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The Growth of Low-Income Population in Floodplains: A Case Study of Austin, TX

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Abstract

This study seeks to examine the exposure of low-income people to floods in Austin. This exposure of low-income people could financially and psychologically be more serious than that of others because they have less capacity to recover from the hazards. This study conducts four methods to track the vulnerability of the population. The results are as follows: first, property values are lower inside floodplains than outside floodplains; second, many floodplain areas have been developed for multi-family housings, mobile homes, and single family housings in the very low-income neighborhoods between 1990 and 2000; third, low-income people are more likely to live in floodplains, compared to higher-income people and the number has grown in floodplains; fourth, people with the lower income are more likely to live in the areas including more floodplain. The more serious exposure and the increase of low-income people in the floodplains could give a rationale for policy intervention in floodplain management and regulation. This study proposes several policies for Austin to reduce property damage in floodplains, where low-income people tend to live.

Keywords: *low-income population, floodplains, social vulnerability, social impact*

1. Introduction

In recent, U.S. cities have experienced a rapid population growth. This population growth has resulted in not only urban sprawl, which is the spreading out of a city and its suburbs over more and more rural land at the periphery of an urban area, but also the conversion of open space into built-up, developed land over time within the city limits. According to Burby, Nelson, and Parker (2001), cities that have experienced rapid population growth may increase their exposure to natural hazards and higher losses within their city limits because the residential users may be forced into environmentally sensitive areas such as the floodplains through a lack of available land in the community.

Hazard mitigation literature argues that hazardous land such as floodplains is "a major location of affordable housing" due to its low land price, and, consequently, low-income people are more vulnerable to the natural hazards (Godschalk *et al*., 1999). This exposure of low-income people could be more serious, financially and psychologically, than that of others because they have less capacity to recover from the hazards. According to studies by Peacock (Godschalk *et al.,* 1999), the poor are less likely to succeed in gaining access to the disaster assistance system and receiving needed benefits after a disaster. This greater exposure and vulnerability among low-income people, in reality, has resulted in the group's highest disaster mortality and morbidity rates (Mileti, 1999). The literature on natural disasters, however, has focused on the uneven damage of low-income people aftermath the natural hazards. There, despite the seriousness of these studies, are few studies that investigate how much and many low-income people will be at risk of the future natural hazards.

This study seeks to estimate whether many low-income people live in floodplains and whether these exposures have increased over time. It is based on a hypothesis that many low-income people are likely to live in the floodplains where less expensive housing can be provided, and tend to increase continuously over the years. If many low-income people are exposed to flooding by living in the areas, this study's result would give planning groups the better ideas for floodplain management programs. That is, the continuous growth of population, especially the increase of low-income people in the floodplain areas, could give a rationale for policy intervention in floodplain management and regulation. More efforts must be devoted to stop population growth in the floodplain areas, but we also must consider the social equity issue, such as providing low-income housing stock.

2. The Literature on Natural Hazards Management and Impacts

2.1 Natural Hazards in the United States

Natural hazards in the United States have increased as more people and property have become exposed to natural hazards.

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According to the Federal Emergency Management Agency (FEMA), between 1990 and 1999, a total of 460 disaster declarations have been made by the president, resulting in disaster relief expenditure of more than $25.4 billion by FEMA for declared disasters and emergencies, compared to $3.9 billion (current dollars) in disaster aid for the 1980-89 period. Of the costs from natural hazards from 1975 to 1994, more than 80 percent were imposed by disasters related to climate, such as floods and hurricanes, and about 10 percent were the result of earthquakes and volcanoes (Mileti, 1999). Following disasters in the early 1990s, the U.S. Congress directed FEMA to place its highest priority on natural hazard mitigation, shifting FEMA's emphasis from responding to and recovering from disasters to mitigating future hazard events. This was a fundamental change: moving from a reactive to a proactive national emergency management policy. But this policy trend is relatively recent.

Floods are the most costly natural hazard and the most ubiquitous and common hazard in the United States. Floods account for about 70 percent of presidentially declared disasters in the United States each year (Schwab, 1998). The damage from floods has historically continued to increase. Between 1990 and 1997, U.S. flooding caused $4.2 billion per year in damage, and an average of 100 people per year lost their lives in floods (FEMA, 2000). The massive nationwide loss of lives and property from flooding drove the creation of the National Flood Insurance Program (NFIP) in 1968. A FEMA (1991) report that from 1978 to 1990, about $2.5 billion has been paid for flood losses insured under NFIP. As a result, while the loss of life is on the decline, the damage from floods is increasing.

In order to control or mitigate flood hazard damage, several types of measures have been adopted. Two main types of measures have usually been established: structural and non-structural (FEMA, 1992). Structural measures such as dams, levees, and floodwalls dominated the field of floodplain management until the 1960s. But as flood damage continued to increase despite these efforts, it became clear that structures alone would not solve the problem. Increasingly, federal and local planners have focused on non-structural measures, such as zoning, subdivision regulations and land acquisition, and relocation programs, in combination with structural measures. "Non-structural measures do not seek to control flood water, rather they try to control activities within floodprone areas" (Taylor, 1997). In particular, FEMA (1998) has encouraged a buyout program of repetitive loss properties on a voluntary basis, pointing out that the properties are a major factor in the increasing costs of floods.

Opportunities for planners to mitigate flood hazards are extensive, in large part because flood risks are so much more clearly definable for land-use purposes than almost any other hazards. The mapping functions of NFIP provide an effective basis for establishing floodplain management regulations through zoning, subdivision controls, and other measures within defined areas with readily quantifiable risk factors.

2.2 Uneven Impacts of Natural Hazards

Over the past several years it has become clear that individuals and groups with special socio-economic characteristics were affected more than others by natural disasters. In particular, Paterson (1998) argued that "natural disasters are not always fair and equal in their impacts". Many low-income groups, who are largely minorities and women, frequently live in hazardous areas because property values and housing costs are lower there (Paterson, 1998; Goshalk *et al.,* 1999). These groups are consequently exposed and vulnerable to hazards and disaster impacts.

Greene and Schulz (1993) found that the Loma Prieta Earthquake of 1989, which caused about $6 billion in damage and killed 63 people, unevenly impacted low-income residents in emergency shelter and replacement housing. Comerio (1995) also pointed out that many low-income residents were affected by the Northridge Earthquake. After the Midwest Floods of 1993, the report by the Interagency Floodplain Management Review Committee (IFMRC, 1994) documented that, of over 60 communities affected by the flood, the neighborhoods in floodplains had lower income and lower-value housing. Recent analyses of the wind damage and flooding caused by Hurricane Katrina also found that the impact of the storm was disproportionately borne by the African American Community, by people who rented their homes, and by the poor and unemployed (Logan 2006; Muro *et al*., 2005). This fact means that "they lived in the floodplains out of economic necessity rather than choice" (Platt, 1998).

After a natural disaster, people or households at the low end of Socioeconomic Status (SES) are more likely to experience severe economic hardship because they have smaller financial and/or economic capital in a time of crisis (Chappell *et al.,* 2007). These people are less likely to be able to take advantage of the recovery process after hazards. Godshalk *et al.* (1999) identified that minorities and the poor may feel constrained from access to post-disaster assistance and mitigation programs. Dash *et al.* (1997), in a study of the impact of Hurricane Andrew, found that the poor and poor communities received less aid from disaster assistance programs than others because of the complex application process and transportation problems. Taylor and Silver (2006) found that in the New Orleans areas after Hurricane Katrina, most f the loans regarding disaster home lending approved were for families in affluent communities, while small portion were for families residing in poor neighborhoods. As a result, this group's poverty is exacerbated by disasters. Recently, Zhang and Peacock (2010), examining the changes in housing recovery trajectories after Hurricane Andrew, found that black and low-income neighborhoods experienced higher losses in home value compared to white and high-income neighborhoods and take more time to return to the prior status. In particular, abandonments were more concentrated in lower income and minority neighborhoods. Lee (2012) also found that the impacts of natural disasters on lower-income neighborhoods are more severe and long lasting than that on upper-income neighborhoods.

Although hazard mitigation programs have played a major role in public efforts to solve these problems, the programs sometimes raise an equity issue related to housing. According to Comerio (1990)'s study of the 1987 Whittier-Narrows Earthquake, many of the low-income housing units in California were torn down or seismically retrofitted and upgraded for safety after the disaster. However, these mitigation efforts resulted in an increase in housing price and then a shortage of affordable housing. Similar concerns were expressed about the buyout program following the 1993 Midwest Floods. Efforts to buy out properties to reduce exposure to floods reduced the amount of affordable housing available as a consequence (Paterson, 1998; Goshalk *et al*., 1999).

Many researchers have suggested that the different sub-population impacts should be considered in hazard planning and practice (Dash *et al.*, 1998; Deyle *et al.*, 1998; Goshalk *et al*., 1999; Mileti, 1999; Paterson, 1998; Zhang and Peacock, 2010; Lee, 2012). Goshalk *et al.* (1999) argued that "special sensitivity to equity in disaster assistance and mitigation is needed and special strategies, such as mitigation targeted to certain neighborhoods and based in the community, may also be necessary."

3. Data and Methods

3.1 Overview of Austin, TX

Austin is employed to estimate the exposure of low-income population to floods. Austin is the capital of Texas, which is currently the seventeenth-largest city in the United States. The city is one of the fastest growing cities in the nation, with a population of 656,562 in 2000, which accounts for 52.5 percent of the population in the Austin-San Marco MSA. From 1940 to 2000, Austin's population grew at an average of 40 percent per decade. Austin's urbanized area extended outward, corresponding to the population growth. Despite Austin's rapid growth in population and decline in poverty, Austin's poverty rate remains higher than that of the nation. While, in 2000, Austin's median household income was $45,790, the median income of low-income households in Austin was $36,632. Approximately 14.4 percent of all city residents (92,011) had incomes below 80 percent of the city's median income.

According to the City's Consolidated Plan 2005–2009, Austin's median rent, $802, was much higher than other major cities in Texas in 2002. Sixty-six percent of all Austin residents could not afford these high rents. Fullerton (1998) pointed out that in Austin, "much of what is sold as 'affordable' housing isn't all that affordable for much of the city's rental population." In 2003, over 10 percent of low-income households could not find affordable housing and, in particular, most of the extremely low-income households, who had incomes below 30 percent of the city's median household income, had trouble finding affordable housing.

Austin is located in the central Texas hill country and covers a total land area of 272 square miles. Austin is divided into the hills and bluffs of the west and the broad plains of the east. Due to these topographical characteristics, creeks in the east create more floodplains than in the West. According to FEMA, an estimated 10 percent of the city is floodplains. Due to Austin's topographical features, the city's socioeconomic characteristics may result in the different exposure of people to floods in the east and west. While moderate- and high-income people live in the west and suburbs of Austin, people with low incomes are mainly concentrated in the eastern area of the city. The fact that there are many more floodplain acres of land in the east could indicate that more people are exposed to floods in this area than in other areas. Therefore, people who are exposed to floods are likely to be low-income people.

Austin regulates land use in floodplains through its floodplain management and regulation (City of Austin, 2012). Encroachment of buildings and parking areas in the 25-year floodplain are prohibited and that in the 100-year floodplain are restricted. The city lets proposed development not result in additional adverse flooding on other property and requires a site plan for all development proposed within the 100-year floodplain. But the city does not include any policies or programs in its floodplain regulation to deal with the exposure of low-income population to flood risks.

3.2 Estimating the Exposure to Floods

To estimate the exposure of low-income people to flood risks, this paper investigates whether such people are more likely to live in floodplains. Floodplain is defined as a low plain adjacent to a river that is subject to flooding. It is measured as the 100-year floodplain, the area with 1 percent chance of being flooded in any year (Randolph, 2004). NFIP uses the 100-year floodplain as a criterion to determine future flood risks to the structures and provides GIS maps of the 100-year floodplain for all counties in the United States. And four methods are employed to investigate whether low-income people have grown in the floodplains: property values, land use change, population change, and the relationship between income and floodplains.

The first method is to compare the values of the property inside floodplains with those outside floodplain in Austin. It is based on an assumption that there is a correlation between median household income and property values. The correlation analysis and ANOVA model are used to confirm whether median household income is related to property values in Austin and whether low income people tend to live in low property value houses, respectively. If there is a correlation between both and then property values inside floodplains are lower than those outside, it would be likely that many low-income people live in floodplains. For more precise results, property values within floodplains were compared with those outside of floodplains, both being within the same block groups.

The second method is to investigate the change of land use in floodplains between 1990 and 2000. This study focuses on residential use because it seeks to examine whether the number of low-income people who live in floodplains has increased between 1990 and 2000. The City of Austin divides residential

use into four categories: large-lot single-family homes (which means lots with over 10 acres), single-family homes, mobile homes, and multi-family homes (City of Austin, 2012). Of these categories, mobile homes and multi-family homes are focused on as housing types for low-income people. The average price of a mobile home is lower than that of a single-family home, and the per square foot cost of a new mobile home is about 50% of a new single-family home (Shen, 2005). At the same time, single family housing is investigated in four income level: low-income, very low-income, and extremely low-income and higher income, which includes moderate income and high income. So, in floodplains, the increase of mobile homes, multi-family homes and single-family homes in low-income areas means the increase of low-income people in the areas.

The third method is to examine the growth of low-income population in floodplains. The census data by the block level are used to understand the increase in concentration of people in floodplains. Low-income people are measured as follows: a household with below 80% of the area median household income is a "low-income household"; 30-50% of it is "very low-income household"; below 30% of it is "extremely low-income household"; a household with above 120% of the area median household income is a "high-income household"; 120-150% of it is a "very high-income household"; and above 170% of it is an "extremely high-income household." (Federal Department of Housing and Urban Development (HUD)).

Due to the inconsistency between the boundary of census data and that of floodplain, however, we are hard to calculate the concise number of population in floodplains. Therefore, the definition of the census unit in floodplains is necessary. For example, Fig. 1 shows census blocks that are overlain on floodplains. Block 3022007 and Block 3023002 are overlain on floodplains by 25% and 88%, respectively. Although Block 3023002 is overlain much more than Block 3022007, Block 3023002 does not have any buildings in floodplains, while Block 3022007 has some buildings. Therefore, it may not be reasonable to define blocks that are overlain on floodplains by a certain degree as "census blocks in floodplains."

For the more accurate analyses, five scenarios are employed based on how much the census blocks are overlain on floodplains: the census blocks that are overlain on floodplains over 20, 40, 60, 80, and 100%, respectively. In all scenarios, the growth of population in floodplains, especially low-income people, is calculated and the average of the five scenarios' increase is compared with that of the world city of Austin. If, despite the different scenarios, each scenario has a similar growth rate of low-income population, we can say that the number of low-income people has increased in the floodplains or not.

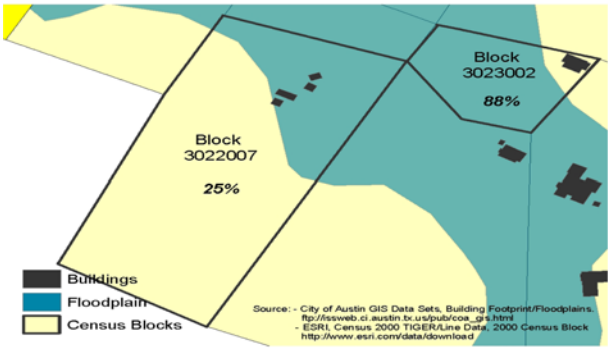

Fig. 1. Census Blocks in Floodplains, Austin, TX

The last method is to investigate the relationship between floodplain, which is defined as the percent of area of floodplain, and median income. This is to examine the possibility that low-income people may live in floodplains. Linear Regression analysis is used to confirm whether floodplain is related to median income in Austin. It is based on an assumption that the more floodplain a census block has, the lower median income it has. If there is a correlation between both, it is likely that low-income people are living in floodplains.

4. Results

4.1 Lower Property Values in Floodplains

In Austin, household income is positively related to property values. Table 1 presents the result of a correlation analysis between median household income and property values at the census tract level. The correlation between both is 0.742 with the significance at the 0.01 level. This means that the lower income households have, the lower-valued houses they live in. On the contrary, the higher income households have, the higher-valued houses they live. If the property values inside floodplains are lower than those outside floodplain, it may mean that low-income people are more likely to live in floodplains.

Table 2 shows the descriptive analysis of median home values according to income by census block level. Income was divided into three groups: low-income, middle-income and high-income.

According to tests of between-subjects effects of Table 3, the F ratio is 33.95 which is a large value, and the p-value is 0.000, which is very small and statistically significant. Therefore, we can conclude that there are indeed differences among the property values of home according to three income groups. Fig.

Table 1. Correlation between Property Value and Median Household Income, by Census Tract Level

Correlations	Median Household Income	Property Values
Median Household Income	1	0.742**
Property Values	0.742**	1

**Correlation is significant at the 0.01 level (2-tailed)

Table 2. The Descriptive Statistics of Median Home Values according to Income in Austin, by Census Block Level

Income Level	Mean ($)	Std. Deviation	Number of Block
Low-Income	95,471	54,552	62
Middle-Income	122,978	55,871	58
High-Income	212,923	119,384	62
Total	144,248	96,772	182

Table 3. Tests of Between-Subjects Effects for Median Home Values ($) according to Income in Austin, by Census Block Level

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	466,155,577,129	2	233,077,788,565	33.95	.000
Intercept	3,759,255,486,046	1	3,759,255,486,046	547.58	.000
Income Level	466,155,577,129	2	233,077,788,565	33.95	.000
Error	1,228,876,836,991	179	6,865,233,726		
Total	5,481,984,390,000	182			
Corrected Total	1,695,032,414,120	181			

R squared = .275 (Adjusted R squared = .267)

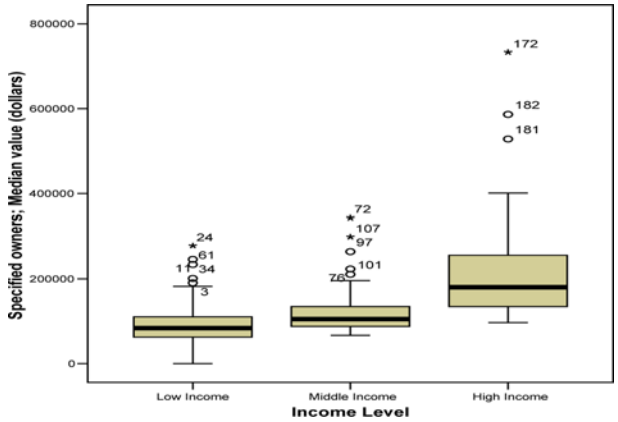

Fig. 2. Box Plot in ANOVA Model for Median Home Values according to Income in Austin, by Census Block Level

2 illustrates that low-income people tend to live in the lower-priced home while high income people tend to live in higher-priced homes.

Table 4 illustrates the degree of exposure of houses to floods for each creek in Austin. Barton Creek and Bull Creek in the West have 162 and 39 houses in floodplain, respectively. On the other hand, Onion Creek and Tannehill Creek in the East have 1,477 and 640 houses in floodplain, respectively. Moreover, Onion Creek (23.52%) and Tannehill Creek (28.14%) have much higher percentages of houses in floodplains to total houses in census block groups adjacent to each creek than Barton Creek (2.64%) and Bull Creek (0.76%). Especially, the median household income ($73,065) for census block groups adjacent to Onion Creek is about three times higher than those ($27,248) adjacent

Table 4. The Number and Percentage of Houses in Floodplains for Census Block Groups Adjacent to Each Creek

Watershed		Houses in Floodplains	
		Number	Percent*
Center	Blunn Creek	33	2.21%
	East Bouldin Creek	109	1.53%
	Shoal Creek	402	5.69%
	Waller Creek	368	11.98%
	West Bouldin Creek	104	4.21%
	Williamson Creek	759	8.00%
East	Boggy Creek	249	5.95%
	Fort Creek	307	7.55%
	Johnson Creek	41	4.00%
	Little Walnut Creek	471	7.90%
	Onion Creek	1,477	23.52%
	Tannehill Creek	640	28.14%
	Walnut Creek	368	5.67%
West	Barton Creek	162	2.64%
	Bull Creek	39	0.76%

Note: *means the percent of houses in floodplains to all houses in census block groups adjacent to each creek.
Source: City of Austin GIS Data Sets, Floodplains & Creeks, Available at ftp://issweb.ci.austin.tx.us/pub/coa_gis.html
U.S. Bureau of the Census, American Factfinder, SF1, 1999. Available at http://www.census.gov/

Table 5. Example of Property Values Inside and Outside Floodplains

Creeks	Block Group ID	Houses in Floodplains		Property Value per Acre		Property Value per Parcel	
		Number	Percent*	Inside**	Outside**	Inside**	Outside**
Barton Creek	19064	30	5.67%	$879,555	$654,987	$299,609	$334,389
	19062	29	5.78%	$921,396	$844,352	$285,000	$308,005
Shoal Creek	02016	44	9.57%	$1,110,503	$1,468,432	$221,280	$245,220
	15014	29	11.84%	$457,500	$744,473	$229,623	$202,347
	18172	73	14.23%	$863,772	$916,335	$160,992	$172,967
Onion Creek	24072	34	5.64%	$201,861	$235,688	$170,043	$136,353
	24183	201	31.26%	$625,315	$973,602	$217,411	$230,600
	24204	642	49.92%	$512,872	$547,111	$81,991	$99,220

*The percentage of houses in floodplains to all houses in census block groups adjacent to each creek.
**Inside and outside floodplains that are determined based on location of residential structure.
Source: City of Austin GIS Data Sets, Floodplains & Creeks. Available at ftp://issweb.ci.austin.tx.us/pub/coa_gis.html
Travis Central Appraisal District, Appraisal Roll, Total Market Value, 2004. Available at http://www.traviscad.org
U.S. Bureau of the Census, American Factfinder, SF1, 1999. Available at http://www.census.gov/

to Tannehill Creek. Therefore, it seems that many low-income people are exposed to floods in Austin, especially around Tannehill Creek.

Table 5 compares property values inside and outside floodplains. Considering the geographical characteristics, Barton Creek in the west, Shoal Creek in the center, and Onion Creek in the east were selected to investigate the difference between property values inside and outside floodplains. In most block groups, property values, including property value per acre and property value per parcel, are lower inside floodplains than outside floodplains.

Regarding property value per acre, all block groups adjacent to Shoal Creek and Onion Creek have lower values inside floodplains than outside floodplains. Except for two block groups (15014 and 24072), property value per parcel inside floodplains is also lower than that outside floodplains. In all block groups adjacent to Barton Creek, however, property value per acre inside floodplains is higher than that outside floodplains, while property value per parcel inside floodplains is lower than that outside floodplains.

This result is related not only to geographical characteristics but also to the size of the parcel. Some floodplain parcels contain houses built completely outside the floodplain. In the block groups of 19064 and 19062 adjacent to Barton Creek, properties in floodplains have great views because they are located on the hill. The property values are relatively high, compared to values of properties outside, although they have smaller parcels than properties outside. In these block groups, therefore, property value per acre in floodplains is higher than outside floodplains. On the contrary, in block group 15014, the parcel size for the properties in floodplains (0.5 acre) is also larger than outside floodplains (0.28 acre) (see Fig. 3). Property value per parcel inside floodplains is higher than that outside floodplains. Therefore, it would seem that if the parcel sizes inside and outside floodplains are similar, both property value per acre and per parcel inside floodplains are lower than those outside.

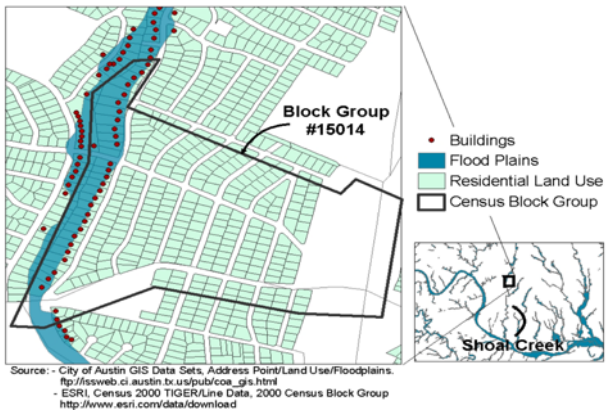

Fig. 3. Properties in Census Block Group 15014 adjacent to Shoal Creek

According to Fig. 2, in Austin, low-income people are likely to live in lower-priced houses. Also, Table 5 shows that property values inside floodplains tend to be lower than outside floodplains. Therefore, low-income people are likely to live in floodplains due to low property values. As a result, in Austin, low-income people tend to be more vulnerable to floods than high-income people.

4.2 Growth of Homes for Low-Income People in Floodplains

Over the last 10 years, Austin's rapid population growth has

Table 6. Residential Use in 1990 and 2000 (Acres)

1990	Inside Floodplain*		Outside Floodplain*		Whole City	
	Area	Percent	Area	Percent	Area	Percent
Single Family;	1,561.6	83.0%	27,370.1	84.7%	28,931.7	84.6%
In Very Low-Income Areas	21.3	1.1%	933.9	2.9%	955.2	2.8%
In Low-Income Areas	291.9	15.5%	3,534.8	10.9%	3,826.7	11.2%
In Higher Income Areas	1,248.4	66.3%	22,901.4	70.9%	24,149.8	70.6%
Mobile Home	57.5	3.1%	809.4	2.5%	866.9	2.5%
Multi Family	263.2	14.0%	4,137.3	12.8%	4,400.5	12.9%
Total	1,882.3	100.00%	32,316.8	100.00%	34,199.1	100.00%

2000	Inside Floodplain		Outside Floodplain		Whole City	
	Area	Percent	Area	Percent	Area	Percent
Single Family;	1,714.0	78.1%	33,359.9	81.7%	35,073.9	81.5%
In Very Low-Income Areas	73.5	3.4%	966.1	2.4%	1,039.6	2.4%
In Low-Income Areas	388.5	17.7%	5,892.3	14.4%	6,280.8	14.6%
In Higher Income Areas	1,252.0	57.1%	26,501.5	64.9%	27,753.5	64.5%
Mobile Home	111.1	5.1%	1,283.1	3.1%	1,394.2	3.2%
Multi Family	368.7	16.8%	6,199.1	15.2%	6,567.8	15.3%
Total	2,193.80	100.00%	40,842.10	100.00%	43,035.90	100.00%

Note: *Inside/outside floodplains that are determined based on location of residential structure.
Source: City of Austin GIS Data Sets, Floodplains & Land Use. Available at ftp://issweb.ci.austin.tx.us/pub/coa_gis.htm

led the encroachment on floodplains. Many floodplains have been developed for residential land use. Table 6 shows the change of this residential land use inside and outside floodplains between 1990 and 2000. The number of single family homes in extremely low-income census blocks is very small in floodplain. So, these homes are included in single-family homes in very low-income census block.

In 1990, residential land use in floodplains was 5.5% of total residential use in the city. It has increased by 16.6 percent, from 1,882 acres to 2,194 acres, between 1990 and 2000, while by 18.1% outside floodplains. Although the area of single family homes has increased in the whole city, the percent of them to total residential uses has decreased in and outside floodplains as well as in the whole city. The percent of single-family homes are similar in (83% in 1990 and 78% in 2000) and outside floodplain (85% in 1990 and 82% in 2000). In 1990, the percentage of single-family homes in very low-income areas in floodplain (1.1%) was lower than that outside floodplain (2.9%), while that in the low-income areas in floodplains (15.5%) is higher than that outside floodplain (10.9%). In 2000, however, the percentage of single-family homes in the very low-income areas in floodplain increased to 3.4%, which increased by 245 % in the area, while that outside floodplain decreased to 2.4%. On the other hand, single family homes in the higher income areas in floodplain have decreased from 66.3% to 57.1%.

In both inside and outside floodplains, the rates of mobile homes and multi-family homes have increased between 1990 and 2000. The proportion of mobile homes is higher in floodplains (3.1% in 1990 and 5.1% in 2000) than outside floodplains (2.5% in 1990 and 3.1% in 2000). Although the difference of the percentages between multi-family housing in and outside floodplain became smaller, the rate of the housing in floodplain is still higher than that outside floodplain.

In single family homes, those in the very low-income areas have increased by 71% from 1990 to 2000 in floodplain, while those in the higher income areas have increased by just 0.3% (see Table 7). It is very high growth, compared to single family homes in very low-income areas outside floodplains (3.3%). The growth rate of mobile homes is also higher in floodplain (48%) than outside floodplains (37%). Although proportion of mobile homes (6.6% in 1990 and 7.9% in 2000) and single family homes in the very low-income areas (2.2% in 1990 and 7.1% in 2000) in floodplain to total mobile homes and total single family homes in the areas are small, the growth of both should be paid attention because these housing types may be the most affordable housing for low-income people. These increases in both housing types can indicate the increase of low-income people in floodplains. As mobile homes are more structurally vulnerable to natural hazards, the exposure of low-income people to floods can become more serious. Fig. 4 presents this increase of multi-family homes inside and outside floodplains in the southeastern area of Austin.

Table 7. The Growth Rates of Residential Use between 1990 and 2000

	Inside Floodplain	Outside Floodplain	Whole City
Single Family;	8.89%	17.96%	17.51%
In Very Low-Income Areas	71.02%	3.33%	8.12%
In Low-Income Areas	24.86%	40.01%	39.07%
In Higher Income Areas	0.29%	13.58%	12.98%
Mobile Home	48.24%	36.92%	37.82%
Multi Family	28.61%	33.26%	33.00%
Total	14.20%	20.87%	20.53%

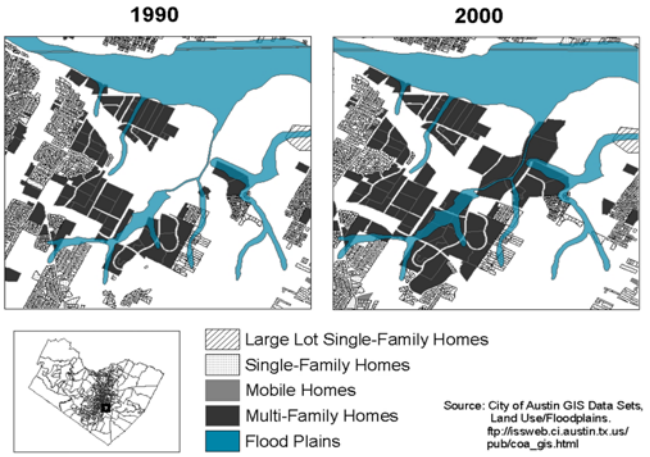

Fig. 4. Residential Land Use Change in Floodplains between 1990 and 2000

In Austin, mobile homes have been concentrated on floodplains from 1990 to 2000. Mobile homes are the most affordable housing for low-income people. The increase in mobile homes indicates the increase of low-income people in floodplains. As mobile homes are more structurally vulnerable to natural hazards, the exposure of low-income people to floods can become more serious.

4.3 Increase in Low-Income Population in Floodplains

From 1990 to 2000 the population increase in Austin has caused more people to live in floodplains. In particular, the number of poor people who live in floodplains has increased, and the rate of poor people in floodplains is higher than that in the whole area of Austin.

Table 8 represents the number and the percentage of low-, middle-, and high-income people who live in "the census blocks in floodplains." In all scenarios, the number of people who live in floodplains has increased between 1990 and 2000, along with the number of people in the whole city. The number of low-income people in floodplains has also increased in all of five scenarios, while the number of high-income people in floodplains has greatly decreased. The percentage of low-income people to total population in floodplains in 2000 is higher than that in 1990 for all scenarios. The large size of census blocks, relative to floodplains, causes some areas in census blocks to lie inside the floodplain while the other parts lie outside of floodplains.

Table 8. The Change of Population in Census Blocks in Floodplains for Each Scenario

Census Block	Low- Income	Middle-Income	High-Income	No Data	Total		
20%*	1990	Number (Percent)	15,824 (32.9%)	16,175 (33.6%)	16,054 (33.4%)	27 (33.4%)	48,080 (100.0%)
	2000	Number (Percent)	29,607 (42.5%)	22,582 (32.4%)	13,726 (19.7%)	3,706 (5.3%)	69,621 (100.0%)
40%*	1990	Number (Percent)	5,809 (28.5%)	8,217 (40.3%)	6,356 (31.1%)	27 (0.1%)	20,409 (100.0%)
	2000	Number (Percent)	16,231 (55.1%)	10,932 (37.1%)	2,008 (6.8%)	314 (1.1%)	29,409 (100.0%)
60%*	1990	Number (Percent)	2,990 (32.2%)	3,637 (39.2%)	2,651 (28.6%)	0 (0.0%)	9,278 (100.0%)
	2000	Number (Percent)	4,850 (41.0%)	5,913 (50.0%)	1,067 (9.0%)	12 (0.1%)	11,842 (100.0%)
80%*	1990	Number (Percent)	1,658 (27.9%)	2,816 (47.7%)	1,466 (24.7%)	0 (0.0%)	5,940 (100.0%)
	2000	Number (Percent)	3,011 (45.0%)	3,448 (51.5%)	232 (3.5%)	2 (0.0%)	6,693 (100.0%)
100%*	1990	Number (Percent)	943 (35.0%)	1,509 (56.0%)	242 (9.0%)	0 (0.0%)	2,694 (100.0%)
	2000	Number (Percent)	1,004 (35.0%)	1,852 (64.6%)	10 (0.4%)	2 (0.1%)	2,868 (100.0%)
Average	1990	(Percent)	(31.3%)	(43.3%)	(25.4%)	(0.0%)	(100.0%)
	2000	(Percent)	(43.7%)	(47.1%)	(7.9%)	(1.3%)	(100.0%)
Whole City	1990	Number	149,406	151,953	239,286	2,144	542,789
		(Percent)	(27.5%)	(28.0%)	(44.1%)	(0.4%)	(100.0%)
	2000	Number	260.875	205.909	221.613	9,671	698,068
		(Percent)	(37.4%)	(29.5%)	(31.8%)	(1.4%)	(100.0%)

Note: *means how much the census block is overlain on floodplains.
Source: City of Austin GIS Data Sets, Floodplains, Available at ftp://issweb.ci.austin.tx.us/pub/coa_gis.html
U.S. Bureau of the Census, American Factfinder, SF1 & SF3, 1989, 1999. Available at http://www.census.gov/

In the "40%" scenario, especially, the percentage of low-income people has rapidly increased by 26.6%, from 28.5% to 55.1%, and the percentage of high-income people has greatly decreased by 24.3%, from 31.1% to 6.8%. In the average of the five scenarios, which is highlighted, while more low-income people lived in floodplains in 1990 than high-income people by 5.7%, they were exposed to floods in 2000 by 35.8%. Between 1990 and 2000, the number of high-income people has rapidly decreased by 17.5%, and the number of low-income people has increased by 12.4%.

Compared to the growth in the whole city, the percentage of low-income people in floodplains is higher in 1990 and 2000, by 3.8% and 6.3%, respectively. In particular, in 2000, the percentage of high-income people in floodplains is much lower than that in the whole city. These results may identify that, between 1990 and 2000, more low-income people have come to live in floodplains and many more high-income people have left floodplains. Thus, this may mean that low-income people have been concentrated more and more on floodplains in Austin. Fig. 5 presents this change of population between 1990 and 2000.

The comparison of the growth rates of population in floodplains and the whole city makes it clear that low-income people have been concentrated on floodplains. Table 9 and Fig. 6 show the growth rates of low-, middle-, and high-income people in the census blocks in floodplains. Between 1990 and 2000, in the whole city, the number of low-income people has increased by 74.6%, while the number of high-income people has decreased by just 7.4%. Similarly, in an average of the five scenarios, the number of low-income people has increased by 83.4%, while the number of high-income people has decreased by 64.5%. Compared with the whole city, in the floodplains the growth rate of low-income people is higher and the decrease of high-income people is so much higher.

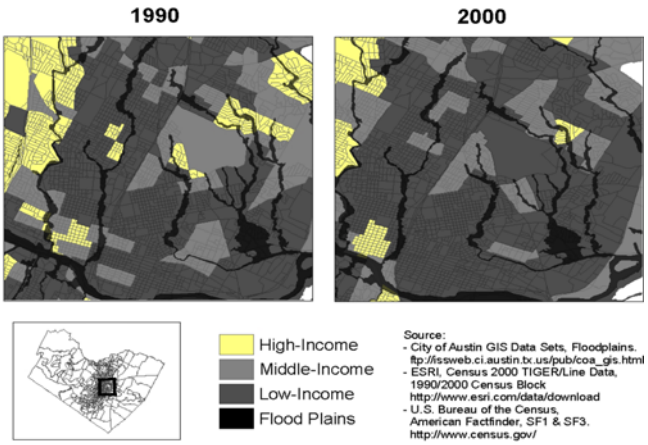

Fig. 5. Population Change between 1990 and 2000

This growing tendency for more low-income people to live in

Table 9. The Growth Rates of Population by Census Blocks in Floodplains between 1990 and 2000

	Low-Income	Middle-Income	High-Income	Total
20%*	87.1%	39.6%	-14.5%	44.8%
40%*	179.4%	33.0%	-68.4%	44.5%
60%*	62.2%	62.6%	-59.8%	27.6%
80%*	81.6%	22.4%	-84.2%	12.7%
100%*	6.5%	22.7%	-95.9%	6.5%
Average	83.4%	36.1%	-64.5%	27.2%
Whole City	74.6%	35.5%	-7.4%	28.6%

Note: *means how much the census block is overlain on floodplains. Low-Income: Not More than 80% MFI; Middle-Income: 80-120% MFI; High-Income: More than 120% MFI

Source: City of Austin GIS Data Sets, Floodplains, Available at ftp://iss-web.ci.austin.tx.us/pub/coa_gis.html
U.S. Bureau of the Census, American Factfinder, SF1 & SF3, 1989, 1999. Available at http://www.census.gov/

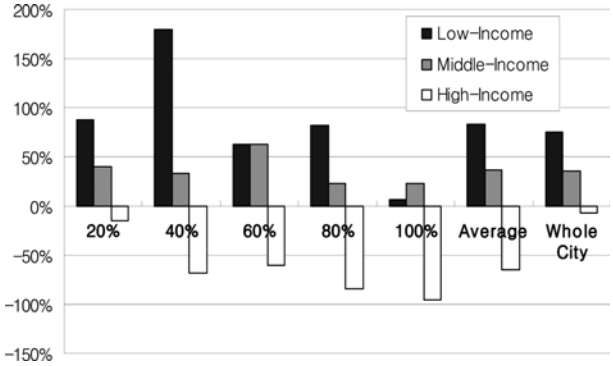

Fig. 6. The Growth Rates of Population by Census Blocks in Floodplains between 1990 and 2000

floodplains could result in the increased exposure of low-income people to flooding in Austin. This exposure of low-income people to floods may be more serious than that of other people, because low-income people cannot financially recover from the floods as resiliently.

4.4 Negative Relationship Between Income and Floodplain

In Austin, income is negatively related to floodplain. According to the result of regression analysis between median household income and the percentage of area of floodplain at the census block group level (see Table 10), the values of coefficients are -0.175 and -0.188 with the significance at the 0.00 levels in 1990 and 2000, respectively. This means that since 1990 in Austin, people with the lower income have lived in the areas with more floodplain, and on the contrary, people with the higher income have lived in the areas with the less floodplain. In other words, low-income people tend to live in the floodplain. In addition to, this exposure of low-income people is likely to have increased during this period.

Table 10. Relationship between Floodplain and Median Income in 1990 and 2000

	1990	200
Dependent Variable: percent of area of floodplain at census block group level		
Median Income	-0.175*	-0.188*

*Significance: 0.00

5. Conclusions

The purpose of this study was to explore the exposure of low-income people to floods in Austin. In particular, it was to confirm the growth of the number of low-income people in floodplains. The main findings of this study are as follow: First, household income is positively related to property value in Austin. Property value, including property value per acre and property value per parcel, are lower inside floodplains than outside floodplains. Therefore, many people who live in floodplains are likely to be low-income people. Second, many floodplain areas have been developed for residential land use between 1990 and 2000. The rate of development for residential land use is higher in floodplains than in the whole city of Austin. Of these rates, the rate of mobile home, which are affordable for low-income people, has substantially increased in floodplains, while the rate of single-family homes has decreased over 10 years. Third, low-income people are more likely to live in floodplains. Between 1990 and 2000, the number of low-income people has rapidly increased in floodplains, while that of high-income people has sharply decreased. This growth of low-income people in floodplains is higher than in the whole city of Austin. Fourth, people with the lower income tend to live in the areas with more floodplain. These findings identify that the growth of low-income communities in floodplains may result in the increased exposure of low-income communities to floods in Austin. And Austin's low-income people are likely to be unfairly vulnerable to floods.

Ultimately, the better way for a community to avoid the danger and damage from flooding is to avoid buildings in floodplains altogether. Other choices, such as the building of structural flood control projects, do not guarantee safety. According to literature review, low-income people are more likely to live in homes in floodplains and to be the more vulnerable to flooding. This study empirically showed the increasing exposure of low income people in the floodplain areas in Austin. Although Austin has tried to mitigate flood damage, the city has not yet developed special policy strategies, for example, mitigation targeted to certain populations such as low-income people. Therefore, the development of more various policy strategies may be necessary to reduce the vulnerability of low-income people to floods. Here, some policy issues can be recommended to be considered for better floodplain management in Austin. The important policy issues from the findings of this study are about land use planning, hazard area maps, and a comprehensive approach.

First, land use planning can be a powerful tool for reducing losses from natural disasters and has many potential advantages for mitigation of natural hazards. It can reduce more effectively long-term damages and loss of life. And, it can have a potential

for substantial long-term cost savings. Also, it can protect valuable features and elements of natural environment. Finally, it can promote human settlement patterns to be more sustainable, environmentally and socially. So, the local governments' land use plans can be an effective tool of restricting development in the environmentally sensitive areas and the state or federal government's mandate can lead the local governments to adopt such land use plans.

Second, the local governments should seek to set appropriate standards of criteria of vulnerability to natural hazards. These include improving clear and authoritative maps of hazard areas and identifying who pay and who benefit. These should reflect local political setting. These standards and criteria are significantly related to adoption of good plans and successful implementation. This task is a first step to build local networks, capacity and consensus because the clear standards and criteria for land use planning are likely to lead active citizen participation who can understand the planning process.

Finally, the most important policy issue is a comprehensive approach. It is significantly related to low-income people. The local governments' programs to reduce losses from floods sometimes raise an equity issue related to housing. The mitigation efforts after natural disasters have resulted in an increase in housing price and then a shortage of affordable housing. So, local governments should implement comprehensive approaches for low-income housing. Also, the local governments' comprehensive approaches through collaboration with other agencies can help minimize the exposure of low-income people to natural disasters including floods. And, special mitigation strategies are necessary in considering low-income people. For example, although the acquisition program is a desirable way to mitigate flood damage, the program can result in the unintended consequence of reducing the supply of affordable housing. When a community clears out its floodplains, it must ensure that opportunities for affordable housing elsewhere are made available. Therefore, the comprehensive approach through cooperation with other agencies can help minimize the exposure of low-income people to floods.

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