposite characteristics. Although it can be said that money has been spent on reducing flood hazard in both types of neighborhoods, clearly damming has the effect of enticing residents to weave ever-greater amounts of urban fabric, both in and adjacent to the floodplain, while buyouts have the effect of removing sizable swatches. In the case of the former, it does not require a great leap of logic to see the development dynamic described by Gilbert White, whereby flood-hazard mitigation actually has the effect of increasing flood hazard even though it decreases flood risk, proliferating in Bexar County. In the case of the latter, it is equally obvious that poor, minority neighborhoods, although arguably benefiting from having their houses removed from the floodplain, are nonetheless bearing the additional burden of undergoing a socio-spatial dismantling and relocation process (the idea that this is the net effect of a federally funded, progressively characterized urban development program is probably not shocking to many minority community leaders). Regardless whether the procedural implications of this trend are manna for future research, it can nonetheless be said, based on the results of this chapter, that flood hazard and the mitigation techniques applied to it, are spatially coincident with distinct urban geographies within Bexar County.

CHAPTER 8

CONCLUSION

Overview

This chapter contains in two sections. First it synthesizes the results of the tests of the three hypotheses posed in the introduction. Each hypothesis was crafted as a separate, but interrelated, effort to explore the changing geography of flood hazard in Bexar County and San Antonio, Texas. The synthesis integrates these separate pieces and provides a comprehensively describes the geographic trends that have characterized flood hazard and flood hazard management in the county. The second section of this chapter offers a prescription, based on the results of the analysis, for Bexar County and City of San Antonio floodplain managers to direct future floodplain development to reduce the negative long-term impacts of flooding (as opposed to the short-term impacts of the next flood) and to continue to support the development of a viable urban tax-base. Only a solution that achieves the latter, will garner the support of floodplain managers for the former.

The Spatial Evolution of Flood Hazard

Urban development never sleeps. It is in a constant state of change. In the case of 150 years of San Antonio's history, it has at times crept, and at others lurched, outward across the spatial extent of Bexar County. One of the many influences on the pace and character of this progression has been the stochastic natural phenomenon of flooding. As Bexar County has expanded, it has engulfed an increasing amount of the geographically diffuse floodplains of the San Antonio River and its related tributaries. The goal of this dissertation was to study the degree to which human interaction with these floodplains, and the flood risk engendered therein, have affected the form, character, and progression of San Antonio's urban geography. Taken together this can be seen as an analysis of the spatial evolution of urban flood hazard. Three hypotheses were formulated in order to examine this evolution.

The first hypothesis proposed that the history of flood-hazard management in San Antonio would emerge as distinct periods punctuated by flood events and their resulting reactive flood management projects rather than as a continuum of preventative efforts. It was also proposed that these management eras would be characterized by the nature and extent of floodplain constituents during each period. An examination of the historical record, in the form of popular press reports, engineering reports, and various municipal documents yielded a history of flood management that was clearly punctuated by four particularly destructive flood events in 1913, 1921, 1946, and 1998. With each event there emerged a more diverse and spatially expanded constituency of affected populations.

The flood of 1913, the effects of which focused primarily on the newly emergent, economically vibrant San Antonio CBD, galvanized the burgeoning commercial district and elicited calls for heroic, structural efforts to protect the urban core. Proposals to build Olmos Dam matched the business community's one-time, big-fix investment philosophy and left the already expanding residential areas out of the immediate remedy. When the flood of 1921 reminded San Antonians of the awesome destructive powers of flooding in their community, there was an immediate response by the business community: the dam was built, the river was straightened, and the channels were cemented and deepened. As the flood of 1946 would illustrate, these efforts had rendered San Antonio's CBD nearly invincible. Ironically, the greatest damages from this flood event were felt in the residential ring that was quickly expanding well beyond the protection of Olmos Dam and these early channel improvements. The period following the flood of 1946 saw a rapid rise and spatial expansion of San Antonio's population. Growing suburban populations found a willing flood control patron in the expanding machinery of the federal government following World War II. Federal assistance, and dollars, poured into San Antonio's floodplain in the form of extensive channel improvements well beyond the CBD and copious flood control dams spread out across the city's suburban fringe.

As the dominant paradigm of structural engineering in the 1950s and 1960s gave way to a "multi-faceted" approach to floodplain management built firmly on the solid ground of a federally backed flood insurance program, San Antonio's floodplain constituency expanded further into its undeveloped floodplains and permanently plugged itself into the national constituency of United States floodplain residents. The CBD argued that the success of its residential workers depended on its safety and as a result it continued to garner its share of structural engineering monies expended on the city. These expenditures were manifested as San Antonio River channel improvements, similar improvements to many of the recently occupied tributaries, and, in an effort reminiscent of the engineering heroics of Olmos Dam, the construction of two 20 foot diameter tunnels designed to quietly swallow flood waters upstream of the CBD and then deposit them back into the river channel in the southern portions of the San Antonio River. By the flood of 1998, suburban residential floodplain occupants had become inextricably entwined with the larger, federally-supported national community of floodplain residents and the commercial district had continued to match flood-might with engineering prowess. However the economic impacts of the flood were so great and so spatially diffused that it was immediately clear that new approaches would be necessary to prepare the city for the next "great flood."

The flood of 1998 has sparked another shift in the management history of San Antonio's floodplains. In many tangible ways the mitigation efforts that had been applied previous to the flood proved effective, but the overwhelming cost of the event underscored the fact that there were many areas of town that were simply beyond protecting and that the geography of flood hazard in the city had become so large and diverse that it now spanned numerous municipal jurisdictions. One post-flood impact has been the implementation of FEMA's property buyout program, which accesses federal funds to support the removal of structures in the urban floodplain. In a very literal sense portions of the floodplain are being returned to their original owner. The second post-flood impact has been the casual airing of proposals to create a single management entity for Bexar County and the City of San Antonio. The San Antonio River Authority is the obvious choice for this responsibility, assuming this role would simply constitute an expansion of their current jurisdiction within the county. Whether this will happen before or after the next flood is anyone's guess. However, these two approaches to flood hazard management have the cumulative effect of institutionalizing the reactive, periodic nature of San Antonio's flood management history in two ways.

First, the funding for the buyout program, whether managed by local municipalities or a single flood management agency, is only made available as a result of a flood disaster. This means that the process of paying people to move out of the floodplain is destined to flow following a flood disaster and ebb in periods in between. Second, the creation of a single governmental floodplain management entity will save taxpayers some management funds as a result of an economy of scale and the removal of redundant services. However, if it is to expand its activities, something that a new bureaucracy entrusted with protecting its constituents from disaster will undoubtedly seek to do, then it will require an ever-increasing level of funding to meet its goals. If history is any indicator, these funds will be most abundant in periods immediately following flood disasters, and the taxpayers that provide these surges of funding will be doing so with the memory of the last flood's impacts in mind, rather then the guaranteed continuum of floods in San Antonio's future. The effect of this will again be an ebb and flow of reactive management efforts rather than a sustained approach to permanently reduce flood hazard.

The second hypothesis proposed in this dissertation stated that urban development, at the individual property parcel-scale, would exhibit distinct patterns associated with floodplain occupancy. Cadastral data for the entire county and for the entire period of development were subjected to difference-of-means analysis for parcels inside versus parcels outside the floodplain. The cadastral attributes of land value, improvement value, and age of structure were tested for statistically significant differences in both the concentric and adjacent occupancy of the floodplain. Results indicated that, although there have been minor fluctuations in the progression of parcels located in the floodplain there have not been abrupt changes in the development of the floodplain at a county-wide, decadal scale. Analysis at a finer scale illustrated that the first impulse of residential development has been to develop parcels outside the floodplain, with subsequent development seeping into the more risky flood zones. This indicates that human interaction with the floodplain, in the form of residential land development, has been characterized by a risk adjustment pattern overall. This pattern held for land and improvement value, as residential parcels outside the floodplain tended to exhibit higher values, again belaying a preference for the less risky, non-floodplain locations. Commercial parcels tended to have the opposite experience, with parcels inside the floodplain exhibiting slightly higher improvement values. This indicates that either the costs of flood damages have been more thoroughly capitalized into their landscapes or commercial landholders are prepared to pay a premium to locate closer to Bexar County's riverine environments. Both the residential and commercial patterns held up for most of the geographic subdivision of above and below the Balcones Fault line and among SARA management basins. Clearly the geography of Bexar County's floodplain has been rendered distinct by human adjustments in the form of economy and sequential occupancy patterns.

The final hypothesis proposed that flood mitigation, in the form of flood control dams and property buyouts, would also be coincident with unique geographies within Bexar County. This hypothesis was tested by comparing contemporary and time-change attributes for United States Census Bureau census tracts with these mitigation applications to those without. Results indicated that for ethnic and economic attributes both mitigation techniques spatially coincide with flood hazard mitigation efforts. Tracts with flood-control dams tended to have higher percentages of white populations and higher levels of economic affluence. Tracts experiencing property buyouts following the 1998 flood contained higher minority, lower income populations. This analysis also indicated that these patterns have held up, or emerged, over time. Time-change analysis indicated that tracts with dams have experienced higher net amounts of growth as well as higher rates of change, while tracts experiencing buyouts have tended to be those tracts that have experienced slowing growth rates. Again, human interaction with flood hazard has generated unique geographies. The fact that the two mitigation programs are associated with such diverse populations indicates that the geography of flood hazard mitigation is to some extent influenced by the social geography of the urban area (i.e. different solutions for different populations).

The spatial evolution of flood hazard in Bexar County and San Antonio, Texas has been characterized by reactive periods of management resulting from the interaction of stochastic flooding in an ever-expanding urban fabric. The spatio-temporal development of San Antonio's urban geography throughout these management periods has exhibited spatial adjustments to the distinct floodplain space, and has therefore produced unique floodplain geographies. Various flood hazard management techniques applied throughout San Antonio's urban development have both supported and reflected the diverse social landscape of San Antonio, again rendering unique flood hazard geographies within the urban area. In short, it can be said that San Antonio's urban geography reflects the evolving nature of its human occupants' interaction with flood risk and thus hazard has indeed modified space. It cannot however be said that these modifications have always resulted in a safer landscape. Rather, flood mitigation has tended to underestimate the trajectory of long-term flood hazard in San Antonio at the same time that urban development pressures have tended to overwhelm the human ecological response of risk avoidance.

Directing Floodplain Development

What can be done to reverse the trend presented in the above conclusion? First it is clear that flood hazard mitigation must achieve something akin to a trans-generational perspective if it ever hopes to achieve a managed landscape that is truly prepared for the "next" flood rather then a reoccurrence of the last flood. In this way, flood hazard is no different than any other environmental hazard. The idea that current generations have some responsibility to use and manage the natural environment in a manner that preserves the long-term viability of our natural systems has emerged as a primary premise of environmental philosophy at scales from community-wide environmental justice activism to worldwide discussions of global warming and atmospheric change. Flood hazard, despite the degree to which we have built governmental and economic structures to control and mitigate its impacts, is ultimately no different.

The trend has been to first avoid, then occupy, and, most recently, abandon urban floodplains. In this way, land developers, and the municipal agencies that regulate and support them, have been allowed to economically "farm" the floodplain. Developing the floodplain, and exposing a greater number of people to flood risk, generates both commercial profits and municipal taxes. This is fine for a period of time, or for a critical frequency of flooding, which ever comes first. Eventually repetitive losses reduce the floodplains ability to produce capital outputs and the solution is to abandon the site and

Figure 8.1. Hypothetical growth patterns: Outside floodplain as primary annex.

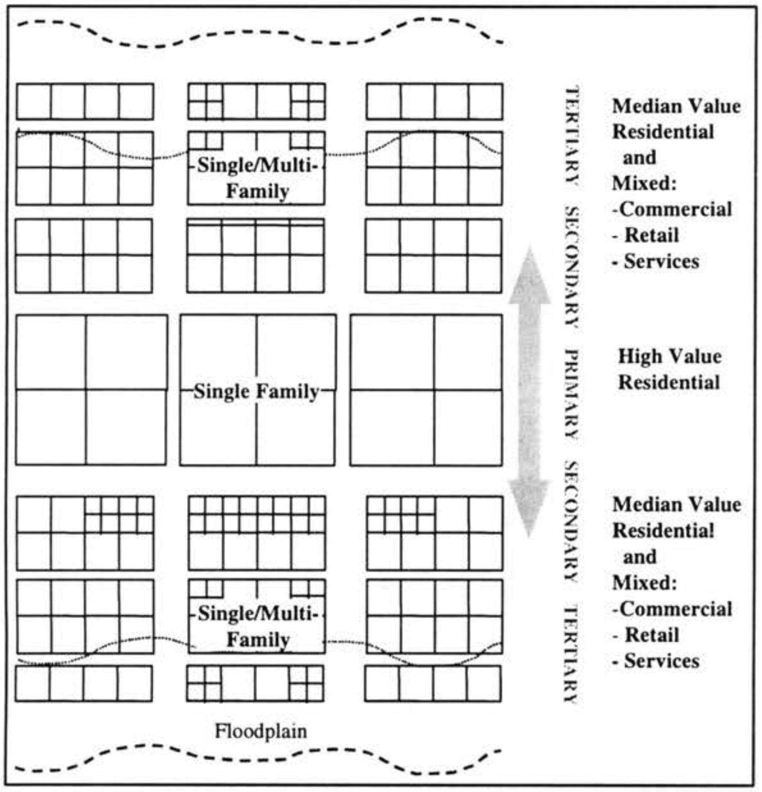
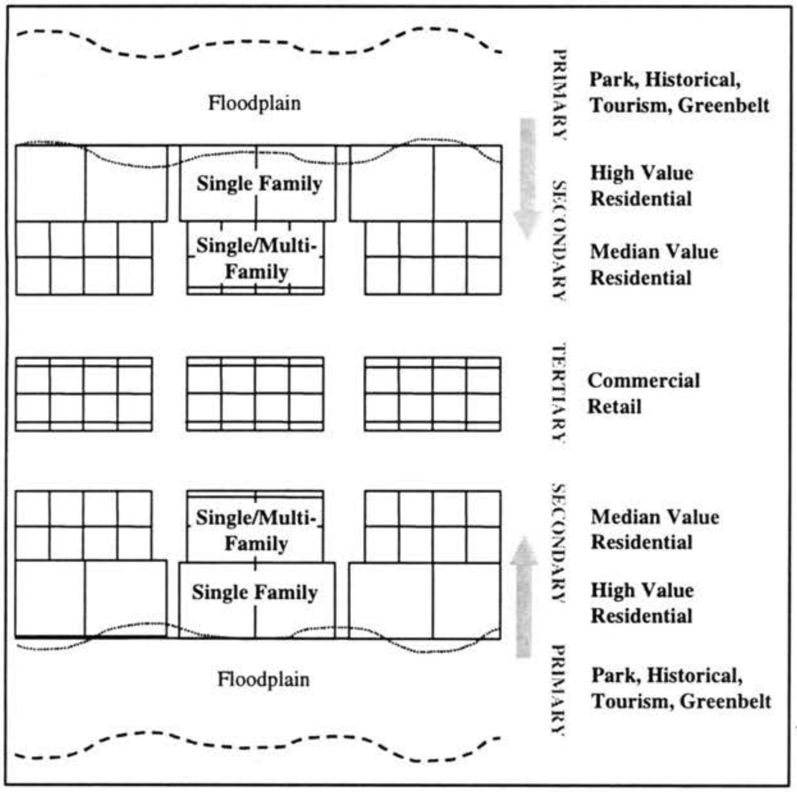


Figure 8.2. Hypothetical growth pattern: Inside floodplain as primary annex.



move to "fresh" ground. In order to permanently reduce the impacts of flooding, this cycle must be broken at its inception. A sense of long-term responsibility to future urban occupants must be expressed in the contemporary management of our urban floodplains.

As was discovered in the cadastral analysis of San Antonio's urban floodplain, the first impetus of urban residential development has been to occupy the non-floodplain areas of the suburban fringe as the city expands. Areas outside the floodplain become the region of "primary urban annex." This has the effect of producing landscapes similar to that described in Figure 8.1. In this form of land development, the floodplain becomes the logical recipient of lower-valued residential and commercial land uses. Figure 8.2 presents one possible outcome to reversing this trend. Cities, such as San Antonio have often extended their urban annex, and dictated the character of development in those areas, out along main roadways in anticipation of future growth. If the same idea were applied to the extra-urban floodplain, the long-term affect would be to drive development away from the riskier areas and still promote a viable urban tax base. This is one possible long-term solution to flood hazard. There are undoubtedly more. However, as long as our management and mitigation remain reactive and short-term, rather then proactive and long-term, solutions such as this one will remain untenable and urban occupants will remain at risk.

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Curriculum Vitae

Ronald R. Hagelman III

University of New Orleans / Lakefront
Department of Geography
New Orleans, LA 70148
Department: (504) 280-6296 / 7133
Office: (504) 280-7135
Email. rhagelma@uno.edu

Home Address·
2308 Houma Blvd., #609
Metairie, LA 70001
Telephone: (504) 887-5057

Education

Ph.D. Environmental Geography, 2001, Southwest Texas State University, San Marcos, TX
Dissertation: *The Spatial Evolution of Urban Flood Hazard in San Antonio, Texas*
Advisor. Dr. John Tiefenbacher

M.A.G (Master of Applied Geography), 1997, Southwest Texas State University, San Marcos, TX
Thesis: *The Socio-Spatial Patterns of Acute and Chronic Toxic Air Releases in Texas, 1987-89*
Advisor. Dr. John Tiefenbacher

B.A. 1988, University of Texas, Austin, TX
Major. History
Minor: Geography

Publications

Tiefenbacher, John P., and Ron R. Hagelman. 1999. Environmental Equity in Urban Texas: Race, Income, and Patterns of Acute and Chronic Toxic Air Releases in Metropolitan Counties. *Urban Geography* 19, no. 6: 516-533.

Tiefenbacher, John. P., R. R. Hagelman and R.J. Cecora. 2000. California Citrus Freeze of December 1998: Place, Perception and Choice - Developing a Disaster Reconstruction Model. National Science Foundation Grant No. CMS-9632458. Natural Hazards Center at the University of Colorado, Boulder: Quick Response Report #125.

Publications in Review or Preparation

Hagelman, Ronald, R., Stephanie J. Garcia, and John P. Tiefenbacher. Risk and the Urban Environment: The Case of San Antonio, Texas. *Professional Geographer.* Status: In preparation.

Tiefenbacher, John P. and Ronald R. Hagelman. Disaster-Induced Change, Reconstruction, and the Evolution of the Hazards-of-Place. *Environmental Hazards.* Status: Revising for resubmission

Tiefenbacher, John P., Ronald R. Hagelman, and Reno J. Cecora. California Citrus Freeze of 1998: Place, Perception and Choice. *Disasters.* Status: In preparation.

Tiefenbacher, John P. and Ronald R. Hagelman. Technological Innovation and the Changing Spatial Characteristics of Risk: The History of the Pesticide Driftscape. *Historical Geography.* Status: In preparation.

Grants and Funding

2000 *Small Business in a Small Town: Recovery in the Wake of Hurricane Disaster*, Quick Response Research Program, Natural Hazards Center, Boulder CO. Submitted October 16. Status: Approved, pending appropriate disaster event.

Book Reviews

2000 Review of Geological Hazards: Their Assessment, Avoidance and Mitigation (by F. G. Bell, E&FN Spon, 1999). *Geomorphology*. Forthcoming.

Professional Presentations and Field Trips

2000 Bexar County's Dammed Development
Southwestern Association of American Geographers (SWAAG), Fort Worth, TX

2000 *Three Feet High and Rising: Urban Geography and the Floodplain: San Antonio, TX*
SWAAG, College Station, TX
Student Paper Competition (First Place)

1999 Field trip Co-Host (Dr. Craig Colten, Host): *Texas Rivers and the Guadalupe River Basin*
SWAAG, San Marcos, TX

1998 *An Historical Geography of Disaster, Development, and Human Response in Texas' Matagorda Bay Region*
SWAAG, Baton Rouge, LA
Student Paper Competition (Third Place)

1997 *The Influence of Ethnicity and Place on College Students' Environmental Focus*
Association of American Geographers (AAG), Fort Worth, TX.

1996 *Do Sex and Place Influence College Students Definition of the Environment?*
SWAAG, Norman, OK

1995 *The Long-Term Commercial Impacts of Hurricane Damage on Texas Coastal Counties*
SWAAG, Las Cruces, NM

Service

Social Science Ph.D. Planning Committee University of New Orleans, Fall 2001 - present

SWAAG Session Chair	2001: Special Session *Urban Environments*
Graduate-Faculty Liaison	Ph.D. Representative, Graduate Student Forum, Fall 1998
Assistant Editor	*Southwestern Geographer,* Fall 1997 - Summer 1998
Graduate-Faculty Liaison	Masters Representative, Graduate Student Forum, Spring 1997

Research Positions

Graduate Research Assistant	Fall 1997 - Spring 2001 Spring/Summer 1996	Dr. John Tiefenbacher
Graduate Research Assistant	Spring 1999 Natural Hazards Quick Response Grant	Dr. John Tiefenbacher
Graduate Research Assistant	Summer 1997 Faculty Research Enhancement Grant	Dr. John Tiefenbacher

Teaching Positions

University of New Orleans – Lakefront, Department of Geography

Assistant Professor	Spring 2001- Present

University of Texas – Austin, Department of Geography

Human Use of the Earth	Spring 2001

Southwest Texas State University, Department of Geography

World Regional Geography	Summer 2000 - Spring 2001 Fall 1997 - Fall 1999
Physical Geography (Lab)	Fall 1995 - Spring 1996

Texas Alliance for Geographic Education Summer Teacher's Training Institutes
Summer 2001

Texas Alliance for Geographic Education Summer Teacher's Training Institutes
Summer 2000

Texas Alliance for Geographic Education Summer Teacher's Training Institutes
Summer 1999

Professional Awards

Elizabeth Sterry Graduate Award - SWTSU	2001
SWAAG Student Paper Competition (First Place)	2000
Prentice-Hall Graduate Student Teaching Award - SWTSU	2000
Outstanding Graduate Student In Geography - SWTSU	2000
SWAAG Student Paper Competition (Third Place)	1998
Outstanding Graduate Student In Geography - SWTSU	1997
Rand McNally Graduate Award - SWTSU	1997

Professional Affiliations

Association of American Geographers (AAG)
- Hazards Specialty Group
- Historical Geography Specialty Group

Southwestern Association of American Geographers (SWAAG)