COMPARISON OF FEMA AND NON-FEMA DISASTER RESPONSE TO PRIOR HAZARDOUS EVENTS IN THE CITY OF HOUSTON, TEXAS

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1. INTRODUCTION

The ongoing climate crisis decimates landscapes, species, and human survivability. Environmental disasters and hazards are occurring more frequently in part because the climate crisis is becoming increasingly more costly by the year and is showing increasing negative consequences for our biosphere. According to the National Oceanic and Atmospheric Administration (NOAA), the total cost of U.S. billion-dollar disasters over the last 5 years (2016-2020) has exceeded $600 billion, with a 5-year annual cost average of $121.3 billion, setting two new records. From 2011 to 2020, the U.S. cost of disasters was also historically large, totaling nearly $900 billion from 135 separate events (Smith 2021).

This disaster research centers on the city of Houston, Texas, the fourth most populous city in the United States at 2,304,580 as well as being the ninth most expansive city in the U.S. at 640.4 square miles (mi^2). The city is primarily contained within Harris County with small sections of the city extending into Fort Bend and Montgomery Counties. The city and the communities that call Houston home experience various environmental hazards and emergencies on a frequent basis.

The city of Houston is located along the upper Texas Gulf Coast, approximately 50 miles northwest of the Gulf of Mexico at Galveston, thus the city experiences numerous negative impacts from hazards such as hurricanes, storm surge, and flooding. While Houston's expansive area and population may be seen as a benefit in many ways, its coastal plain topography and proximity to the Gulf of Mexico increases the risk for major natural disasters and other types of emergencies. According to the Federal Emergency Management Agency (FEMA), Texas has experienced 371 federally declared disasters since 1953 until 2023 (Grubbs 2019).

With the communities and ecosystems of this city experiencing frequent hazards in the past and present, one might ask: How hazardous is it to live in the city of Houston and what are the human and physical impacts of these hazards? By using the historical analysis of past observations, written documents, as well as statistical analysis of the data recovered to look at past natural and technological hazards, such as the 1994 Southeast Texas Floods and the San Jacinto River Fire (1994) and Tropical Storm Allison (2001), as well as identifying physical hazards and the variables of human impact, this research will assess, on a micro level, the status of physical and human vulnerability in Houston and the impacts that these hazards made. This comparative analysis aims to look at similarities and differences between different FEMA vs. Non-FEMA disaster events by using quantitative and qualitative data to identify physical and human impacts. By using the method of comparative analysis, this allows for the examination of historical events to create explanations that can be used beyond that time and place.

From the analysis of these case studies, we will offer recommendations for the city for moving forward on resiliency, response, and recovery. The assessment of the future of communities and ecosystems of this area is critical to the continuous assessment of risk and vulnerability of the Houston community by learning from the experiences of prior hazardous events, and the associated responses. The information gathered from those events will be valuable for application to the response and recovery efforts of current and future disasters.

2. BACKGROUND: HOW HAZARDOUS IS THE CITY OF HOUSTON?

2.1 Geology and Climate

The city of Houston, Texas is in the southeastern part of the state and is known for its unique landscape and geology. The region of Texas is characterized by gently rolling hills, prairies, and forests that are typical of the Gulf Coast region. The city sits on top of a large sedimentary basin on the upland surface between the San Jacinto and Brazos River valleys with characteristics of flat terrain, low elevation, and poor draining soils (Hardin et al. 2007). The area is filled with layers of sand, clay, and limestone formed millions of years ago by the deposition of sediment from nearby rivers and the gradual sinking of the land. The soft sediments of this area of Houston and the Gulf Coast have yet to be compacted and in time will become siltstone, sandstone, and claystone but now they are called “young” soils. Due to the city's landscape being situated between river valleys and the geologic soil composition, Houston is prone to sinkholes and other geological hazards. Subsidence, a geologic hazard, results in the compaction of soils due to a variety of human and environmental factors caused by groundwater removal through pumping and oil and gas extraction. Further, these activities cause the settling of the clay, silt, and sand particles to lay flat and decreases the permeability of the medium (Clark 2021). The emptying out of the pore space provides the opportunity for sediments to compact and subside. When heavy rainfall occurs, the water has nowhere to go, and the soil cannot absorb it quickly enough, leading to flash flooding in many areas. Houston lies in a hurricane prone area which can cause storm surges and exacerbate flooding in coastal regions.

Texas is comprised of three main climate regions, the Interior Highlands in the west, the Central Plains, and the Gulf Coast to the east. The plains of the Gulf Coast are comprised of relatively flat, low elevation terrain amounting to an area of over 100,000 mi^2 in Texas. The climatology of Texas varies across the state due to westerly winds bringing dry continental air from the mountains in the west along with its proximity to the Gulf of Mexico that supplies abundant moisture to the eastern area of the state where the region is humid subtropical. Generally, extreme daily precipitation events occur in the late spring to early fall, but the daily rainy season in eastern Texas extends the whole year. As previously stated, the proximity to the Gulf of Mexico makes Texas highly susceptible to the extreme rainfall of tropical cyclones and hurricanes. Methods of measuring precipitation are obtained by using instruments like rain gauges that are either tipping buckets or a weighing rain gauge. These physical instruments may be combined with technology such as, weather radars, weather balloons, and satellites to produce precipitation data. NOAA's National Weather Service Center produced a "Precipitation Frequency Data Server" (PFDS) to deliver precipitation frequency estimates for the United States based on the temporal distribution of heavy precipitation, trends in annual data, and seasonality analysis (Perica et al. n.d.).

There are several well-known major bodies of water, including the Houston Ship Channel, which connects the city to the Gulf of Mexico. The channel has been a major factor in the city's economic growth, allowing for easy transportation of goods and resources. Additionally, the city is located near several large oil and gas fields, which have played a significant role in the region's development. As the city of Houston continues to develop and expand, more areas are being paved over, reducing the amount of permeable land, and exacerbating the flooding problem. While the city has implemented various flood control measures over the years, including drainage ditches and retention ponds, the region's unique geology and landscape present ongoing challenges for managing and mitigating flood risk.

2.2 Risk, Resiliency, and Vulnerability

The city of Houston's landscape and geology contribute significantly to its frequent flooding. The city is located on a flat coastal plain only a few feet above sea level, making it susceptible to flooding during heavy rainfall events and tropical storms. Additionally, the soil in

Houston is primarily composed of clay, which has poor drainage capabilities and prevents water from quickly absorbing into the ground. According to a study by the Houston-Galveston Area Council, the city loses about 4,000 acres of wetlands and prairies to development every year, reducing the amount of permeable land that can absorb rainwater and exacerbating the flooding problem. As a result, Houston has experienced several catastrophic flooding events, including the floods caused by Hurricane Harvey in 2017, which resulted in 68 fatalities and caused an estimated $125 billion in damages.

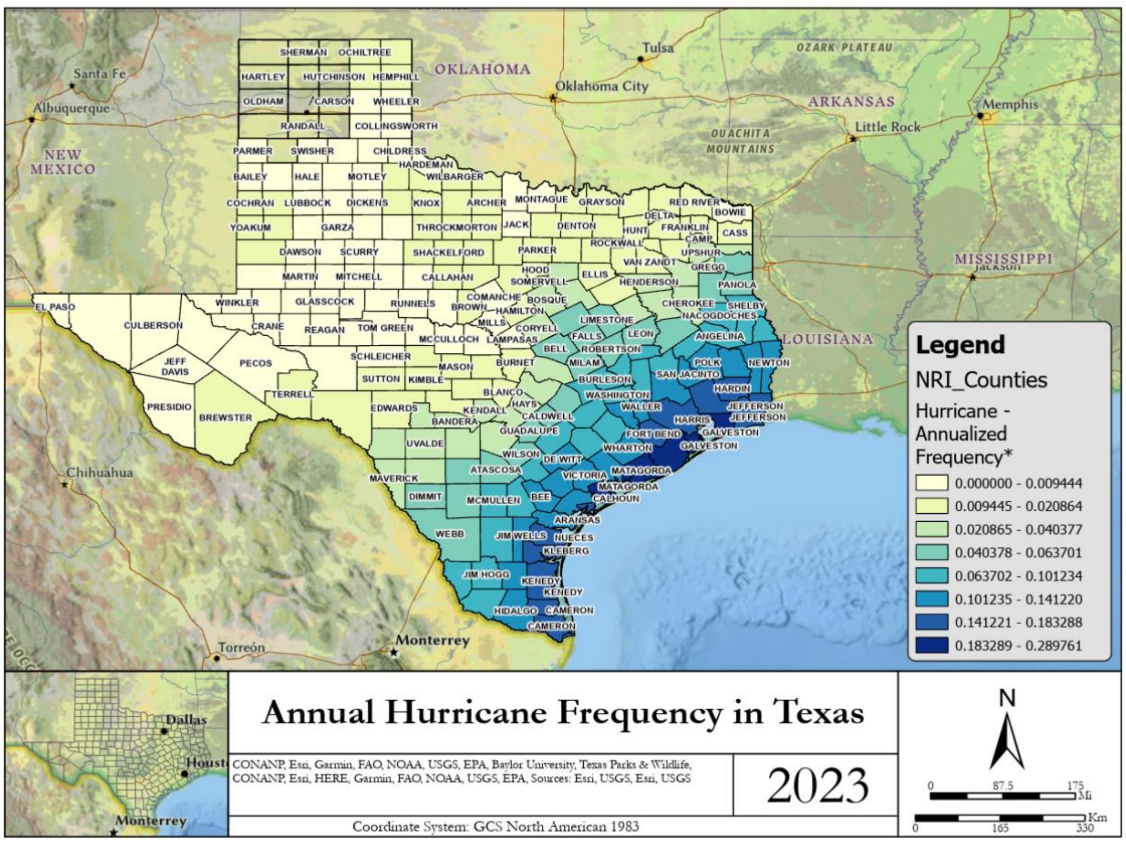

Figure 1. *Map showing the annual hurricane frequencies of Texas counties in recorded hazard occurrences over a given period. Data obtained from the FEMA National Risk Index Annualized Frequency Values of 0.2 events per year and 37 events on record. Period of record: East 1851-2021, West 1949-2021.*

Historically and geographically, the city of Houston has a higher risk for certain natural hazards and disaster events when compared to other states or even other counties within Texas. This comparison is evident through the application of "The National Risk Index," created through FEMA's Natural Hazards Risk Assessment Program (NHRAP). This "index" helps visualize the various major hazards and communities at high risk throughout the country. A risk baseline measurement was created by analyzing source data of community risk factors and natural hazards for each county and census tract in the United States (FEMA, "Learn More | National Risk Index" n.d.).

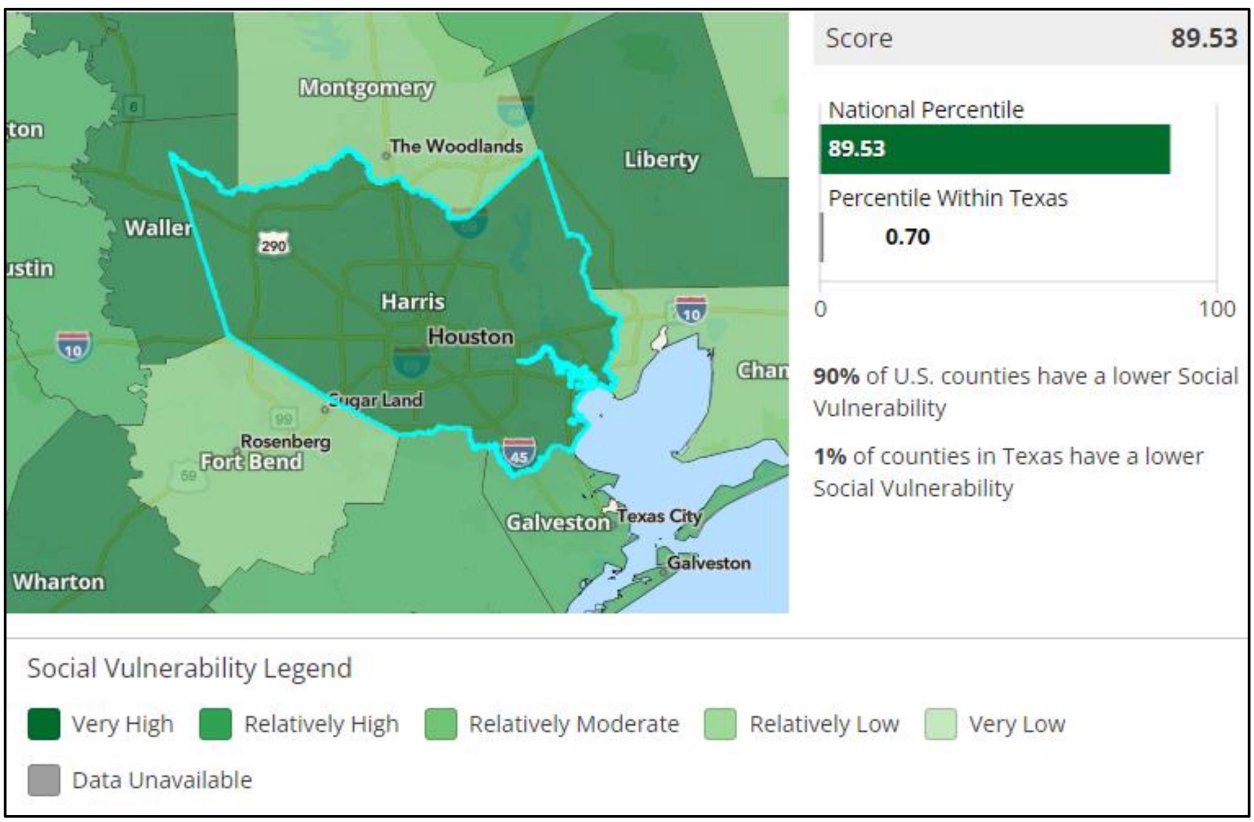

Figure 2. FEMA National Risk Index Social Vulnerability score. Harris County, TX scores 89.53 indicating that this area is highly susceptible to the impacts of natural hazards ("Community Report - Harris County, Texas | National Risk Index" n.d.).

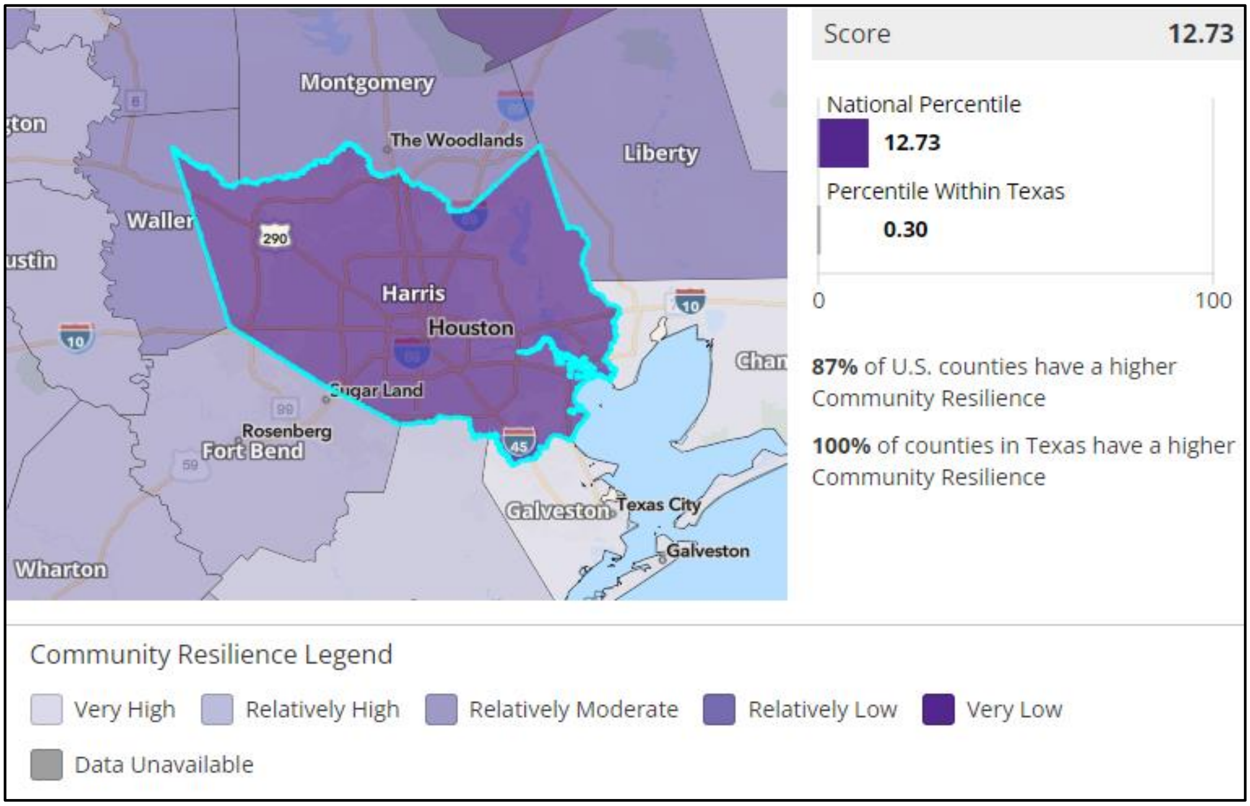

Figure 3. FEMA National Risk Index report of Community Resilience. A score of 12.73 indicates that Harris County, TX has a very low ability to prepare for anticipated hazards (“Community Report - Harris County, Texas | National Risk Index” n.d.).

Several factors contribute to the relatively high vulnerability/low resilience of Houston, Texas, and the surrounding region to environmental disasters. Some of the major factors include:

- Geography
- Infrastructure
- Development patterns
- Social vulnerability and community resilience

As previously discussed, Houston contains flat terrain in combination with dense urban developmental patterns, which may exacerbate flooding and cause management difficulties. Continual rapid urban growth and development is mixed in with aging infrastructure which needs modernization and investments as many of Houston's flood control measures such as, drainage channels, levees, and pumping stations, are several decades old and were not designed to withstand the strength and frequency of recent and future weather events (The National Risk Index n.d.). Based on data gathered by FEMA in the National Risk Index, Harris County have a Risk Index (RI) scoring Very High when compared to the rest of the United States as well as other counties in Texas. Expected Annual Loss and Social Vulnerability also score Very High with Community Resilience scoring Very Low. These measures of risk show that Harris County has a low ability to prepare for anticipated natural hazards and a very high susceptibility of impacts of natural hazards as well as a high rate of expected loss each year. The calculations made to determine these values are based on several formulas and baseline indicators. According to FEMA, calculating social vulnerability is measured by the Social Vulnerability Index (SVI) published by the Centers for Disease Control and Prevention (CDC) and community resilience is measured based on data using the Baseline Resilience Indicators for Communities (HVRI BRIC) that has been published by the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) (Federal Emergency Management Agency n.d.). Due to the high urbanization and development in the area, natural wetlands and floodplains have had their permeability altered, leading to increased runoff and flooding in areas that are historically less prone to flooding hazards (Mayor's Office of Resilience and Sustainability 2022).

Calculations:

Risk Index = Expected Annual Loss × Social Vulnerability ÷ Community Resilience

Expected Annual Loss = Exposure × Annualized Frequency × Historic Loss Ratio

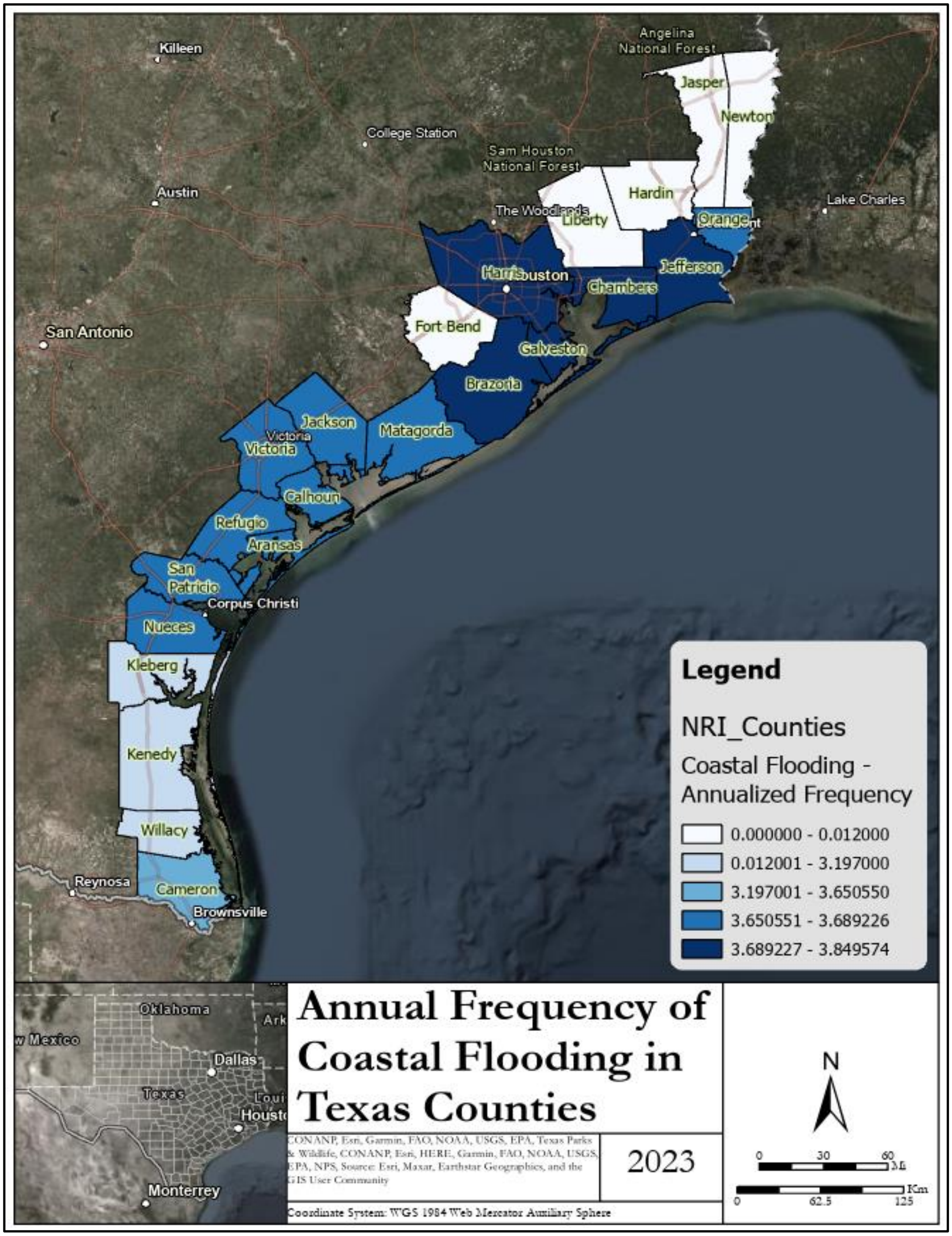

Figure 4. Annual frequency of coastal flooding of counties along the coastline. Annualized Frequency Values obtained from FEMA National Risk Index at 3.8 events per year.

The city of Houston’s large population is highly diverse, with disparities in education, income, and access to resources. Disparities further worsen the impacts of environmental hazards and disasters on vulnerable communities, significantly affecting low-income communities and flood-prone areas. In tandem with resilience, Houston rates high on levels of risk when faced with environmental disasters. Some factors to be considered include geographic location, climate change, infrastructure, and urbanization. Previously discussed was the coastal plain geography of Houston, its proximity to various water sources, and its proneness to tropical storms, flooding, and hurricanes. Increased risk factors due to climate change are expected to increase the frequency and intensity of extreme weather events and other environmental hazards. The city's urbanization, like resilience, has negatively affected natural floodplains and wetlands, reducing their natural ability to manage floodwaters. Due to the degradation and destruction of these natural areas, old flood control systems, and other weaknesses in infrastructure, Houston officials are becoming decreasingly effective in managing environmental hazards and potential damages. These systems need modernization and investment by various agencies (Beccari 2016; Berke 2017).

2.3 Emergency Management History

Federal disaster policy has been critical to responding, recovering, and mitigating hazard events and disasters. Following a disastrous fire in Portsmouth, New Hampshire, in December of 1802, the first legislative act of Federal disaster relief was implemented by the Congressional Act of 1803, which provided relief to affected individuals by suspending the payment of bonds for a length of time. In the following decades since the event in 1802, destructive hazards that occurred in Chicago, Illinois, in 1871 and Johnstown, Pennsylvania, in 1889 pointed to a greater need for response and involvement of the federal government (Federal Emergency Management Agency 2019). To broaden emergency management in the United States, Congress passed several disaster relief and emergency management policies. The Disaster Relief Act of 1950 was one of the laws passed that gave power to a state government to request federal assistance through the President and allowed the President to declare a major disaster, as well as the Federal Civil Defense Act of 1950, which created a cohesive nationwide system for civil defense authorities. After the Three Mile Island Generating Station experienced a partial meltdown in Harrisburg, Pennsylvania, the ensuing response that occurred was insufficient, thus on April 1st, 1979, President Jimmy Carter signed Executive Order 12127 which established the Federal Emergency Management Agency (FEMA) along with Executive Order 12148 on July 20th, 1979, which then gave FEMA the mission of emergency management and civil defense. Since the establishment of FEMA there have been several policies that have been enacted that are important to emergency management, critically, The Disaster Relief and Emergency Assistance Act of 1988, which was amended by the Disaster Relief Act of 1974 to be named the Robert T. Stafford Disaster Relief and Emergency Assistance Act, more commonly known as the Stafford Act. This act gave clear direction for emergency management and established the current regulatory framework for the response and recovery of disaster events through presidentially declared disasters. With the establishment of a federal emergency management agency and enacted laws and policies, the response, recovery, and preparedness for hazard events have greatly improved (Haddow et al. 2021).

3. COMPARISON OF FEMA AND NON-FEMA RESPONSE TO DISASTER

The aim of this paper was to compare response to a natural hazard major occurrence that would fall under the jurisdiction of FEMA, versus a major human-induced, or technological hazard that would require assistance from other sources. FEMA (Federal Emergency Management Agency) is a government agency in the United States responsible for managing responses to natural disasters, while environmental disasters often fall under the control of federal agencies such as, the Environmental Protection Agency (EPA) or the U.S. Army Corps of Engineers.

Major hazard events, such as floods, hurricanes, and earthquakes may be categorized as a FEMA event if a Presidential Declaration has been called for, as well as whether the location and its leadership have ensured that their city or town meets certain criteria for federal assistance. FEMA events declared by the President of the United States then triggers federal assistance for affected individuals, businesses, and governments.

Natural events that are not major, as well as, technological hazards, are seen as non-FEMA events that do not meet federal assistance criteria and rely on local and state resources for response and recovery efforts. The categorization of an event as FEMA or non-FEMA will significantly impact the level and type of support available to affected communities.

3.1 FEMA Response to a Natural Disaster: 2001 Tropical Storm Allison

On June 5th, 2001, Tropical Storm Allison formed 80 miles off the coast of Galveston, Texas, causing historic widespread flooding in Texas, leading to 22 deaths and over $5 billion in damages. This event was one of the most disastrous rain events in United States history. Tropical

Storm Allison deposited nearly 80% of the area's average rainfall, affecting more than 2 million individuals. The resulting fatalities, industrial, and property damage left 31 counties in Texas with declared disasters and other affected areas in Louisiana, Florida, Mississippi, and Pennsylvania to invoke disaster declarations from the storm ("Harris County's Flooding History" n.d.). The significant death toll, property damage, and economic loss allowed the tropical storm to be classified as a FEMA disaster and, thus, received federal assistance.

The Federal Emergency Management Agency (FEMA) responded to this disaster by providing significant assistance, including individual and public assistance, hazard mitigation, and temporary housing. FEMA declared the event a major disaster, which triggered federal assistance for affected individuals, businesses, and governments. The response from FEMA included efforts to repair damaged infrastructure, help displaced residents find temporary housing, and provide financial assistance to those who suffered losses. The response to Tropical Storm Allison highlighted the importance of federal assistance in managing disaster events and the need for effective planning and investment in infrastructure and flood risk management to mitigate the impacts of future disasters.

3.2 Mixed FEMA and Non-FEMA Response to a Natural Disaster: 1994 Southeast Texas Floods

In comparison, prior to Tropical Storm Allison, the 1994 Southeast Texas floods were a major flooding event that occurred in October 1994, causing extensive damage to homes, businesses, and infrastructure and several fatalities. Similarly, as in Tropical Storm Allison in June 2001, the Southeast Floods caused significant flooding, leading to dozens of deaths, extensive property damage, and economic losses. While both events were classified as FEMA disasters and received federal assistance, there were differences in the response. The 1994 floods led to the creation of the Sabine River Authority, which manages flood control projects in the area. In contrast, Tropical Storm Allison led to establishing the Harris County Flood Control District, which oversees flood risk management in the Houston area. The differences in response to these two events highlighted the need for effective planning and investment in infrastructure and flood risk management to mitigate the impacts of future disasters.

In connection with the 1994 Southeast Texas Floods was the San Jacinto River Fire. While the overall event of the 1994 Flooding initiated a FEMA response, the San Jacinto River Fire did not. Tropical Storm Allison and the San Jacinto River Fire are two examples of disasters that received different response levels from FEMA and non-FEMA entities.

3.3 Non-FEMA Response to an Environmental Disaster: 1994 The San Jacinto River Fire

On March 22nd, 1994, a major fire broke out on the San Jacinto River near Houston, Texas, in the aftermath of the remnants of Hurricane Rosa in Mexico. Moisture from the Gulf of Mexico and a low-pressure system over the southern Rocky Mountains triggered severe rainfall and flooding. The fire was caused by a spill of chemicals, including gasoline and industrial solvents, from a nearby storage tank facility owned by the petroleum company, Vopak. The spilled chemicals flowed into the river and ignited, causing a massive fire that burned for several hours.

The fire was fueled by the chemicals in the river, which caused the flames to reach heights of up to 100 feet. Thick black smoke billowed into the air, creating a hazardous situation for nearby residents and workers. The fire was so intense that it melted the steel on a nearby railroad bridge, causing it to collapse (Fedarko 1994). This incident was a wake-up call for

Houston and the surrounding area. It highlighted the dangers of industrial facilities near major waterways and the potential for environmental disasters. The San Jacinto River fire also sparked public outcry and led to increased regulations on the storage and handling of hazardous materials in the area (McManamy 1994).

In the aftermath of the fire, Vopak and other companies were fined for violating environmental regulations. The Texas Commission on Environmental Quality also launched an investigation into the incident and made recommendations for improving safety measures in storing and handling hazardous materials. Though FEMA did not respond to the San Jacinto River fire, because of the Southeast Floods, 29 of 38 counties were declared disaster areas and approved $54 million in disaster assistance, but only because of the flooding. The event led to the closure of the Houston Ship Channel, one of the busiest ports in the world, and caused millions of dollars in property damage. The San Jacinto River fire remains one of Houston's most significant environmental disasters. It serves as a reminder of the importance of responsible industrial practices and the need for continued vigilance in protecting the health and safety of local communities and the environment.

In contrast, the San Jacinto River Fire 1994 occurred in the same region and did not receive FEMA assistance as it was not declared a major disaster. Instead, local and state agencies were responsible for response and recovery efforts. The lack of federal support for the San Jacinto River Fire resulted in a slower and less coordinated response, highlighting the importance and effectiveness of FEMA in managing disaster events. FEMA did provide aid in the form of disaster unemployment benefits, crisis counseling, and Small Business Administration loans to affected individuals and businesses. However, the response was primarily led by local and state agencies. The key difference between the two responses was the scale of the disasters and the level of federal involvement. Tropical Storm Allison was a much larger disaster and was declared a major disaster, triggering significant federal assistance. While still a significant event, the San Jacinto River Fire of 1994 did not reach the same level of impact as Tropical Storm Allison and thus did not receive the same level of federal support.

The difference between a federal response to an environmental hazard and a response by state or local authorities can be significant, as federal resources and expertise can be critical in responding to large-scale disasters. When a disaster occurs, state and local authorities are usually the first to respond and are responsible for coordinating the initial response efforts. However, if the disaster is severe enough, they may request federal assistance through FEMA, which can provide additional resources and support. Federal assistance may include personnel, equipment, and funding to help with search and rescue, medical care, and sheltering.

One of the key advantages of a federal response is the ability to coordinate resources and expertise from multiple agencies. For example, during the Deepwater Horizon Oil Spill of 2010, the federal government coordinated the response efforts of 17 agencies, including the EPA, the Coast Guard, and the Department of Defense. This allowed for a more comprehensive and effective response to the disaster (U.S. Government Accountability Office, 1991).

4. CONCLUSION

Texas' geology, geography, and climate influences the frequency and severity that the Houston area experiences hazardous events. According to the Harris County Flood Control District, a major flood occurs in Harris County about every two years. Most flooding occurs in developed areas built before the current understanding of the region's flood potential and before regulations that restrict construction in certain flood-prone areas. Even though large flood damage reduction projects have reduced the risk of flooding in the Houston area, more flood insurance funds have been paid to individuals in this area than any other National Flood Insurance Program participating community. Analyzing historical events like Tropical Storm Allison in 2001, the 1994 Southeast Texas Flood events and the San Jacinto River Fire allows us to understand disaster responses from the past as well as consider what could have been done differently. Reviewing historical events allows us to take away information of potential wrongdoings or mistakes and compare them with current disaster or emergency response practices, then implement them into a better response that is more efficient for future disaster events. Today, countries worldwide face the challenge of managing the increased risks from climate change and climate variability. Strategies to adapt to climate change, reduce disaster risk, and implement effective emergency management planning share common objectives across countries. Examples of sharing strategies and goals for risk reduction and emergency management include the United Nation's Sustainable Development Goals, the Paris Agreement on Climate Change, and the Sendai Framework for Disaster Risk Reduction. These documents stress the need for the participation of various stakeholders in different countries and international cooperation efforts to manage and reduce the growing risk of increasingly negative climate impacts. When looking back at historical disasters such as, Tropical Storm Allison, while this event largely impacted Houston, Texas, natural hazards of this nature also happen in other parts of the world. The emergency management practices implemented in such events can be translated into other hazardous events of the same type or even different types. Analyzing the risk, resiliency, and recovery of communities is critical in areas and countries impacted by natural or man-made disasters. Understanding the past is crucial towards improving emergency management and disaster responses in the future.

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