Climate Resiliency: Application of GIS Methods to Assess Flood Risk, Vulnerability, Potential Impacts, and Resiliency in Hidalgo County, Texas

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CLIMATE RESILIENCY: APPLICATION OF GIS METHODS TO ASSESS FLOOD RISK, VULNERABILITY, POTENTIAL IMPACTS, AND RESILIENCY IN HIDALGO COUNTY, TEXAS

A Thesis

by

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ABSTRACT

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A contemporary concern towards the increased force of storms and massive rainfall occurrences caused by climate change are issues that can cause socio-economic disturbances, destruction of property, and loss of life. The implementation of techniques towards enhancing preparedness, planning, and mitigation, such as assessing risk and vulnerabilities through a Geographic Information System (GIS), can promote climate resiliency. This study measures the risk and vulnerabilities of assets within Hidalgo County through GIS spatial analysis. STATA and GIS results were used to summarize the number of vulnerable assets and assets at risk as well as assets exposed to flooding at the County and City scale. Data analysis results obtained for the major cities of Edinburg, McAllen, and Mission indicated a large proportion of aged buildings located in Special Flood Hazard Areas (SFHA's) such as 100-year and 500-year flood zones.

DEDICATION

Dedicated to my beloved Grandfather, Pedro "Papa Pete" Duran, who passed away during the process of conducting my thesis on December 23, 2019. This thesis is dedicated to the late nights spent at the hospital providing company and care for my beloved Grandfather. This is also dedicated to my parents for their unfaltering support and encouragement towards my academic fulfillment. Finally, I would like to dedicate this to my relatives and friends for their advice and source of inspiration.

ACKNOWLEDGEMENTS

I wish to thank my committee members, Dr. William Donner and Dr. Arlett Lomeli, for their kind support and effort to provide time and guidance during my thesis. A special thanks to Dr. William Donner's support, insight, and feedback in research methods during this process. Notably, I wish to express my deepest gratitude to Dr. Dean Kyne, who served as my committee chairman for his encouragement, patience, selfless dedication, and availability. I am indebted by Dr. Dean Kyne's incalculable hours dedicated to discussion and guidance during the process of this study.

A special acknowledgment and thanks to the Disaster Studies program, Hidalgo County Appraisal District (GIS Department), Hidalgo County Planning Department, and McAllen GIS, for providing me with the resources, tools, data, and knowledge to conduct research. Finally, I would like to thank my parents for their continued support and encouragement that made the completion of this process an enjoyable and stress-free experience.

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CHAPTER I

INTRODUCTION

1.1 Climate Change

Climate change has caused an increase in temperatures in Texas and has further intensified the magnitude of torrential rains and hurricanes. According to the National Oceanic and Atmospheric Administration (NOAA), during the turn of the 20th century, the mean annual temperature in Texas rose by one-degree Fahrenheit (Runkle, 2017). Climate change has a considerable deal of sway towards intensifying precipitation, which exacerbates the risk of flooding, especially for those residing in warmer climate areas. As global temperatures rise sea-levels rise and expand, the swift acceleration of sea-level rise sets low-lying areas near the Gulf coast in danger in the direction of increased force of storms and frequent rainfall events (Schwab, 2017, P. 209).

1.2 Climate Resiliency

Climate resilience in this study is defined as a city's capacity to prepare, plan, mitigate, and augment steps to neutralize the imminent impacts of natural disasters. A significant leap towards climate resiliency should assess the level of risk and vulnerability for municipalities and enhance its capacity to cope and withstand climatic disturbances. Implementing climate resiliency in local governments through GIS mapping can enable cities and counties to grok their levels of risk and vulnerability and can empower them to plan, prepare, and mitigate against climate related emergencies and disasters.

Floods are pervasive and common hazards in the United States, according to FEMA, ninety percent of all-natural disasters in the U.S. involve flooding (FEMA, n.d.). During 2017 Hurricane Harvey targeted Corpus Christi and Port Aransas as a category four hurricane and proceeded to wreak havoc towards the Galveston Bay Area into the city of Houston, causing approximately $73.5 billion in economic loss and displacing over 61,000 individuals (Hobbs, 2017). According to Keller, Hitchcock, Texas near Galveston was not only adversely affected by Hurricane Harvey, but it was also a victim of FEMA's faulty flood zone maps. Keller explains that before Hurricane Harvey struck, FEMA flood zone maps had not been updated since the early 1980s (Keller, 2017). Specious and complex flood maps can place buildings as well as individuals in danger by creating a false sense of security towards flood vulnerability, which, in turn, create uninsured businesses and homeowners. As a result, it is an urgent need for municipalities to promote climate resiliency and formulate strategies in order to plan, mitigate, and prepare for climate related emergencies and disasters.

1.3 Research Goal

The primary goal of this study is to empirically measure the vulnerability and risk of residential and commercial structures in Hidalgo County using a geographic information system (GIS)-based spatial analysis.

1.4 Study's Contribution

The study's findings are expected to contribute to a better understanding of potential food risks associated with the residential and commercial structures and their vulnerability. In this study, risk is assessed by measuring an asset's market value and exposure to flood hazard areas while, vulnerability identifies the degree of an asset's ability to cope with or withstand extreme flood events and its exposure to flood prone areas. Research findings of risks and vulnerabilities within Hidalgo County can contribute in two ways. First, the findings are expected to indicate areas where assets comprise of high risk and vulnerability. Second, after understanding the geographical risks and vulnerabilities in the city scale, recommended actions are also expected to improve community resilience through flood ordinances and flood insurance. In elaboration, the study's findings could be applied to municipalities within Hidalgo County to help understand the risk and vulnerabilities of buildings, properties, and critical infrastructure located near flood hazard areas. Findings are expected to improve the current status of building ordinances enforced in communities to advance floodplain management programs through the Community Rating System (CRS). At the same time, GIS maps in this study can create an acute awareness amongst community members, business owners, the county's and cities' officials towards the risk and vulnerability of their properties. The illustrations of risk and vulnerabilities of assets in Hidalgo County are also expected to promote a preparedness culture by encouraging business and residential owners to purchase flood insurance to mitigate economic and property losses.

This thesis is organized as follows. Chapter II reviews literature on flooding risk in the Lower Rio Grande Valley. Next, it is followed by a discussion on methods and data collection. Chapter IV discusses on the study's findings. Finally, it concludes with recommendations.

CHAPTER II

FLOODING RISK OF THE LOWER RIO GRANDE VALLEY

2.1 Description of the Lower Rio Grande Valley

The Lower Rio Grande Valley (LRGV) consists of four counties which are situated in the most southern part of Texas and it borders with the Mexico along the Rio Grande river. Among the four counties, Hidalgo County is one of the largest counties in the LRGV as well as in the State of Texas, its elevation varies from 40 to 200 feet (Garza, 2010). The county host a population of about 0.9 million; the population mushroomed from 860k in 2017 to 865k in 2018 (Hidalgo County, n.d.). Economically, the cities of McAllen, Mission, and Edinburg have had an annual 1.09% increase in employment rates from 2017 to 2018 pushing Hidalgo County's employment from 334k individuals to 338k. Leading careers in Hidalgo County entail Health Care, Retail Trade, Social, and Educational Services (Hidalgo County, n.d.).

2.2 Flood History

A total of 64 flood events have been recorded in Hidalgo County, Texas, since 1966. According to FEMA records, Hidalgo County has declared a total of 25 disasters between 1953-2019, 21 of those declarations were attributed to hurricanes, severe storms, and flood-related events (Historical Flood Risk and Costs, 2020). For over a century, the LRGV has experienced numerous storms and hurricanes that have created economic disasters and disruptions. One of the earliest recorded flood disasters in South Texas identified as a storm that dumped an extraordinary 26 inches of rain that pummeled the entire city of Brownsville in September 1886. During the early 1930s, the LRGV experienced intense flooding due to storm surges that caused populations to abandon the coastal area until after World War II (U.S. Department of Commerce & NOAA 2017). It was not until the late 1960s that the LRGV received hard hits from Category 3 Hurricane Beulah causing an unprecedented number of tornadoes, storm surges, and inundation in Southcentral and Southeast Texas (Major Hurricane Beulah, 2017). This calamitous event was accounted for a total of 58 deaths and $250 million worth of damage costs, which is equivalent to a contemporary $1.59 billion (Major Hurricane Beulah, 2017).

Throughout history, the Rio Grande Valley has demonstrated its vulnerability towards flooding. On July 23rd, 2008, Hurricane Dolly was inimical to Cameron, Hidalgo, Willacy, and even Starr County, causing over $1 billion in damage costs and pouring between 12 to 18 inches of rain (U.S. Department of Commerce & NOAA, 2017). Further in 2010, bouts of episodic rainfall flooded the cities of McAllen and Mission from April 12th through 18th. A couple of months after, on June 30th, Hurricane Alex's convective bands brought up to 50 mph winds into Willacy, Cameron, and eastern parts of Hidalgo county and producing up to five inches of rain (U.S. Department of Commerce & NOAA, 2016). It is estimated that Alex's damage costs in Hidalgo County totaled to about $10 million and left 9,000 people without power (Pasch, 2010).

More recently, during June 2018 the Rio Grande Valley was buffeted by torrential rainfall that corroded the RGV with floods. NOAA calculated that approximately five inches of rainfall per hour bashed the RGV affecting at least 20,000 residential properties and causing up to $250 million in damage. According to FEMA over 7,000 businesses and residences were categorized as "minor to destructive" in terms of damage (U.S. Department of Commerce & NOAA, 2018). Torrential rains rapidly inundated the eastern portion of McAllen stretching to the outskirts of Harlingen. In Weslaco, the Mid Valley Airport received over 11 inches of rain within a three-hour span and over a hundred businesses and 2500 residential properties were destroyed by 18 inches of floodwater (U.S. Department of Commerce & NOAA, 2018). Past disasters that have occurred in the LRGV help demonstrate how future storms can be detrimental to Hidalgo County. With the advent of increased precipitation and impervious surfaces, Hidalgo County's infrastructure, property, and human safety become vulnerable to extreme weather events.

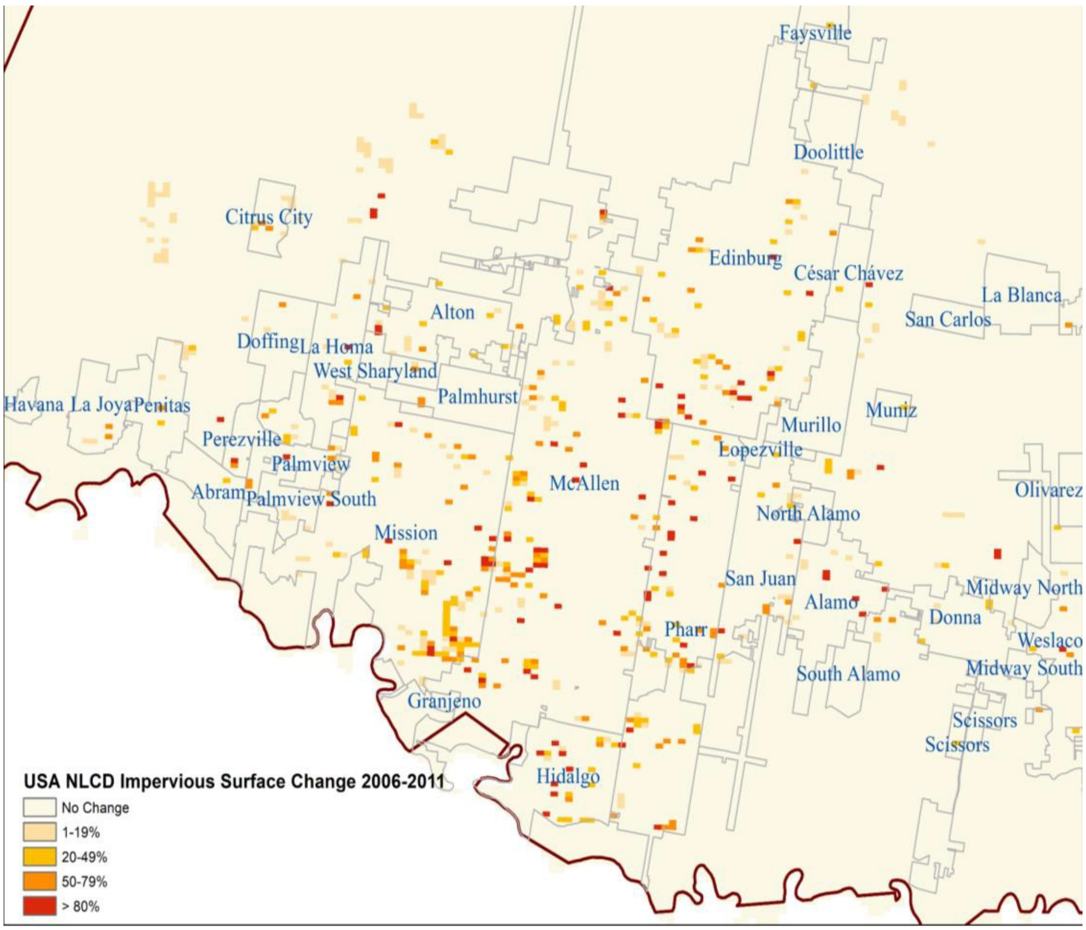
Clearly, the LRGV is no stranger to flood events and there is no doubt that the topography, population, and the number of impervious surfaces has increased within the past couple of decades in Hidalgo County, yet many FEMA flood maps have stayed in place since the early 1980s. It is imperative to underscore that FEMA flood maps do not account for a city's capacity to drain water, the recent increase of impervious surfaces and land use, and is in the necessity of maps that indicate unique risks and vulnerability involving assets to improve resilience. Although FEMA flood maps do not account for a city's capacity to drain water, cities and communities must adequately understand their current level of flood risk. A county that comprises of clear, informative, and updated flood maps that are comprehendible for communities and businesses can bolsters resilience and raise awareness towards risks and vulnerabilities of Hidalgo County. One of the main issues that is a constant albatross for Hidalgo County are outdated FEMA flood maps and the insufficiency of maps that depict clear future precipitation patterns to expose potential flood risks. According to Scata, FEMA is responsible for updating flood maps every five years, and more than half of FEMA flood maps are rendered to be outdated (2017). Many areas in Hidalgo County are using FEMA flood maps from the 1980's such as some areas in the city of McAllen, La Joya, Donna, Alamo, San Juan, Pharr, and Hidalgo (FEMA Flood Map, n.d.). Further, Scata eloquently stated that FEMA "looks back into time" when considering flood maps (2017). In other words, FEMA uses past weather events and topographic data to decipher flood prone areas as opposed to determining potential flood risks through future climatic changes. Respectfully, Flood Insurance Rate Maps (FIRM's) and Flood Insurance Studies (FIS's), can also become convoluted with flood depth measures, base floodway elevations, and various flood zone areas that can be difficult to comprehend for average community members and business owners. FEMA flood maps can be used in conjunction with GIS mapping to produce clear, informative, simple, and attractive maps that demonstrate potential hazard areas for community and business members. Thus, integrating GIS maps to assess potential flood risks and vulnerabilities for assets in Hidalgo County is a significant step towards building community resilience and situational awareness.

2.3 Types of Flood

According to NOOA, flash flooding is caused by an abundance of rain within a brief period. Flash floods can occur shortly after the collapse of a dam or a levee (NSSL, n.d.). Flash floods can also evolve rapidly and submerge streets and homes in a matter of hours (NSSL, n.d.). Geographer Gilbert F. White classifies extreme bouts of episodic rainfall that cause inundation in less than 48 hours, known as "sharp-crested floods" caused by cloudburst storms (White, 1945, p. 42). White also adds that sharp-crested floods, which comprise of "greater water velocities," could occur in any location where drainage capacity is weak at any season (1945). Notably, Hidalgo County has experienced a series of sharp-crested floods that have been exacerbated by outdated drainage, particularly in Colonias. According to Valley Central news, during the June 2018 floods, ten Colonias were submerged with over 10 inches of rain within hours (Hernandez, 2018).

Further, NOAA asserts how densely populated areas are most at risk when it comes to flash floods. These flood risks are shaped by the increase of impervious surfaces such as highways, driveways, parking lots that create runoff due to lack of water absorption (U.S. Department of Commerce & NOAA, 2017). Flood-plain "occupance" is another term used to define human land uses. According to White, the term "flood-plain "occupance" is used to define human land use, which encompasses landscape development, social, and environmental adjustments. Some examples of "occupance" include residential, commercial, agricultural, recreational, governmental, and manufactural adjustments (White, 1945, p. 46). With the advent of new businesses and residential growth of cities within Hidalgo county, an increased number of impervious surfaces can create unfortunate circumstances during massive rainfall events. Data files provided by Esri, the international Geographic Information System Company, provided data for increase of impervious surfaces between 2006-2011. Figure 1, created through ArcGIS desktop, illustrates the increase of impervious surfaces in Hidalgo County. It is important to mention that scattered outdated FEMA maps in Hidalgo County from the 1980s have not caught up with the recent increase of impervious surface changes within the city scale.

FIGURE 1 IMPERVIOUS SURFACE CHANGES 2006-2011



Conversely, Inland flooding is caused by "moderate precipitation" that takes longer than flash floods to develop. Gradual inland flooding can create nuisance flooding in a matter of days. Nuisance flooding can be characterized as flooding that causes difficulties or inconveniences, such as road closures, damage to roads and infrastructure, and submerged storm drains (U.S. Department of Commerce & NOAA, 2017). In addition, White similarly distinguished inland flooding to "broad-crested floods," which may be classified as flooding that develops within 70 hours or more (White, 1945, P. 42). This assessment will consider both flash and slow inland flooding when assessing flood risks and vulnerabilities.

2.4 Assessing Vulnerability

The City of Asheville, North Carolina's assessment report, measures vulnerability through adaptive capacity and potential impact. Adaptive capacity (AC) involves an asset's ability to withstand and cope with potential disasters which can also be known as, resiliency. The potential impact (PI) to an asset depends on its exposure towards flood prone areas. This study determines the degree of vulnerability in three levels based on potential impact and adaptive capacity from high, medium, and low. For instance, a structure that was built before 1995 acquires the lowest AC, units built between 1995 and 2010 hold medium AC while units built after 2010 hold the highest level of AC due to the advent of building regulations, new building materials, and flood-proofing methods.

Notably, high-level PI characteristics include commercial and residential buildings that are in a Special Flood Hazard Area (SFHA) also known as "A" zones. An "A" zone is also known as a base floodplain or 100-year flood zone (Schwab, 2017 P.228). 100-year floodplains have a 1% chance of flooding each year or once every decade (Schwab, 2017, P. 229). A medium level PI includes commercial and residential buildings, warehouses, storage facilities, residential or commercial inventory structures located in an X500-year flood zone which is an area that has a 0.2 percent chance of flooding each year (Schwab, 2017, P.229). The lowest level of PI's are "X" zones which are areas that comprise of minimal flooding hazards that include a structure with high or medium AC (Rogers, 2018).

It is imperative to mention that combinations of high adaptive capacities and high potential impacts are not mutually exclusive. For instance, a commercial building that was built after 2010 that is in a SFHA is associated with a high AC and high PI, which is equivalent to a medium level of vulnerability. A different combination that helps demonstrate the association between AC, PI, and vulnerability would be a residential building built in 1986 that was constructed in a 500-year flood zone. The residential building would be classified as having low AC since it was built before 1995 and Medium PI since it is in a 500-year flood zone, which corresponds to high vulnerability. The relationship between adaptive capacity, potential impact, and vulnerability can be interpreted as

"vulnerability = potential impact – adaptive capacity" (Rogers, 2018).

Table one demonstrates a vulnerability matrix tool that helps equate adaptive capacities and potential impacts into levels of vulnerability.

TABLE 1 ADAPTIVE CAPACITY AND POTENTIAL IMPACT

Adaptive Capacity \ Potential Impact	Low (Zone X)	Med (Zone X500)	High (Zone A)
Low (Before 1995)	M	H	H
Med (1995-2010)	L	M	H
High (After 2010)	L	L	M

Borrowing from Rogers' concepts, this matrix table helps interpret vulnerabilities based on the location and year built of a building. However, this assessments' year-built classification for buildings that measure AC does not emulate Rogers' AC classification; this is due primarily to Rogers' insufficiency towards justifying why the year-built classifications were selected to identify AC levels. For instance, Rogers explains how buildings built before 1980 are classified as having the lowest AC, while buildings built between 1980-2010 acquire medium AC, and buildings built after 2010 acquire the highest levels of AC (2018). Although Rogers assessment report explains that buildings built before 1980 are categorized as having low AC because they are not included in recent "flood ordinances," it still does not sufficiently elaborate on what type of ordinances and fails to explore building inadequacies based on the age of a structure. Therefore, this study modifies Rogers' year-built classifications based on the American Housing Survey (AHS) funded by the Department of U.S. Housing and Urban Development (HUD).

As mentioned, this study classified homes older than 25 years (before 1995) with low resiliency or low adaptive capacity due to inadequate physical conditions. According to the American House Survey (AHS) in 2011, buildings built before the advent of "federal building standards" in 1976 were deemed inadequate (Furman, 2015). Furman asserts that the AHS concluded how 10.6 percent of buildings built before federal building standards and 10.8 percent of buildings built between 1985-1990 are in unsafe conditions (2015). In addition, AHS states that units also built before the Department of Housing and Urban Development's regulations update in 1994, were also considered inadequate. Mainly, physical inadequacies associated with homes built before 1995 involve exterior water leaks, sewer failures, holes in the roof, cracked or crumbling foundations, and broken windows (Furman, 2015). Therefore, this study classifies buildings built before 1995 as acquiring the lowest adaptive capacity as opposed to Rogers' "before 1980" classification.

Particularly, before the 1970s building codes were rare and a small number of states enforced statewide building requirements (Schwab, 2017, P.717). Between 1994 and 2010, local governments codified stringent regulations in order to participate with the National Flood Insurance Program (NFIP). The National Flood Insurance Reform Acts of 1994 and 2008 pushed local governments to place ordinances such as zoning ordinances, subdivision ordinances, which include freeboard requirements and floodproofing methods (Flood Insurance Reform, 2019). These ordinances were developed to receive federal aid in the form of appropriations, grants, and loans. More recently after 2010, state and local governments placed more considerable emphasis on enforcing minimum International Council Code (ICC) building requirements for new structures while older structures built before newly placed building codes "grandfathered" them (NFIP Grandfathering Rules, 2016).

In 2015, the Texas State Collaborative listed opportunities to develop resilience within Hidalgo County. Texas State Collaborative advised the City of McAllen to adhere to ICC minimum standards, such as freeboard requirements over 12" of base flood elevations (BFE) and applying impact resistant class 4 shingles that resist strong winds, torrential rains, and hail (Texas State Collaborative, 2015). The City of McAllen has adopted the 2012 International Residential Standards developed by the ICC, while Hidalgo County has not adopted obligatory official residential requirements. According to the Hidalgo County planning department, Hidalgo County's only minimum requirements towards flood resiliency are floor elevations requirements for preliminary plats, which is 18 inches above natural ground (Hidalgo County, 2018, P. 61). Further, new building codes do not apply to structures built in the past unless they have undergone "substantial improvements," which means that they have made improvements that exceed 50 percent of the market value of their building (Substantial Improvement, n.d.). That is why low adaptive capacity is associated with antiquated buildings built before new building code requirements that have not undergone substantial improvements. In contrast, contemporary buildings hold higher adaptive capacities due to new building materials, higher floor elevations, and floodproofing methods.

2.5 Risk Criteria

The associations between adaptive capacity, potential impact, and vulnerability are much like measuring risk. For instance, the risk of a parcel is determined by consequence and probability. In this study, consequence is identified as potential adverse outcomes or potential losses of an asset if flooding were to occur. The consequence of an asset is assessed through its median market value. For instance, if an asset acquires a market value above the county's median market value, it would hold higher consequences than those acquiring a market value below the county's median market value. Probability defines an asset's likelihood of flooding and is determined by its level of exposure to flood-prone areas. According to Rogers, merging probability with consequence generate a measurable degree of flood risk (2018). Although Rogers' formula to assess risk does not quantify loss calculations, it is still a valid indicator towards investigating risk by measuring the value and exposure of an asset. Rogers measures the degree of consequence of an asset based on its median market value. In this case, the median market value for Hidalgo County is $74,527. Units above the median market value are classified as having a high consequence, while buildings below the median market value will be classified as having a medium level consequence. Probabilities of flooding are based on FEMA flood maps provided by the City of McAllen GIS and include flood zones such as A, X500, and X. For instance, a commercial building that acquires a median market value of $148,000 that is located near a floodway/100-year flood zone would be classified as "high risk" due to its potential to face far-reaching consequences. The following table demonstrates a risk matrix tool that equates risk based on consequence and probability.

TABLE 2 CONSEQUENCE AND PROBABILITY

Median Market Value= $74,527

Consequence \ Probability	Low (Zone X)	Med (Zone X500)	High (Zone A)
High Above Median	M	H	H
Med Below Median	L	M	H

It is important to note that the risk matrix table does not include lands such as, vacant lots, rural lands, or any type of open space land. Since this study is only concerned with residential and commercial related structures it did not associate empty parcels with risk and vulnerability, due to the absence of structures. The Hidalgo County Appraisal District has more than 10 different categories for lands with no structures. Lands with no structures that were not involved in the risk matrix assessment were Vacant lots, Land tracts, Colonia lots, Rural land non-qualified open space land, and rural land qualified open space land, qualified and non-qualified land for improvements and others.

CHAPTER III

METHODS AND DATA

3.1 Data Sets

This study includes seven datasets from three sources (Figure 1). First, the three shape files, namely HCAD_Parcel, City_Limit_2019, and ETJ_2019.shp were received from the Hidalgo Appraisal District which include property ID numbers, extra-territorial jurisdictions, and city limits. CSV file 2019_CSV comprised of property ID numbers, tax information, market values, addresses, and building classification and property data and was received from Hidalgo County Appraisal District. Next, FEMA.shp a shapefile that consisted of flood hazard areas for Hidalgo County was received from GIS McAllen. Finally, Bodies_of_water_1.shp and Bodies_of_water_2.shp included reservoirs, basins, lakes, rivers, and canals from Hidalgo County Planning Department.

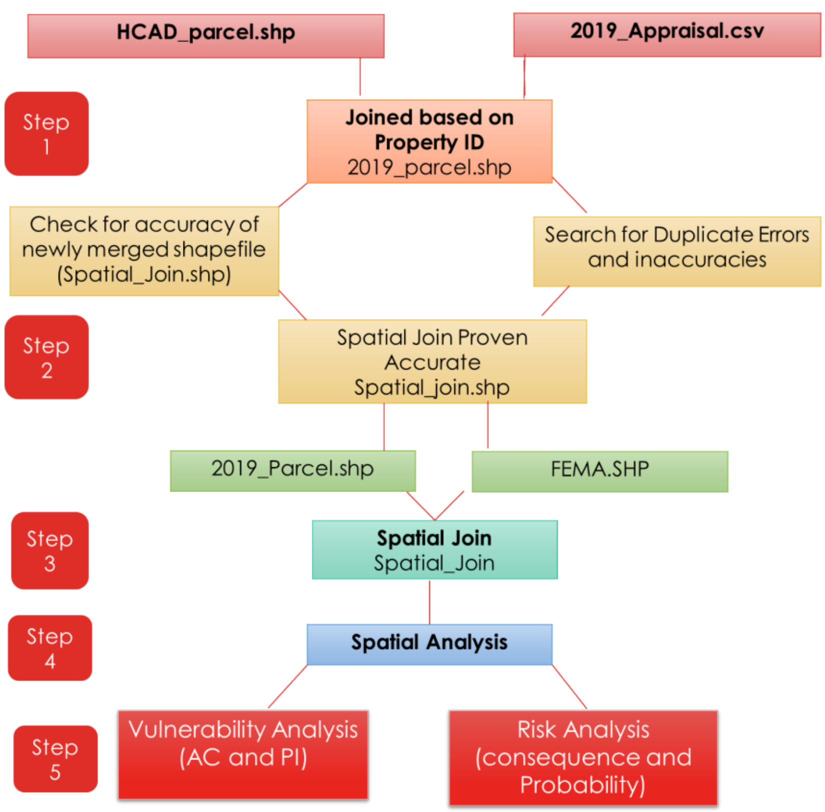
FIGURE 2 DATA USED IN THE STUDY

File Name	Source	Type	Description
HCAD_Parcel.shp City_limits_2019.shp ETJ_2019.shp	Hidalgo County Appraisal District	Shapefile (Polygon)	Property ID, Extra territorial jurisdiction, and City Limits
2019_Appraisal.csv	Hidalgo County Appraisal District	Excel File	Property ID, Property type and structures, lots, Tax information, Market value, Year built, City, Zip code, Land Value and Improvements.
FEMA.shp	GIS McAllen	Shapefile (Polygon)	Special Flood Hazard Areas. A, ANI, X500, and X
Bodies_of_Water_1.shp Bodies_of_Water_2.shp	Hidalgo County Planning Dept.	Shapefile (Polygon) Shapefile (Polyline)	Lakes, Reservoirs, Basins, and Canals

3.2 Methods

The data analysis includes the following steps. First, the HCAD_parcel.shp file and 2019_Appraisal.csv file were joined by property ID to create a new 2019_parcel.shp file. Secondly, the newly joined shapefile named 2019_parcel was checked for accuracy, then spatially joined with FEMA.shp shapefile creating Spatial_join shapefile. Finally, Spatial_join enters the Spatial analysis process where flood vulnerabilities and flood risks are assessed to create visualizations and summaries through GIS mapping.

FIGURE 3 DATA ANALYSIS FLOW CHART



Notably, in the checking for accuracy stage for shapefile named 2019_parcel.shp involved a careful review of parcel data and totals to scan for duplicate errors and inaccuracies. ArcGIS attribute table indicated that many property ID's were associated with having numerous parcels. Thus, increasing the total number of property IDs on the attribute table. In other words, the 2019_appraisal.csv excel sheet on property and tax information listed 294,762 parcels while newly merged shapefile on ArcMap listed 296,306 parcels. For example, the property ID "246472" was associated with a parcel count of 10 on ArcMap attribute table.

FIGURE 4 CHECKING DATA ACCURACY

Table

Sum_Output_2

OID	PROP_ID	Count_PROP_ID	First_state_cd
8766	246472	10	D1

Table

Spatial_Join

FID	Shape *	Join_Count	TARGET_FID	OBJECTID_1	MODIFIEDUS	QUICKREF	PROP_ID	Shape_STAr	Shape_STLe	prop_id_1	prop_type_	state_cd
88436	Polygon	1	88436	91381	HCAD0507	0	246472	1136301.90605	4505.500016	246472	R	D1
88437	Polygon	1	88437	91382	HCAD0507	0	246472	930303.690372	4039.994776	246472	R	D1
88438	Polygon	2	88438	91383	HCAD0507	0	246472	1696506.47564	5210.009989	246472	R	D1
88459	Polygon	2	88459	91405	HCAD0507	0	246472	1044002.17352	4209.99668	246472	R	D1
88460	Polygon	2	88460	91406	HCAD0507	0	246472	943866.426667	4210.591868	246472	R	D1
88499	Polygon	1	88499	91445	HCAD0507	0	246472	412795.823662	2569.987012	246472	R	D1
88500	Polygon	1	88500	91446	HCAD0507	0	246472	435200.934435	2640.002554	246472	R	D1
88501	Polygon	1	88501	91447	HCAD0507	0	246472	857996.550564	3919.995274	246472	R	D1
88502	Polygon	1	88502	91448	HCAD0507	0	246472	838494.768963	3889.989048	246472	R	D1
13112	Polygon	1	131122	135995	HCAD1206	0	246472	409602.012247	2560.006299	246472	R	D1

To make sure data were not duplicated, CSV file was used to check the accuracy of the newly merged shapefile using property ID. Steps to check for accuracy involved thoroughly auditing the total number parcels and certifying that each parcel was not listed more than once. The following table is a screenshot of 2019_Appraisal.CSV data that demonstrates how property ID "246472" (highlighted row) is associated with 10 addresses and was not duplicated on excel sheet rows. It also verifies how 10 addresses are attributed to one owner ID "246472".

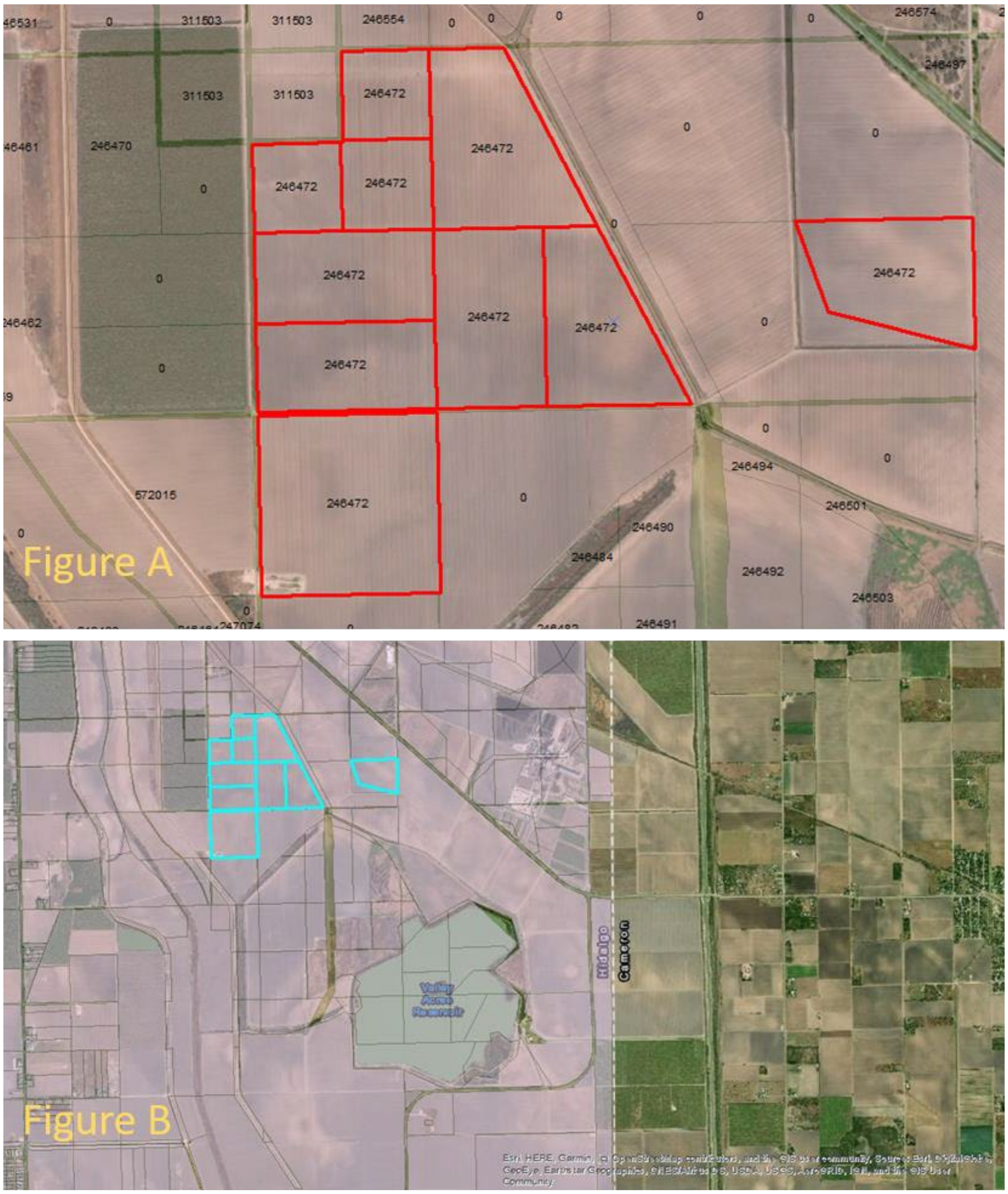
FIGURE 5 AN EXAMPLE OF ONE PROPERTY ID ASSOCIATED WITH MULTIPLE ADDRESSES

A88464 246472

	A	K	L	M	N	O	P	Q
88457	246459	WESLACO	TX	78599	17752	MILE 14 1/2- N-INSIDE LEVY	TX	NORTH CAPISALLO BK 2342 22.19 AC
88458	246460	WESLACO	TX	78599	15672	MILE 15N-INSIDE LEVY	TX	NORTH CAPISALLO BK 2343 19.59 AC
88459	246461	WESLACO	TX	78599	13208	MILE 15N-INSIDE LEVY	TX	NORTH CAPISALLO BK 2344 16.51 AC
88460	246462	WESLACO	TX	78599	11560	MILE 14 1/2 N-INSIDE LEVY	TX	NORTH CAPISALLO BK 2345 14.45 AC
88461	246463	PROGRES(	TX	78579	16688	MILE 14N-INSIDE LEVY	TX	NORTH CAPISALLO-31.08AC BLK 2346 20.86AC NET
88462	246464	PROGRES(	TX	78579	4936	MILE 14N-EAST OF LEVY	TX	NORTH CAPISALLO-W6.92AC-NE 10.61AC BLK 2347 6.17AC NET
88463	246470	MERCEDE!	TX	78570	2488	MILE 15 N-LEVY	TX	NORTH CAPISALLO BLK 2351 3.11 AC FLODD LEVEE
88464	246472	LA FERIA	TX	78559	1595895	MILE 14 1/2 N-E OF LEVY	TX	NORTH CAPISALLO BLKS 2353 TO 2363 2365 2366 & 2369 TO 2371 SW31.18AC BLK 2372 ALL 2373 TO 2375 455.97AC NET
88465	246479	PROGRES(	TX	78579	2712	MILE 14 N-INSIDE LEVY	TX	NORTH CAPISALLO-SW3.77AC BLK 2359 3.39AC NET
88466	246480	MERCEDE!	TX	78570	3384	MILE 14 N-LEVY	TX	NORTH CAPISALLO BLK 2359 4.23 AC LEVEE
88467	246482	SANTA RC	TX	78593	28688	MILE 14N	TX	NORTH CAPISALLO BLK 2360 35.86 AC EXEMPT WATER DIST RESERVOIR
88468	246484	SANTA RC	TX	78593	4184	MILE 14 1/2 N	TX	NORTH CAPISALLO BLK 2361 5.23 AC EXEMPT WATER DIST RESERVOIR
88469	246490	SANTA RC	TX	78593	8424	MILE 14 1/2 N	TX	NORTH CAPISALLO BLK 2366 PT 10.53 AC EXEMPT WATER DIST RESERVOIR
88470	246491	SANTA RC	TX	78593	13336	MILE 14N	TX	NORTH CAPISALLO BLK 2367 16.67 AC EXEMPT WATER DIST RESERVOIR
88471	246492	SANTA RC	TX	78593	20704	MILE 14 N	TX	NORTH CAPISALLO BLK 2368 25.88 AC EXEMPT WATER DIST RESERVOIR
88472	246494	SANTA RC	TX	78593	3784	MILE 14 1/2 N	TX	NORTH CAPISALLO BLK 2369 PT 4.73 AC EXEMPT WATER DIST RESERVOIR
88473	246497	SANTA RC	TX	78593	96272	MILE 2 & HWY 107	TX	NORTH CAPISALLO NE 4.73AC N OF HWY 107 FOR IMPS BLK 2372 4.73AC
88474	246501	SANTA RC	TX	78593	5600	MILE 14 1/2 N	TX	NORTH CAPISALLO BLK 2374 7.00 AC EXEMPT WATER DIST RESERVOIR
88475	246503	SANTA RC	TX	78593	34888	MILE 14 N	TX	NORTH CAPISALLO BLK 2375 43.61 AC EXEMPT WATER DIST RESERVOIR
88476	246504	WESLACO	TX	78599	165000	FM 491	TX	NORTH CAPISALLO BK 2376 S 30 AC
88477	246505	WESLACO	TX	78599	51095	FM 491	TX	NORTH CAPISALLO BK 2376 N 9.29 AC
88478	246506	WESLACO	TX	78599	55000	FM 491	TX	NORTH CAPISALLO BK 2376 S 10 AC OF N 19.29

Checking for accuracy stage concluded that the newly merged shapefile was accurate, and there was one property ID per data entry. This process was repeated with other property IDs that also identified with various parcels. Notably, when property IDs were associated with multiple parcels, it expressed that land parcels were located differently and were owned by the same owner. In addition, newly merged shapefile property IDs were linked to various parcels and listed numerously on attributes table because Arcmap does not assign unique property IDs for parcels. Instead, parcels that share the same owner are assigned the same property ID, thus, increasing the amount of parcel data listed on attributes table. In addition, the 10 different parcels outlined on figure 5 from ArcMap are owned by Property ID, "246472".

FIGURE 6 PROPERTY 246472 DISPLAYED IN MULTI LOCATIONS



3.3 Spatial Analysis

After carefully examining the newly merged shapefile, FEMA.shp flood zone data that illustrated geographical areas of flood zones were spatially joined with 2019_parcel.shp data retrieved from Hidalgo County Appraisal District and GIS McAllen. New shapefile was spatially joined with FEMA.shp flood maps creating the shapefile "spatial_join." Subsequently, the classification process involved producing three separate categories for residential and commercial buildings by year built, such as category 1 for buildings built after 2010, category 2 for buildings built between 1995-2010, and category 3 for buildings built before 1995. This classification, in conjunction with the type of buildings, locations, and median market values, were employed to formulate a vulnerability and risk syntax for STATA to produce matrix tables.

While coding for STATA, over 69,000 parcels were dropped, totaling to 225,011 parcels. After careful examination of data, it was discovered that thousands of residential and commercial buildings were not documented correctly by the Hidalgo County Appraisal District. Issues such as inaccurate zip codes, misspelled city names, misplaced addresses, and missing information on year built of structures caused a significant drop in the total amount of parcels. Hidalgo County Appraisal District was notified and advised about these errors and will document and report typing errors to property records. The significant drop of parcels was also impacted by the exclusion of lands with no structures since this study was only focused on commercial and residential related buildings.

CHAPTER IV

RESULTS

4.1 Adaptive Capacity and Potential Impact

FIGURE 7 ADAPTIVE CAPACITY AND POTENTIAL IMPACT

VULNERABILITY TOTAL : Potential Impact

Adaptive Capacity	Low Zone X	Med Zone X500	High Zone A	Total
Low Before 1995	52,695 M	47,635 H	7,959 H	108,291
Med 1995-2010	42,404 L	39,969 M	5,160 H	87,533
High After 2010	15,514 L	11,483 L	2,190 M	29,187
	110,613	99,089	15,309	225,011

VULNERABILITY RESIDENTIAL : Potential Impact

Adaptive Capacity	Low Zone X	Med Zone X500	High Zone A	Total
Low Before 1995	49,399 M	44,311 H	7,430 H	101,140
Med 1995-2010	39,756 L	36,468 M	4,695 H	80,919
High After 2010	14,495 L	10,577 L	2,003 M	27,075
	103,650	91,356	14,128	209,134

VULNERABILITY COMMERCIAL : Potential Impact

Adaptive Capacity	Low Zone X	Med Zone X500	High Zone A	Total
Low Before 1995	3,288 M	3,326 H	526 H	7,140
Med 1995-2010	2,648 L	3,209 M	464 H	6,321
High After 2010	1,019 L	906 L	187 M	2,112
	6,955	7,441	1,177	15,573

The matrix tables above illustrate the results from STATA regarding the vulnerabilities of all assets combined except for parcels with no structures from Hidalgo County appraisal records. Parcels with the absence of structures that were dropped from STATA matrix tables included parcels such as rural lands, Colonia lots, land tracts, open space, vacant lots, and others, since they acquired no risk and vulnerability. The vulnerability total matrix table comprises of commercial properties, single and multi-family residential units, mobile homes, storage units, warehouses, commercial and residential inventory, the energy supply chain, electric companies, telephone companies, natural gas distributions, oil refineries, railroads, and critical infrastructure. Next, the residential vulnerability table includes all types of residential units except for residential warehouses, barns, storage rooms, and inventory units. Finally, the commercial property vulnerability table includes buildings that serve as businesses including critical infrastructure facilities such as hospitals, city halls, schools, police, and fire departments. According to Hidalgo County Appraisal records, CSV file and property records, commercial properties, organizations, critical infrastructure facilities and some city-owned facilities such as water resources and public work facilities are classified as state code "F1". Code "F1" is a state code classification defined as "Commercial Real Property."

Further, commercial and residential properties that comprise of low and medium adaptive capacities located in floodplains can be affected by floodwaters causing structural damage and business interruption. According to the vulnerability table, there are a total of 7,959 highly vulnerable residential and commercial related structures that were built before 1995 and located in a 100-year flood zone. It is also imperative to underscore that medium and low-level vulnerable assets are still susceptible to floodwaters even though they are newly built and located outside special flood hazard areas. Although the June 2018 floods can be considered as an anomaly in the LRGV, the June 2018 floods had one of the most adverse effects on business interruptions and economic loss, effecting over 20,000 properties causing up to $250 million in damage costs (U.S. Department of Commerce & NOAA, 2018).

4.2 Consequence and Probability

FIGURE 8 CONSEQUENCE AND PROBABILITY

Median Market Value= $74,527

Total Risk

Consequence \ Probability	Low Zone X	Med Zone X500	High Zone A	Total
(High) Above Median	57,648 M	60,463 H	7,760 H	125,871
(Med) Below Median	53,106 L	38,682 M	7,573 H	99,140
Total	110,754	98,924	15,333	225,011

Median Market Value= $74,527

Residential Risk

Consequence \ Probability	Low Zone X	Med Zone X500	High Zone A	Total
(High) Above Median	51,399 M	53,629 H	6,691 H	111,719
(Med) Below Median	52,251 L	37,727 M	7,473 H	97,415
Total	103,650	91,356	14,128	209,134

Median Market Value= $74,527

Commercial Risk

Consequence \ Probability	Low Zone X	Med Zone X500	High Zone A	Total
(High) Above Median	6,115 M	6,723 H	1,044 H	13,882
(Med) Below Median	840 L	718 M	133 H	1,691
Total	6,955	7,441	1,177	15,573

Notably, the consequence of an asset being affected by flooding is associated with Hidalgo County's median market value of $74,527. Figure 7 risk matrix tables include all buildings and structures and exclude lands with no structures. Much like residential vulnerability tables, residential risk tables also include all residential buildings except for warehouses, barns, storage rooms, or any structure used for inventory. Commercial Risk tables exclude warehouses or inventory storage structures and only involve buildings classified as state code "F1" under Hidalgo County Appraisal District. In addition, risk table results from STATA expose that 75,796 assets (33.6%) in Hidalgo County are in flood-prone areas such as 100-year and 500-year flood zones and obtain market values above $74,527, placing them at high risk from flooding.

4.3 GIS Spatial Patterns, Results and Summaries

Figure 8 provides a comprehensive view of the County's flood zone areas and cities that fall within it. Further, this study also provided a closer look at the three largest cities in Hidalgo County known as, McAllen, Mission, and Edinburg. These cities acquire a homeownership rate of 68.6%, exceeding the national average of 63.9% and serves as an influential fragment for the economy by employing over 338k individuals (Hidalgo County, n.d). In addition, through GIS spatial mapping, this study captured the dense vulnerability of critical areas within the three principal cities as well as providing a summary of the total amount of vulnerable assets and exposure to flooding. In elaboration, a summary for each city was developed to illustrate the vulnerable proportions of residential and commercial units.

FIGURE 9 HIDALGO COUNTY FLOOD ZONES

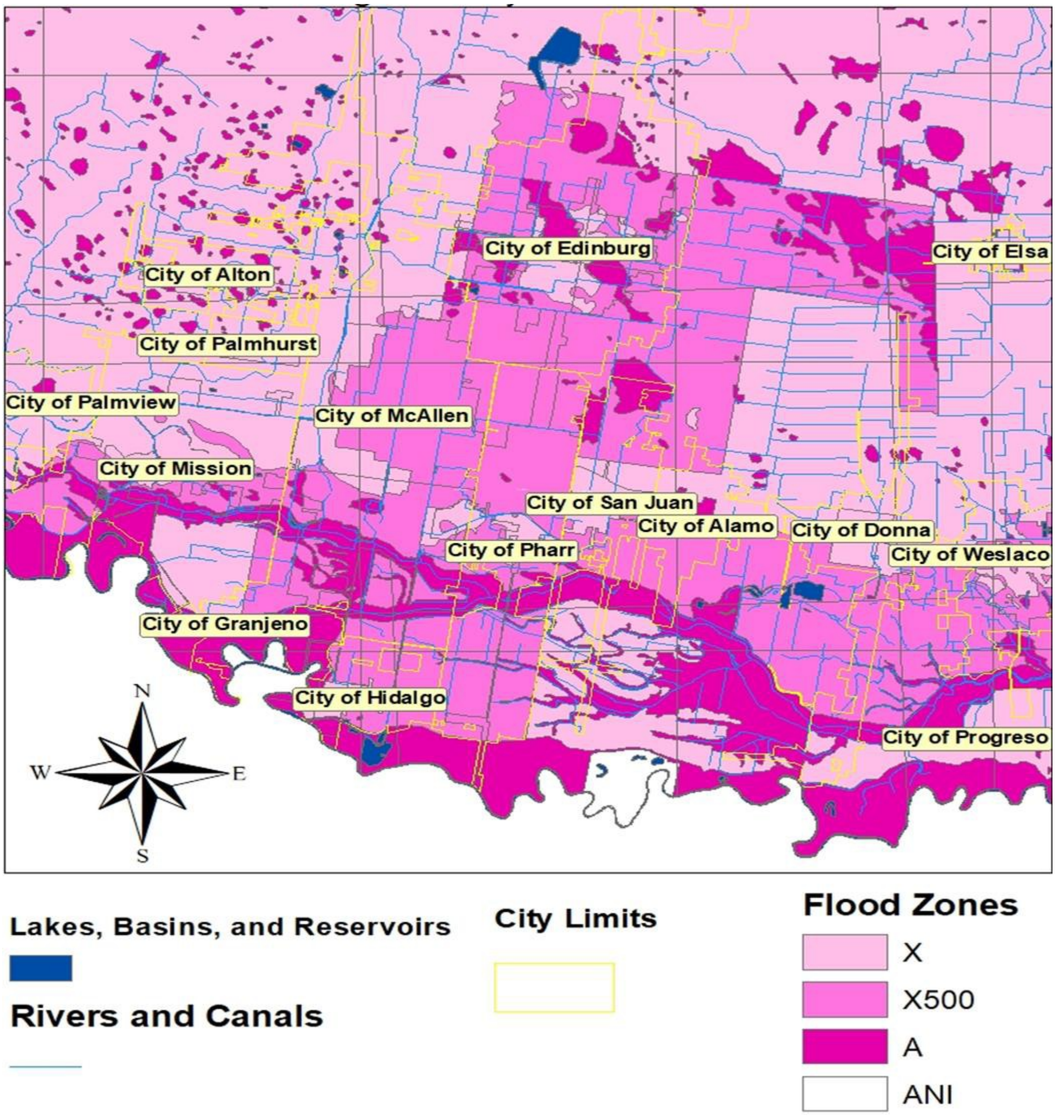


FIGURE 10 CITY OF MCALLEN SUMMARY

FIGURE 11 FLOOD ZONES IN MCALLEN, TEXAS

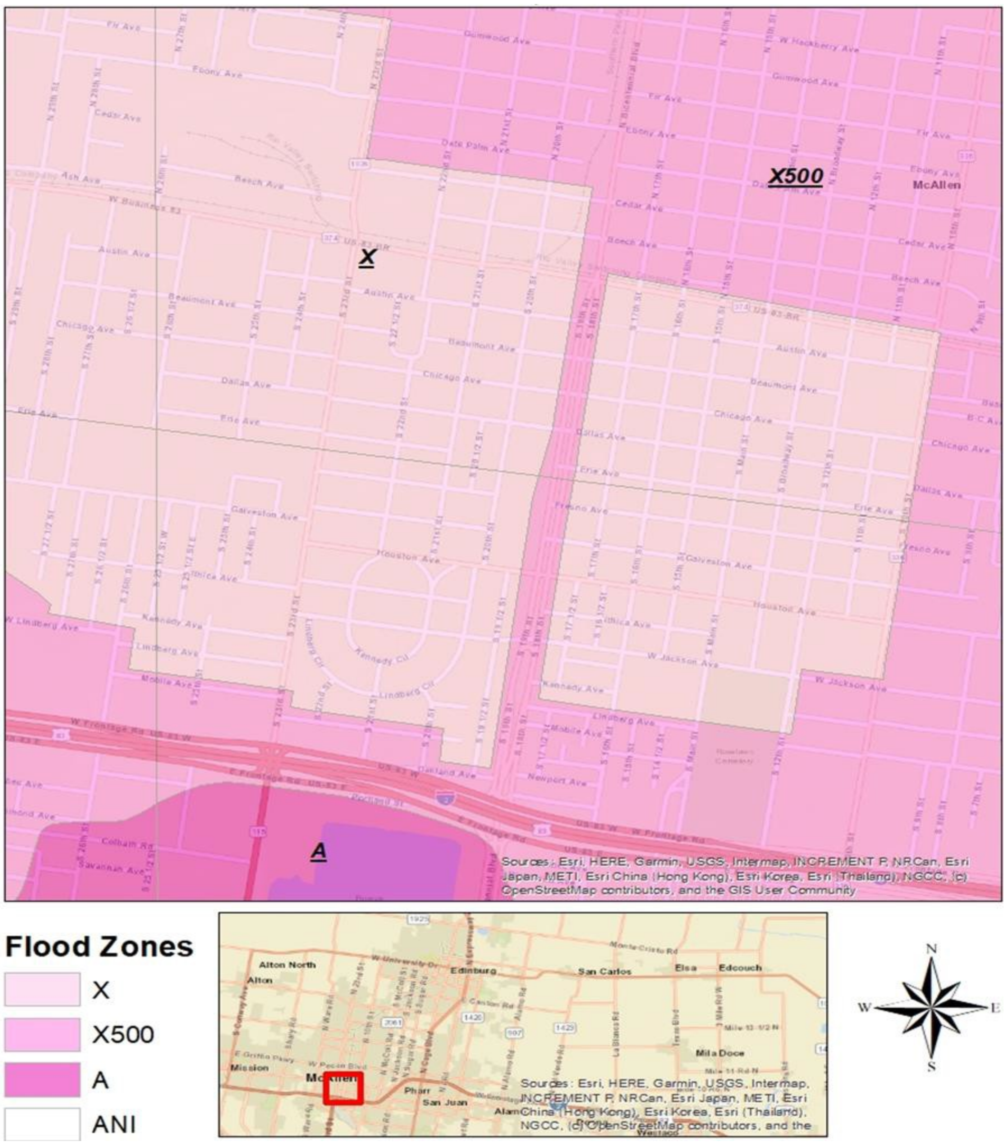


FIGURE 12 FLOOD VULNERABILITY IN MCALLEN, TEXAS

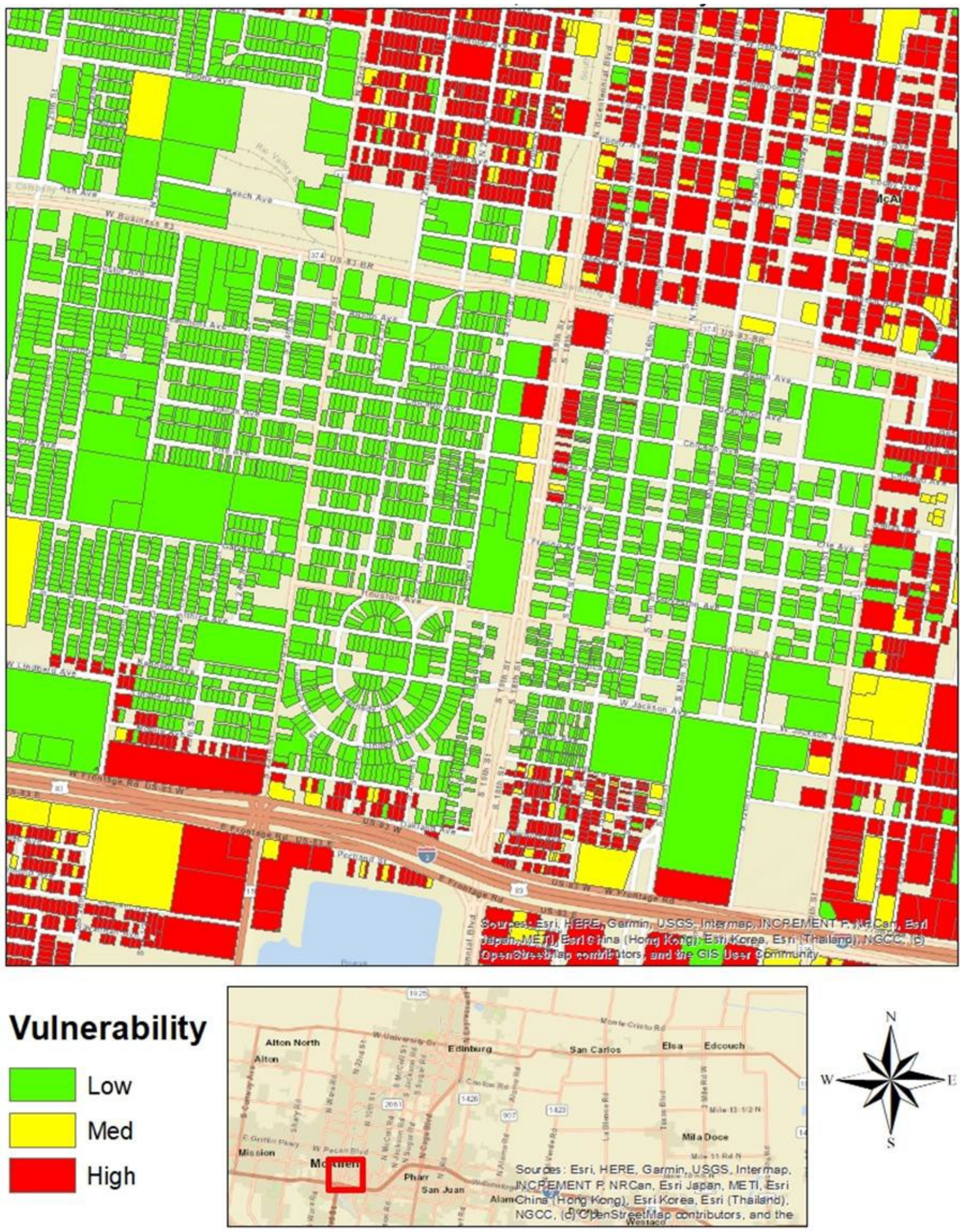


FIGURE 13 CITY OF MISSION SUMMARIES

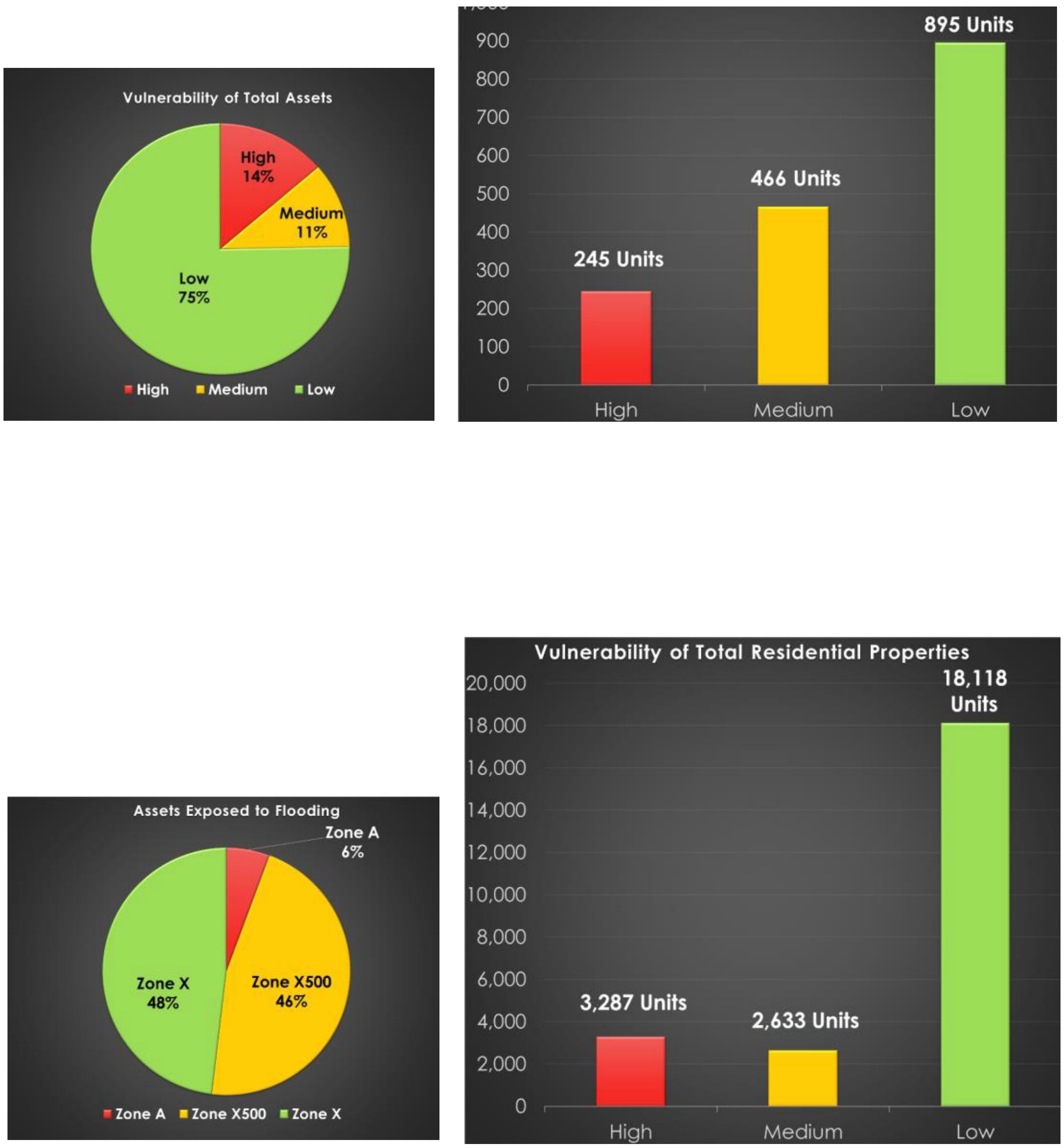


FIGURE 14 CITY OF MISSION FLOOD ZONES

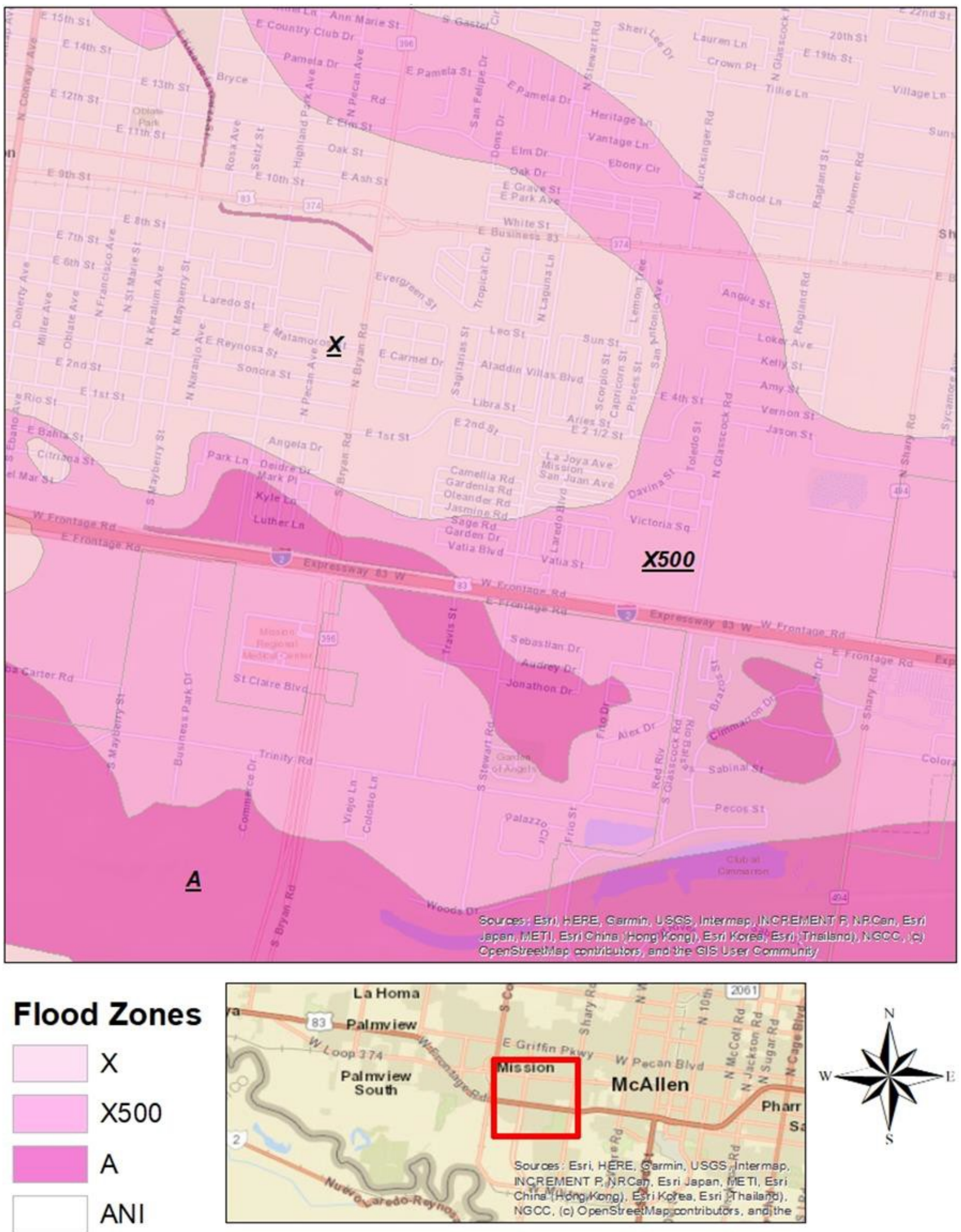


FIGURE 15 CITY OF MISSION VULNERABILITY

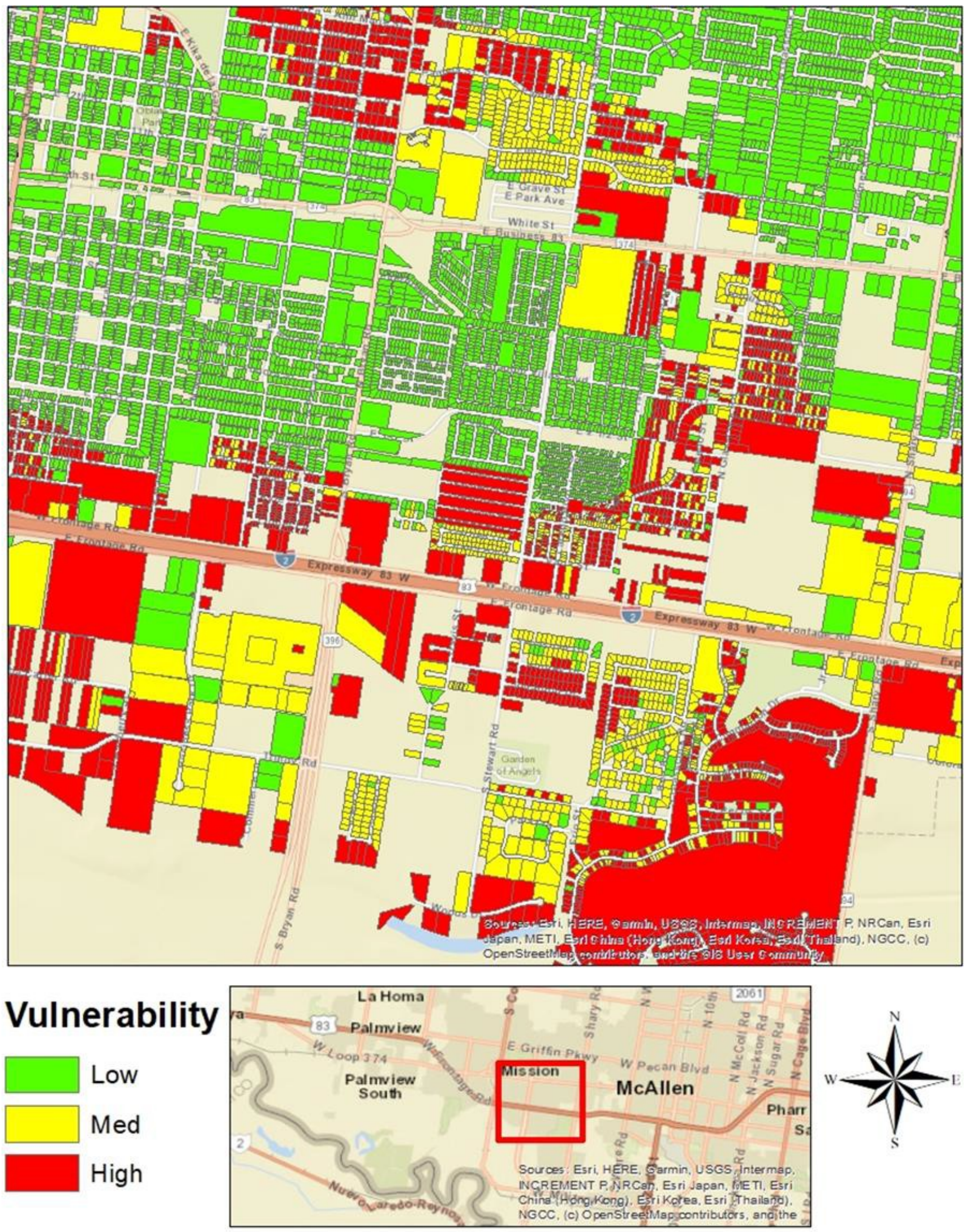
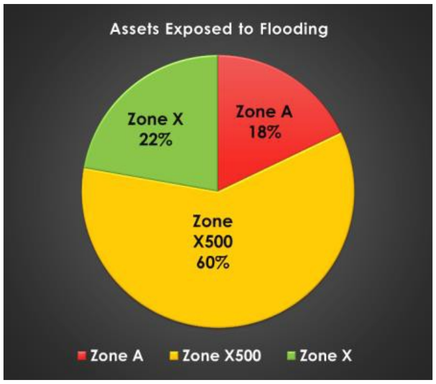
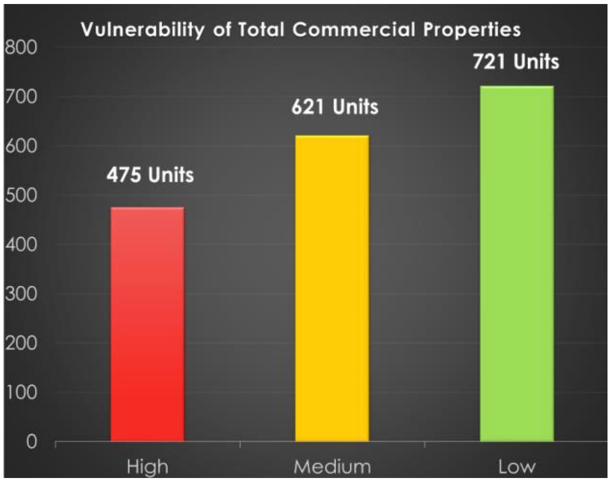
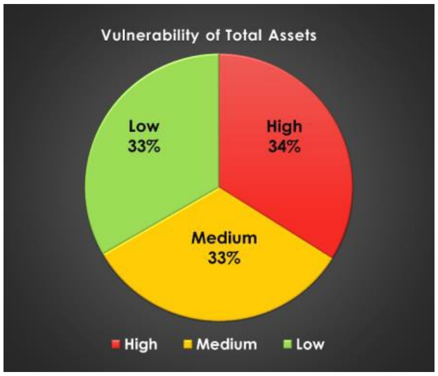


FIGURE 16 CITY OF EDINBURG SUMMARIES







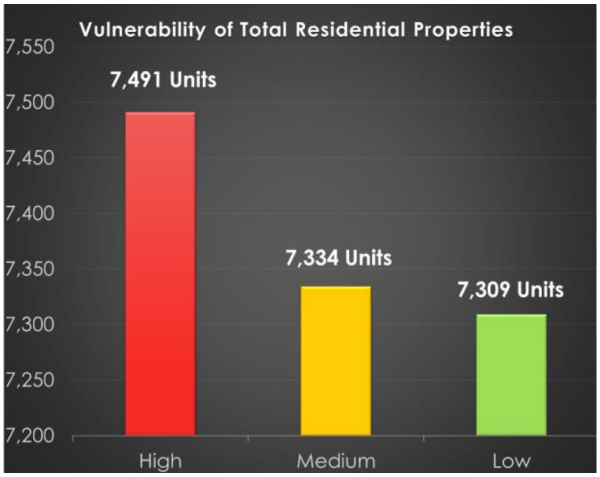


FIGURE 17 CITY OF EDINBURG FLOOD ZONES

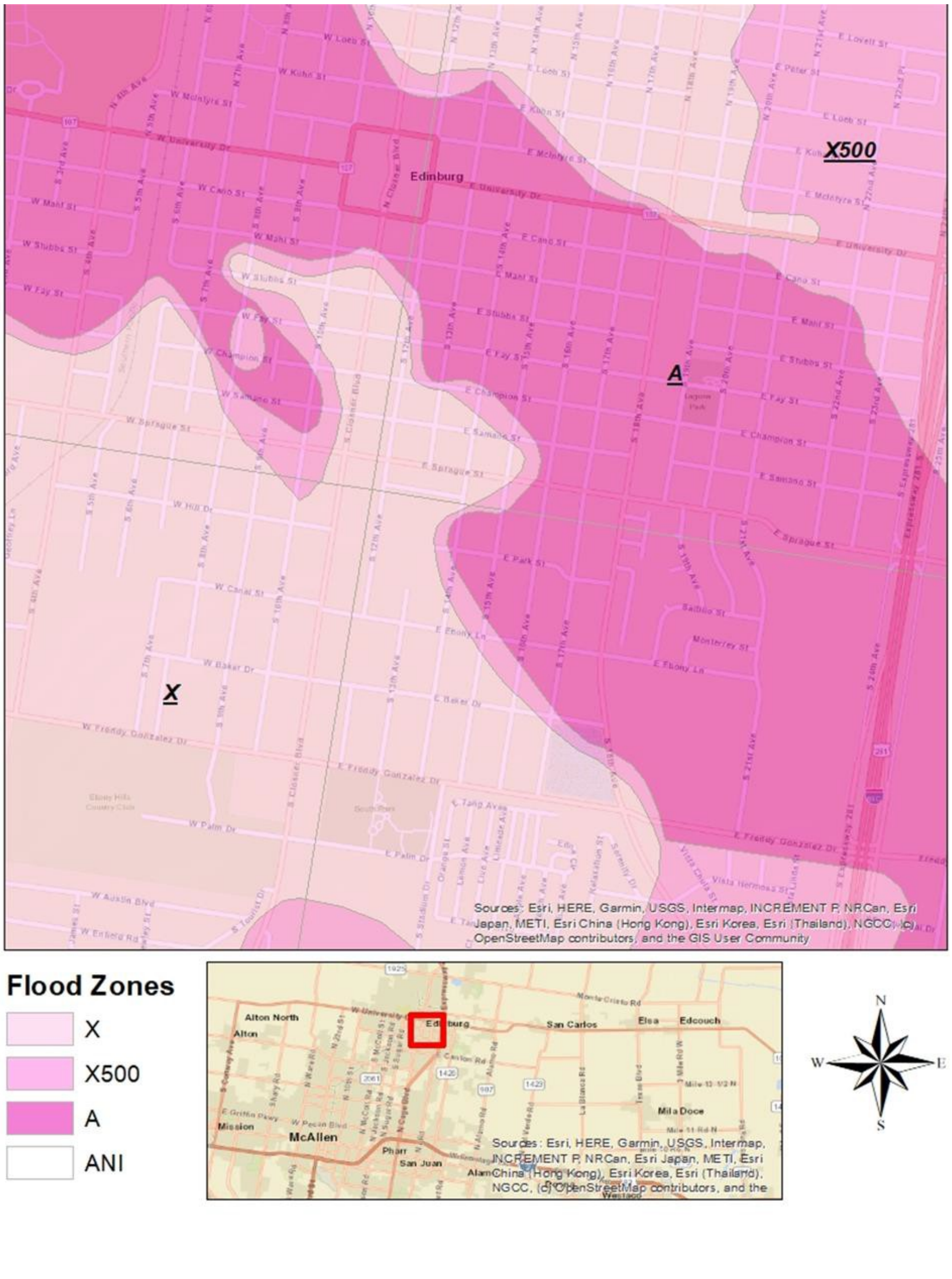
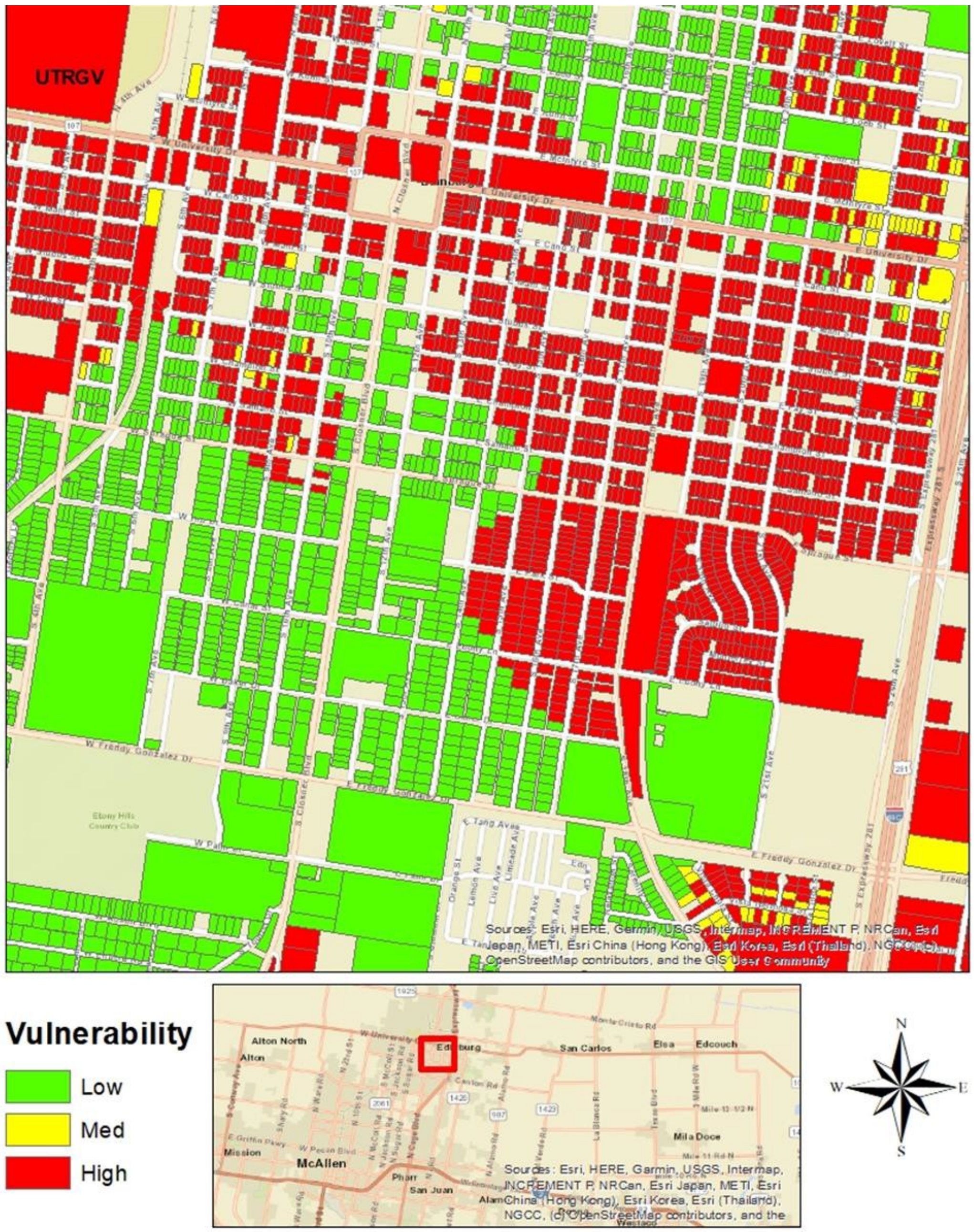


FIGURE 18 CITY OF EDINBURG VULNERABILITY



4.4 Conclusion and Discussion of Results

For the obtainable data, it was detected through GIS spatial analysis that, a large proportion of aged buildings built before 1995 are in SFHA's in all three cities. SFHA's such as Zone A's (100-year floodplains) and 500-year flood plains are dominantly populated with highly vulnerable buildings aged 25 years and older. Units 25 years and older are the most vulnerable, especially those that are in flood-prone areas due to lack of building codes, base elevations, and floodproofing methods. Interestingly, the Joined_Variables shapefile on ArcGIS that was created to include and illustrate vulnerable assets through a choropleth map eerily shadows FEMA flood zone shaded areas. For instance, the choropleth map layer that illustrates highly vulnerable assets in color red was nearly identical in shape to FEMA shaded A zone areas. In other words, a significant proportion of buildings 25 years and older are situated in the most critical areas prone to flooding. It is imperative that commuters and businesses owners located in SFHA’s become insured to mitigate economic and property losses.

Notably, within the municipality scale, it was found that 500-year flood zones significantly impact buildings built before 1995. Further, a more substantial proportion of highly vulnerable assets were constructed in 500-year flood zones within the city of McAllen. Assets exposed to medium levels of flood exposure known as X-500-year flood zones totaled to 61%. In elaboration, there were 46% of highly vulnerable assets in the city, while only 4% of total assets were exposed to the highest flood-prone areas known as 100-year flood zones.

Patterns from the city of Edinburg and Mission reflected how 500-year flood zones also largely impacted buildings built before 1995. More than half (60%) of Edinburg's total assets were built in 500 year-flood plains. The city of Edinburg's total percentage of highly vulnerable assets stood at 38% and assets at medium vulnerability at 33% while only obtaining 18% of total assets in 100-year flood zones. The city of Mission expressed the best results for vulnerable assets on held a total of 14% of highly vulnerable assets and 75% of low vulnerable total assets. On the other hand, 46% of total assets were exposed to 500 year-flood plains while only 6% were built in 100 year-flood plains. The low number of total assets located in zone A's is primarily due to the large proportion of 100-year flood plains consisting of lands with no structures such as golf courses, commercial and residential vacant lots, and lands with an absence of structures.

CHAPTER V

CONCLUSION

5.1 Limitations

This study was concerned with the flood risks and vulnerabilities of structures located in Hidalgo County and associated vulnerability and risk with age of the structure, location, and median market value. This study is limited to assessing risk and vulnerability based on the number of buildings that adhere to building ordinances that enforce floodproofing methods and stringent freeboard requirements above base flood elevations. Due to lack of resources, this study was not able to accurately assess unnumbered A zone areas for Hidalgo County that lack base flood elevations, depths, and topographical data to decipher accurate requirements for base flood elevations and building codes.

5.2 Conclusions and Recommendations

This study aimed to conduct a spatial analysis on measuring risk vulnerability associated with properties located in Hidalgo County. Risk and vulnerability maps, tables, and graphs of parcels within Hidalgo County can enhance climate resiliency for municipalities and can serve as a tool to improve steps towards mitigation, planning, and zoning. Overall observations involved results and summaries for the cities of McAllen and Edinburg for obtaining large proportions of highly vulnerable assets within 500-year zones as well as illustrating the significant impact of 500-year flood zones towards buildings older than 25 years.

According to GIS spatial data and STATA results, Edinburg and McAllen acquire a high density of buildings that fall into SFHA's. 46% of McAllen's assets are classified as highly vulnerable, while Edinburg's total amount of highly vulnerable assets stands at 34%. These cities must take proactive measures towards mitigation, planning, and zoning, areas highly dense with impervious surfaces are most vulnerable to slow nuisance flooding. Conversely, the city of Mission, a less crowded area of impervious surfaces, acquires 75% of total assets classified with low vulnerability and 14% highly vulnerable assets while consisting of only 6% of their total assets exposed to 100 year-flood zones. However, the large number of buildings located in Non-Special Flood Hazard Areas (NSFHA) in the city of Mission is not an excuse for residents and city officials to let their guards down. According to Schwab, a fourth of U.S flood events develop in NSFHA's (2017).

Hidalgo county has not updated their flood ordinances since the 1980s. It is recommended for city officials to update flood ordinances to improve their Community Rating System to receive affordable flood insurance premium rates. In addition, city officials should improve planning and zoning ordinances and discourage future builders, construction companies, and homeowners from building on SPFHA's and strongly encourage flood insurance. Based on summary results from this study, municipalities within Hidalgo County should commit to developing an emergency preparedness program and reach out to property owners residing in

SFHA's to promote resilience, information management, and coordination during flood disasters. Finally, residents and business owners are strongly advised to purchase flood insurance and develop wet-proofing or dry-proofing improvements to avoid loss of property and economic losses.

Future studies should include GIS spatial data analysis that illustrates areas that consist of current outdated drainage systems and recent drainage projects as well as including each city's capacity to drain rainfall to mediate the level of risk and vulnerability within municipalities. It is also recommended for prospective studies to consider the elevations of structures above freeboard requirements to assess vulnerability since building ordinances are relevant to Counties and various builders and constructions companies have different preferences towards height elevations.

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BIOGRAPHICAL SKETCH

Joe Chavez was born in McAllen, Texas, and graduated from Hidalgo Early College High School in 2009. He received an associate of arts in Sociology at South Texas College in 2014. In 2016 he graduated from the University of Texas Rio Grande Valley and acquired a Bachelor of Arts in Sociology (Cum Laude). In 2018, he joined the Disasters Studies Master of Arts Program at the University of Texas Rio Grande Valley and was hired as a Geographic Information System (GIS) teaching assistant for GIS for disaster management graduate course under the supervision of Dr. Dean Kyne. On May 2020 he earned a Master of Arts in Disaster Studies from The University of Texas Rio Grande Valley. His research interest areas involve using GIS for disaster management, social inequality, religion and society, and race and ethnicity. Mr. Chavez can be reached via e-mail at joe.chavez01@utrgv.edu or joe.chavez@rocketmail.com.