INVESTIGATING THE INFLUENCERS OF ADOPTION AND IMPLEMENTATION OF LARGE-SCALE INFRASTRUCTURE PROJECTS IN RESPONSE TO FLOODING HAZARDS.

by

Kholoud Mamouni

A thesis submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Master of Science in
Construction and Facilities Engineering

Charlotte

2023

Approved by:

____
Dr. Stephanie F. Pilkington

____
Dr. Katherine Idziorek

____
Dr. Nicole Barclay

ABSTRACT

KHOLOUD MAMOUNI. Investigating the Influencers of Adoption and Implementation of Large-Scale Infrastructure Projects in Response to Flooding Hazards.
(Under the direction of DR. STEPHANIE PILKINGTON)

Flooding is increasingly becoming a significant issue in the United States, with recent incidents causing substantial damage. This article examines the challenges of flood mitigation, focusing on the interplay of societal vulnerabilities, institutional responses, and technical elements. It analyzes factors leading to lengthy implementation periods for large-scale flood mitigation projects, especially in light of looming climate change threats. The study underscores the importance of a community-centric approach in disaster risk management, incorporating socioeconomic factors into mitigation strategies.

The research assesses various flood mitigation methods in the U.S., both structural and nonstructural, emphasizing recent projects in the southern region. The findings highlight the necessity of proactive planning and policy development in response to climate change, advocating for collaboration among local communities, policymakers, and experts. Additionally, the study explores the impact of demographic and socioeconomic factors on the effectiveness of flood mitigation.

In conclusion, the paper advocates for a holistic approach to flood mitigation. This strategy should proactively integrate social vulnerabilities, economic considerations, and environmental impacts to formulate solutions that not only mitigate flood risks but also prevent exacerbating inequality and increasing vulnerability to future disasters.

Table of Contents

List of Tables

List of Figures

CHAPTER 1: Introduction

1.1 Statement of the Problem

Flooding is a common natural hazard that impacts countless communities across the world. In 2019, the U.S. was impacted by several large-scale, inland flood events across many Midwestern and Southern Plains states. The damage costs were at least $20.0 billion, which makes it one of the most costly U.S. floods on record (NOAA, 2022). The anticipated cost of damage in 30 years is $16.9 billion (Ramirez, 2021). Such events can severely damage infrastructure, disrupt daily life, and endanger human safety. Effective flood mitigation measures can be implemented to lessen these communities' susceptibility and the socioeconomic and environmental effects of flooding. However, the lengthy implementation period for large-scale flood mitigation projects is an issue of concern when considering that several communities will soon experience enhanced flooding risk due to climate change (IPCC, 2019). To create solutions that expedite mitigation and improve community resilience, it is critical to first comprehend the underlying causes and effects of the implementation period.

Delayed flood mitigation mostly affects vulnerable communities, such as those in flood-prone areas or with limited resources (Tate et al., 2021). The extended duration needed to put flood mitigation measures in place means that areas remain vulnerable to frequent flooding. While the lengthy timeline is a contributing factor, the complexities of cost, conflicting priorities, and practicality, among others, also play significant roles in this ongoing issue. This unfortunate situation amplifies property damage, leads to displacement, and results in significant income loss (SAMHSA, 2017). Project implementation delays also have severe economic and environmental repercussions. Flooding can cause significant economic losses related to infrastructure damage, losses to agriculture, higher insurance prices, and the requirement for post-disaster recovery operations (IPCC, 2019; FAO, 2021). Extended implementation schedules compound these economic effects by enabling recurrent flooding disasters to happen before practical solutions are in place (SAMHSA, 2017). Flooding can also have negative effects on the environment, including ecosystem deterioration, habitat destruction, and water contamination (FOA, 2021); However, it's not invariably negative since flooding is a part of the natural cycle.

Investigating flood mitigations and the time it takes to put them into effect is critical for reducing community vulnerability, minimizing flood socioeconomic and environmental impacts, and informing policy and planning decisions. This thesis aims to address this issue by conducting a preliminary study that explores the factors that may contribute to accelerated or lengthened timelines regarding the implementation of select flood mitigation infrastructure projects and policies.

1.2 Scope of Research

Flooding is the third-most common natural hazard after earthquakes and storms, and about ninety percent of natural disasters in the US are associated with floods (*Homeland Security*, 2022). The International Panel on Climate Change (IPCC) report states that floods are projected to increase in the future (2019). Flood risk can be man-made, natural, or a combination of both (U.S. Army Corps of Engineers Headquarters, 2023). The US has implemented various approaches, ranging from local community infrastructure projects to initiating mitigation measures to reduce the impact that floods have on buildings The United States Army Corps of Engineers (USACE) conducted an extensive feasibility study to evaluate a range of proposed solutions for flood risk management. These solutions included the construction of seawalls, levees, and tide gates, as well as the restoration of wetlands and the development of vegetated dunes, all standard practices within the USACE's operations. In fiscal year 2020, the benefits realized from USACE's riverine flood risk management (FRM) projects were estimated at $257.9 billion. Moreover, over the ten years from fiscal year 2011 to 2020, the average annual benefit from these FRM projects was calculated to be approximately $161.8 billion. These national economic benefits are derived by estimating the annual flood damages that were prevented by USACE's FRM projects.

Through a literature review, it was revealed that the majority of proposed measures predominantly involved reactive mitigation methods, which are actions taken after a crisis has occurred. These reactive strategies often lead to higher expenses and extended recovery times compared to preventative interventions. This approach results in a cycle of damage and repair without addressing the underlying causes of disasters, consequently leaving communities unprepared for future crises and vulnerable to recurring impacts., which are projects that are established post disaster. The goal of this research is to investigate historical flood mitigation projects proposed in the southeastern U.S. region, according to the regional division established by FEMA (FEMA, 2021), more specifically the states of Louisiana, Florida, and North Carolina. The study intends to examine the progression of these projects from the onset of a disaster through full implementation, with a focus on the timeframes associated with each step of development.

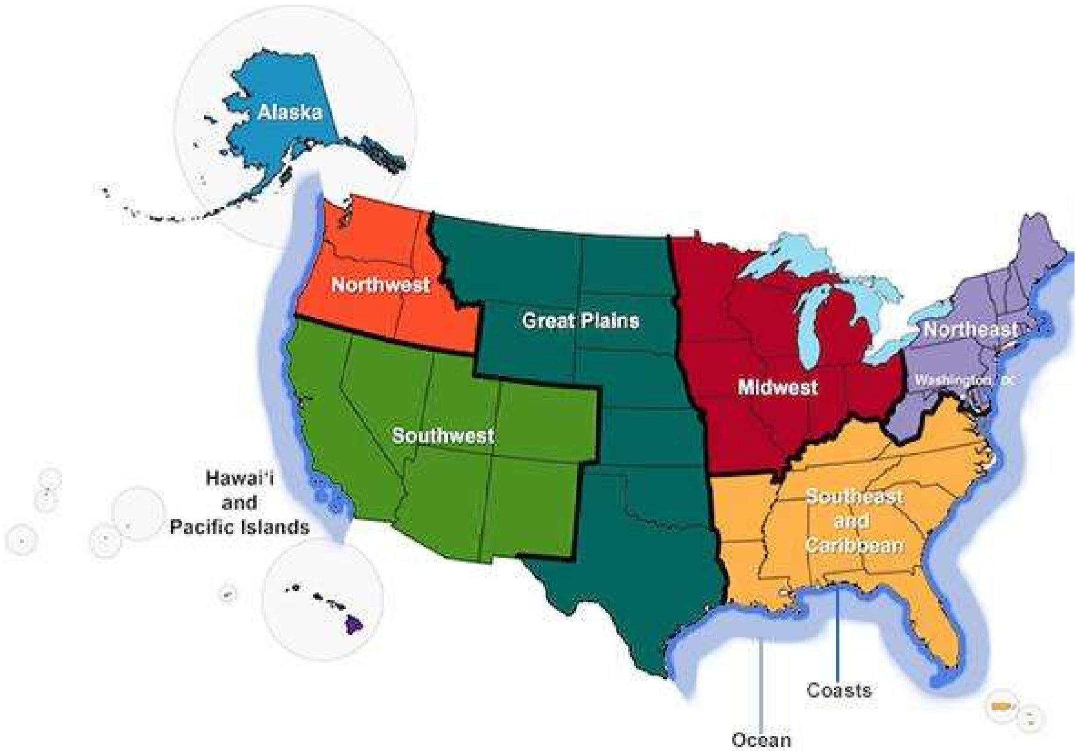

Figure 1- Regional division (FEMA's 4TH National Climate) (FEMA, 2021).

This study will focus on infrastructure projects that were implemented following the occurrence of an extreme flooding event, i.e. reactive mitigation measures. Focusing on projects inspired by a specific event will provide a starting point for the timeline to implementation, which is the focus of this study. Additionally, extreme events that result in such drastic measures often have more documentation, and therefore relevant data, available. The objectives of this study are to:

1) gather data on such projects regarding scale, scope, community demographics, and characteristics of the hazard event inspiring the project in question, and
2) to determine relationships between these variables and the resulting time between the occurrence of a significant flooding hazard event and completed project implementation.

The research discussed in this thesis aims to establish a hypothesis regarding flood mitigations, the time it takes to put them into effect, and the variables that may influence that timeline.

CHAPTER 2: Background & Literature Review

2.1 Climate Change and Flooding Impacts

The IPCC reports, with six volumes to date, utilize climate science to help inform policy. Since the publication of the First Assessment Report in 1990, these reports have played a critical role in defining the climate change debate. They are a comprehensive collection of scientific information on the human impact of climate change, its consequences, and the risks linked to it. Furthermore, these reports offer insights into methods and solutions for dealing with the issues posed by climate change. The IPCC reports are a significant effort to integrate scientific knowledge, enlighten policymakers, and inspire global collaboration in addressing the pressing issue of climate change.

The latest assessment from the IPCC indicates firmly that human activities are having a larger impact on the climate than ever before (2019). The report provides solid scientific data demonstrating that human-caused greenhouse gas emissions, principally from fossil fuel combustion and deforestation, are the primary cause of observed global warming and accompanying climatic changes. Rising temperatures, changing precipitation patterns, melting ice caps and glaciers, and an increase in the frequency and severity of extreme weather events are all examples of this.

The Sun drives Earth's climate by emitting energy at relatively short wavelengths, mostly in the visible or near visible (e.g., ultraviolet) range of the spectrum. Approximately one-third of the solar energy that reaches the top of the Earth's atmosphere is reflected back into space. The remaining two-thirds is absorbed by the atmosphere and, to a lesser extent, the surface. To balance the absorbed incoming energy, the Earth must emit the equivalent amount of energy back into space on average. Because the Earth is colder than the Sun, it radiates at far longer wavelengths, especially in the infrared. Much of the heat radiation released by land and sea is absorbed by the atmosphere, including clouds, and reradiated back to the land and sea. This is called the greenhouse effect (IPCC, 2007).

The greenhouse effect is important in the Earth's climate system, and human actions have a considerable impact on it. While the greenhouse effect is a natural process that keeps the planet's temperature balanced, manmade emissions augment it by disrupting the equilibrium between incoming and outgoing radiation (Mitchell, 1989). Radiative forcing, which measures the net energy balance between what the Earth maintains and what it loses to space, quantifies this disruption. Radiative force is measured in watts per square meter (W/m2), with a positive number representing an increase to the Earth's energy budget and a negative value representing a reduction in it. (Forster et al., 2007).

The increase in greenhouse gas concentrations since 1750 can be linked to human activities throughout the industrial age. The number of greenhouse gas molecules present per million or billion molecules of air is measured in parts per million (ppm) or parts per billion (ppb) (EPA, 2022).

Human activities cause the emission of four principal greenhouse gases: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and halocarbons (fluorine, chlorine, and bromine gases). As a result of numerous human actions, these gases are released into the atmosphere, causing an accumulation and eventual increase in their concentrations over time. Figure 1 depicts how the amounts of these gases have increased significantly over the industrial period. It is vital to stress that these increases are directly related to human activity, emphasizing our involvement in altering the composition of the Earth's greenhouse gases and contributing to the continuous changes in the global climate (Forster et al., 2007).

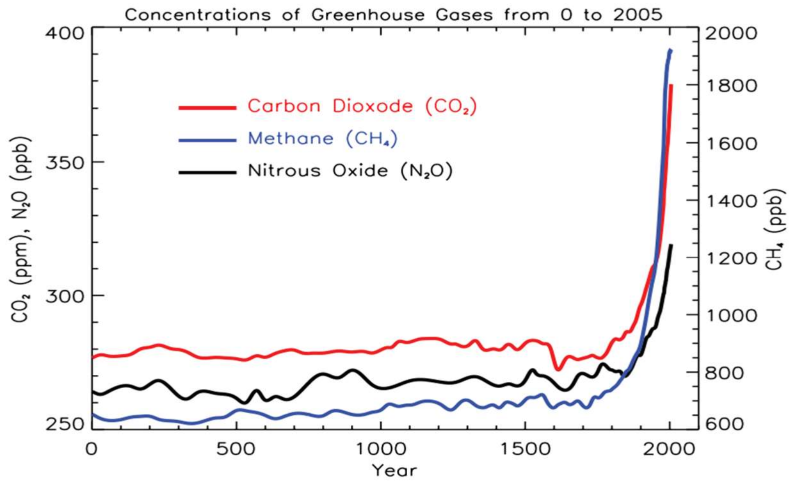

Figure 2- The increase in greenhouse gases in the last 2000 years (Forster et al., 2007)

Climate change significantly impacts the frequency and intensity of floods, primarily by intensifying extreme rain events. As global temperatures rise, the Earth's atmosphere can hold more moisture. This is quantified by the Clausius-Clapeyron equation, which states that for every 1°C increase in temperature, the air's moisture-holding capacity increases by approximately 7%. This results in more severe and intense precipitation events (US National Academy of Science, 2020)

Extreme rainstorms, exacerbated by climate change, can rapidly overflow both natural and man-made drainage systems, leading to flash floods and widespread flooding. The IPCC's 2012 report indicates that a warmer climate boosts evaporation rates from oceans and other water bodies, which in turn results in more atmospheric moisture and consequently, more frequent severe downpours. Additionally, climate change contributes to rising sea levels as ice caps and glaciers melt and seawater undergoes thermal expansion, aggravating coastal flooding. This becomes particularly critical when intense rains occur alongside high sea levels, as the already high water levels in rivers and drainage systems impair their ability to handle additional runoff, thereby elevating flood risks.

Climate change also alters storm patterns, resulting in storms that are capable of producing more significant rainfall within shorter durations. This alteration in storm behavior, combined with the other effects of climate change, amplifies the risk and severity of flood events, posing major challenges for effective flood management and mitigation strategies (Hirsch & Archfield, 2015).

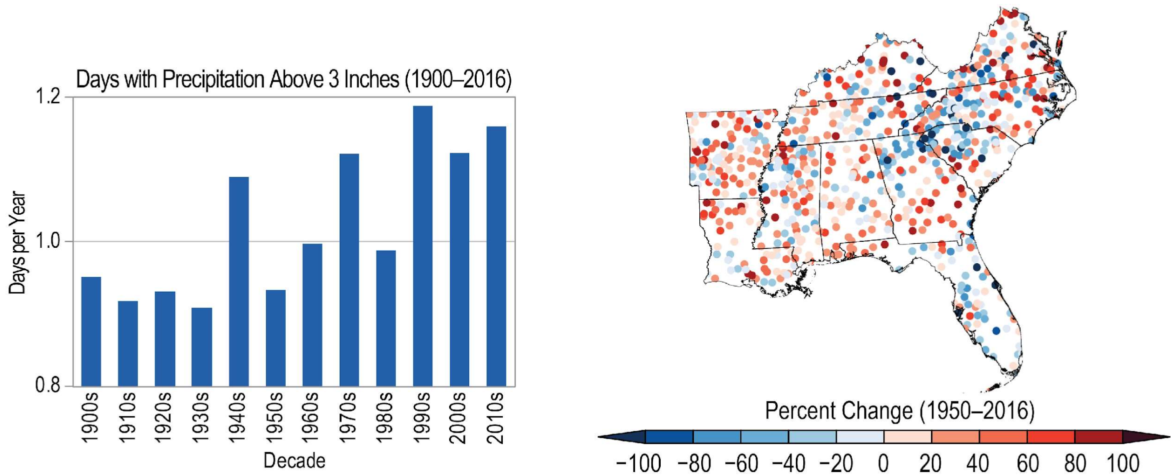

Figure 3-Trends in Heavy Precipitation Events: Decadal Analysis (1900-2016) and Station Observations (1950-2016) (Reidmiller et al., 2018)

The left graph indicates a growing frequency of days with more than three inches of rainfall in the US from 1900 to 2016, with notable peaks occurring in the 1940s and again in the 2010s. On the right, the map visualizes changes in heavy precipitation at individual stations across the Southeastern United States from 1950 to 2016, using red and blue dots to denote decreases and increases, respectively. Blue dots predominate, revealing a general increase in heavy precipitation days, particularly where the dots are darker in color. The fewer red dots suggest fewer areas with decreased heavy precipitation. Along the Gulf Coast, the intermixing of red and blue dots highlights a complex pattern of changing precipitation trends.

These trends carry significant implications: regions with more frequent heavy rainfall face increased risks of flooding, stress on infrastructure, and agricultural challenges. Conversely, areas with fewer heavy rainfall days may struggle with water shortages and drought conditions.

Although the map does not provide detailed statistical analysis, the visual data indicates ongoing trends that may be connected to broader climate changes, such as global warming, which influences weather patterns and precipitation levels.

Since 1990, the IPCC reports have been instrumental in shaping the climate change discourse, underscoring the significant role of human activities, like fossil fuel consumption and deforestation, in driving climate change. These changes have notably increased the frequency of extreme weather events, thereby escalating flood hazards. The Clausius-Clapeyron equation reveals that warmer atmospheres can hold more moisture, leading to heavier and more severe precipitation events. Additionally, rising sea levels further exacerbate both inland and coastal flooding. The growing incidence of floods underscores the urgent need for effective flood control measures and robust climate change mitigation strategies.

2.2 Types of Flood Mitigation Projects

Climate change-induced flood risks necessitate effective flood mitigation efforts to protect communities and reduce disaster impacts. Mitigation involves interventions to reduce greenhouse gas emissions. The National Conference of State Legislation (NCSL) distinguishes between structural and nonstructural flood mitigation approaches, including physical barriers like floodwalls and levees and strategies like property buyouts and zoning regulations. Flood Defenders advocates for proactive flood prevention strategies, including stormwater ponds, flood insurance, beach renourishment, levees, flood maps, shoreline protections, stormwater drainage improvements, floodgates, and property buyouts.

Building on the understanding of climate change's impact on flood frequency and intensity, mitigation efforts become crucial. The IPCC defines mitigation as a “human intervention to reduce the sources or enhance the sinks of greenhouse gases” (IPCC, 2014a). The National Conference of

State Legislation (NCSL, 2023) divides flood mitigation into two approaches; the first being structural, which includes floodwalls, seawalls, floodgates, and levees. These are barriers that are structured to reduce the damage that a flood may have on properties/people. Alternatively, nonstructural measures, which may consist of property buyouts, zoning subdivisions, and building codes, focus on minimizing damage by relocating individuals and property away from high-risk areas (NCSL, 2023). These measures involve the strategic removal of people and assets from flood-prone zones, thereby reducing the potential harm and losses caused by flooding events.

In addition to the flood mitigation measures categorized by the NSCL and outlined above, a menu of additional potential flood protection strategies is suggested by Flood Defenders, a non-profit organization founded by people who have personally witnessed the devastation caused by floods, and that emphasizes proactive over reactive measures, advocating for a preventative approach to flood management. Their major aim is to help others survive such disasters by advocating for the prioritization of flood prevention and preventive actions well in advance, rather than simply responding after the event. The Flood Defenders provide a menu of possible flood protection strategies, designed to provide concise summaries of each solution and how it can enhance the safety of your community in the face of flooding. They are defined as follows:

2.2.1 Stormwater Ponds:

Dry detention ponds, also called dry ponds, extended detention basins, detention ponds, or extended detention ponds, are meant to temporarily store runoff for a set period of time, usually 24 hours (Richard, 2021). The goal of this detention is to enable particles and contaminants to settle while also reducing peak flow rates (Richard, 2021). Dry detention ponds, unlike wet ponds, do not have permanent huge pools of water, though small pools are frequently present around the basin's inflow and outlet (Richard, 2021). While dry detention ponds were previously widely used for flood management, their popularity has declined due to their ineffectiveness in providing water quality improvement (Richard, 2021). They are built in urban or suburban areas to collect and temporarily store excess rainwater, lowering the risk of floods and the impact on neighboring waterways. Each form of the stormwater pond has small differences in design and function to suit distinct purposes. Here are some examples of several types of stormwater ponds:

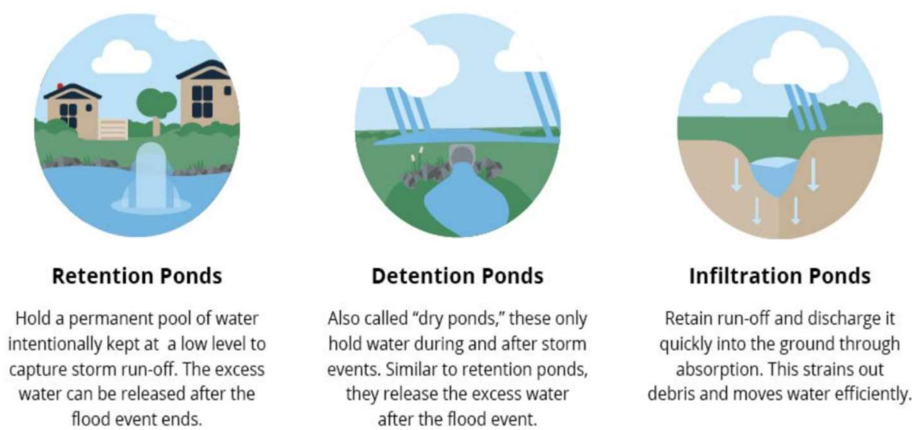

Figure 4- Types of Stormwater Management Ponds: Retention, Detention, and Infiltration.

2.2.2 Flood Insurance:

The National Association of Insurance Commissioners (NAIC) defines the National Flood Insurance Program (NFIP) as a federal program, managed by the Federal Emergency Management Administration (FEMA). The program has three components: to provide flood insurance, to improve floodplain management, and to develop maps of flood hazard zones (2022).

The usefulness of the National Flood Insurance Program remains unclear as only around 5% of flood-prone towns in the United States have completed the qualifications to qualify for the regular program (Costa, 1978).

2.2.3 Beach Renourishment:

Beach renourishment is the process of adding silt to a beach or nearshore area. This process has various advantages, including storm protection for coastal structures, the creation of new habitats, and increased recreational value for the beach (Beach Nourishment U.S. National Park Service, n.d.). Sediment is often acquired through offshore dredging and then either pumped straight onto the beach or deposited nearshore using a hopper dredge. Sediment may be sourced from inland sites in some situations.

Some beach nourishment efforts concentrate on property protection by building berms or filling gaps in dunes to absorb wave energy (U.S. Army Corps of Engineers, 2007). Beach nourishment is frequently required to counteract the erosional impacts of hard structure stabilization on surrounding coasts. For example, jetties were built in the 1930s to stabilize the Ocean City Inlet, which is located along the barrier island that ultimately became Assateague Island National Seashore (NPS, 2016). These construction projects, however, hindered natural sediment transport processes, resulting in sand deficiencies and higher erosion rates on downdrift beaches. As a result, severe geomorphic changes occurred throughout the shoreline, affecting delicate habitats, and limiting storm protection for the mainland (NPS, 2016). Millions of cubic yards of sediment have been deposited both onshore and offshore to restore the islands' natural characteristics and nearshore (Beach Nourishment U.S. National Park Service, 2019)

2.2.4 Levees:

A levee, whether organic or artificial, serves as a barrier to keep water from flowing into undesirable places. Its goal is to produce more habitable land or reroute water to use the fertile soil of rivers or seabeds for agriculture. Levees play an important function in safeguarding cities from flooding and hurricanes caused by rivers. However, it is critical to remember that if a levee fails or breaks, the effects can be disastrous, resulting in extensive flooding, severe property damage, and even loss of life (Costa et al., 2022).

The National Levee Database was established by the US Congress in 2007 to gather and provide detailed data on levees throughout the country to help with flood risk management, floodplain mapping, emergency response planning, and infrastructure evaluation. The National Levee Database is a public view into the information that builds understanding of the benefits and potential risks levees pose for the communities in which they exist," said Eric C. Halpin, P.E., USACE deputy dam and levee safety officer (U.S. Army Corps of Engineers, 2018). The scarcity of thorough data for analysis frequently hinders detailed assessments of failing levees. The main explanation for this limitation is the significant loss of data and information during levee failures, which makes conducting in-depth studies difficult (Özer et al., 2020).

2.2.5 Flood Maps:

Flood maps play an essential role in determining a community's vulnerability to flooding. These maps show the flood zone, floodplain limits, and base flood elevation for a given community. They are essential resources for property owners, insurance agents, and lenders since they assist in determining the necessary flood insurance requirements and policy costs. Stakeholders can make educated judgments about flood insurance coverage and take appropriate measures to limit the risks associated with anticipated flooding disasters by consulting flood maps (*FEMA Flood Maps Explained*, n.d.).

The challenge at hand is a lack of regular updates to flood maps. Many of FEMA's Flood Insurance Rate Maps (FIRMs) are severely out of date and fail to account for changing climate and development trends that have altered flood risk. These out-of-date maps fail to take into account factors such as the capacity of local drainage systems and the growth in impermeable ground cover. As a result, the flood maps' accuracy and efficacy in reflecting current flood risks are compromised (Office of Inspector General, 2017).

Aside from the issue of frequently outdated maps, experts have raised methodological concerns about how FEMA calculates flood risk. In 2018, a study published in the journal Environmental Research Letters emphasized the findings of advanced modeling, which found that about 41 million Americans live within 100-year riverine floodplains. This figure far outnumbers FEMA's estimate of only 13 million people living in flood-prone areas. These inconsistencies cast doubt on FEMA's flood risk estimates and highlight the need for new methodology to provide a more comprehensive knowledge of flood exposure across the United States (Wing et al., 2018).

2.2.6 Shoreline Protections:

Because estuarine coastal erosion is common in North Carolina's broad sounds and tidal rivers, many property owners seek solutions to minimize and prevent further erosion by stabilizing their shorelines (*Estuarine Shoreline Stabilization Options | NC DEQ*, n.d.). Shoreline stabilization is a comprehensive method that tries to protect coastal areas from erosion while also preserving the shoreline's structure. It entails the use of a variety of approaches, including constructed structures, vegetation planting, and land management strategies. The primary goal is to prevent or reduce land loss caused by natural processes such as wave action, tidal currents, and storm occurrences.

While seawalls (vertical walls or barriers built of concrete or other materials) are a popular form of shoreline stabilization, they are not the only alternative. Indeed, there is a rising awareness of the significance of considering alternate ways that have a lower environmental impact and provide extra advantages to ecosystems (*Estuarine Shoreline Stabilization Options | NC DEQ*, n.d.)

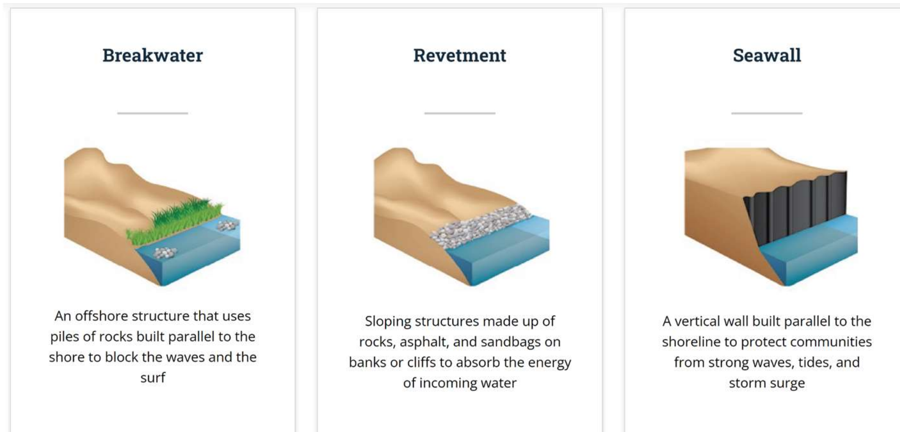

Figure 5- Shoreline Protection Solutions. (Flood Defenders, 2022)

2.2.7 Stormwater Drainage:

Hurricane Fran destructed eastern North Carolina in 1996, causing major damage to the area. This powerful hurricane produced damaging wind gusts of up to 100 mph and deposited 8 to 10 inches of rain, causing widespread devastation. Hurricane Florence caused $5 billion in damage to North Carolina. River Bend, in Craven County, was one of the devastated communities, with significant water damage as a result of the storm (FEMA, 2011).

The occurrence of Hurricane Fran is a significant example of the difficulties that communities like River Bend experience while dealing with natural catastrophes. The American Society of Civil Engineers (ASCE), which was founded in 1852, diligently examines the nation's infrastructure through its Report Card for America's Infrastructure. This thorough examination ranks the status of key infrastructure components and determines the necessary investments. The country obtained a D rating for its stormwater infrastructure in the most recent study, underlining the urgent need for development (ASCE, 2021).

River Bend local officials applied to the North Carolina Division of Emergency Management (NCEM) for funds under FEMA's Hazard Mitigation Grant Program (HMGP) to get financial support for a project to improve the stormwater system. The HMGP provides funding to qualifying states and local governments for the implementation of mitigation measures following major disaster declarations (FEMA, 2011).

In the case of River Bend, their initiative intended to improve the stormwater system cost $519,709. FEMA supplied $392,501 in funds, accounting for nearly 75% of the project cost. The remaining price of $127,208 was covered by the state (FEMA, 2011).

River Bend's project aimed to improve the town's existing stormwater management system to reduce flooding hazards. The renovations largely involved boosting the piping system's capacity and installing extra pipes across the municipality. These renovations were intended to improve stormwater flow, preventing it from backing up on properties after heavy rains or storms (FEMA, 2011)

The project includes five different locations throughout town where plumbing improvements were made. Residents in these places now face lower chances of flooding during future storms as a result of these improvements. Two sets of floodgates were added, as well as two detention ponds, to improve the town's flood resilience. These methods aid in the collection and management of excess water as it flows through the area (FEMA, 2011)

2.2.8 Floodgates:

Flood gates and flood barriers provide a strong defense mechanism to protect low-lying coastal areas. They provide great protection against flooding by acting as physical barriers. These safeguards are especially important in protecting extremely susceptible and valuable coastal metropolitan centers and key infrastructure from the damaging effects of flooding (Climate Adapt, 2016)

The Seabrook Sector Gate Complex (SGC) is a floodgate project administered by the USACE New Orleans District. Its major goal is to protect against 100-year storm events by preventing storm surges from breaking the Inner Harbor Navigation Canal (IHNC). By keeping storm surge outside the canal, the Seabrook SGC serves an important role in protecting New Orleans businesses and citizens during severe flood conditions (M. Anwar Zahid & M. Badre Enam, 2013)

The Seabrook Floodgate Complex cost around $165 million to build. This structure is an important component of the region's complete flood protection system, operating alongside other flood control measures to reduce the potential impact of storm surges and improve the resilience of affected areas (M. Anwar Zahid & M. Badre Enam, 2013).

The effective completion of the project by June 1, 2012, was an important milestone on the timeline of its implementation. (M. Anwar Zahid & M. Badre Enam, 2013)

2.2.9 Buyouts

In the context of flood natural disasters, the phrase "buyout" refers to a specific sort of property acquisition in which a government agency (typically a local municipality) purchases private properties, demolishes the structures on it, and maintains the area as open space. Buyouts enable interested homeowners to relocate while lowering total flood risk: preserving land in perpetuity as public, undeveloped space (for parkland, stormwater management, wetland restoration, recreation, and so on) permanently reduces the risk of flood damage on that property (Moore & Weber, 2019). An example of this solution is the floodplain buyout program enacted in the Charlotte, NC metro area. This floodplain buyout program in Charlotte began in 1999 and is funded by three main sources: FEMA Grants, which fund the majority of the buyouts, Local Risk-Based buyouts, and Quick Buys (Cardwell, 2021). Figure 4 shows the process that a FEMA-funded buyout must go through to get to the owner. According to the Natural Resources Defense Council (NRDC)'s review of almost 30 years of FEMA data on buyout funding, it was found that it takes on average more than five years between the natural hazard (flood in this case) and the completion of a funded buyout project (Moore & Weber, 2019).

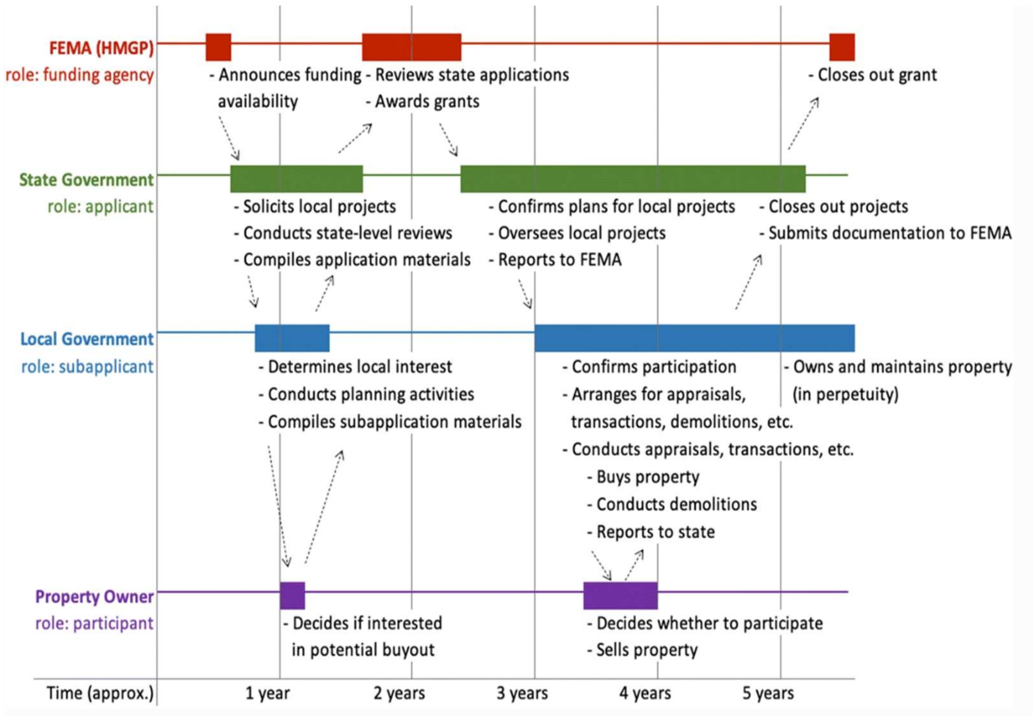

Figure 6- Timeline of a typical HMGP-funded buyout (Moore & Weber, 2019)

2.2.10 Flood Mitigation Approaches and Challenges in the U.S

Choosing appropriate flood mitigation measures is a complex task, involving a thorough assessment of various factors and input from a range of stakeholders with differing preferences and expertise. This complexity often leads to contradictory criteria, complicating decision-making and causing delays in implementing effective risk-reduction strategies, as Costa (1978) noted. Dams, for instance, serve as barriers to control hydrologic flows, detaining floodwaters to protect downstream communities during intense rainfall. Their purpose is to contain upstream floodwaters and release them gradually, mitigating potential damage downstream. However, during exceptionally severe events, a dam's capacity may be exceeded, leading to uncontrolled flood flows downstream. This scenario was evident during the 2011 spring floods on the Missouri River when overflowing dams contributed to the breaching of downstream levees. Under such extreme conditions, dams can fail, releasing vast volumes of water and causing significant damage or destruction to downstream levees and communities (USGS, 2019).

In flood risk management planning, various control options are available, and the final decision on which measures to implement hinges on evaluating multiple criteria and accommodating the preferences of different stakeholders. While it's crucial to educate decision-makers and provide them with the necessary skills to analyze and select from these options, the decision-making process remains challenging, even with adequate information. Equipped decision-makers can make more informed choices, but they must still navigate the complexities inherent in the process. This includes balancing conflicting interests and priorities, which makes implementing successful flood risk reduction techniques a demanding yet vital task.

Flood mitigation in the United States is a multi-layered process involving federal, state, local, and NGOs. The Federal Government, including agencies like FEMA and the Army Corps of Engineers, funds, plans, and executes flood mitigation projects. State agencies collaborate with federal bodies to provide resources and support. Local governments execute flood mitigation strategies like zoning, land use planning, and maintaining waterways and barriers. Non-governmental organizations contribute through research and advocacy, ensuring a comprehensive and effective response to flood mitigation.

To manage and respond to flood events, the United States, via the previously mentioned agencies, implements a diverse array of mitigation solutions. Although the initial objective of this research was to identify proactive flood mitigation strategies implemented by the United States, the majority of the studies and published findings pertain to reactive measures were primarily reactive. The goal of this literature review is to provide a thorough overview of the current knowledge and understanding of these mitigations.

2.3 Proactive versus Reactive Mitigation Projects

Emergency Management involves preparedness, response, mitigation, and recovery. Figure 5 depicts the connections between the four stages of emergency management, representing an ongoing cycle intended to reduce the effects of disasters, mitigation encompasses techniques to decrease or eliminate risks before a disaster occurs, which directly feeds into the preparedness phase. In this phase, plans and procedures are developed to deal with potential emergencies. When a disaster strikes, the response phase is initiated, utilizing the preparedness strategies to effectively manage the situation. Following the immediate response, the recovery phase focuses on restoring the affected community to normal or safer conditions. These recovery strategies then feed back into mitigation, where lessons learned can lead to improved measures to mitigate the impact of future disasters, thereby completing the loop and restarting the cycle. This ongoing practice ensures that communities are continually enhancing their resilience against disasters. Its importance stems from the fact that communities are always engaged in at least one phase of emergency management at any given moment (Bullock et al., 2013). Proactive mitigation projects fall under the preparedness stage, and reactive mitigation projects fall under the response stage. These types of projects are discussed in further detail within this section (Bullock et al., 2013).

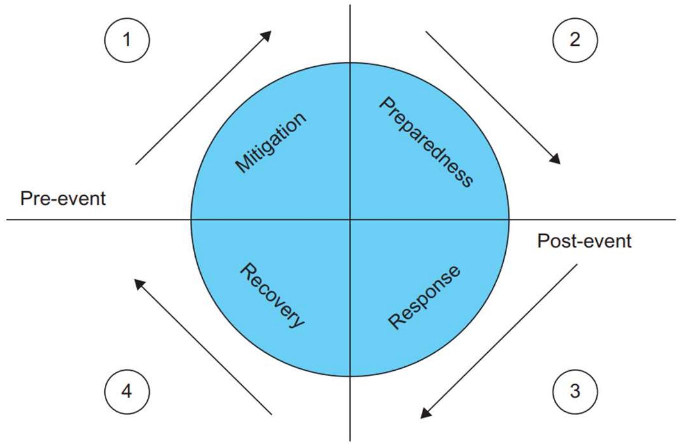

Figure 7- The four classical phases of disaster management (Bullock et al., 2013)

2.3.1 Proactive Mitigation:

Proactive mitigation projects try to reduce the possible consequences of extreme events before they happen. Predictive models, risk assessments, and historical data analysis are typically used to perform these initiatives (Bea, 2005; RiskOptics, 2023). In this case, the goal is to make communities and infrastructure systems less vulnerable and more resilient.

In an article published by the Pew Charitable Trusts, Tompkins states that one option for reducing flood costs is to set policies in federally funded projects that account for future flood risk (2019). Communities and states may therefore be better prepared for and respond to flooding in a more proactive manner. By combining risk assessments and preventive actions into project planning and implementation, this proactive strategy strives to lessen the financial burden associated with flood damage.

The E-SHMP (Enhanced State Hazard Mitigation Plan) was last revised in 2018 by the Risk Mitigation Branch of North Carolina Emergency Management in partnership with a consulting organization. The plan meets FEMA requirements and incorporates climate projections into risk and vulnerability assessments using credible NOAA data. The North Carolina Flood

Mapping Program generated digital flood hazard maps for all counties based on historical data, without including predicted climate change modeling, to estimate flood hazard threats (Burnstein & Rogin, 2002.). There were no records as to when this project was completed.

The E-SHMP shows remarkable collaboration among local communities and government entities. However, it provides limited coverage of social vulnerability and does not incorporate it into the risk and vulnerability assessment process. North Carolina's mitigation initiatives include direct state government engagement, such as property acquisition and elevation. However, the plan continues to emphasize encouraging and supporting local hazard mitigation plans by permitting local governments to employ specific land use and taxing powers (Burnstein & Rogin, 2002)

Following Hurricane Florence, Governor Roy Cooper issued Executive Order 80, demonstrating North Carolina's commitment to combating climate change and transitioning to a sustainable energy economy. The executive order calls for the formation of a Climate Change Interagency Council and mandates that each agency analyze the effects of climate change on its programs. It also calls for an annual status report to track the order's implementation progress (Burnstein & Rogin, 2022). This executive order highlights the state's proactive approach to mitigating future flood damage.

2.3.2 Reactive Mitigation:

Reactive flood mitigation refers to a variety of tactics and procedures implemented in response to a flood event. These precautions include emergency response and evacuation procedures to safeguard the safety of those in danger, the use of temporary flood barriers such as sandbags and water-filled barriers to redirect or confine floodwaters, and the installation of pumping and drainage systems to remove excess water. Furthermore, flood warning systems are critical in giving timely alerts and notifications to people and authorities, allowing for immediate action (FEMA, 2005).

Other reactive measures include floodplain management and zoning restrictions to control growth in flood-prone areas, public awareness campaigns to educate populations about flood dangers and safety precautions, and attempts to strengthen key infrastructure resilience. Post-flood recovery and rehabilitation procedures are also important in providing financial assistance, temporary housing, and infrastructure repairs to affected areas. While reactive flood mitigation is critical for rapid reaction and recovery, proactive flood mitigation is required to prevent future flood risks and improve long-term resilience (FEMA, 2005).

FEMA granted $21.6 million under its Hazard Mitigation Grant Program to incentivize state and local governments to fund projects targeted at supporting communities in eliminating or limiting disaster damage. This grant is designed to support activities that promote long-term safety and well-being of affected communities by increasing resilience and reducing the impact of future disasters (*FEMA*, 2020).

The federal government invested $14.5 billion to restore New Orleans' levee system in reaction to Katrina's catastrophic floods and avoidable loss of life. When tested by Hurricane Ida's Category 4 winds and heavy rainfall, the levee system performed well in protecting lives and property. Nonetheless, flooding did occur in disadvantaged neighborhoods outside the levee system's border, indicating that the construction is inadequate (Shultz et al., 2022).

This study's initial research question was to investigate all types of large-scale flood mitigation techniques established in the southeastern United States and analyze the factors that contributed to a successful implementation and the association timeframe. However, due to limited data availability, the emphasis changed to primarily investigating more reactive methods, as there are more studies published on these projects. Specifically, projects spurred from a specific extreme event, such as those similar to the example described above, provide a starting point in establishing a timeline.

2.4 Social Vulnerability and Disaster Response

The Social Vulnerability Index (SoVI) is a composite metric that evaluates the overall social vulnerability of each county, calculated by integrating factor scores derived from various socioeconomic and demographic variables with the original county data. These scores, utilized in an additive model, determine the SoVI for each county, ensuring that every factor contributes equally to the county's overall vulnerability. As a relative measure, the SoVI indicates greater vulnerability with higher positive values and lesser vulnerability with lower negative values. In cases of ambiguous factor impacts, their absolute values are considered. This index plays a crucial role in pinpointing the most and least vulnerable counties (Cutter et al., 2003)

Further illustrating the importance of specific indicators within the SoVI, the percentage of single-parent households, as identified by the U.S. Census Bureau, stands out as a key quantitative indicator of social vulnerability. This metric reflects households led by a single parent with dependent children and is critical for assessing social vulnerability due to the unique challenges these households face. These challenges include limited financial resources and caregiving responsibilities, which can hinder their ability to respond to disasters. Quantitative indicators like this provide objective, data-driven insights into different communities' risk levels during disasters, encompassing demographic, socioeconomic, and housing characteristics. By quantifying factors such as income levels, poverty rates, age, race/ethnicity, housing quality, and transportation access, these indicators enable a deeper understanding and more effective targeting of disaster preparedness, response, and recovery efforts. This approach is key in addressing socioeconomic disparities that impact vulnerability and resilience. (Spielman et al., 2020).

Although population estimates are useful for determining the general magnitude of flood exposure, they do not indicate the precise features of the individuals or groups affected. It is critical to identify susceptible populations since socially vulnerable groups tend to disproportionately live in flood-prone locations (Tate et al., 2021). This phenomenon can be linked to underlying factors such as socioeconomic stratification, which leads to a lack of political and economic power as well as limited access to resources, restricting disadvantaged people's options for avoiding hazardous regions.

The Census Bureau produces demographic data that can aid in emergency planning, preparedness, and recovery efforts. These data include a wide range of statistics, including race, ethnicity, age demographics, socioeconomic characteristics, and housing features. Table 1 is created using a 29-variable indicator set obtained from the most recent edition of the Social Vulnerability Index (SVI) (Tate et al., 2021). Tate and his colleagues conducted an extensive study on flood exposure and social risk in the United States using a multifaceted technique. They extracted social, economic, and demographic characteristics from the American Community Survey to create a Social Vulnerability Index (SVI) for each census tract in the contiguous United States. These variables were analyzed using principal components analysis to form the SVI for their study. The researchers assessed population flood vulnerability by combining geospatial flood hazard data with land cover data from the National Land Cover Database and the EnviroAtlas dasymetric population map. This approach enabled them to compute the proportion of flood-exposed habitable area per census tract. Furthermore, they employed bivariate Local Indicators of Spatial Association statistics to identify geographic clusters with high flood risk and high social vulnerability. They also discovered prominent demographic characteristics, such as larger percentages of mobile homes and specific racial demographics, in these high-risk areas. The study culminated in the establishment of a set of social vulnerability indicators specifically adapted to the context of flood exposure in the United States, enhancing understanding and aiding in the development of targeted flood mitigation strategies. Social vulnerability pertains to a community's resilience in the face of external forces that influence human well-being, such as natural catastrophes, man-made crises, and disease epidemics. We can reduce human suffering and economic costs by reducing societal vulnerability. Individuals with unique needs, such as those without access to transportation, people with impairments, older individuals, and those with inadequate English proficiency, are considered socially vulnerable (CDC/ATSDR, 2022).

The data for the variables in Table 1 are sourced from the American Community Survey. These variables cover various aspects of social vulnerability, providing insights into the social, economic, and demographic factors that contribute to vulnerability in different areas. They have been identified as particularly effective in clarifying the relationship between social vulnerability and disaster impacts, as demonstrated in the literature review that links social vulnerability to natural disasters.

Table 1- Input social vulnerability indicator (Tate et al., 2021).

Dimension	Indicator
Age	Population <5 years or > 65 years (%) Median age
Dependence	Households receiving social security benefits (%) Nursing home residents per capita
Education	Less that 12th grade education (%)
Employment	Civilian unemployment (%) Employment in extractive industries (%) Employment in service industry (%)
Ethnicity	Hispanic (%)
Family Structure	**Children living in married-couple families (%)** Female-heading households (%) People per housing unit
Gender	Female (%) Female participation in labor force (%)
Health	Population without health insurance (%)
Housing	Renters (%) Rent burdened (%) **Median gross rent** Mobile homes (%) Unoccupied housing units (%)
Income	Poverty (%) **Households earning over $200,000 annually (%)** **Per capita income**
Language	Limited English proficiency (%)
Mobility	Housing units with no car (%)
Race	Asian (%) Black (%) Native American (%)
Wealth	**Median housing value (%)**

***Boldface indicates variables that decrease in value with increasing social vulnerability.**

Social vulnerability indices have been critical in measuring and displaying the human components of hazard exposure over the last 10 years. Early research laid the framework for modeling social vulnerability, and the following studies broadened the scope to include considerations of scale, time-related changes, specific hazards, uncertainty, validation methodologies, and the integration of social and physical vulnerability characteristics. Despite these changes, there is still a striking consistency in the approaches used to produce these indices, demonstrating a persistent reliance on existing methodology even as the scope and complexity of social risk analysis has risen. While this represents an increasing consensus among modelers, it also shows the difficulties of using composite indicators to capture the complexities of social vulnerability processes. If factors related to risks are omitted or less influential dimensions are overrepresented, uniformity may lead to incorrect findings (Rufat et al., 2015).

The first important finding revealed by the analyzed studies is the variety of variables and concepts connected with social vulnerability. Researchers have identified numerous factors contributing to social vulnerability: such as resource availability, social capital, physical constraints, built-environment characteristics, age, income, social networks, and neighborhood characteristics. The table below shows the list of variables that were found to be the most useful in shedding the light on the relationship between social vulnerability and disaster during the literature review linking social vulnerability to natural disasters. These variables are important for assessing susceptibility to natural and man-made disasters because they provide a comprehensive picture of the factors influencing a community's ability to plan for, respond to, and recover from adverse events.

Understanding social vulnerability is key in disaster management, highlighting the unique needs and challenges faced by different communities. One important aspect of this is resource availability, which includes access to essential resources like food, clean water, and healthcare. Communities with limited access to these resources are often more severely impacted by disasters, underscoring the importance of addressing these vulnerabilities in disaster preparedness and response strategies.

Table 2- Frequency of Variable Mention in Social Vulnerability Literature.

Variable	# Mentioned in Literature	Cited Work
Income	15	(Aldrich & Benson, 2008); (Barron, 2000); (Blackwood & Cutter, 2023); (Drakes & Tate, 2022); (Fatemi et al., 2017); (Flanagan et al., 2011); (*Greater Impact: How Disasters Affect People of Low Socioeconomic Status*, 2017); (Hallegatte et al., 2020); (Lee et al., 2022); (Mah et al., 2023; Rumbach et al., 2020); Rufat et al., 2015; (Schmidtlein et al., 2008); Singh et al., 2014; Spielman et al., 2020
Poverty	14	Aldrich and Benson, 2008; Barron, 2000; Blackwood and Cutter, 2023; Fatemi et al., 2017; Flanagan et al., 2011; "Greater Impact: How Disasters Af…, 2017"; Hallegatte et al., 2020; Lee et al., 2022; Mah et al., 2023; Rufat et al., 2015; Rumbach et al., 2020; Schmidtlein et al., 2008; Singh et al., 2014; Spielman et al., 2020
Age	15	Aldrich and Benson, 2008; Barron, 2000; Blackwood and Cutter, 2023; Drakes and Tate, 2022; Fatemi et al., 2017; Flanagan et al., 2011; "Greater Impact: How Disasters Af…, 2017"; Hallegatte et al., 2020; Lee et al., 2022; Mah et al., 2023; Rufat et al., 2015; Rumbach et al., 2020; Schmidtlein et al., 2008; Singh et al., 2014; Spielman et al., 2020
Race/Ethnicity	15	Aldrich and Benson, 2008; Barron, 2000; Blackwood and Cutter, 2023; Drakes and Tate, 2022; Fatemi et al., 2017; Flanagan et al., 2011; "Greater Impact: How Disasters Af…, 2017"; Hallegatte et al., 2020; Lee et al., 2022; Mah et al., 2023; Rufat et al., 2015; Rumbach et al., 2020; Schmidtlein et al., 2008; Singh et al., 2014; Spielman et al., 2020
Lack of vehicle access	4	Aldrich and Benson, 2008; Barron, 2000; Schmidtlein et al., 2008; Rufat et al., 2015
Single-parent households	5	Barron, 2000; Fatemi et al., 2017; Flanagan et al., 2011; "Greater Impact: How Disasters Af…, 2017"; Singh et al., 2014;
Mobile homes	10	Aldrich and Benson, 2008; Barron, 2000; Blackwood and Cutter, 2023; Fatemi et al., 2017; Flanagan et al., 2011; "Greater Impact: How Disasters Af…, 2017"; Lee et al., 2022; Mah et al., 2023; Rufat et al., 2015; Rumbach et al., 2020; Schmidtlein et al., 2008; Spielman et al., 2020
Disability	9	Barron, 2000; Blackwood and Cutter, 2023; Fatemi et al., 2017; "Greater Impact: How Disasters Af…, 2017"; Hallegatte et al., 2020; Mah et al., 2023; Rufat et al., 2015; Rumbach et al., 2020; Singh et al., 2014;

In times of disaster, social capital—comprising the networks and relationships within a community—plays a crucial role in fostering collective action and assistance. It significantly enhances a community's resilience and efficiency in responding to disasters. Integrating social capital into disaster management is relevant both to the factors previously mentioned (such as income, age, and disability) and to subsequent discussions. It can amplify or mitigate the vulnerabilities associated with these individual characteristics. For instance, strong social networks may provide crucial support to those with limited income or mobility challenges. Moreover, social capital is interconnected with broader issues like physical limitations and built-environment features, underlining its vital role in strengthening community safety and effective emergency response.

Physical limitations, encompassing various disabilities and impairments, may significantly restrict an individual's movement or ability to evacuate during an emergency, substantially increasing their vulnerability. This situation is often worsened by inadequate emergency planning, which fails to adequately consider the needs of those with physical limitations. This highlights the urgent need for more inclusive and accessible emergency strategies to ensure the safety and well-being of these individuals (DOL, 2023)

Built-environment features include aspects of a community's physical infrastructure, such as housing quality, transit systems, and availability of emergency services. Vulnerability can be increased by poorly planned structured surroundings (Rasper, 2016)

Age is an important demographic element influencing susceptibility. During disasters, both elderly people and children may encounter particular challenges, such as difficulty evacuating or receiving adequate healthcare (*Greater Impact: How Disasters Affect People of Low Socioeconomic Status*, 2017)

Income is a critical economic factor related to an individual's ability to cover expenses associated with an extreme hazard event. Individuals and households with lower incomes frequently have restricted access to resources and demonstrate lower economic resilience in the face of disasters (*Greater Impact: How Disasters Affect People of Low Socioeconomic Status*, 2017).

Disaster response and recovery are heavily dependent on social networks. Individuals with robust social networks often have access to emotional and material support, whereas those with fewer social connections may be more vulnerable. Additionally, neighborhood characteristics such as crime rates, educational opportunities, and accessibility to community resources can significantly affect vulnerability. These factors influence a community's capacity to prepare for and recover from disasters. Understanding these elements is crucial for a comprehensive grasp of social vulnerability and for developing effective emergency risk mitigation strategies. While these aspects are not included in this research, due to a focus on social vulnerability rather than social networks, their inclusion is recommended for future studies.

2.5 Challenges in Social Vulnerability for Disaster Management

Several studies have emphasized how the outcomes of the Social Vulnerability Index (SoVI) are notably affected by the choice of methodology used. Schmidtlein et al. (2008) and Cutter & Finch (2000) show how the selection of variables, the combination of methods, and rotation procedures can significantly influence SoVI results. These methodological decisions can drastically alter vulnerability rankings, which underscores the need for extreme caution, as well as consistency and transparency in defining and justifying the criteria for vulnerability assessments.

Attention has also been drawn to the impact that computational methods have on the identification of social vulnerability. Schmidtlein et al. (2008) highlighted that algorithmic choices can lead to varied vulnerability rankings among different study areas. Researchers are encouraged to thoroughly document their algorithmic approaches and engage in sensitivity analysis to determine how changes could affect their results, thus enhancing the reproducibility and reliability of such evaluations.

As noted by Blackwood and Cutter (2023) and Rufat et al. (2015), accurately defining vulnerability across different geographic scales is a complex task due to the interplay of various factors. The issue of vulnerability heterogeneity is paramount, as vulnerability variables can significantly vary between regions; what is critical in one area might be irrelevant in another. This variance complicates the adoption of a uniform vulnerability assessment approach for different geographic areas. Another challenge is the granularity and availability of data. At smaller scales, such as neighborhoods or towns, the necessary detailed data for assessing vulnerability might not be available or may lack the required depth for a thorough analysis. and conversely, at larger scales, like national or regional levels, data tends to be more aggregated, potentially obscuring local subtleties and individual vulnerabilities. This issue is crucial since it directly influences the identification of vulnerable groups and the distribution of resources. Therefore, researchers and policymakers need to meticulously examine the geographic scope of their evaluations and devise methods that enable meaningful cross-scale comparisons. Such attention ensures that vulnerability assessments are relevant and effective in directing resource distribution and policymaking, especially in translating large-scale data into actionable local-level strategies.

The importance of Social Vulnerability Indices in disaster management is underscored by Flanagan et al., 2011 and Blackwood & Cutter (2023), who also point out limitations such as data timeliness and regional focus. To maintain the relevance of SVIs for disaster management, frequent updates of data and attention to the regional distribution of vulnerability are necessary.

Advanced data collection strategies, including real-time data sources and community surveys, are recommended to overcome these issues.

Fatemi et al. (2017) discuss social vulnerability as highly context-dependent and influenced by factors such as exposure to severe events, preparedness measures, and community resilience. This suggests that mitigation of disaster risks requires tailored local interventions. Drakes & Tate (2022), further this perspective by advocating for a multi-hazard approach in disaster risk management, acknowledging the complex interplay between various types of hazard risks and societal vulnerabilities.

Finally, the quality of data underpinning vulnerability assessments is critical. Reputable sources, such as the American Community Survey, are essential for collecting socioeconomic and demographic data, as pointed out by the literature. Mah et al. (2023) call for further research to compare and validate various social vulnerability indicators, arguing that a comprehensive and up-to-date dataset is necessary to refine the accuracy and practical application of these measures in disaster risk management.

2.6 Summary

Flooding presents a significant challenge, especially for vulnerable communities, due to the protracted process of enacting flood prevention strategies, which can span from as little as nine months to well over a decade. Flood frequency and severity are increasing due to storm intensification and rising sea levels, which are mostly caused by human-contributed climate change. Flood mitigation uses a variety of structural and non-structural solutions to address this issue, such as floodwalls, stormwater ponds, and levees. The National Flood Insurance Program, which provides flood insurance and improves floodplain management, is limited by outdated flood maps. Understanding and stopping land loss requires the use of the National Levee Database and coastal stabilization technologies. However, future flood control measures may be hindered by a lack of data.

Floodgate installations and property acquisitions, such as the Seabrook Sector Gate Complex, show the effectiveness of floodgate installations and buyouts in mitigating flood risk. The decision-making process for flood risk management is complex, including multiple criteria and stakeholder preferences. Predictive models are used in proactive mitigation attempts to improve community resilience. This research focuses on reactive mitigation initiatives, which are crucial in addressing immediate flood damage typically incurred during significant flooding events. These initiatives encompass not only emergency repair and reinforcement efforts but also strategic planning for potential future flood disasters. The effectiveness of these reactive strategies is evaluated based on their ability to quickly restore functionality, reduce future flood risks, and bolster overall community resilience. This study delves into the speed and efficiency of such reactive measures, with a particular emphasis on the timeframe from the event to project completion. Key factors influencing this timeline, including the availability of resources, the severity of flood damage, and the level of coordination among various stakeholders and government agencies, receive special attention. By examining reactive mitigation projects, such as those enacted post-Hurricane Katrina and in response to other major flooding incidents in the southeastern United States, this research aims to shed light on the practical aspects of flood response and recovery. It explores the challenges and successes encountered in these real-world scenarios, with the ultimate goal of enhancing our understanding of how reactive mitigation can be effectively integrated into broader flood risk management strategies.

A variety of factors determine societal vulnerability, which has a significant impact on the severity of disasters and the recovery process. Social vulnerability indices are effective tools for assessing and mapping human vulnerability to flood risks. As a result, social demographics may also influence the complete implementation of a flood mitigation infrastructure project. Although FEMA grants are meant to mitigate flood dangers and increase long-term resilience, poor construction can lead to flooding in low-income neighborhoods (Flood Authority, 2023).

The purpose of this literature review is to give a comprehensive overview of flood mitigation strategies, climate change consequences, infrastructure projects and legislation, and the relevance of societal vulnerability within the context of managing and mitigating flood risks.

CHAPTER 3: Methods

3.1 Determination of Relevant Data

The aim of this research is to formulate a hypothesis about the factors influencing the 'time to implementation' of large-scale flood mitigation infrastructure projects following an extreme event. To achieve this, the first step involves identifying data variables to create an initial dataset for analysis. The variable selection process entailed identifying the types of flood mitigation projects and variables that provide information about the project, including the severity of the hazard event it was a response to, and refining a list of 29 social vulnerability indicators down to those most pertinent in the context of flood exposure and social risk.

This research specifically focuses on projects that were approved as a result to extreme flooding events, categorizing them as reactive mitigation. This approach allows for a clear delineation of a timeline from the date of the event to the date of project completion. The time taken for project implementation, serving as the dependent variable in this analysis, demands consistent measurement. Additionally, the nature of the hazard is considered to potentially affect the speed of project implementation. Thus, characteristics such as maximum storm surge and maximum 24-hour precipitation are included to correlate the severity of the event with the potential 'urgency' of project implementation.

A 'large-scale project' in flood mitigation is defined in literature as an endeavor that involves considerable expenditure, significant personnel involvement, and a completion time of at least a year (Banks, 2019; Cambridge, 2023). It is also defined as projects that are suitable for extreme events due to their capacity to make more space for water (Vojinovic et al., 2021). Due to the fact that there was no clear consensus amount in the literature, we chose $10,000,000 as a starting point for budget estimates based on research and data collection process. This figure serves as a baseline for initial planning and comparison, but actual costs will vary significantly depending on the specific requirements of the project, its location, and the nature of the flood risk that needs to be mitigated. Examples of such projects include major infrastructure undertakings like flood gates, levees, beach renourishment, and dams. These initiatives are characterized by their extensive scope, substantial resources, and the need for meticulous planning and organization. In this research, the flood mitigation projects that were chosen are floodgates, levees and beach renourishments. These projects were chosen through a sophisticated decision-making process that entailed evaluating various factors and balancing the perspectives and expertise of multiple stakeholders. The complexity of aligning differing criteria among these stakeholders presents challenges, yet it is crucial for implementing effective risk-reduction strategies. Designed to either physically block floodwaters or minimize damage by relocating assets and people from flood-prone areas, these projects take into account the complexities and varied impacts of each measure, including potential effects on community safety and environmental considerations like fish life. Variables such as income, poverty rate, age, race/ethnicity, lack of vehicle access, single-parent families, mobile homes, and disability were selected to assess the impact of flood mitigation projects on different population segments. These factors focus on elements like economic resilience, evacuation challenges, access to political and recovery resources, availability of transportation, housing vulnerability, and the specific needs of vulnerable groups like the elderly, the young, and people with disabilities, ensuring a thorough understanding of diverse needs in flood disaster scenarios. Specific flood mitigation criteria led the designation of "large-scale infrastructure project" and the identification of particular projects as data points.

The inclusion of the magnitude and location of these projects along with social vulnerability factors sought to determine if the social qualities of persons affected by the event, rather than merely their proximity to the project site, influenced project execution. The social vulnerability indicators are from the county-level geographical scale for this research because it provided a good combination of detail and manageability. These social vulnerability characteristics were narrowed down to eight variables and are justified and defined as follows (all social data is extracted from the U.S. Census (Bakkensen et al., 2017).

Income [U.S. dollar]: Median household income per county, sourced from census data. Included because lower-income individuals and households are more vulnerable during disasters due to limited resource access and economic resilience. (Hallegatte et al. 2020)

Poverty Rate [percentage]: Calculated by the proportion of individuals below the poverty line in each county. A higher percentage suggests greater struggle in securing resources during natural hazard events, which can affect the ability of the population to prepare, respond and recover from the disaster (Bureau, 2023).

Age [percentage]: Determined by adding the population aged 65 and up and those under five, then dividing by the total county population. Older and younger populations may face evacuation challenges, which helps in understanding the proportion of the population that might require special attention in case of natural disasters (Aldrich & Benson, 2008).

Race/Ethnicity [percentage]: Minority population percentage is calculated by adding all non-Caucasian ethnicities, indicating potential limitations in political access and recovery resources, and dividing that value by the total population (Bureau, 2022a).

Lack of vehicle access [percentage]: Represents the proportion of people without vehicle access in a county, affecting evacuation and access to emergency services (*Greater Impact: How Disasters Affect People of Low Socioeconomic Status*, 2017).

Single-parent household [percentage]: Defined by the U.S. Census Bureau, this metric includes households with one parent and dependent children. It is crucial because it can include limited financial resources and limited ability to relocate in case of emetgency (Barron, 2000).

Mobile homes [percentage]: Defined as movable housing units. Mobile homes, often situated in disaster-prone areas, are associated with higher vulnerability due to structural limitations. The United States Census Bureau determines the proportion of mobile homes by collecting data on new manufactured housing shipments via the Manufactured Housing Survey (MHS), which employs a systematic sample of approximately 405 houses each month from each of the four Census regions. This information is then used to calculate the percentage of mobile homes in the broader housing market (Rumbach et al., 2020, Bureau, 2022b).

Disability [percentage]: The number of people with disabilities divided by the total population in an area (Barron, 2000).

Table 4 presents a structured overview of the key social vulnerability variables, their respective scales, and the sources from which the data is derived, primarily the decennial census by the Census Bureau, 2010. This table also provides a summary of significant social vulnerability variables, complete with their descriptions and associated themes. To enhance clarity and coherence, these variables can be classified based on their primary areas of influence or importance within the context of social vulnerability. This categorization helps in understanding how each variable contributes to the overall picture of social vulnerability and aids in the effective analysis and interpretation of their impacts in flood mitigation scenarios.

Table 3- Socio-economic Variables' spatial and temporal scales and the data source.

Variable	Description	Spatial Scale	Temporal Scale	Theme	Data Source
Income	Average household income	County Level	2010 Census	Socioeconomic Status	Census Bureau
Poverty Rate	Percentage of people living below poverty rate	County Level	2010 Census	Socioeconomic Status	Census Bureau
Age	Percentage of population under 5 and over 65	County Level	2010 Census	Household Characteristics	Census Bureau
Race/Ethnicity	Percentage of non-caucasian ethnicities	County Level	2010 Census	Racial & Ethnic Minority Status	Census Bureau
Lack of Vehicle Access	Percentage of households without vehicles	County Level	2010 Census	Housing type & Transportation	Census Bureau
Single-Parent Households	Percentage of single-parent homes	County Level	2010 Census	Household Characteristics	Census Bureau
Mobile Homes	Percentage of mobile homes	County Level	2010 Census	Housing type & Transportation	Census Bureau
Disability	Percentage of people with disabilities	County Level	2010 Census	Household Characteristics	Census Bureau

These data variables were also determined based on availability from accessible sources, such as the Census Bureau's and the U.S. Army Corps of Engineers. The Census provides social demographics variables at multiple geographic levels and is a credible and reliable source often used for social vulnerability assessments. The decennial census provides social demographic information across various geographic levels and is a reliable and widely used source for assessing social vulnerability. The United States Army Corps of Engineers gathers data on flood risk management and infrastructure development. The Corps is responsible for analyzing and maintaining data on flood protection structures, water resources, and related environmental conditions, crucial for planning and implementing flood risk reduction and infrastructure maintenance activities.

Data collection and integration from various sources will yield a rich and complex social vulnerability dataset that may effectively influence disaster risk management strategies and responses. Extensive research has emphasized the complexities of assessing and treating social vulnerability in disaster risk management. SVIs play a crucial role in identifying vulnerable populations and regions, which aids in disaster preparedness, response, and recovery. A multi-hazard strategy acknowledges the interconnectivity of hazards and the importance of coordinated risk mitigation initiatives. Incorporating social vulnerability into financial models highlights the economic effects and advocates for equitable resource allocation. Reliable data sources, such as the Census Bureau's American Community Survey, are essential for accurately gauging vulnerability. To customize solutions to specific neighborhood concerns, a comprehensive social vulnerability dataset is being established.

The selection of the social vulnerability variables was influenced by their relevance and impact on the populations under investigation. These SVIs were chosen because they directly represent the socioeconomic and demographic aspects critical to a community's ability to adapt to, recover from, and prepare for environmental pressures or hazardous events. This emphasis on specific factors aims to provide a comprehensive understanding of the existing vulnerabilities and resilience capacities. This choice was not arbitrary; it was based on previous research and empirical data that underscore the importance of these variables in measuring social vulnerability.

3.2 Data Gathering & Cleaning

Data for the study was gathered through open-source data portals and project datasets made available by government agencies such as the Federal Emergency Management Agency (FEMA), the United States Army Corps of Engineers (USACE), USGS, NOAA, and the websites of State Emergency Management Agencies in the southeastern region of the United States. These agencies often publish regular updates, progress reports, and specific deadlines related to ongoing and completed flood prevention initiatives. Data may also be gathered from published research studies for select projects.

This research aims to create a preliminary dataset that includes detailed information on project schedules, funding allocations, project locations, project costs, funding sources, and the hazard events that inspired these projects. During the data collection phase, 10 unique data points (projects) were collected, which included both individual projects and those that were components of larger mitigation efforts, such as those in Louisiana (Project IDs 1 through 4 in Table 5). The data also includes projects that were influenced by more than one hazard (Project IDs 6 and 8). These projects were categorized into three types: levees, floodgates, and enhancements to water bodies. Through the previously mentioned agencies, we were able to gather details on project expenses, storm-related precipitation, and maximum surge levels related to the hazards that caused the damage in the region of interest, project locations, costs, and the sources of funding (outlined in Table 4).

Table 4- List of selected projects (FEMA, USACE, NOLA, Census, NOAA, USGS)

Project ID	Project sub-ID	Project Type	Project Location	Project Cost	Funding Source	Inspiring Hazard Event
1	1.1	Levee	Orleans	$25,467,475	Local	2005 Hurricane Katrina
	1.2	Levee	St. Bernard		Local	2005 Hurricane Katrina
2	2.1	Levee	Orleans	$22,595,265	Local	2005 Hurricane Katrina
	2.2	Levee	St. Bernard		Local	2005 Hurricane Katrina
3	3.1	Levee	Orleans	$9,351,590	Local	2005 Hurricane Katrina
	3.2	Levee	St. Bernard		Local	2005 Hurricane Katrina
4	4.1	Levee	Orleans	$22,600,000	Local	2005 Hurricane Katrina
	4.2	Levee	St. Bernard		Local	2005 Hurricane Katrina
5	5	Flood gate	Orleans	$14,142,977	NA	2005 Hurricane Katrina
6	6.1	Improvements to bodies of water	Brevard	$8,400,000	County	2017 Hurricane Irma
	6.2	Improvements to bodies of water	Brevard		County	2016 Hurricane Matthew
7	7	Improvements to bodies of water	Brunswick	$8,400,000	State	2019 Hurricane Dorian
8	8.1	Improvements to bodies of water	St. Johns	$15,179,050	County	2017 Hurricane Irma
	8.2	Improvements to bodies of water	St. Johns		County	2016 Hurricane Matthew
9	9	Flood gate	Orleans	$165,000,000	NA	2005 Hurricane Katrina
10	10	Improvements to bodies of water	New Hanover	$13,600,000	NA	2018 Hurricane Florance

Table 4 presents the chosen flood mitigation projects, each with a unique identifier, project type, associated cost, and location. Projects in this dataset are categorized by their primary IDs. Some projects also have sub-IDs, indicating that they are components of a larger project, are located in different areas, or have been impacted by multiple disasters over time. For instance, Projects 1, 2, and 3 were all parts of a larger initiative. Sub-IDs such as 1.1 and 1.2 have been assigned to distinguish the different counties affected by Hurricane Katrina within Project 1. The selection of infrastructure projects for this preliminary study is based on specific criteria such as project scale, funding source, and project completion date. However, this process was challenging due to limited access to detailed project documentation, variability in reporting across different jurisdictions, and the potential for underreporting or non-public disclosure of relevant data. Consequently, these challenges led to the selection of a total of 10 infrastructure projects for the study.

The infrastructure projects chosen were initiated and funded based off the devastation caused by the "Inspiring Hazard Event" listed in Table 5. As such, variables that required a spatial location, such as social demographics, are associated with the location of the impacts that the project is trying to mitigate in the future. For example, Project 1, initiated as a result of Hurricane Katrina and the devastation it caused in Orleans, St. Bernard, St Tammany, and Plaquemines Parishes, contains the social variables specific to the most affected parishes. The project itself is located in Orleans and St. Bernard Parishes. Table 6 shows all relevant data variables for Project 1.1. All other Projects have similarly formatted data. The division of projects into sub-IDs presents both opportunities and challenges for data analysis. It allows for a more granular analysis of complex projects but can complicate comparisons across different projects.

Table 5- Full list of variables and an example of the data collected.

Data Variables	Examples From Project 1.1 (Levee in Orleans Parish)
Dependent Variable	
Time from hazard event to project completion [months]	252
Independent Variables	
Project Cost	$25,467,475
Max. Storm Surge [ft.]	9
Max. Precipitation [in.]	8
Total Population	347,858
% of Population below Poverty Level	15.10%
% of Population either over the age of 65 or under 5 years of age	17.50%
% of Population non-Caucasian	37.50%
% No Vehicle Access	8.60%
% Single-parent Household	26.50%
% Mobile Homes	1.30%
% Disability	4.70%
Primary Funding Source	Federal
Primary Funding Source Obligation	$16,553,858.75
Secondary Funding Source	Local
Secondary Funding Source Obligation	$8,913,616.25

Associating demographic data with each project required cross-referencing project locations with census or demographic survey data, which tends to be challenging due to discrepancies in geographic boundaries, changes in demographic data over time, and lack of updated information for all areas. This leads to the subsequent analysis being reliant on the decennial census data accuracy.

To determine the possible impact on local communities, data from the 2010 Census was used to address the aspect of social vulnerability. The 2010 decennial census is more accurate than the ACS and the closest census to each hazard event listed in Table 4. This information was acquired at the county level due to the geographical extent of the projects, which in some cases spanned multiple counties.

Figures 8 shows the map of Orlean parish boundary lines, and figure 9 shows the depth of flooding that was caused by hurricane Katrina.

Figure 8 Orleans parish boundaries (Where Is Located, n.d.)

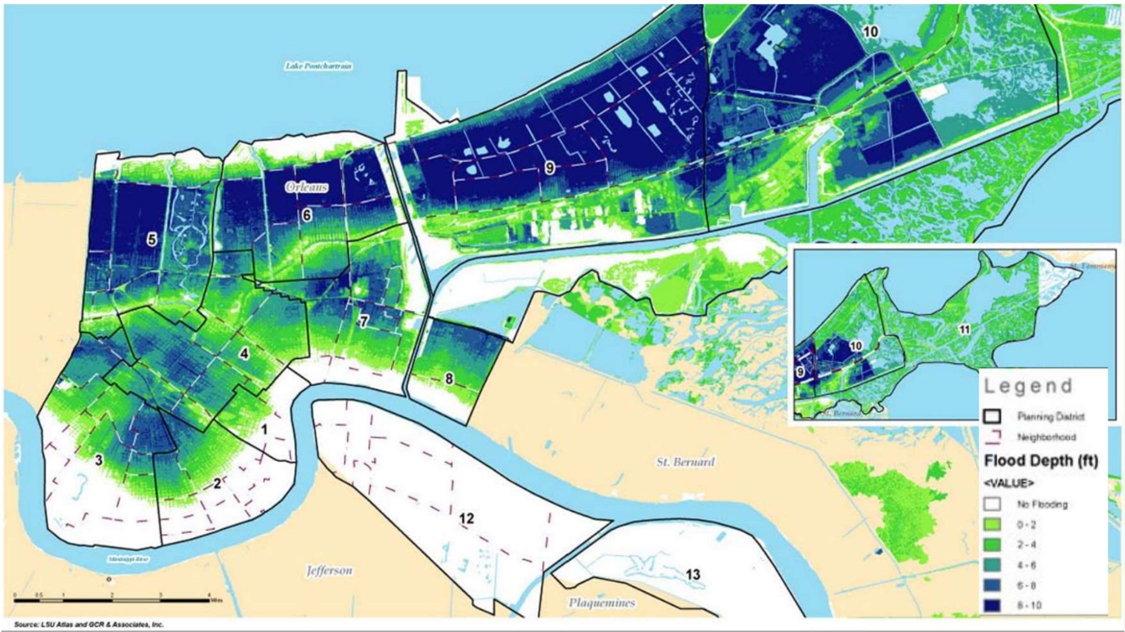

Figure 9- Depth of Flooding (as measured on August 31, 2005) (Boyd, 2011)

This comparison of flood inundation (Figure 9) with county boundaries (Figure 8) allows for a determination of spatial scale when collecting social vulnerability factors from U.S. Census. The flooding extent for this event encompassed Orleans and St. Bernard counties and not just sub-sections of those counties, such as census block groups. As a result, Projects 1 – 4 of this research have social vulnerability variables as given by these counties. This approach is how the spatial scale was determined for gathering social variables for each project within this research.

Gathering social vulnerability data at the county level enabled us to examine various factors that influence a community's resilience and response capabilities when faced with hazards that the mitigation strategies intend to counter. We examined a range of key demographic and socio-economic indicators, including age distribution, economic status, housing stability, and the presence of disabilities within the population. This information is crucial for understanding the disparate impacts of natural disasters on different communities and identifying the necessary resources for a robust response.

Variables like poverty, age, race, lack of car access, single-parent households, mobile housing, and disability are key for ensuring data comparability and appropriate scaling across various project sizes and locations. These standardized measures enable reliable comparisons across different areas. They effectively capture crucial aspects of community demographics and socioeconomic status, crucial for evaluating the impact of programs in diverse settings. Additionally, these factors facilitate adjustments according to project size and scale, ensuring that the specific needs and challenges of different communities are addressed effectively. This approach is vital for customizing programs to local requirements and understanding their broader implications in terms of resilience and resource management.

3.3 Data Analysis

In this research, we delve into the dynamics for timely implementation of flood mitigation projects. The main goal is to identify the factors influencing the timeline of these initiatives from their inception to completion. Understanding these elements is crucial for enhancing the efficiency and effectiveness of future flood prevention efforts. To achieve this, we employed a data analytics approach, incorporating both cross-tabulation and regression analysis. Cross-tabulation offers a more detailed view of the interactions between distinct categorical variables, highlighting potential patterns and relationships that might otherwise remain hidden. Regression analysis complements this by quantifying these associations and, potentially, forecasting outcomes. This dual-method approach allows for a thorough examination of the data, facilitating insights into how project costs, social, economic, and environmental factors collectively impact the progression of flood prevention mitigations.

Cross-tabulation analysis is a robust statistical technique that enables researchers to discover potential correlations between several categorical variables. This strategy is particularly useful in researching flood preparedness. Instead of limiting the analysis to a preset table format, cross-tabulation allows for a more flexible exploration of the data, revealing how various categories interact and connect (ChePa et al., 2016).

Using cross-tabulation and regression analysis on household survey data, the study by De Silva and Kawasaki examined the socioeconomic impact of floods and droughts in Sri Lankan rural communities, and it reveals how different economic groups are affected by natural disasters. A key finding is the increased vulnerability of low-income households to floods and droughts due to their reliance on natural resources for livelihood, experiencing significantly greater absolute and relative losses compared to higher-income groups. The research also highlights the disproportionate impact on the poor, who not only suffer greater proportional losses but also face longer recovery times. It underscores the importance of considering occupational dependence on natural resources in assessing vulnerability, particularly for those fully reliant on agriculture. The findings point to the critical need for targeted policies and interventions that enhance the resilience of socioeconomically disadvantaged groups against water-related disasters (Appleby-Arnold et al., 2021)

Furthermore, cross-tabulation can help identify segments within the population that are either overly or underprepared for flooding. This information can guide targeted interventions and policy decisions, enabling policymakers and disaster management authorities to develop more effective, location-specific strategies to enhance flood resilience. By thoroughly examining the interplay between geographical location and preparedness levels, more nuanced and effective flood mitigation plans can be formulated. (De Silva & Kawasaki, 2018)

Cross-tabulation analysis delves into potential patterns that emerge between variables, allowing for a more detailed examination of their distributions and relationships. This method provides raw counts and percentages, offering a nuanced view of the variables influencing the timely implementation of large-scale infrastructure projects. By understanding these distributions and trends, we can tailor strategies to meet specific regional needs, thereby enhancing the effectiveness and efficiency of large-scale infrastructure project implementation. This approach is key to customizing strategies for each region, ensuring that the implementation of these projects is both timely and effective (How to Use Cross-Tabulation Analysis on Your Survey Results, 2023).

Quantitative data analysis is a crucial approach in research, involving several key steps. It begins with the collection of numerical data relevant to the study's question. The analysis then advances to a descriptive phase, where frequency counts and percentages are used to effectively summarize the data. Next, statistical tests are employed to investigate the relationships between variables and to test hypotheses. The final stage involves interpreting these data, and forming conclusions about the dynamics and connections between variables based on the statistical test results. This method is vital across various fields, such as market research, social sciences, and epidemiology, as it offers a structured and insightful way to uncover patterns and relationships within categorical data. An example of its application could be analyzing whether a person's city of residence influences their choice of baseball club, or if these variables are independent of each other.

Cross-tabulation is a statistical method that helps in identifying categorical variables within a dataset, enhancing desired results, and simplifying data management (How to Use Cross-Tabulation Analysis on Your Survey Results, 2023). It reduces errors associated with extensive datasets by breaking them down into representative subgroups, making them more manageable and reducing the likelihood of errors. Cross-tabulation also reveals more profound insights by examining the relationships between categorical variables, uncovering nuanced patterns that might elude traditional analytical approaches.

The efficiency of cross-tabulation, which allows for rapid comparisons between variables, offers a distinct advantage when applied appropriately. This method leads to the swift identification of key relationships, providing stakeholders with actionable information. The clear and simplified presentation of data through cross-tabulation facilitates prompt decision-making and aids in the formulation of strategies based on the insights gained. Utilizing cross-tabulation as the initial stage in research analytics serves a strategic purpose: it lays the groundwork for more in-depth regression analysis. This preparatory step is crucial as it identifies initial patterns and relationships that inform the development of hypotheses and strategies. For the research discussed herein, the insights gained from cross-tabulation lead into the subsequent regression analysis, ensuring that it is tailored to be robust and directly relevant to the specific research questions and objectives at hand.

Similarly, regression emerges as a pivotal tool in statistical analysis, providing insights into the interactions between variables and revealing predictable patterns. Regression, at its foundation, aims to answer two critical questions: first, how well can a cluster of predictor variables predict the trajectory of the outcome variable? Second, which specific variables have a significant influence on the result, as indicated by the magnitude and direction of the beta estimates? (Regression - Statistics Solutions, 2023)

Consider a situation in which a dependent variable, also known as the result, criteria, or regress is associated with one or more independent variables, also known as exogenous variables, predictors, or regressors. This interaction is represented in a simple equation:

$$y = c + bx. \tag{1}$$

Where *y* represents the estimated dependent variable score, *c* represents the constant, *b* represents the regression coefficient, and *x* represents the score on the independent variable. (Linear Regression Equation Explained - Statistics By Jim,2023)

There are numerous terminological distinctions in this subject, reflecting the varied nature of regression. The dependent variable can have several different identities (for example, outcome variable, criterion variable, or endogenous variable), whereas the independent variables demonstrate their diversity as exogenous variables, predictor variables, or regressors (Regression - Statistics Solutions, 2023)

The R-squared (R^2) value is a statistical metric that measures the fit of data to a regression model — specifically, it represents the proportion of variance in the dependent variable that can be predicted from the independent variable(s). An R^2 score of 0% indicates that the model does not explain any of the variability of the response data around its mean, while an R^2 value of 100% indicates that the model explains all of the variability (Chicco et al., 2021). The R^2 value is determine by

$$R^2 = 1 - \frac{\sum_{i=1}^{m} (X_i - Y_i)^2}{\sum_{i=1}^{m} (\underline{Y} - Y_i)^2} \quad (2)$$

$$\underline{Y} = \frac{1}{m} \sum_{i=1}^{m} Y_i \quad (3)$$

where X_i is the predicted i^{th} value, and the Y_i element is the actual i^{th} value, and $\underline{Y}$ is the mean of true values. The regression method predicts the X_i element for the corresponding Y_i element of the ground truth dataset variability (Chicco et al., 2021).

Although a higher R^2 value often suggests a better fit of the model to the data, it is not a definitive measure of a model's validity. R^2 does not determine whether the independent variables causally affect the dependent variable; it only quantifies the degree to which the two variables are related within the model (Sohil et al., 2022).

Furthermore, R^2 alone does not confirm whether the model is adequate, whether it has omitted important independent variables, whether it has been influenced by outliers, or whether it includes unnecessary variables. Therefore, it should be evaluated alongside other metrics and diagnostic tools in regression analysis (Sohil et al., 2022). For the purposes of this research, the regression analysis, as previously determined from the cross-tabulation analysis, serves to establish a hypothesis that future research could then explore using additional analytical methods and metrics.

As we explore the practical applications of regression analysis, three fundamental objectives become apparent. Firstly, regression serves as an evaluative tool, examining the effectiveness of predictors in our model and gauging its forecasting power (Regression Analysis: The Complete Guide - Qualtrics, 2023). This evaluation is crucial for assessing the strength and predictive potential of various factors, such as societal vulnerability, socioeconomic circumstances, and environmental (hazard event) influences, in relation to the timing of project implementation.

Regression analysis serves as a predictive mechanism, enabling the forecasting of the impact of various factors. This predictive capacity is crucial for identifying key determinants of vulnerability in disaster scenarios, providing a solid quantitative basis for our hypotheses. It aids in pinpointing influential factors for future research and targeted interventions in disaster risk management. (Regression Analysis: The Complete Guide - Qualtrics,2023).

To address different research needs, we utilize a variety of regression techniques. Simple linear regression forms the foundational framework of our analysis, while multiple linear regression involves several independent variables. Logistic regression is applied for binary outcomes, ordinal regression for scenarios with an ordinal dependent variable, and multinomial regression for those with nominal dependent variables (Types of Regression Techniques in ML - GeeksforGeeks, 2023).

Through these diverse applications (evaluative, predictive, and trend forecasting) regression analysis offers a comprehensive approach to unraveling the complexities surrounding the implementation of flood mitigation projects. Choosing a regression model requires a delicate balance between model fitting and the risk of overfitting. Complex models can overemphasize chance-related statistical significance, undermining the model's generalizability. The challenge lies in crafting a model that strikes the right balance between explanatory power and simplicity. (Sohil et al., 2022)

To analyze the historical dataset that has been collected, the method of analysis will begin by leveraging the efficiency of cross-tabulation for a comparison between variables, to identify significant associations in the dataset. Following the identification of these relationships, the objective is to use linear regression analysis to delve deeper into predictive patterns and identify the specific variables that have a significant influence on the outcome. This step-by-step technique will smoothly combine the instant insights of cross-tabulation with the use of linear regression to establish potential patterns necessary for hypothesis development.

This study examines variables across project details, social demographics, and hazard events to understand influencers regarding the time required for a project to move from idea to complete implementation. The dependent variable is the number of months required to complete flood mitigation projects, which measures the timeliness of such interventions. Independent variables include project cost, hazard severity, and socioeconomic demographics as outlined in Table 6. Cross-tabulation is used to identify connections and trends among these variables, while linear regression analysis is employed to explore predictive dynamics. The R-squared value is crucial for determining the model's fit to the data and the variance in project completion times. The methodological design includes setting variables with a y-intercept of zero, where applicable. For example, if there is no project cost (x=$0), then there is no project (y=$0) This approach helps pinpoint the direct effects of each independent variable on project timelines, enhancing the study's utility in informing disaster risk management strategies.

CHAPTER 4: Results

4.1 Cross-Tabulation:

The cross-tabulation analysis is conducted for each variable outlined in the previous chapter and involves comparing these variables to three timeframes for project complete: less than 2 years, 2 to 10 years, and longer than 10 years. This allows for a general assessment of variable patterns as the time to completion increases. The data points that fell within these time frames were then summed up such that, for example, the total project costs for projects with a less than 2-year completion time are shown in the cross-tabulation.

Table 6, shown below, displays an example breakdown of different project types related to flood management, and the Percent of the population below the poverty line and the project cost, categorized by the estimated years to completion (2-10 years, 2 years or less, and over 10 years). These results show that the trial Percent of the population below poverty for projects that take two years or less is 0.315, and it increases to 0.459 for the two-to-ten-year designation, then reaches 0.755 for projects that take over ten years to complete.

The analysis was applied to all the collected variables, including income, age demographics (above 65 and below 5), racial and ethnic composition, single-parent households, vehicle availability, disability status, funding sources, and project-related hazards such as precipitation and storm surge.

Storm surge, income, age above 65 and below 5, race, vehicle access, and single-parent households are all variables that showed a direct correlation similar to the example provided for poverty. A linear regression analysis was then performed.

Table 6- Infrastructure Project Costs and Impact on Poverty by Estimated Completion Time.

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Population below Poverty		0.151	0.151	0.302
	Percent of Project Cost		$ 165,000,000.00	$ 14,142,977.00	$ 179,142,977.00
Improvements to bodies of water	Percent of Population below Poverty	0.315	0.308		0.623
	Percent of Project Cost	$ 22,000,000.00	$ 23,579,050.00		$ 45,579,050.00
Levee	Percent of Population below Poverty			0.604	0.604
	Percent of Project Cost			$ 80,014,330.00	$ 80,014,330.00
Total Percent of Population below Poverty		0.315	0.459	0.755	1.529
Total Percent of Project Cost			$ 188,579,050.00	$ 94,157,307.00	$ 304,736,357.00

The variables that are similar to the results from disability are not explored further within the linear regression analysis, since its total for projects that take two years or less is greater than that for projects that take more than ten years. This observation suggests that the relationship between disability and project duration might not be linear or straightforward, prompting the researchers to exclude it from the linear regression analysis.

Table 7- Infrastructure Project Costs and Impact on Disability by Estimated Completion Time

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Disability		0.047	0.047	0.094
	Percent of Project Cost		$ 165,000,000	$ 14,142,977	$ 179,142,977
Improvements to bodies of water	Percent of Disability	0.258	0.259		0.517
	Percent of Project Cost	$ 22,000,000	$ 23,579,050		$ 45,579,050
Levee	Percent of Disability			0.188	0.188
	Percent of Project Cost			$ 80,014,330	$ 80,014,330
Total Percent of Disability		0.258	0.306	0.235	0.799
Total Percent of Project Cost		$ 22,000,000	$ 188,579,050	$ 94,157,307	$ 304,736,357

For additional figures and details regarding the cross-tabulation, refer to the Appendix. The overall trends and the variables selected for the linear regression are outlined in Table 8.

Table 8- Variables with patterns related to project completion time found through cross-tabulation.

	Years to Complete		
Variable	≤ 2 years	2 – 10 years	> 10 years
Project Cost	$22,000,000	$188,579,050	$94,157,307
Storm Surge [ft]	15	19.9	45
Precipitation [in]	49	34	40
Percent Population <5yrs of age	0.105	0.173	0.320
Percent Population >65yrs of age	0.343	0.482	0.555
Percent Population Single-Parent Householder	0.288	0.41	1.325
Percent Population with a Lack of Vehicle Access	0.059	0.125	0.430
Percent Population non-Caucasian	0.384	0.699	1.875
Percent Population Below Poverty	45.9%	31.50%	75.5%
Percent Above US. Avg Income	2	3	5
Percent Population with Disability	0.258	0.306	0.235
Percent Mobile homes	0.119	0.322	0.065

4.2 Linear Regression:

Based on the cross-tabulation analysis, linear regression analysis was set up with the time to completion in months designated as the dependent variable (y). The project cost, which was chosen to communicate an aspect of the size of the infrastructure project, is, based on current knowledge and practices, most likely to contribute to the project timeline. Figure 8 shows the results of the linear analysis for project cost versus time to completion, with the y-intercept set to zero. In this figure, where there is an R^2 value of 16.5%, there is an outlier project of 165 million. When that outlier is removed (Figure 9), project costs are a very significant predictor, with an R^2 value of 84.82%.

Figure 10- Correlation between the project cost ($) and the project completion time.

Figure 11- Correlation between the project cost ($), excluding the outcast, and the project completion time.

The severity of an extreme hazard event, which could inspire a reactive mitigation measure, may be an influencer to how quickly a project is completed. The assumption behind utilizing variables such as precipitation and storm surge is that the more severe the event was, the more motivated the community would be to employ a new mitigation measure so the same devastating impacts won't happen next time. Precipitation did not show much of a distinguishable pattern in the cross-tabulation analysis, but storm surge did and the subsequent regression analysis is shown in Figure 10, with an R^2 value of 35.6%.

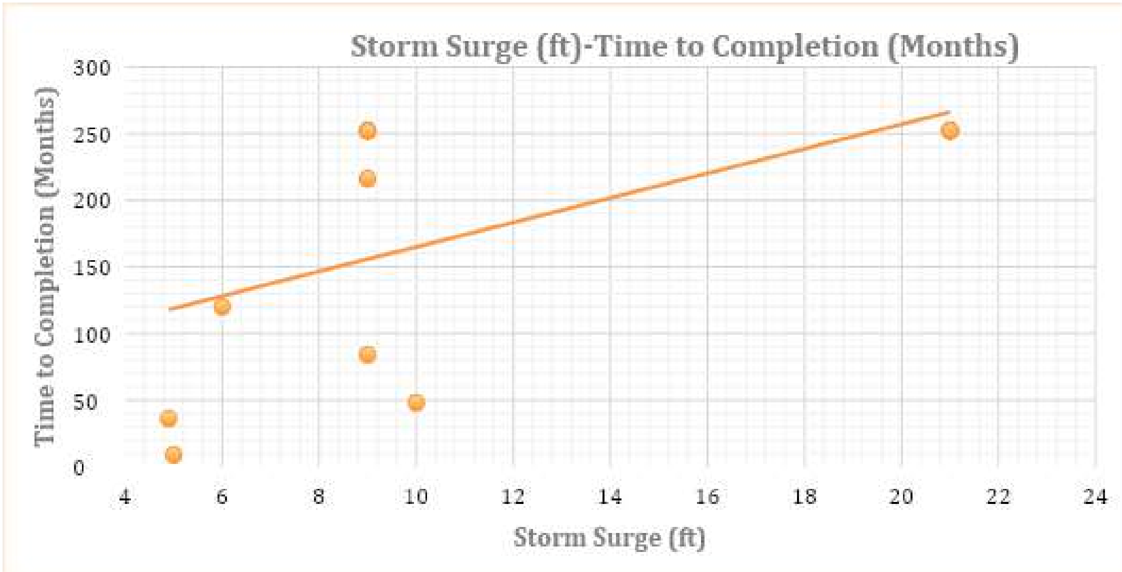

Figure 12- Correlation between the hazard's storm surge(ft) and the project completion time.

Next, the social variables' linear regression analysis with respect to project completion time are shown. The graph in Figure 11 shows a regression line indicating a positive relationship between age and time to completion. The R^2 value of 0.5469 indicates that 54.69% of the variance in time to completion could be explained by age percentage. The model's "goodness of fit" is moderate since it falls between 0.3 and 0.5 explaining more than half of the variability in the outcome variable (Chicco et al., 2021).

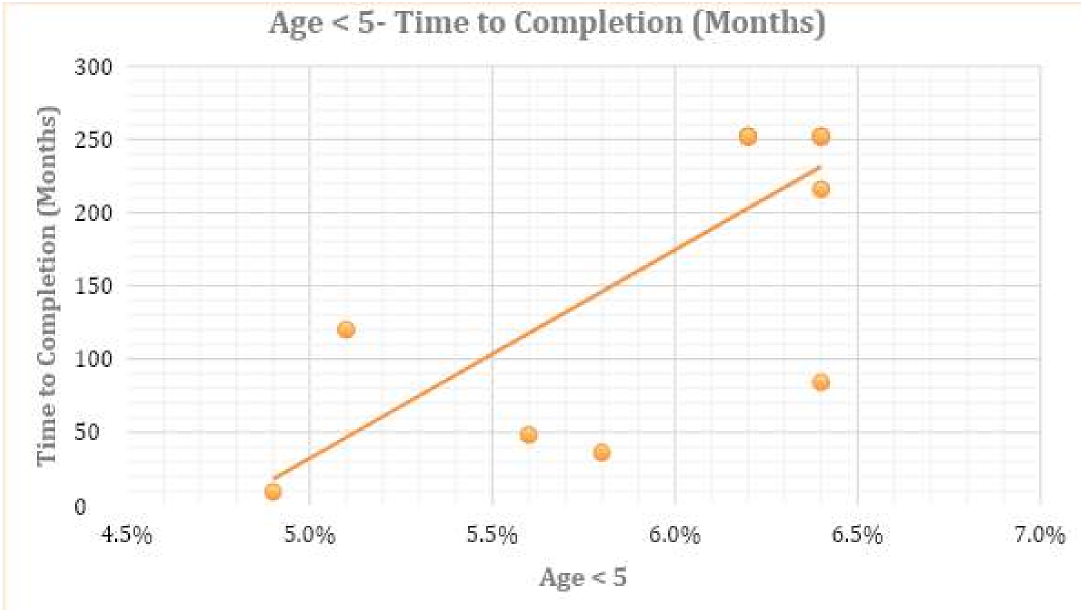

Figure 13- Correlation between % of Population under the age of 5 and the project completion time.

In contrast, the proportion of the population over 65 years old has a negative correlation but still has a moderate association with 51.8% of the variance.

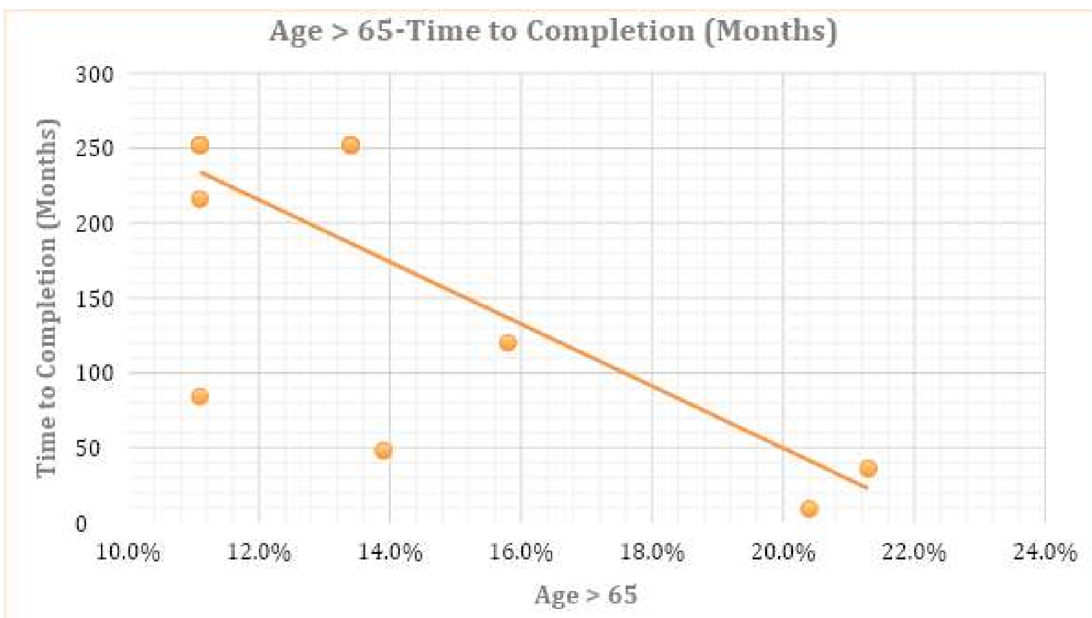

Figure 14- Correlation between the % of Population over the age of 65 and the project completion time.

Single-parent households also appear to be a significant factor, explaining 56.49% of the variance, which suggests a moderate to strong association. This variable is also positively correlated to the time to completion.

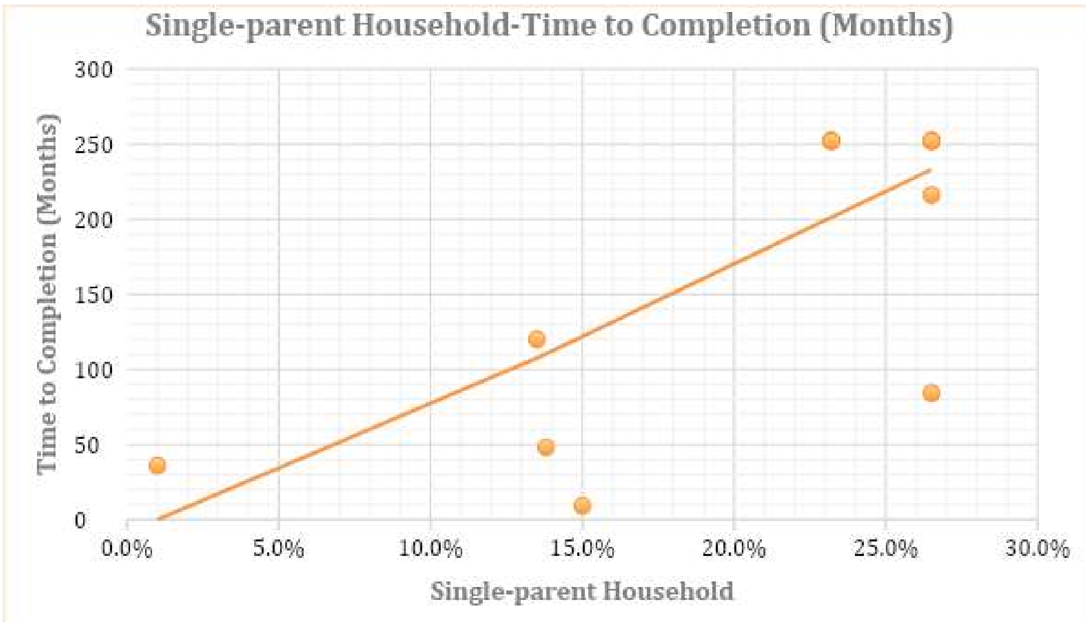

Figure 15- Correlation between the % of single-parent household and the project completion time.

Access to vehicles (Figure 14) and median income (Figure 15) are relatively poor predictors, explaining only 2.38% and 2.47% of the variance, respectively.

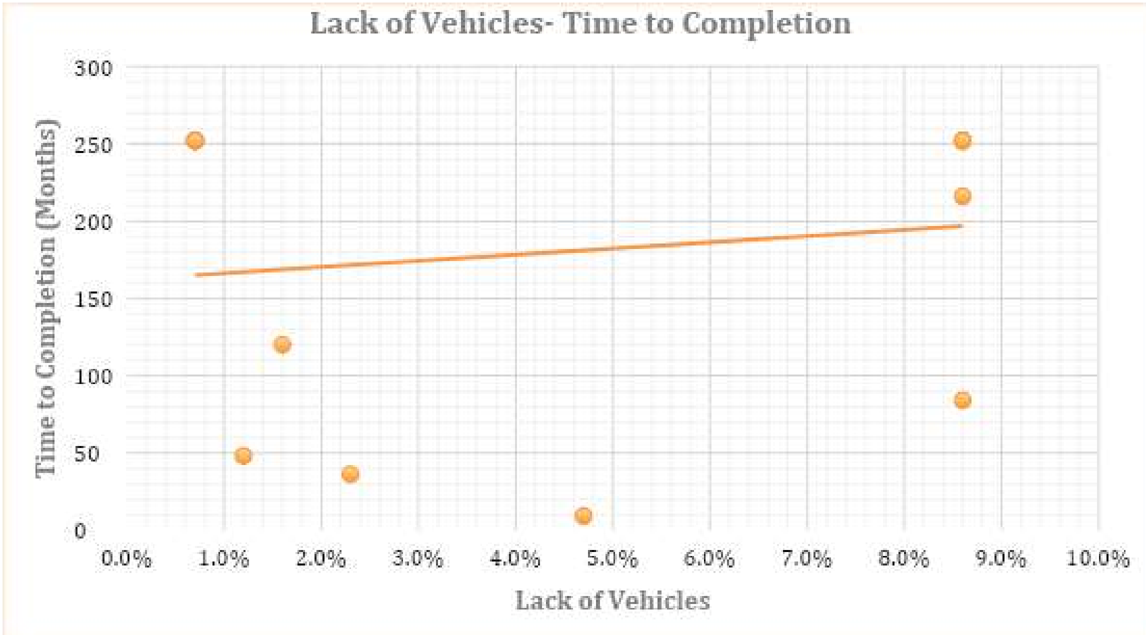

Figure 16- Correlation between the lack of vehicle access and the project completion time.

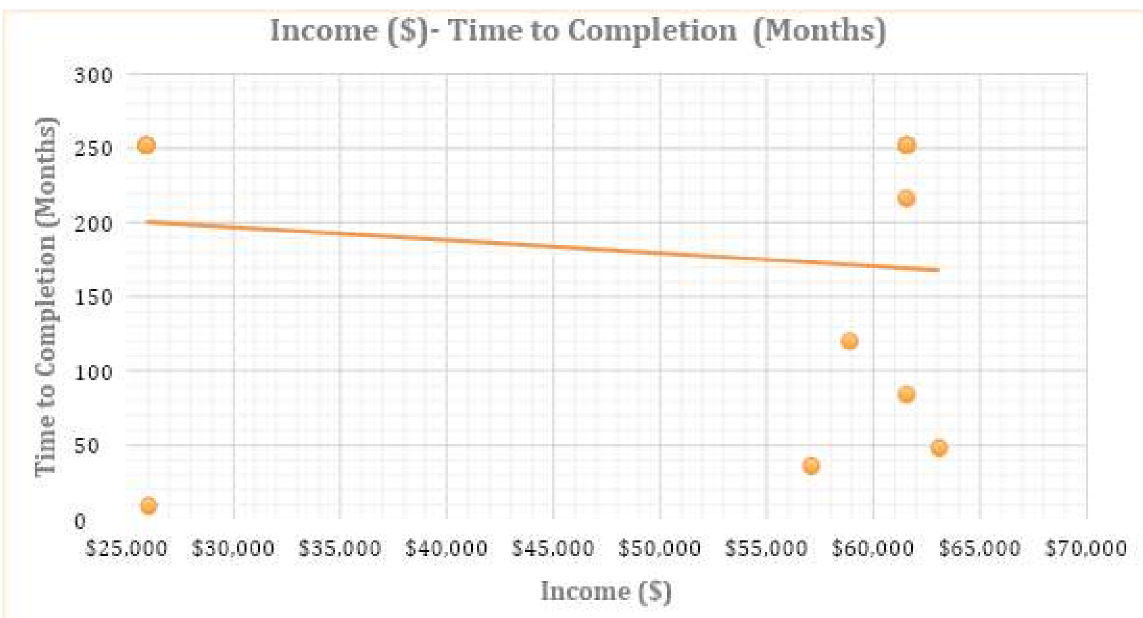

Figure 17- Correlation between the annual mean income ($) and the project completion time.

The percentage of non-Caucasian individuals in a population is a more robust predictor, with an R^2 of 59.58%, indicating a moderately strong association. The positive correlation between these variables may indicate that severely impacted areas that have a higher percentage of their population as non-white may take a longer time to see mitigation measures successfully and completely enacted.

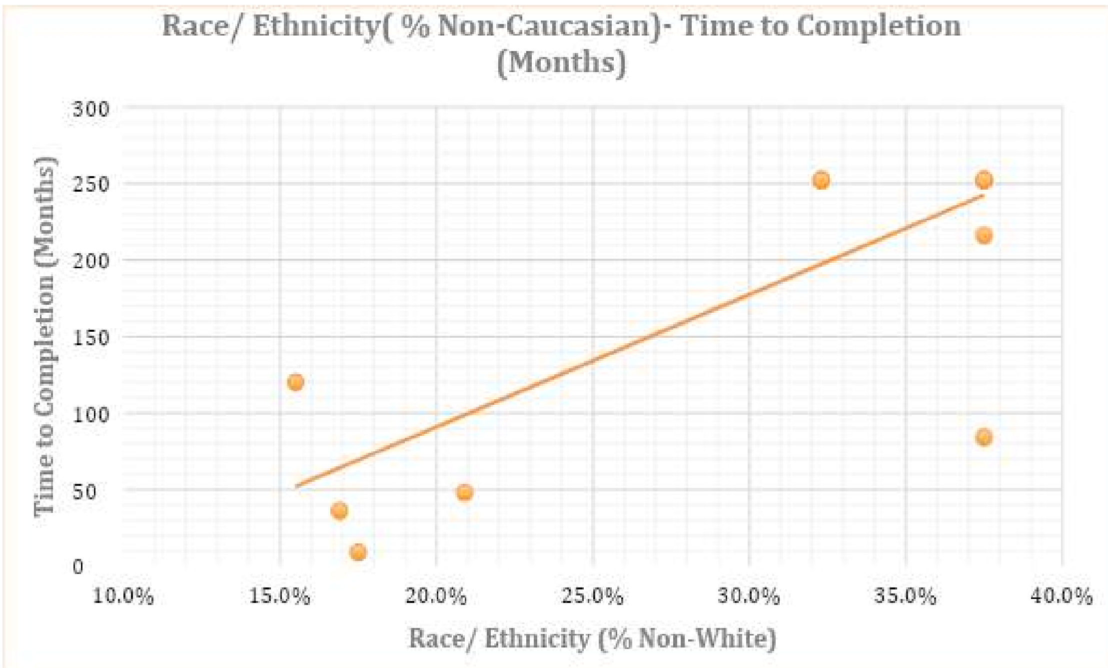

Figure 18- Correlation between the % of non-Caucasian and the project completion time.

The percentage of individuals living below the poverty line is associated with 17.62% of the variance, which points to weaker associations.

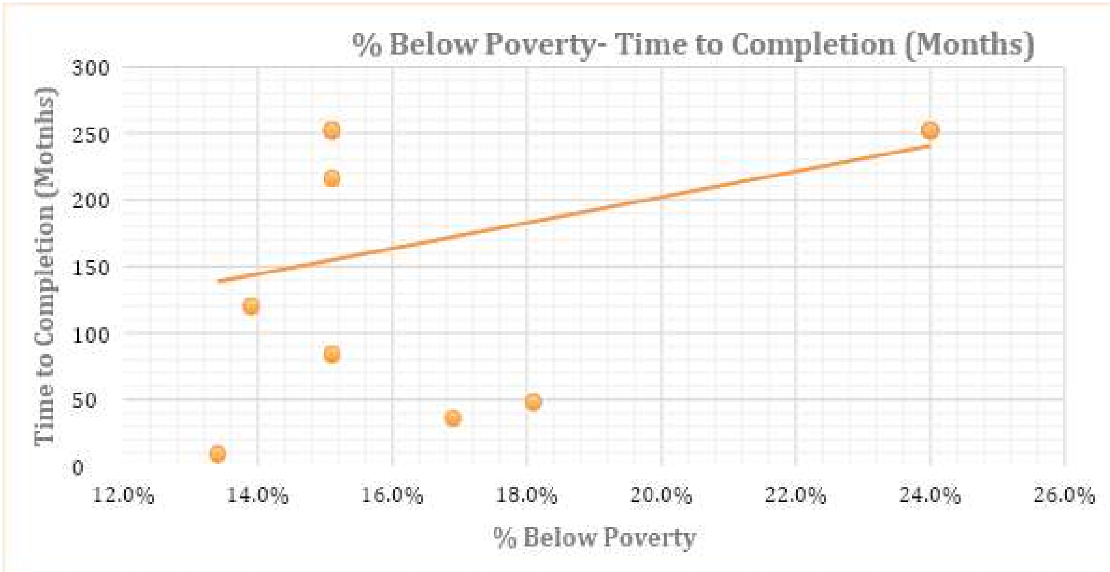

Figure 19- Correlation between the % of population below poverty and the project completion time.

The table below summarizes the R-squared values from the linear regression analysis performed. The strongest correlations, as relate to the time to complete a flood mitigation project as a reactive measure, were found to be the project cost (without the consideration of the outlier project), percent of population that is not white, percent of population that is considered a single-parent household, and percent of a population under 5 years of age.

Table 9- R-squared values indicating the degree of variance explained by the socioeconomic variables in the regression model. (highlighted cells indicate variables that influence the outcome of mitigations)

Variable	**R^2 value**
Project Cost ($)	0.1646
Project Cost ($) (No Outlier)	0.8482
Storm Surge (ft)	0.3560
% Age <5	0.5469
% Age >65	0.5183
% Single-parent Household	0.5649
% Lack Access to Vehicles	0.0238
% Race (No-Caucasian)	0.5958
% Below Poverty	0.1762
Income ($)	0.0247

CHAPTER 5: Discussion of Results and Future Research

5.1 Discussion of Results:

The findings highlight significant differences in the predictive power of various project , hazard, and socioeconomic variables, encompassing both statistical and practical dimensions. The project schedule for any infrastructure project is tied to project cost, such that costlier projects tend to indicate large, potentially more complex, projects project, which tend to require more time to complete (Park, 2021). As such, the high correlation, of approximately 85%, between these variables is anticipated and serves as a baseline measure in which the other variables analyzed can be compared to. The large contrast in the explanatory power of project costs with and without outliers (84.82% vs. 16.46%) is notable. The outlier project driving these differences is the Seabrook Floodgate Complex in Louisiana. This project has a high cost of $165 M, which is largely attributable to the strategic importance of its location in protecting the Industrial Canal and surrounding areas from storm surges from Lake Pontchartrain. (Flood Authority, 2023)

The $165 million Seabrook Floodgate Complex in Louisiana is a n example of how strategic significance and location can significantly influence project duration. This critical infrastructure is essential for protecting the Industrial Canal and surrounding communities from Lake Pontchartrain's storm surges, underscoring the interplay between economic factors and infrastructure development (Flood Authority, 2023). The discussion of this project, especially its expedited completion, sheds light on the prioritization of economic variables in infrastructure initiatives. The complex serves a vital defensive role while also safeguarding the region's economic stability and future. The Industrial Canal, a key commercial center, must be protected from flooding to maintain the area's economic health.

This scenario highlights the importance of integrating economic elements with technical and environmental considerations in infrastructure planning. The Seabrook Floodgate Complex acts as a case study, demonstrating the interaction among these various factors. The prioritization and allocation of resources for this project reflect a deep understanding of the economic implications of potential flooding and storm surges. Additionally, this example could be leveraged to promote a more comprehensive analytical approach in future research projects regarding the influencers to completion time of such large-scale infrastructure projects. Employing methods like multi-regression analysis could provide a deeper understanding and quantification of the complex interplay among economic, environmental, and social variables. Such an approach would enable more informed decision-making, ensuring that projects are not only technically robust but also economically viable and socially beneficial.

The robust predictive power associated with the proportion of non-Caucasian individuals points to racial demographics as having a substantial impact on the outcomes being studied, potentially due to various structural, economic, or social reasons. The social variables in this project are relative to the area impacted and not necessarily the area funding the flood mitigation project or, in some cases, even the area in which the project is being implemented. This indicates that the race and/or ethnicity of the individuals impacted during an extreme flooding event may influence the perceived urgency of a large-scale infrastructure project. In the field of social vulnerability research, race and ethnicity have been consistently identified as pivotal factors influencing how different groups are affected by disasters. These demographic aspects substantially affect both the immediate impact of disasters on various populations and their capacity for recovery. Particularly, communities of color and economically disadvantaged groups are more vulnerable to hazards. This vulnerability is not just due to their physical living conditions, such as residing in hazard-prone areas or inadequate housing, but also stems from broader, systemic challenges. These include economic constraints, limited access to disaster preparedness resources, and societal inequities linked to socioeconomic status, age, immigration status, gender, and disabilities. Consequently, these disparities in social vulnerability led to more severe and prolonged negative outcomes for these groups in the wake of disasters. These outcomes manifest in many forms, including higher rates of injury, loss of property, prolonged displacement, and deeper psychological impacts, which further exacerbate their existing vulnerabilities and hinder effective recovery and resilience building. Therefore, understanding and addressing these disparities is crucial for equitable disaster management and resilience efforts (Howell & Elliott, 2018).

The analysis indicates that the proportion of children under the age of five, population over 65, and the presence of single-parent households are moderately to strongly correlated with the dependent variable. These relationships are statistically significant, and the magnitude of these correlations, as quantified by R-squared values, suggests their practical significance. This means that these variables, related to family composition and age demographics, are reliably associated with the dependent variable and account for a substantial portion of its variability. Family composition and age demographics are essential in assessing community vulnerability and resilience during catastrophes, often providing valuable insights. These factors not only highlight a community's unique challenges and capabilities but also underline the potential for mutual support among family members and the specific needs of various age groups in crisis situations. Additionally, research indicates that fundamental components of vulnerability at the individual or household level commonly encompass socioeconomic status, gender, race, ethnicity, and age. This comprehensive approach is instrumental in devising targeted and effective plans for emergency preparedness and response (Bergstrand et al., 2015). This analysis suggests that the dynamics of family composition and age structure are critical determinants in the timely implementation of large-scale infrastructure projects. These factors significantly influence the overall project timelines and the effectiveness in addressing community-specific needs.

Conversely, characteristics such as the proportion of access to vehicles, and income levels show weak associations with the dependent variable, suggesting that these factors may be less relevant or are influenced by additional variables not accounted for in the analysis. This may be because these aspects, while important in many socio-economic analyses, might not directly or strongly impact the specific outcomes being measured in this context. For example, access to vehicles and income levels could be less influential in scenarios where public infrastructure or community resilience play more significant roles (SAMHSA, 2017).Additionally, these factors might interact with other variables in complex ways not captured by the analysis, requiring a more nuanced approach to fully understand their impact. The weak relationships between poverty levels and initial project costs could indicate complex interactions between economic factors and the dependent variable that are not fully captured by a linear model.

Using U.S. Census and American Community Survey (ACS) data at the county level presents several challenges, primarily concerning data accuracy. The 2020 Census, for instance, encountered numerous issues, including undercounts and overcounts, which significantly impact communities. Undercounts are especially problematic for young children and certain racial and ethnic groups, leading to misallocation of resources and inaccuracies in political representation. Moreover, changing demographics and the presence of hard-to-count populations further compound these challenges, emphasizing the need for careful consideration when utilizing this data for county-level analysis and decision-making (Ordway et al., 2019).

Census survey methods, including self-response and follow-up procedures, can lead to inaccuracies and inconsistencies. High levels of non-response or incorrect responses significantly impact data quality, a concern that is particularly pronounced in complex and diverse county contexts (Tienda, 2018). Moreover, key census processes that ensure accuracy, such as matching population estimates with government records and surveys, can be affected by missing or incorrect data. These challenges are compounded by evolving data collection methods over time, highlighting the need for vigilance in maintaining the integrity of census data (Cohn, 2020). Additionally, applying census data at the county level may not effectively capture the unique intricacies and specific challenges of each county. For instance, accurately reflecting the demographic and socioeconomic conditions in smaller or rapidly evolving counties can be challenging. This might lead to the generation of generic data that does not reliably inform local decision-making processes. Such limitations highlight the need for more nuanced data collection and analysis methods to address the specific needs of diverse county populations (Jacobsen, 2023).

The inclusion of economic factors, alongside other social variables, such as the percentage of the population proficient in English, could expand up this preliminary research. Economic variables play a pivotal role in how communities cope with and recover from diverse crises, influencing their access to resources and support networks. For example, the Seabrook Gate Project carries regional significance, affecting employment and overall economic stability. Given that this project was an outlier event in that it was one of the most expensive but also the quickest project to reach completion, shows that including more economic variables in future analysis may be of importance when considering the interplay between multiple variables. Employing multi-regression analysis could provide insights into how these factors interact and influence both local and regional outcomes.

Implementing reactive flood mitigation initiatives in socially vulnerable communities is a complicated process, often involving extended timelines. In areas where social vulnerability is pronounced, the communities' economic influence is typically limited, posing challenges in securing the necessary financial, logistical, and governmental support and investment for mitigation efforts. This issue is further compounded by the need to tailor these flood mitigation initiatives to the specific needs of the community. Ensuring that the solutions are not only effective in flood protection but also accessible and beneficial to all residents, particularly the most vulnerable, is a priority. The process of community engagement, crucial for identifying and addressing these unique needs, involves extensive consultations, meetings, and the integration of feedback, all of which contribute to extending the project timeline. These steps are essential but add complexity and time to the overall implementation process.

5.2 Future Research:

The results of this research lead to the proposal of the following hypothesis: ***the socioeconomic vulnerability of affected populations impacts the timeliness for implementing large-scale flood mitigation projects***. Previous research has illustrated that areas with higher social vulnerability indices (SVIs) tend to face more challenges in the recovery process and are more prone to increased disaster severity, often due to factors like poor construction quality and outdated infrastructure. The correlations found in this research indicate a potential link between a community's social vulnerability and the effectiveness of flood mitigation measures implemented in that area.

CHAPTER 6: Conclusion

This research sheds light on the diverse nature of flood mitigation initiatives, highlighting the intricate interplay between project challenges, societal vulnerabilities, and institutional responses. The findings reveal that the timeliness of flood mitigation infrastructure is closely intertwined with the socioeconomic context of the affected areas and is not solely dependent on technical solutions. The observed relationship between social vulnerability and the timelines for implementing flood mitigation projects underscores the need for a more inclusive, community-focused approach in disaster risk management.

Furthermore, the study underscores the necessity of proactive planning and policy formulation. As climate change increases the frequency and severity of flooding events, it becomes crucial for communities, especially those most vulnerable, to have the necessary infrastructure and resources to effectively manage these risks. Achieving this requires a collaborative effort involving local communities, policymakers, and experts in the field to create and execute strategies that are not only technically competent but also socially equitable and economically feasible.

While it is evident that proactive planning and policy formulation are crucial aspects of disaster management, it's important to acknowledge that policy formation is just one component of a larger set of challenges. There are likely to be several hurdles in this area, including issues related to ensuring equality in the allocation of federal funds, enhancing program efficiency, and making effective response choices that consider environmental consequences.

According to the findings, there is a clear need for comprehensive change that anticipates and integrates these various factors to prevent the exacerbation of inequality and the heightened vulnerability to future disasters.

References

Aldrich, N., & Benson, W. F. (2008). Disaster preparedness and the chronic disease needs of vulnerable older adults. Preventing Chronic Disease, 5(1), A27.

Appleby-Arnold, S., Brockdorff, N., Jakovljev, I., & Zdravković, S. (2021). Disaster preparedness and cultural factors: A comparative study in Romania and Malta. Disasters, 45(3), 664–690. https://doi.org/10.1111/disa.12433

Bakkensen, L. A., Fox-Lent, C., Read, L. K., & Linkov, I. (2017). Validating Resilience and Vulnerability Indices in the Context of Natural Disasters. Risk Analysis, 37(5), 982–1004. https://doi.org/10.1111/risa.12677

Banks, C. B. (2019, November 12). Looking At What Sets Large-Scale Projects Apart | Analyze. https://analyze.co.za/looking-at-what-sets-large-scale-projects-apart-from-regular-projects/

Barron, W. G. (2000). U.S. CENSUS BUREAU William G. Barron, Jr.,.

Beach Nourishment (U.S. National Park Service). (n.d.). https://www.nps.gov/articles/beach-nourishment.htm

Bea, R. G. (2005). Design for Reliability: Human and Organisational Factors. In Elsevier eBooks (pp. 939–999). https://doi.org/10.1016/b978-0-08-044381-2.50019-9

Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards. Social Indicators Research, 122(2), 391–409. https://doi.org/10.1007/s11205-014-0698-3

Blackwood, L., & Cutter, S. L. (2023). The application of the Social Vulnerability Index (SoVI) for geo-targeting of post-disaster recovery resources. International Journal of Disaster Risk Reduction, 92, 103722. https://doi.org/10.1016/j.ijdrr.2023.103722

Barendrecht, M. H., McCarthy, S., & Viglione, A. (2021). A comparative analysis of the relationship between flood experience and private flood mitigation behaviour in the regions of England. Journal of Flood Risk Management, 14(2), e12700. https://doi.org/10.1111/jfr3.12700

Boyd, E. (2011). Fatalities due to Hurricane Katrina's impacts in Louisiana [Doctor of Philosophy, Louisiana State University and Agricultural and Mechanical College]. https://doi.org/10.31390/gradschool_dissertations.2734

Bullock, J. A., Haddow, G. D., & Coppola, D. P. (2013). Mitigation, Prevention, and Preparedness. Introduction to Homeland Security, 435–494. https://doi.org/10.1016/B978-0-12-415802-3.00010-5

Bureau, U. C. (2022a, June). Measuring Racial and Ethnic Diversity for the 2020 Census. Census.Gov. https://www.census.gov/newsroom/blogs/random-samplings/2021/08/measuring-racial-ethnic-diversity-2020-census.html

Bureau, U. C. (2022b, July). Manufactured Housing Survey (MHS). Census.Gov. https://www.census.gov/programs-surveys/mhs.html

Bureau, U. C. (2023, June). How the Census Bureau Measures Poverty. Census.Gov. https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html

Cambridge. (2023, November 22). LARGE-SCALE PROJECT collocation | meaning and examples of use. https://dictionary.cambridge.org/us/example/english/large-scale-project

Cardwell, J. (2021). Community Perceptions of a Floodplain Buyout Program in Charlotte, North Carolina. https://doi.org/10.21203/rs.3.rs-916278/v1

CDC/ATSDR Social Vulnerability Index. (2022, October 26). https://www.atsdr.cdc.gov/placeandhealth/svi/at-a-glance_svi.html

ChePa, N., Hashim, N. L., Yusof, Y., & Hussain, A. (2016). Adaptive Emergency Evacuation Centre Management for Dynamic Relocation of Flood Victims using Firefly Algorithm. 8(8).

Chicco, D., Warrens, M. J., & Jurman, G. (2021). The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. PeerJ Computer Science, 7. https://doi.org/10.7717/peerj-cs.623
Chakraborty, L., Thistlethwaite, J., Minano, A., Henstra, D., & Scott, D. (2021). Leveraging Hazard, Exposure, and Social Vulnerability Data to Assess Flood Risk to Indigenous Communities in Canada. International Journal of Disaster Risk Science, 12(6), 821–838. https://doi.org/10.1007/s13753-021-00383-1

Choosing the Correct Type of Regression Analysis—DataScienceCentral.com. (n.d.). Retrieved October 5, 2023, from https://www.datasciencecentral.com/choosing-the-correct-type-of-regression-analysis/

Climate Adapt. (2016, June 7). Storm surge gates and flood barriers. https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/storm-surge-gates-flood-barriers

Cohn, D. (2020, December). How accurate will the 2020 U.S. census be? We'll know more soon. Pew Research Center. https://www.pewresearch.org/short-reads/2020/12/14/how-accurate-will-the-2020-u-s-census-be-well-know-more-soon/

Costa, H., Hall, H., Rutledge, K., Ramroop, T., Boudreau, D., Hunt, J., McDaniel, M., Teng, S., & Sprout, E. (2022, November 29). Levee. Education. https://education.nationalgeographic.org/resource/levee/

Costa, J. E. (1978). The dilemma of flood control in the United States. Environmental Management, 2(4), 313–322. https://doi.org/10.1007/BF01866671

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. Social Science Quarterly, 84(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Curran-Groome, W., Haygood, H., Hino, M., BenDor, T. K., & Salvesen, D. (2021). Assessing the full costs of floodplain buyouts. Climatic Change, 168(1–2). https://doi.org/10.1007/s10584-021-03178-x

De Silva, M. M. G. T., & Kawasaki, A. (2018). Socioeconomic Vulnerability to Disaster Risk: A Case Study of Flood and Drought Impact in a Rural Sri Lankan Community. Ecological Economics, 152, 131–140. https://doi.org/10.1016/j.ecolecon.2018.05.010

Drakes, O., & Tate, E. (2022). Social vulnerability in a multi-hazard context: A systematic review. Environmental Research Letters, 17(3), 033001. https://doi.org/10.1088/1748-9326/ac5140

Environmental Protection Agency. (2022). Climate Change Indicators: Atmospheric Concentrations of Greenhouse Gases. https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases

Estuarine Shoreline Stabilization Options | NC DEQ. (n.d.). https://www.deq.nc.gov/about/divisions/coastal-management/estuarine-shorelines/estuarine-shoreline-stabilization/estuarine-shoreline-stabilization-options

FAO. (2021). Damage and loss - the impact of disasters and crises on agriculture and food security. http://clh-ckan.apps.fao.org/en/dataset/33894406-395c-49bb-9f0b-70c2417d55ce/resource/71c22884-e6b2-4167-8e30-0c0ac64f3cac

Fatemi, F., Ardalan, A., Aguirre, B., Mansouri, N., & Mohammadfam, I. (2017). Social vulnerability indicators in disasters: Findings from a systematic review. International Journal of Disaster Risk Reduction, 22, 219–227. https://doi.org/10.1016/j.ijdrr.2016.09.006

FEMA. (2011). Tested and Proven Success: Stormwater Improvement System Prevents Flooding. https://www.fema.gov/case-study/tested-and-proven-success-stormwater-improvement-system-prevents-flooding

FEMA. (2021). Nature-Based Solutions, Climate Change & Future Conditions. https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html

Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management, 8(1). https://doi.org/10.2202/1547-7355.1792

Flood Authority. (2023). Seabrook Floodgate Complex. Flood Protection Authority East. https://www.floodauthority.org/the-system/seabrook-floodgate-complex/

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D. Fahey, J. Haywood, J. Lean, D. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz & R. Van Dorland (2008): Changes in Atmospheric Constituents and in Radiative Forcing. In Climate Change 2007: The Physical Science Basis. https://www.cambridge.org/catalogue/catalogue.asp?isbn=9780521705967

Greater Impact: How Disasters Affect People of Low Socioeconomic Status. (2017). SAMHSA. https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M., & Beaudet, C. (2020). From Poverty to Disaster and Back: A Review of the Literature. Economics of Disasters and Climate Change, 4(1), 223–247. https://doi.org/10.1007/s41885-020-00060-5

Hirsch, R. M., & Archfield, S. A. (2015). Not higher but more often. Nature Climate Change, 5(3), 198–199. https://doi.org/10.1038/nclimate2551

Howell, J., & Elliott, J. R. (2018). As Disaster Costs Rise, So Does Inequality. Socius: Sociological Research for a Dynamic World, 4, 237802311881679. https://doi.org/10.1177/2378023118816795

How to interpret R-squared in regression analysis? (2023, September 13). Knowledgehut. https://www.knowledgehut.com/blog/data-science/interpret-r-squared-and-goodness-fit-regression-analysis

How beach nourishment projects work - United States Army. (2007). https://www.iwr.usace.army.mil/Portals/70/docs/projects/HowBeachNourishmentWorksPrimer.pdf

How stormwater ponds help protect communities from flooding. (n.d.). Flood Defenders. https://www.flooddefenders.org/how-stormwater-ponds-can-help-reduce-flooding-in-your-county

Jacobsen, L. (2023, February 10). How Accurate Was the 2020 Census—And Why Should You Care? PRB. https://www.prb.org/resources/how-accurate-was-the-2020-census-and-why-should-you-care/

Lee, S., Dodge, J., & Chen, G. (2022). The cost of social vulnerability: An integrative conceptual framework and model for assessing financial risks in natural disaster management. Natural Hazards, 114(1), 691–712. https://doi.org/10.1007/s11069-022-05408-6

Mah, J. C., Penwarden, J. L., Pott, H., Theou, O., & Andrew, M. K. (2023). Social vulnerability indices: A scoping review. BMC Public Health, 23(1), 1253. https://doi.org/10.1186/s12889-023-16097-6

M. Anwar Zahid & M. Badre Enam. (2013). Seabrook Sector Gate Complex—How We Arrived Here After Hurricane Katrina. https://ascelibrary.org/doi/epdf/10.1061/9780784413067.055

Mitchell, J. F. B. (1989). The "Greenhouse" Effect and Climate Change. Rev. Geophys., 27(1), 115–139. doi:10.1029/RG027i001p00115.

NOAA. (2019, February 1). Watersheds, flooding, and pollution. National Oceanic and Atmospheric Administration. https://www.noaa.gov/education/resource-collections/freshwater/watersheds-flooding-and-pollution

Ordway, D.-M., July 2, T. J. R., & 2019. (2019, July 2). 2020 census: How undercounts and overcounts can hurt US communities. The Journalist's Resource. https://journalistsresource.org/environment/2020-census-research-undercount/

Park, J. E. (2021). Cost Overruns and Schedule Delays of Major Projects: Why We Need Reference Class Forecasting. https://doi.org/10.7916/D8-9CN7-C433

Ramirez, R. (2021, December 13). US businesses to lose a collective 3.1 million days of operation from flooding in 2022, report shows. CNN Business. https://www.cnn.com/2021/12/13/business/flood-cost-business-climate-risk/index.html

Reidmiller, D. R., Avery, C. W., Easterling, D. R., Kunkel, K. E., Lewis, K. L. M., Maycock, T. K., & Stewart, B. C. (2018). Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018

Ridzuan, F., & Wan Zainon, W. M. N. (2019). A Review on Data Cleansing Methods for Big Data. Procedia Computer Science, 161, 731–738. https://doi.org/10.1016/j.procs.2019.11.177

RiskOptics. (2023, May 11). Proactive vs. Reactive Risk Management Strategies. Reciprocity. https://reciprocity.com/resources/proactive-vs-reactive-risk-management-strategies/

Rufat, S., Tate, E., Burton, C. G., & Maroof, A. S. (2015). Social vulnerability to floods: Review of case studies and implications for measurement. International Journal of Disaster Risk Reduction, 14, 470–486. https://doi.org/10.1016/j.ijdrr.2015.09.013

Rumbach, A., Sullivan, E., & Makarewicz, C. (2020). Mobile Home Parks and Disasters: Understanding Risk to the Third Housing Type in the United States. Natural Hazards Review, 21(2), 05020001. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000357

SAMHSA. (2017). Greater Impact: How Disasters Affect People of Low Socioeconomic Status. Disaster Technical Assistance Center Supplemental Research Bulletin. https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf

Schmidtlein, M. C., Deutsch, R. C., Piegorsch, W. W., & Cutter, S. L. (2008). A Sensitivity Analysis of the Social Vulnerability Index. Risk Analysis, 28(4), 1099–1114. https://doi.org/10.1111/j.1539-6924.2008.01072.x

Shultz, J. M., Trapido, E. J., Kossin, J. P., Fugate, C., Nogueira, L., Apro, A., Patel, M., Torres, V. J., Ettman, C. K., Espinel, Z., & Galea, S. (2022). Hurricane Ida's impact on Louisiana and Mississippi during the COVID-19 Delta surge: Complex and compounding threats to population health. Lancet Regional Health - Americas, 12, 100286. https://doi.org/10.1016/j.lana.2022.100286

Sohil, F., Sohali, M. U., & Shabbir, J. (2022). An introduction to statistical learning with applications in R: By Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani. Statistical Theory and Related Fields, 6(1), 87–87. https://doi.org/10.1088/24754269.2021.1980261

Spielman, S. E., Tuccillo, J., Folch, D. C., Schweikert, A., Davies, R., Wood, N., & Tate, E. (2020). Evaluating social vulnerability indicators: Criteria and their application to the Social Vulnerability Index. Natural Hazards, 100(1), 417–436. https://doi.org/10.1007/s11069-019-03820-z

Tate, E., Rahman, A., Emrich, C. T., & Sampson, C. (2021). Flood exposure and social vulnerability in the United States. Natural Hazards, 106(1), 435–457. https://doi.org/10.1007/s11069-020-04470-2

Tienda, S., Thompson,. (2018, April). The 2020 Census: The Risks of Getting It Wrong. Council on Foreign Relations. https://www.cfr.org/event/2020-census-risks-getting-it-wrong

Tompkins, F. (2020). New Decade Brings Timely Opportunities for Proactive Flood Policy. The Pew Charitable Trusts. https://www.pewtrusts.org/en/research-and-analysis/articles/2020/01/31/new-decade-brings-timely-opportunities-for-proactive-flood-policy

Two Years After Hurricane Florence, $2 Billion Provided for N.C. Recovery | FEMA.gov. (2020, September 14). https://www.fema.gov/press-release/20230110/two-years-after-hurricane-florence-2-billion-provided-nc-recovery

U.S. Army Corps of Engineers Headquarters. (n.d.). Flood Risk Management. https://www.usace.army.mil/Missions/Civil-Works/Flood-Risk-Management/

US Department of Commerce, NOAA. (2005, August 30). Hurricane Katrina—August 2005. https://www.weather.gov/mob/katrina

USGS. (2019, February 25). Summer 2011 Missouri River Basin flood. https://www.usgs.gov/mission-areas/water-resources/science/summer-2011-missouri-river-basin-flood

Vojinovic, Z., Alves, A., Gómez, J. P., Weesakul, S., Keerakamolchai, W., Meesuk, V., & Sanchez, A. (2021). Effectiveness of small- and large-scale Nature-Based Solutions for flood mitigation: The case of Ayutthaya, Thailand. Science of The Total Environment, 789, 147725. https://doi.org/10.1016/j.scitotenv.2021.147725

Wing, O. E. J., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. Environmental Research Letters, 13(3), 034023. https://doi.org/10.1088/1748-9326/aaac65

APPENDIX A – DATA SET TABLE

Project ID	Project sub-ID	Project Type	Flood gate	Flood barrier	Levee	Improvements to bodies of water	Part of a larger project	Project Cost	Storm Surge [ft]	Precipitation [inch]	Hazard Name	Parish
1	1.1	Levee	0	0	1	0	1	$25,467,475	9	8	Katrina	Orleans
	1.2	Levee	0	0	0	0			21	9	Katrina	St. Bernard
2	2.1	Levee	0	0	1	0	1	$22,595,265	9	8	Katrina	Orleans
	2.2	Levee	0	0	0	0			21	9	Katrina	St. Bernard
3	3.1	Levee	0	0	1	0	1	$9,351,590	9	8	Katrina	Orleans
	3.2	Levee	0	0	0	0			21	9	Katrina	St. Bernard
4	4.1	Levee	0	0	1	0	1	$22,600,000	9	8	Katrina	Orleans
	4.2	Levee	0	0	0	0			21	9	Katrina	St. Bernard
5	5	Flood gate	1	0	0	0	0	$14,142,977	9	8	Katrina	Orleans
6	6.1	Improvements to bodies of water	0	0	0	1	0	$8,400,000	5	17	Irma	Brevard
	6.2	Improvements to bodies of water	0	0	0	1	0		6	7	Matthew	Brevard
7	7	Improvements to bodies of water	0	0	0	1	0	$8,400,000	4.9	10	Dorian	Brunswick
8	8.1	Improvements to bodies of water	0	0	0	1	0	$15,179,050	6	16	Irma	St. Johns
	8.2	Improvements to bodies of water	0	0	0	1	0		6	7	Matthew	St. Johns
9	9	Flood gate	1	0	0	0	0	$165,000,000	9	8	Katrina	Orleans
10	10	Improvements to bodies of water	0	0	0	1	0	$13,600,000	10	32	Florance	New Hanover

Project ID	Income	Above US Avg. Income	Below US Avg. Income	Total Population	Total Number of Housing Units/Households	Population below Poverty	Population over 65	Population under 5	Race/ Ethnicity	Lack of vehicle access	Single-parent household
1	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
	$25,910.00		1	35,897.00	18,330.00	24%	13.40%	6.20%	32.30%	0.7%	23.20%
2	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
	$25,910.00		1	35,897.00	18,330.00	24%	13.40%	6.20%	32.30%	0.7%	23.20%
3	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
	$25,910.00		1	35,897.00	18,330.00	24%	13.40%	6.20%	32.30%	0.7%	23.20%
4	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
	$25,910.00		1	35,897.00	18,330.00	24%	13.40%	6.20%	32.30%	0.7%	23.20%
5	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
6	$26,022.00		1	543,376.00	269,864.00	13.40%	20.40%	4.90%	17.50%	4.7%	15.00%
	$26,022.00		1								
7	$57,088.00	1		107,431.00	77,482.00	16.90%	21.30%	5.80%	16.90%	2.3%	1.00%
8	$58,888.00	1		191,323.00	89,830.00	13.90%	15.80%	5.10%	15.50%	1.6%	13.50%
9	$61,561.00	1		347,858.00	142,093.00	15.10%	11.10%	6.40%	37.50%	8.6%	26.50%
10	$63,093.00	1		202,667.00	101,436.00	18.10%	13.90%	5.60%	20.90%	1.2%	23.20%

Project ID	Mobile homes	Disability	Time to Completion	Years to Complete	Primary Funding Source	Primary Funding Source Obligation	Secondary Funding Source	Secondary Funding Source Obligation	Population under 5	Race/ Ethnicity
1	1.3%	4.7%	252	Over 10 yrs.	Federal Gov	$ 16,553,858.75	Local	$ 8,913,616.25	6.40%	37.50%
	16.1%	14.8%	252		Federal Gov	$ 16,553,858.75	Local	$ 8,913,616.25	6.20%	32.30%
2	1.3%	4.7%	252	Over 10 yrs.	Federal Gov	$ 14,686,922.25	Local	$ 7,908,342.75	6.40%	37.50%
	16.1%	14.8%	252		Federal Gov	$ 14,686,922.25	Local	$ 7,908,342.75	6.20%	32.30%
3	1.3%	4.7%	252	Over 10 yrs.	Federal Gov	$ 6,078,533.50	Local	$ 8,911,000.00	6.40%	37.50%
	16.1%	14.8%	252		Federal Gov	$ 6,078,533.50	Local	$ 8,911,000.00	6.20%	32.30%
4	1.3%	4.7%	252	Over 10 yrs.	Federal Gov	$146,900,000.00	Local	$ 7,910,000.00	6.40%	37.50%
	16.1%	14.8%	252		Federal Gov	$146,900,000.00	Local	$ 7,910,000.00	6.20%	32.30%
5	1.3%	4.7%	216	Over 10 yrs.	Federal Gov	$ 14,142,977.00	NA		6.40%	37.50%
6	7.9%	14.6%	9	2 years or less	FEMA	$ 7,350,000.00	County	$ 1,005,000.00	4.90%	17.50%
7	23.3%	15.7%	36	2 - 10 years	FEMA	$ 11,622,601.00	State	$ 3,874,201.00	5.80%	16.90%
8	7.6%	10.2%	120	2 - 10 years	Federal	$ 4,401,924.50	County	$10,777,125.50	5.10%	15.50%
9	1.3%	4.7%	84	2 - 10 years	Federal Gov	$165,000,000.00	NA		6.40%	37.50%
10	4.0%	11.2%	48	2 yrs or less	Federal Gov	$ 13,600,000.00	NA		5.60%	20.90%

APPENDIX B- Project & Event Description

Project ID	Project Description	Event	Event Description
1	1.7 mile long and 9.6' high levee	Katrina	In August 2005, caused levee breaches in New Orleans, with storm surges up to 25-28 feet and significant rainfall.
2	1.8 mile long- 12.5' high levee		
3	1 mile long levee		
4	2.5 miles long 11.5 feet high levee		
5	The project involves installing a permanent and deployable floodwall system along the Mississippi River at the New Orleans District's Headquarters, including steel sheet and H-piling placement.		
6	228,000 cubic yards of sand in total	Irma	Struck in September 2017 with storm surges surpassing 10 feet in the Caribbean and Florida, accompanied by heavy rains.
		Matthew	Hit Haiti and the southeastern U.S. in October 2016, bringing over 15 inches of rain and storm surges of up to 12 feet in places.
7	555,000 cubic yards of sand for renourishment	Dorian	In September 2019, Dorian affected Brunswick with storm surges and heavy rainfall, causing coastal and inland flooding.
8	1.3 million cubic yards of sand that will be dredged from shoals located within St. Augustine Inlet. Future periodic nourishment events are planned at multi-year intervals.	Irma	Struck in September 2017 with storm surges surpassing 10 feet in the Caribbean and Florida, accompanied by heavy rains.
		Matthew	Hit Haiti and the southeastern U.S. in October 2016, bringing over 15 inches of rain and storm surges of up to 12 feet in places.
9	Floodgate: 600 feet long at a height of 16 feet above sea level. It consists of a 95' foot-wide navigable sector gate that has two pie-shaped gates weighing 220 tons a piece. In addition, it has two 50' foot-wide vertical lift gates that can be lowered to also block the waters of Lake Pontchartrain.	Katrina	In August 2005, caused levee breaches in New Orleans, with storm surges up to 25-28 feet and significant rainfall.
10	The work consists of dredging, screening, and placing beach-quality sand on the beach.	Florence	Made landfall in North Carolina in September 2018, leading to over 30 inches of rain and storm surges of about 10 feet.

APPENDIX C – CROSS-TABULATION TABLES

		Years to Complete			
Project Type		2 yrs or less	2 - 10 years	Over 10 yrs	Grand Total
Flood gate	Percent of Project Cost		165000000	14142977	179142977
	Percent of Storm Surge [ft]		9	9	18
	Percent of Precipitation [inch]		8	8	16
Improvements to bodies of water	Percent of Project Cost	22000000	23579050		45579050
	Percent of Storm Surge [ft]	15	10.9		25.9
	Percent of Precipitation [inch]	49	26		75
Levee	Percent of Project Cost			80014330	80014330
	Percent of Storm Surge [ft]			36	36
	Percent of Precipitation [inch]			32	32
Total Percent of Project Cost		22000000	188579050	94157307	304736357
Total of Storm Surge [ft]		15	19.9	45	79.9
Total of Precipitation [inch]		49	34	40	123

		Years to Complete			
Project Type		2 yrs or less	2 - 10 years	Over 10 yrs	Grand Total
Flood gate	Percent of Above US Avg. Income		1	1	2
	Percent of Below US Avg. Income				
Improvements to bodies of water	Percent of Above US Avg. Income	1	2		3
	Percent of Below US Avg. Income	1			1
Levee	Percent of Above US Avg. Income			4	4
	Percent of Below US Avg. Income				
Total Percent of Above US Avg. Income		1	3	5	9
Total Percent of Below US Avg. Income		1			1

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Race/ Ethnicity		0.375	0.375	0.75
	Percent of Project Cost		$ 165,000,000	$ 14,142,977	$ 179,142,977
Improvements to bodies of water	Percent of Race/ Ethnicity	0.384	0.324		0.708
	Percent of Project Cost	$ 22,000,000	$ 23,579,050		$ 45,579,050
Levee	Percent of Race/ Ethnicity			1.5	1.5
	Percent of Project Cost			$ 80,014,330	$ 80,014,330
Total Percent of Race/ Ethnicity		0.384	0.699	1.875	2.958
Total Sum of Project Cost		$ 22,000,000	$ 188,579,050	$ 94,157,307	$ 304,736,357

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Population over 65		0.111	0.111	0.222
	Percent of Population under 5		0.064	0.064	0.128
	Percent of Project Cost		$ 165,000,000.00	$ 14,142,977.00	$ 179,142,977.00
Improvements to bodies of water	Percent of Population over 65	0.343	0.371		0.714
	Percent of Population under 5	0.105	0.109		0.214
	Percent of Project Cost	$ 22,000,000.00	$ 23,579,050.00		$ 45,579,050.00
Levee	Percent of Population over 65			0.444	0.444
	Percent of Population under 5			0.256	0.256
	Percent of Project Cost			$ 80,014,330.00	$ 80,014,330.00
Total Percent of Population over 65		0.343	0.482	0.555	1.38
Total Percent of Population under 5		0.105	0.173	0.32	0.598
Total Sum of Project Cost		$22,000,000	$ 88,579,050	$ 4,157,307	$ 304,736,357

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Total Number of Housing Units/Households		142093	142093	284186
	Percent of Mobile homes		0.013	0.013	0.026
	Percent of Project Cost		$ 165,000,000	$ 14,142,977	$ 179,142,977
Improvements to bodies of water	Percent of Total Number of Housing Units/Households	371,300	167,312		538,612.00
	Percent of Mobile homes	0.12	0.31		0.43
	Percent of Project Cost	$ 22,000,000	$ 23,579,050		$ 45,579,050
Levee	Percent of Total Number of Housing Units/Households			568372	568372
	Percent of Mobile homes			0.052	0.052
	Percent of Project Cost			$ 80,014,330	$ 80,014,330
Total Number of Housing Units/Households		371,300	309,405	710,465	1,391,170
Total of Percent Mobile homes		0.119	0.322	0.065	0.506
Total of Project Cost		$ 22,000,000	$ 188,579,050	$ 94,157,307	$ 304,736,357

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Disability		0.047	0.047	0.094
	Percent of Project Cost		$ 165,000,000	$ 14,142,977	$ 179,142,977
Improvements to bodies of water	Percent of Disability	0.258	0.259		0.517
	Percent of Project Cost	$ 22,000,000	$ 23,579,050		$ 45,579,050
Levee	Percent of Disability			0.188	0.188
	Percent of Project Cost			$ 80,014,330	$ 80,014,330
Total Percent of Disability		0.258	0.306	0.235	0.799
Total Sum of Project Cost		$ 22,000,000	$ 188,579,050	$ 94,157,307	$ 304,736,357

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Primary Funding Source Obligation		$ 165,000,000	$ 14,142,977	$ 179,142,977
	Percent of Secondary Funding Source Obligation				
	Percent of Project Cost		$ 165,000,000	$ 14,142,977	$ 179,142,977
Improvements to bodies of water	Percent of Primary Funding Source Obligation	$ 20,950,000	$ 16,024,525.50		$ 36,974,525.50
	Percent of Secondary Funding Source Obligation	$ 1,005,000	$ 14,651,326.50		$ 15,656,326.50
	Percent of Project Cost	$ 22,000,000	$ 23,579,050		$ 45,579,050
Levee	Percent of Primary Funding Source Obligation			$ 184,219,315	$184,219,314.5
	Percent of Secondary Funding Source Obligation			$ 33,642,959	$ 33,642,959
	Percent of Project Cost			$ 80,014,330	$ 80,014,330
Total Sum of Primary Funding Source Obligation		$ 20,950,000	$ 181,024,526	$ 198,362,292	$ 400,336,817
Total Sum of Secondary Funding Source Obligation		$ 1,005,000	$ 14,651,327	$ 33,642,959	$ 49,299,286
Total Sum of Project Cost		$ 22,000,000	$ 188,579,050	$ 94,157,307	$ 304,736,357

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Lack of vehicle access		0.086	0.086	0.172
	Percent of Project Cost		$ 165,000,000.00	$ 14,142,977.00	$ 179,142,977.00
Improvements to bodies of water	Percent of Lack of vehicle access	0.059	0.039		0.098
	Percent of Project Cost	$ 22,000,000.00	$ 23,579,050.00		$ 45,579,050.00
Levee	Percent of Lack of vehicle access			0.344	0.344
	Percent of Project Cost			80014330	80014330
Total Percent of People that Lack vehicle access		0.059	0.125	0.43	0.614
Total Sum of Project Cost		$ 22,000,000.00	$ 188,579,050.00	$ 94,157,307.00	$ 304,736,357.00

		Years to Complete			
Project Type		**2 yrs or less**	**2 - 10 years**	**Over 10 yrs**	**Grand Total**
Flood gate	Percent of Population below Poverty		0.151	0.151	0.302
	Percent of Project Cost		$ 165,000,000.00	$ 14,142,977.00	$ 179,142,977.00
Improvements to bodies of water	Percent of Population below Poverty	0.315	0.308		0.623
	Percent of Project Cost	$ 22,000,000.00	$ 23,579,050.00		$ 45,579,050.00
Levee	Percent of Population below Poverty			0.604	0.604
	Percent of Project Cost			$ 80,014,330.00	$ 80,014,330.00
Total Percent of Population below Poverty		0.315	0.459	0.755	1.529
Total Sum of Project Cost		$ 22,000,000.00	$ 188,579,050.00	$ 94,157,307.00	$ 304,736,357.00

		Years to Complete			
Project Type		2 yrs or less	2 - 10 years	Over 10 yrs	Grand Total
Flood gate	Percent of Single-parent household		0.265	0.265	0.53
	Percent of Total Number of Housing Units/Households		142,093.00	142,093.00	284,186.00
	Percent of Project Cost		$ 165,000,000.00	$ 14,142,977.00	$ 179,142,977.00
Improvements to bodies of water	Percent of Single-parent household	0.288	0.145		0.433
	Percent of Total Number of Housing Units/Households	371,300.00	167,312.00		538,612.00
	Percent of Project Cost	$ 22,000,000.00	$ 23,579,050.00		$ 45,579,050.00
Levee	Percent of Single-parent household			1.06	1.06
	Percent of Total Number of Housing Units/Households			568372	568372
	Percent of Project Cost			$ 80,014,330.00	$ 80,014,330.00
Total Percent of Single-parent household		0.288	0.41	1.325	2.023
Total Sum of Number of Housing Units/Households		371,300.00	309,405.00	710,465.00	1,391,170.00
Total Sum of Project Cost		$ 22,000,000.00	$ 188,579,050.00	$ 94,157,307.00	$ 304,736,357.00

APPENDIX D– List of Data sources

Project ID	Name	Link
1	Levee	https://www.mvn.usace.army.mil/Media/News-Releases/Article/3330911/contract-awarded-for-levee-work-for-the-west-shore-lake-pontchartrain-project/
2	Levee	https://www.mvn.usace.army.mil/Media/News-Releases/Article/3378690/contract-awarded-for-levee-work-for-the-west-shore-lake-pontchartrain-project/ https://coastal.la.gov/wp-content/uploads/2016/04/QPR_October2018-Final.pdf
3	Levee	https://www.mvn.usace.army.mil/Media/News-Releases/Article/3252735/contract-awarded-for-levee-work-for-the-west-shore-lake-pontchartrain-project/#:~:text=The%20contract%20was%20awarded%20on,John%20the%20Baptist%20Parish%2C%20Louisiana.
4	Levee	https://www.mvn.usace.army.mil/Media/News-Releases/Article/3501994/contract-awarded-for-levee-work-for-the-west-shore-lake-pontchartrain-project/
5	Flood gate	https://www.highergov.com/contract/W912P820C0039/#status
6	Improvements to bodies of water	https://www.floridatoday.com/story/news/local/2017/09/19/brevard-commissioners-ok-8-4-million-post-hurricane-beach-restoration/679747001/
7	Improvements to bodies of water	https://www.saw.usace.army.mil/Media/News-Releases/Article/1957624/hurricane-dorian-preparation-and-response/
8	Improvements to bodies of water	https://www.saj.usace.army.mil/StJohnsVilanoCSRM/
9	Flood gate	https://www.mvn.usace.army.mil/Portals/56/docs/PAO/FactSheets/SeabrookFloodgateComplex.pdf
10	Improvements to bodies of water	https://www.wect.com/2019/01/10/beach-renourishment-project-carolina-kure-beaches-set-begin-february/