Storm Surge and Evacuations in Pinellas County

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Storm Surge and Evacuations in Pinellas County

by

Christianne Pearce

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Environmental Science and Policy
School of Geosciences
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ABSTRACT

The purpose of this study was to determine evacuation decisions of residents in Pinellas County, a vulnerable area in Florida, during Hurricane Irma in 2017, and whether those decisions will impact their future decisions to evacuate. This study also examines the resident’s perception of storm surge flooding during a hurricane. To understand evacuation decisions and storm surge perceptions a survey was conducted on residents in vulnerable areas of Pinellas County. The survey examined multiple aspects including the role of media, relationships, and sociodemographic status on decision making. Another aspect examined if their decision to evacuate for Hurricane Irma will impact their decision for the future. Residents were also asked to rate how different aspects of the storm influenced their decision, including flooding from storm surge. It was concluded that their decision to evacuate for Hurricane Irma will significantly impact their decision to evacuate for the next hurricane, with many residents claiming they would leave their local area. Storm surge was not perceived as the greatest threat, instead wind speed and size of storm were determined to be the greater threat. Better understanding of evacuation decisions and perceptions about storm surge can be used to update emergency management preparations and planning for the next hurricane..
CHAPTER ONE:
INTRODUCTION

It is no secret that the west coast of Florida, in particular the Tampa area, is vulnerable in the event of a direct impact from a hurricane. Three of these vulnerable counties, shown in figure 1, adjacent to Tampa Bay include: Pinellas County with the cities of St. Petersburg and Clearwater to the West, Hillsborough County with the city of Tampa to the East, and Manatee County with the city of Bradenton to the south. Recently, a study prepared by a risk management company, ranked Tampa, Florida #1 for the country’s most vulnerable city to storm surge (Clark 2015) where storm surge “is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide” (NOAA). There are numerous research papers that focus on the Tampa area, but the research for this study will focus just west and a little south of the Tampa area, in Pinellas County one of the most populous counties in Florida.

Storm surge is not the only risk this area of Florida faces in the event of a major hurricane. Also associated with major hurricanes would be high winds, flooding from rainfall, tornadoes, issues with evacuation and hazards after the storm, including flooded roads, downed power lines, unsafe generator operation, and hazardous debris. This research will examine the population of Pinellas County and their perceptions about evacuation, including reasons to evacuate or not, what influences their decisions, and if storm surge is perceived as a threat. Using Hurricane Irma as a case study, this research will also examine if their decision to evacuate for Hurricane
Irma will impact their decision to evacuate for future storms. First there will be a discussion of research of past Florida hurricanes including, past hurricanes to impact the Pinellas area, storm surge, vulnerability, and evacuations that have taken place in other areas and in Pinellas County.

![Map of counties around Tampa Bay (GIS)](image)

*Figure 1. Map of counties around Tampa Bay (GIS)*

Understanding residents’ evacuation decisions and perception of storm surge could help create better communication and education for the citizens in this area including the importance on preparing their homes and heeding evacuation orders in the event of a major storm which could ultimately save lives.

1.1 History of Florida Hurricanes

Florida has a long, eventful past experiencing hurricanes that have moved through the state leaving behind damage and destruction. Figure 2. may resemble a haphazard scribbling,
but in fact shows the tracks of hurricanes from the past 100 years that have impacted Florida. Some of the most notable storms to make their way through the peninsula include, Donna, Andrew, Charley, Jeanne, Frances, Irma, and most recently Michael and many more, many from the time before storms were named. More information on Florida’s historical hurricanes can be found in Collins et al. (2017).

![Figure 2. Hurricane tracks from the past 100 years. (NOAA)](image)

### 1.1.1 Hurricane Andrew

When the topic of past hurricanes in Florida arises, most people will recall Hurricane Andrew which cut across south Florida in August of 1992 as a category 5 storm. The sustained winds were recorded at 165 mph, the storm surge measured to be more than 4 meters (13ft) (Baker 1993). Hurricane Andrew is listed as the seventh costliest natural disaster for the United States as of 2017 (NHC 2018). The total cost of damages associated with the storm were estimated to be $48.1 billion (Blake et al. 2011). According to the official storm report Hurricane Andrew devasted much of Miami-Dade County in Florida. The assessment after the storm concluded that 137,000 homes were destroyed, 9,000 of those being mobile homes.
This left at least 160,000 people homeless in Dade County alone. Power grids were destroyed, roads were washed away, businesses left in ruin. Even though the physical damage was immense, fatalities were few. The deaths in Florida, directly related to the storm, equaled 15 with another 29 caused indirectly from the storm (Baker 1993).

Hurricane Andrew would prove to be the proverbial eye opener to the possible destruction a major storm could cause coastal cities. Hurricane Andrew would also demonstrate the necessity to have more accurate forecast systems and methods. Andrew proved the need to improve building codes, evacuation methods, preparedness. Andrew changed the way Floridians would prepare for a major storm.

1.1.2 2004 Hurricane Season

The infamous 2004 hurricane season would prove to be a test for the building codes put in place after Hurricane Andrew. An unprecedented four storms crisscrossed the state in a matter of two months. Figure 3 shows where three of the storms intersected the state and the other impacted the panhandle. The estimated losses because of these storms, exceeded $42 billion, about one in five homes in Florida experienced hurricane damage, blue roofs were a common sight in Florida for months after the storms, and 117 people were killed (NCDC 2004).

Sallenger et al. (2006) compared the level of coastal change that occurred during these storms using lidar surveys performed before and after the storms. Sallenger noted that each storm had a different effect on the coast, which could not simply be explained by the hurricane intensity defined by the Saffir-Simpson Scale. Interestingly, Hurricane Charley, the strongest of the four storms, had the least amount of shoreline change.
Even though very intense, Hurricane Charley was a very compact storm that moved through the state rapidly, decreasing the effect of storm surge erosion. Figure 4 shows North Captiva Island before Hurricane Charley and after Hurricane Charley. The image shows the barrier island eroded into two sections. Hurricanes Frances and Jeanne impacted the same coast within weeks of each other. The slow moving, Hurricane Frances occurred before Jeanne and removed much of the sand and sand dunes that would protect against erosion, allowing Jeanne to further erode the shorelines in this area (Sallenger et al. 2006).

Hurricane Ivan would prove to have the most coastal erosion out of the four Florida hurricanes. Ivan is noted to have caused the collapse of a large oceanfront five-story building in Alabama which was built on a large sand dune.
The failure of this structure demonstrated the issues with building on barrier islands. During Ivan, many other barrier islands were completely over washed, pushing sand and debris into the back bay. An average of 20-meter shoreline retreat occurred because of Ivan along the Alabama and Florida panhandle shores (Sallenger et al. 2006).

This study by Sallenger et al. (2006) provided detailed information about coastal erosion during the 2004 hurricane season. The data gathered from the 2004 hurricane season helped develop new ways to scale and predict coastal change that occurs during hurricanes. This information could be important to companies or residents planning build in areas that could be affected by shore erosion during a tropical cyclone. Stronger foundations and improved building codes for these structures is a necessity.
1.1.3 Most Recent Hurricanes

After the 2004 hurricane season, Florida stayed out of the path of hurricanes. In 2016 there was a close call with Hurricane Matthew, the first category 5 hurricane in the Atlantic since 2007. At one point the track for Hurricane Matthew was set to directly hit the Florida East Coast. Most counties along the east coast were under mandatory and voluntary evacuation. Luckily, Hurricane Matthew stayed just off the coast of Florida as a quickly weakening category 4, but still left millions without power and created a damaging storm surge, the highest levels of 2.12 meters (6.96ft) in Fernandina Beach. Inundation was also measured further inland along the St. Johns River. Two deaths in Florida were directly related to Hurricane Matthew. Structural damage due to winds was said to be minimal, more damage was caused by storm surge flooding (Stewart 2017).

In 2017, Florida was in the pathway of Hurricane Irma. The track, changing multiple times, first with the east coast in danger, and shifting more west with every update. In the end the category 4 storm made landfall first in Cudjoe Key, part of the Florida Keys, and a second landfall as a category 3 near Marco Island. Hurricane Irma moved northward through the Peninsula passing as a category 1 between Tampa and Orlando. Though weakening as it moved through Florida, the tropical storm force winds extended up to 360 miles from the center, impacting most of Florida. In southwest Florida the storm surge levels were reported to be between 2-3 meters (6-10ft). Though Irma made landfall on the west coast of Florida, the east coast also experienced storm surge flooding and wind damage. Seven deaths were directly related to Hurricane Irma in Florida alone. The storm was responsible for an estimated $50 billion in damage (Cangialois et al. 2018).
The most recent hurricane to make landfall in the Florida panhandle, demonstrated the power and destruction that accompanies a major hurricane. Making landfall on October 10th, 2018 as a strong category 4 storm, with sustained winds of 155 mph and a storm surge over 4.6 meters (14ft), Hurricane Michael is considered the fourth strongest hurricane, in regard to windspeed, to make landfall in the United States (NOAA 2018). Though, still not concluded, at least 60 fatalities were caused by Hurricane Michael in Florida along the path.

1.2 History of Hurricanes to Directly Impact Pinellas County

Even though Florida has had its share of hurricane activity, Pinellas County has been very fortunate when it comes to direct hurricane hits. Referring to figure 5, it shows there have been several “close calls” to the South Pinellas area. However, this area has only been directly impacted by two storms since the 1900’s. The first arrived in October of 1921 (letter a in figure 4) and the second in October 1946 (letter b in figure 5).

Figure 5. Hurricanes that have impacted Pinellas County (NOAA)

These two storms made landfall in a time before any type of radar or satellite was in use for hurricane detection. A time before the hurricane hunters could fly in and send back
measurements and readings directly from the storm. A time before the internet and social media could spread the warnings and updates in a blink of an eye. A time before storms were assigned names. Predicting where the storms would make landfall, and how intense they would be at landfall was almost an impossible task.

1.2.1 Hurricane of 1921

The unnamed hurricane of 1921, which developed in the west-central Caribbean Sea, was estimated to be a category 3 storm at its strongest, with winds over 100 mph (Landsea et al. 2011). The exact strength of the storm at landfall is still debated among scientists, since the instruments used to record the data during the storm were damaged.

According to Edward Bowie (1921), the forecaster on duty for the Weather Bureau in Washington D.C., hurricane warnings were not issued until the day of landfall for the unnamed hurricane in Tampa. These warnings were passed down via telephone and telegraph wires, until the systems for both went down due to the storm. Citizens of the area actually traveled to the nearest weather office to relay information about the damages and the people assisting those in need, even while the storm was raging outside (Bowie 1921). They reported people fleeing from the rising water. According to the same weather review the storm surge was estimated to be 10.5 feet (Bowie 1921). Figure 6 shows the estimated storm surge model simulation for the storm of 1921. Reports submitted to the Weather Bureau included information like Clearwater Beach and St. Petersburg being completely inundated. A quote in the review read, "I lived on 18th Avenue North on Beach Drive, and water was 3 to 4 feet deep there," Joseph Dew said. "Water came up Central Avenue to First Street, and the Gulf beaches were covered." It was reported that Egmont Key, an island located southwest of the tip of St. Petersburg, and Sanibel Island, located west of.
Fort Myers, were both completely covered by water (Lonon 2011).

The damage from this storm was extensive, even though at the time the Pinellas and Hillsborough county areas were not densely populated. The storm was responsible for 8 deaths. Many buildings and structures were reduced to rubble along the coasts surrounding Tampa Bay. Figure 7 shows the wreckage in Safety Harbor that was left after the storm (NOAA 2011).

From these images, the magnitude of the storms’ power is clearly visualized. High winds and storm surge would have contributed to such devastation. The storm surge model created years after the event show that the flooding due to storm surge was contained along the coastal
regions of Pinellas County, luckily sparing most of the peninsula. Downtown Tampa and areas adjacent to rivers were the most effected.

![Wreckage in Safety Harbor Springs](State archives of Florida)

**Figure 7. Wreckage in Safety Harbor Springs (State archives of Florida)**

### 1.2.2 Hurricane of 1946

The last hurricane on record to directly impact Pinellas County was in early October of 1946. According to the weather report, the hurricane lost most of its intensity before making landfall just south of St. Petersburg. The maximum wind speeds reported were around 75 mph, and those were recorded in the top right quadrant of the storm, where the most severe winds are found (Sumner 1946). The reports also indicated that the storm moved through the state, heading northeast towards Georgia, rapidly.

The citrus crops in Florida sustained the greatest damage. At the time, the damage to the citrus crop alone equaled $2,000,000. Another estimated $200,000 in damages occurred from unusually high tides along the west coast. There were reports of flooding along the beaches and
low lying areas around St. Petersburg and Tampa. Some readings showed that the tides were up by 6 or more feet in certain areas in Pinellas County (Sumner 1946)

### 1.3 Storm Surge

For people who live along a coast, the threat of storm surge is a threat that is all too real. Storm surge is defined by the National Hurricane Center as the abnormal rise of water generated by a storm, above the predicted tides (NOAA). Storm surge occurs when water is being pushed by the winds while moving around a cyclone the pressure difference between the center of the storm and the pressure outside of the storm also accounts for more water being pushed from the center. These winds and waters are initially pushed ashore when the storm makes landfall, causing inundation and destructive, powerful waves along coastal regions. A study by Rappaport (2014) showed that storm surge accounted for 49% of tropical cyclone related deaths in the United States spanning a period from 1963-2012. Research on the cause of death for 2,325 people showed that around 90% of deaths occurred in water related incidents, most of those being drowning (Rappaport 2014).

Storm surge also accounts for a large majority of structural damage that occurs during a tropical cyclone. Storm surge is responsible for billions of dollars in damage in the United States. Storm surge poses a threat to buildings, airports, marinas, infrastructure like roads, bridges, utility grids, sewers, and much more. Figures 8 and 9 show some of the destruction caused by storm surge along a coastal area. According to the U.S. Census, coastal county populations around the Gulf increased by 32% between 1990-2008 and continue to increase. Coastal cities are some of the most populous areas in a given state, which makes them very vulnerable to storm surge events. A comprehensive study by multiple scientists and stake holders concluded that
storm surge of about 7 meters could possibly inundate 67% of interstates, 57% of arterials, 29 airports, and almost all ports along the Gulf Coast (Savonis et al. 2008).

1.3.1 Storm Surge Research

Storm surge associated with tropical cyclones has proven to be one of the costliest and deadliest natural catastrophes to occur around the world. A study done by climatologists, Needham and Keim (2011), illustrated the physical processes of storm surge and created an impact scale. In their research they discuss the fact that understanding the science of storm surge can be very complex due to the many factors that can affect storm surge, which in turn can make predicting storm surge very difficult. Their research included quotes from U.S. government sources, newspapers, and books which they used to create a 4-tier classification system by levels of destruction. The levels ranged from 1 with minor “marine impacts” to 4 “destructive impacts”. Interestingly the results in the different levels showed that major hurricanes, like category 5 Hurricane Beulah in 1967 was considered a level 2, while minor storms like category 2 Hurricane Danny in 1997 was considered a level 4 in this classification method. Their research showed that category alone is not a good estimate of what level storm surge a storm may produce. Many contributing factors, like the shape of the coastline, how fast the storm is moving, the size of the storm, and
bathymetry can affect the level of storm surge (Needham and Keim 2011). This team of scientists also created the first comprehensive storm surge database called SURGEDAT which has compiled data from storm surge events all around the world. The database includes information about the peak height and location for more than 300 surge events in the U.S. dating back to the 1800’s. Using past information like this compiled in SURGEDAT, can help forecasters in the future (Needham and Keim 2012).

SLOSH, which stands for Sea Lake Overland Surges from Hurricanes, is a revolutionary model developed by the National Weather Service to forecast and study storm surge. SLOSH began as a model intended to be used by the National Weather Service and National Hurricane Center as a forecast tool while preparing weather bulletins, but has shown to be very useful in determining coast lines that are vulnerable to storm surge flooding. Figure 10 shows the 38 different SLOSH basins along the Gulf and Atlantic Coasts.

The SLOSH model is run by forecasters when there is a hurricane threatening a coastal area. The parameters used for the model include: (1) storm position as a function of time, (2) the radius of maximum winds, and (3) the pressure difference between the central pressure and the peripheral pressure. Based on the forecast track, the correct basin is used for the model. The model is most accurate when the storm is within a day or two of making landfall which can prove problematic regarding evacuation. The SLOSH model is also used for simulation runs to research how an area could possibly be affected by storm surge given a multitude of various factors. This information is used by emergency management teams in development of their evacuation plans for an area (Glahn 2009).
Another important study on storm surge was conducted by a group of scientists, Fleming et al. (2008) that focused their research on real time storm surge forecasting using ADCIRC. ADCIRC is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions. Their research takes a look at the issues of forecasting storm surge and they developed an automated real-time storm surge forecasting system to address the challenges that come with forecasting storm surge. Once created, they applied the model to a case study to see how the system performed. They used Lake
Pontchartrain in Southern Louisiana as their case study, which was an area affected by storm surge during Hurricane Katrina in 2005. Their methods and techniques include creating an ensemble of five ARDIC storm surge runs based on storm forecasts created by the National Hurricane Center. The model they created also took into account the following challenges usually associated with forecasting storm surge: the uncertainties of hurricane forecasts, accurate wind fields for storm surge computations, timeliness of putting information out there, and reliability. After applying their model to the case study of Lake Pontchartrain, they concluded that this system met the performance and reliability goals which included high resolution results that would pinpoint storm surge at particular infrastructure, a very quick turnaround time from the issue of an advisory from NHC, and capturing the changes of a developing storm. Their model service can also be applied to other geographic areas like Pinellas County (Fleming 2008).

1.3.2 Notable storm surge events

Hurricane Katrina, a category 3 storm and one of the costliest and deadliest storms to impact the United States in August of 2005 (Blake 2011), demonstrated the destruction storm surge can cause in low lying areas. Surveys performed by FEMA after the storm showed that 515,249 homes in Louisiana were damaged due to storm surge or flooding (Current 2015). The fatalities in Louisiana are estimated to be 1,577 directly or indirectly related to Hurricane Katrina (Knabb 2005). One study by Ebersole et al. (2009) focused on the storm surge flooding that affected the low-lying polder, St. Bernard Parish in Louisiana. Figure 11 shows a satellite image of the massive size of Hurricane Katrina in comparison to the St. Bernard Parish located in the red box.
Extreme water levels in this area led to breaches in the levee system, which resulted in major flooding. In their research Ebersole et al. utilized ARDIC and other model systems to demonstrate the development and propagation of storm surge created by Hurricane Katrina into this region. Their study showed that several factors played a role in the surge conditions including, prevailing regional and local wind conditions and patterns, presence of channels, presence of wetlands and other topographic features and the orientation and configuration of the levee system (Ebersole et al. 2009). They also address that a different hurricane striking this same area would have a different impact. Thus, furthering the idea that storm surge events are difficult to predict for any given storm due to the complexities of factors that play a role in the generation of storm surge.

Another notable storm surge event happened when category 2, Hurricane Ike, made landfall in Galveston Texas in September of 2008. Proving that category alone is not a good predictor of the damage a hurricane can cause, especially regarding storm surge. Galveston is a barrier island off the coast of Texas and is no stranger to destructive hurricanes, yet around
50,000 people call the island home and many more visit each year to enjoy the beaches. (Quick 2016). Figure 12 shows the storm surge levels as Hurricane Ike made landfall. Some storm surge levels reached as high as 14-16 feet. Most of the inundation was concentrated in the right quadrant of the hurricane where the water is being pushed towards the shore due to the flow of the storm.

![Figure 12. Storm surge levels for Hurricane Ike (NOAA)](image)

Figures 13 and 14 show the devastation and flooding caused by Hurricane Ike’s storm surge. From the pictures it is clear to see the first level of these buildings that were not on stilts were flooded. Some houses on stilts were damaged very badly or even destroyed.
Roads were impassable and most likely damaged or washed away. Other infrastructure in the coastal areas of Texas were also badly damaged including sewer systems, which can create another set of issues in safety and health.

Other studies (Dolan and Davis 1992; Dolan and Davis 1993; Irish 2008) have demonstrated that the current Saffir Simpson Scale should be updated. The current scale, which was developed in 1969 estimates damage based on wind speed alone. However, wind speed is not always an indicator of storm surge levels, which was shown in the use of the ADCIRC model. Updating of the Saffir-Simpson scale could lead to fewer fatalities and better planning.

Figures 13 and 14 flooding caused in coastal Texas from Hurricane Ike (National Geographic)

1.3.3 Storm Surge: Pinellas County

A thorough study of the impacts of storm surge to this area of Florida was performed by Weisberg and Zheng (2006). They created a model to simulate storm surge given parameters including, size of storm, intensity, direction and speed of the approach, landfall area, pressure fields, topography of the ocean floor, and other parameters. Their study showed that all of these factors make a large difference in regards to storm surge levels to this particular area of Florida. In their study, they ran 11 different scenarios changing these parameters for each. Their research
showed that the highest level of storm surge for Pinellas County would occur when a storm is positioned north of Tampa Bay, so that the maximum winds from the storm are at the mouth of the bay (Weisberg and Zheng 2006). Figure 15 shows a subaerial picture of Pinellas County with 1.5 meters of storm surge and 6 meters of storm surge which could possibly occur if a major hurricane made landfall at or near Pinellas County. Weisberg and Zheng (2006) ran their worst-case scenario model with a category 4 hurricane, which makes this a scenario where storm surge would be catastrophic, but not necessarily the “worst” case.

Figure 15. Bathymetric-topographic Tampa Bay demonstration project data set (NOAA-USGS)
Less storm surge was recorded if the hurricane made landfall further north along the coast. They also note that storms that approach from the north have greater storm surge than those approaching from the south. Another discovery was that storms with higher winds, for example category 4 storms will have a greater storm surge than storms with lower winds. This research is very important because like Needham and Keim’s (2011) research, it illustrates how a change in just one of the parameters of the storm can affect a certain area, like Pinellas County. They also suggested future studies using real time predictions in advance of an actual storm. The research also recognized the need to develop more accurate coastal weather forecasts to improve evacuation methods.

Though not focused on Pinellas County, research by Lin and Emanuel discusses the possibility of ‘grey swan’ storms and their impacts to coastal regions like Tampa in Hillsborough County. Grey swan tropical cyclones are storms with high impact that would not be predicted based on past storms alone but may be foreseeable by using physical knowledge along with historical data (Lin and Emanuel 2016). With the impact of storm surge as the main focal point, they enlisted multiple climate model simulations coupled with a very large synthetic surge database to come up with the worst-case scenario for the Tampa area. The results showed the worst-case scenario for Hillsborough and Pinellas County would be a category 5 storm traveling south to north and making a right turn, directly over Pinellas County. Figure 16 shows the worst case- strong category 5 simulated scenario, where the black line represents the path the storm would take and the resultant storm surge levels reaching 11.1 meters (Lin and Emanuel 2016). One of the reasons for the extreme storm surge is the fact that waves are trapped along the continental shelf as the storm travels northward along the coast (Morey et al. 2006). Once the storm makes landfall the water that was trapped, surges across the Pinellas County peninsula
from high elevation to lower elevations as seen in Figure 16. This will essentially cut off the higher areas of Pinellas County from resources and emergency help. Even though these residents would be spared from flooding from storm surge, they would still face issues when trying to venture out from their homes.

![Figure 16. Worst case scenario model (Lin and Emanuel 2016)](image)

The Tampa Regional Planning Council, along with other stakeholders in the Tampa area developed a plan in the event of a major hurricane impacting the Tampa area, including Pinellas County (Tampa 2010). The fictitious category 5 hurricane was given the name Hurricane Phoenix and the scenario has the hurricane making landfall in Pinellas County. Using SLOSH and HAZUS-MH models, the team could determine the impacts a storm of this magnitude would have in an area like Tampa Bay. Figure 17 shows the path of the storm and the storm surge associated with Hurricane Phoenix. Noticeably, most of Pinellas County is inundated to some extent.
The scenario was used to determine the physical damage, social impacts, and economic losses that were a direct result from this hypothetical hurricane. The results revealed the significant amount of damage Hillsborough and Pinellas counties would have. The number of damaged buildings was most abundant in Pinellas County showing a total of 425,113 with minor to major damage due to storm surge. The scenario also revealed the number of important structures throughout that would be affected including hospitals, schools, and emergency operations. The model also indicated that the airport in St. Petersburg/Clearwater would have significant flooding from storm surge. The number of entire households that would be displaced due to damage from storm surge and winds equaled 383,213 in Pinellas County, 42 percent of

Figure 17. Project Phoenix, storm track, and storm surge levels (Tampa Regional Planning Council 2010)
the county’s population. The estimated number of casualties directly related to the storm in Pinellas County is 889, with another 89 casualties related to post storm issues (Tampa 2010).

1.4 Vulnerability

The idea of what makes an area vulnerable can seem subjective and difficult to quantify in a study. Yet many studies have been focused on the idea of vulnerability, whether geophysical or social. The geophysical features can be more defined as the risk to an area while social systems characterize the vulnerability to an area (Chakraborty 2005). Vulnerability of any type can lead to devastation, especially if an area has multiple forms of vulnerability, as is the case with Pinellas County.

1.4.1 Geophysical Vulnerability

The geophysical vulnerability or risk is determined by the number and type of physical hazards an area is exposed to. These hazards can include events like fires, earthquakes, lightning, tornadoes, and hurricanes, just to name a few. Tobin and Montz (1997) created a list which categorized the components of hazards that contribute to geophysical vulnerability. Those components included: physical mechanism (magnitude, duration, and spatial extent), temporal distribution (frequency, seasonal patterns), spatial distribution (geographic location), countdown interval (preparation time, speed of onset). Some of the contributing factors to geophysical vulnerability in Pinellas County include, low elevation and proximity to large, warm bodies of water during hurricane season which lasts officially from June 1st to November 30th.

Geophysical vulnerability also includes how properties can be damaged or destroyed. During a hurricane, damage can be caused by strong winds, flooding due to storm surge or rain, tornadoes, debris falling, the list goes on. Areas with mobile homes, especially those in flood zones, are at a high risk to be destroyed not only be high winds, but also storm surge. A study on
people’s perceptions of geophysical vulnerability was done during the evacuation process for Hurricane Irma (Senkbeil et al. 2018). Residents at rest stops along their evacuation route were asked to rank their level of concern about how much damage they would receive back at their homes. They were also asked about their perception of the wind speed and at what wind speed damage would occur. This study showed that many people have misperceptions about windspeeds, even though this factor of a hurricane is of great concern.

One way to determine geophysical vulnerability is to utilize models to determine how a natural hazard may impact an area. The HAZUS-MH model, which was created by FEMA, is used to estimate potential losses that can occur from earthquakes, floods, hurricanes, tsunamis (FEMA).

1.4.2 Social Vulnerability

Social vulnerability has been a difficult concept to analyze, mainly because of the many different factors that could potentially affect an area’s social vulnerability. An important study on social vulnerability conducted by Cutter (2003) broke down the categories that characterize an area’s social vulnerability into eleven main factors. These factors included; personal wealth, age, density of built environment, single-sector economic dependence, housing stock and tenancy, race, ethnicity, occupation, and infrastructure dependence. These factors were all combined to create the Social Vulnerability Index (SoVI). An example of Pinellas County’s 2016 (SoVI) map created by the Center for Disease Control, is represented in figure 18. Where those areas with the highest vulnerability are shown in dark blue and those with lowest vulnerability is shown in light yellow.
In 2013, a study by Zhang (2013) discussed the idea of Social vulnerability as being described as the characteristics of a community that can influence their ability to prepare, resist, and then recover from the impacts from a hazard. Though social vulnerability has many contributing factors, as was discussed from Cutter’s (2003) research, it can be broken into two parts; human vulnerability and the ability to access resources (Zhang 2013). The study performed by Zhang, further expanded the idea of social vulnerability into four categories including population, career, economic, and infrastructure vulnerabilities. From these four categories vulnerabilities can be broken down into subcategories, much like Cutter’s (2003) work, but in the case of Zhang’s research, 26 subcategories were chosen to represent the

Figure 18. 2016 Social Vulnerability Index for Pinellas County (CDC)
vulnerability of an area. A few of the 26 subcategories chosen for this research included: population density, household composition, percent unemployed, income, percentage of old houses, and number of fire stations within a certain distance (Zhang 2013).

The built environment has changed drastically in past few decades, these changes in population density, social characteristics, and economic conditions, has led to more people living in highly geophysical vulnerable areas. With the changing social, physical, and economic structures, it is important to adapt emergency plans throughout time to reflect current vulnerabilities (Cutter 2008). Hurricane loss modeling historically has not included the social vulnerability component. However, multiple indices have been created to measure social vulnerability for an area. Some of them perform better than others as shown in the study done by Bakkensen, et. al. (2017) which compared five of the most prominent disaster indices used in the United States. The Social Vulnerability index (SoVI) outperformed the other models for declaring disasters. The SoVI, however did not perform as well when explaining damages or fatalities. This research, solidified the idea that there is no, one, perfect vulnerability index by which to solely depend, but that each, in its own right, can provide important information and further the understanding of how social vulnerability is an important component to include in damage assessments.

A study by Cutter and Emrich (2006), discussed the idea that social vulnerability is not distributed evenly between social groups or different areas and a common, standard approach to handling emergency preparations, response, and recovery may not be the most effective for a given area. In their study, Cutter and Emrich (2006); compared different Orleans Parishes, in Louisiana, impacted by flooding during Hurricane Katrina. Using the SoVI, they were able to see the many differences between the different parishes and their abilities to respond and
recovery after Hurricane Katrina. The primary factors of social vulnerability in these particular parishes are race, gender, and class. Interestingly though, two other factors were found to play a role, economic vitality, which showed that this area which relies heavily on agricultural business becomes more vulnerable since there is no alternative for revenue and employment (Cutter and Emrich 2006). The other important factor was debt/revenue ratio. This study demonstrated that social vulnerability can vary from area to area.

1.5 Evacuations

One effective way to save lives in the event of tropical cyclone storm surge; is to leave the area vulnerable to flooding. Many factors influence whether or not a person will choose to evacuate a particular area, including physical factors, social factors, or psychological factors. It can sometimes be difficult to study people’s behaviors during evacuation situation because like Baker (1979, 1991) and Lindell et al. (2005) mention, evacuees will change their plans as time progresses during a major hazardous event. The other shortcoming when studying evacuation can occur because of the potential for memory decay which can limit the accuracy of the data collected after the event (Stallings 2002). An early study by Baker (1991) documented the results of surveys conducted after hurricanes that took place from 1961-1989 in locations spanning from the coasts of Texas all the way around to the coasts of Maine, to better understand evacuation behavior. His research was an attempt to create a generic model of evacuation that can be used to predict evacuation behavior for any given hazardous event, not just hurricanes.

His research found that people’s reactions to evacuations is a difficult concept to precisely measure. However, the information gathered from three decades of hurricane
evacuations did show common trends, especially regarding factors like, risk area, types of housing, storm threat information, previous hurricane experience, length of residence in hurricane prone area, unnecessary evacuations in the past. He did note that demographic factors, like race and gender, did not play a vital role in evacuation decisions (Baker 1991).

A more recent study by Lazo et al. (2015), sought to analyze people’s decisions to evacuate based on two information conditions; seeing a hurricane forecast versus receiving an evacuation order. They surveyed residents in two different coastal areas, those in the Miami-Dade area of Florida and those in Houston-Galveston area in Texas. Choosing two different areas prone to Hurricane impact, added more information about how factors affecting evacuation decisions can vary across areas. The analysis of the study included many factors that could influence decisions such as, cultural worldviews, past experiences, risk perceptions. The study showed people who evacuated because of a forecast they saw on television or online were more self-motivated not mentioning the need to protect family or pets, and the people who evacuated because of an evacuation order said they did so to protect their family or pets. This study is important because it demonstrates protective actions do influence evacuation decisions. There were a few differences between the two states, which would indicate that differences in culture, experience, and vulnerabilities play a role in evacuation decision making. The study wraps up discussing the importance of having clear, developed evacuation plans and the importance of clearing up any misperceptions about risk and vulnerability (Lazo et al. 2015).

Another study that discusses people’s risk perceptions was done by Demuth et al. (2015). For this study, information was gathered from people to understand how past experiences with hurricanes influence their decisions to evacuate for future hurricanes. As stated in earlier research, past experiences can shape the way a person understands risks, and thus how they will
respond to future risks (Weinstein 1989). Also focusing their attention on the Miami Dade area in Florida, this study analyzed residents’ past hurricane experiences and the impact on evacuation by examining several aspects including, evacuation, property or financial loss, emotional impact, and overall severity of all impacts. What their research showed is that people did report emotional impacts, even when they did not experience any tangible losses like property. These negative effects; heightened residents’ decision to evacuate for the next hazard. Understanding the intangible experiences people have (those not directly related to property damage or injuries) could help provide better understanding to how and why people make decisions when faced with hazard risks. For example, people who did evacuate and incurred property damage (tangible experience) said they were less likely to evacuate the next time because they believed they could better protect their property. Thus, showing that past evacuations may deter people from future evacuations.

In the case of Hurricane Ike, discussed earlier, more than 100,000 residents along the Gulf coast of Texas refused to evacuate when urged. The most common reason people gave for not evacuating was they did not want to be stuck in traffic trying to leave, which was exasperated by the traffic issues that occurred during Hurricane Rita in 2005 when citizens of coastal Texas were asked to evacuate (Pappas 2011). When the 22 ft. storm surge inundated most of the coast after Ike made landfall, close to 2,000 people had to be rescued from the flooding, many even rescued during the storm (Arrillaga et al. 2008). Unfortunately, when storm surge causes this level of flooding, emergency crews cannot easily access the area and must rely on other methods like using boats or helicopters to rescue the residents who stayed behind, which takes more time and resources. Even these methods can be hampered by the amount of debris in the water. After
the flood waters have receded, it can still be difficult for emergency crews to get to people. Figure 19 shows the amount of debris blocking Highway 146 in Seabrook, TX.

![Debris along Highway 146 from Hurricane Ike](image)

**Figure 19. Debris along Highway 146 from Hurricane Ike (National Geographic)**

Seventy-four deaths in Texas alone were attributed to Hurricane Ike whether directly or indirectly (Zane 2008). More than 100,000 homes were flooded and many towns directly on the coast were completely destroyed leaving hundreds of thousands homeless. A study following Hurricane Ike, by Morss and Hayden (2010), demonstrated how people obtain, interpret and use hurricane forecasts and warnings can influence their decisions to evacuate. For their study, 49 residents who were affected by Ike along the Texas coast, were interviewed 5 weeks after landfall to discuss their perceptions of risk and their decisions to evacuate. The residents interviewed; stated they did not think the Saffir Simpson scale did an adequate job conveying the risk Ike posed. This indicates that people perceived there would not be much damage with a category 2 storm, since it is lower on the scale. The interviews also uncovered the variety of sources people used to determine their personal risks and make protective decisions. One important finding from the study is the fact that many of the interviewees had prepared their homes from strong winds, but did not take any precautions against flooding, which proved to be the more destructive force. Ike was a devastating example of what can happen when people
refuse to leave their homes during a mandatory evacuation. In another study that researched people’s perception of the meteorological hazards of a hurricane, the results showed that overall storm surge was perceived as the highest risk (Brommer 2010). Interestingly though, this survey focused on residents of the New Orleans areas as they were evacuating for Hurricane Gustav in 2008, just three years after Hurricane Katrina.

Technology and especially social media has become a valuable tool in researching how people behave in hazardous situations like hurricanes. Seeing the thoughts and reactions of people as they are happening has become an important research tool in analyzing how people react to and use information. A study by Morss et al. (2017) developed a better understanding of the role social media can play in risk communications, conceptualizing hazards, and evacuation decisions. An analysis of Twitter during Hurricane Sandy showed how people use social media platforms to understand, interpret, and pass on storm information. Figure 20 shows the number of Hurricane Sandy related tweets per hour in Rockaway, NY, before, during, and after. The analysis is important because the use of social media platforms is widely used to distribute information, including storm hazards and could impact evacuation decisions.

Though social media can be quite helpful, there is a risk of false information being spread to large amounts of people. False information can cause unnecessary panic. An example of false information was when people used their social media to share stories before Hurricane Irma, about the storm becoming a category 6, which obviously does not exist with the current Saffir-Simpson Scale (Snyder 2017). This type of false information spreads very rapidly on a platform like social media. It is very important that people are getting correct facts, from legitimate sources during times of emergency.
Two recent studies about evacuation decisions by Collins et al. (2017, 2018) provided further understanding into the factors that influence people’s decisions about evacuation. Both studies focused on evacuees and non-evacuees on the coasts of Florida. Both studies distributed surveys to analyze how social connections can affect evacuation behavior. The information gathered from the surveys was used to examine social connections using three dimensions, dependability, density, and diversity. The first storm where these methods were utilized was Hurricane Matthew in 2016. Once the data from the survey were analyzed the study showed that the person’s perceived dependability of social connections significantly impacted their decisions to evacuate or not (Collins et al. 2017). In the case of Hurricane Matthew, those who did not evacuate showed to have more dependable relationships, so they felt more comfortable staying within their community. Density and diversity of the social connections did not significantly influence the decision. The next evacuation scenario to be studied was during Hurricane Irma in 2017. Unlike Hurricane Matthew, Hurricane Irma’s data showed that density and diversity
played a more significant role in people’s decisions to evacuate and dependability did not significantly impact the decision (Collins et al. 2018). The differences that may have impacted these studies is the difference in the area in the cone of uncertainty, recent storms (Irma came very soon after the devastation caused by Hurricane Harvey) and perceived threat of the storm.

1.5.1 Past Evacuations in Florida

Florida citizens are no strangers to evacuation procedures, but unfortunately evacuations do not always run smoothly. The most recent example of a massive mandatory evacuation order was in September 2017 in preparation for Hurricane Irma. Hurricane Irma, a category 5 hurricane, was initially projected to make landfall along the southeast coast of Florida, near Miami. The citizens of Dade and surrounding counties were quick to heed Governor Rick Scott’s evacuation order especially since recollections from Hurricane Andrew, the last category 5 hurricane to strike almost the same area, were still in the minds of many residents. Mandatory evacuations were ordered for Zones A-C on September 7th. Zone A includes all areas that could be affected by an 11ft storm surge and all areas with mobile homes. Zone B includes areas that could be affected by a 15ft storm surge, and Zone Care areas that could be affected by a 20ft storm surge. This created the largest evacuation ever attempted by this area. A projected 650,000 people were instructed to leave their home and ride out the storm in safer areas (Douglas 2017). Figure 21 is an image taken from google maps, via mobile phone, showing the traffic along the interstates as people flee Miami, the Keys and other parts of southern Florida on September 7th (Google Maps). A couple days later, residents from the west coast would join the evacuees, as the storm shifted more to the west. In total, around 6.5 million residents of Florida
were under mandatory or voluntary evacuation orders, making it the largest evacuations ever ordered in the United States (Pinellas County, FL 2017).

![Map of Florida with traffic data](image1)

**Figure 21. Traffic prior to Hurricane Irma (Christianne Pearce, Google Maps)**

With the orders for evacuations, there is always a risk of stranding motorists stuck on interstates and highways due to the high volume of evacuees on the road. To avoid this issue, evacuation orders are issued early to allow people the time to arrive to their destination. The mayor of Miami also suggested to people fleeing to find a local shelter instead of leaving the county or state to avoid clogging the roads. To ease some of the issues with evacuations, Governor Scott lifted the tolls from major highways and advised people to use the shoulder to allow more options for evacuation (Mak 2017). Figure 22 displays the north bound traffic along interstate 75 on September 6th. Resources were running low at gas stations and grocery stores, as
more and more people either decided to ride out the storm in their homes or evacuate from the threatened area.

![Traffic heading north on I-75 (Christianne Pearce)](image)

Figure 22. Traffic heading north on I-75 (Christianne Pearce)

Even with measures taken to avoid gridlock, the issues with massive evacuations in Florida became clear. Gas stations were quickly running out of gas, traffic accidents were frequent, restaurants and stores along the interstate were running out of supplies. To make matters worse, the path for Hurricane Irma shifted and took aim at the west coast of Florida. On September 8th, the first of the mandatory evacuations for the west coast began, adding another 300,000 people to the interstates for escape (Smith 2017). The massive size of Hurricane Irma influenced people’s decision on where to evacuate to, and most headed north towards Georgia, unfortunately, so did Hurricane Irma. Figure 23 shows the final storm track for Hurricane Irma.
The issues concerning the interstates prior to the storm, returned once the storm moved through. Urgent to return to their homes to check for damage, the millions of residents would have to make their way back into Florida. Unfortunately, supplies and gas remained depleted, with the gridlock in the southbound lanes of the interstates now, making supply deliveries to areas in need very difficult.

The uncertainty in the storm’s path may have caused more evacuations than necessary, but it also demonstrated the amount of people willing to evacuate. The data surrounding these evacuations is still underway, but like this research, may provide a better insight who evacuates and why. It will also provide better data on how to handle large scale evacuations in the future.
CHAPTER TWO:
RESEARCH DESIGN

2.1 Problem Statement

The problem addressed in this study is the vulnerability of Pinellas County in the event of worst-case storm surge scenarios associated with hurricanes and people’s decisions to evacuate. This problem is important because according to some of the studies about a worst-case scenario storm surge impact (Weisberg and Zheng 2006; Lin and Emanuel 2016) a majority of Pinellas county will be flooded, which would affect a large percent of the population of Pinellas county. Unfortunately, people’s decisions to evacuate during Hurricane Irma may have impacted their future decisions to evacuate. This study will use a mixed methods approach to explore the areas that could be impacted by storm surge and evacuation decisions of the residents in these vulnerable areas. Failure to evacuate could lead to major casualties in a major storm surge event.

2.2 Objectives and Research Questions

This project attempted to address several research questions concerning storm surge and evacuation methods in Pinellas County. These are:

- Who are the population in Pinellas County that could be affected by a worst-case storm surge scenario as mentioned in previous research?
  - How many people could be affected?
  - What are the demographics of people who could be affected?
  - To what extent might the demographics influence the number of people who
would evacuate?

- For Hurricane Irma, did people under a mandatory evacuation follow the orders to evacuate and why?
  - What factors influenced people’s decisions to evacuate or not (social, physical, economic etc…)?
- What are the main issues people in vulnerable areas faced when trying to evacuate for Hurricane Irma?
  - Will these issues affect people’s decisions to evacuate in the future?
- Do people perceive storm surge to be a risk?
- Does the risk of storm surge flooding impact people’s decisions to evacuate?

2.3 Study Area

Pinellas County is a peninsula surrounded by the Gulf of Mexico and Tampa Bay, making this area vulnerable to storm surge and flooding. This area is a popular tourist destination due to the miles of white sandy beaches, countless water activities, and a multitude of beachfront hotels. It is also a popular area for retirees from the northern states to settle down and escape the snow. Pinellas County is very diverse in regards to demographics. There are areas of extreme poverty adjacent to areas of extreme wealth. Mobile home parks are as prevalent as multi-million dollar mansions. There are hospitals, waste treatment plants, schools, emergency operation facilities, numerous marinas, multiple recreation areas, an airport, and more critical areas that would all be susceptible to storm surge flooding.

Pinellas County has many areas just at or barely above sea level, making most of the county very vulnerable to storm surge associated with a hurricane. At 970,637 people, Pinellas
County is the 6th most populous county in Florida, (Census, 2010). It is important to understand what is at stake when it comes to storm surge damage, especially since this area of Florida has not had a direct hit by a hurricane in almost one hundred years. For the first part of this study, the focus was on the areas identified, by a worst-case scenario model, similar to the ones researched by Weisberg and Zheng (2006) and Lin and Emanuel (2016), to be the most vulnerable to storm surge during hurricane events and the different demographics that lie in these areas. To have a better understanding of how people react and handle evacuations, and to determine how their future decisions might be impacted by past decisions, residents in the vulnerable areas identified were surveyed. Figure 24 shows the Pinellas County evacuation zones and from a first glance it is clear to see that much of the county is in some sort of an evacuation zone.

Figure 25 shows the different emergency management operations sites. Those represented include, fire stations, and police stations. From this image it is clear which are in danger of being affected by storm surge, which could result in less availability in the case of emergencies after the storm due to flooding, debris, or damage to the facility.

Figure 26 shows the location of all the private and public schools, including charter schools around Pinellas county, many could potentially be impacted by storm surge. This would disrupt the school year and contribute to the amount of money needed to rebuild or repair those learning facilities affected.

Figure 27 shows all the medical buildings including assisted living facilities for the elderly. Figure 28 shows the location of the abundance of mobile home parks distributed across the county, many in zones that would be affected by storm surge. Evacuation routes are represented in red in figure 29.
Figure 24. Pinellas County Evacuation Zones 2018 (Pinellas County Emergency Management)
Figure 25. Emergency management systems represented (GIS)
Figure 26. Pinellas County Schools (GIS)
Figure 27. Pinellas county Medical Buildings
Figure 28. Mobile home parks in Pinellas county
Important infrastructure all throughout Pinellas County lies in areas that could potentially be affected by storm surge caused by a hurricane. Even the evacuation routes could be dangerous to cross once conditions deteriorate, and the amount of people from other counties also evacuating adds to the traffic, making it very important to heed evacuation decisions at the start of an emergency. Waiting till the last minute, or even during the storm would be hazardous and many paths may already be damaged or covered with water.
2.4 Data and Methods

2.4.1 Vulnerability Data Collection

To understand the areas in Pinellas County that are geophysically and socially vulnerable, a combination of GIS, Social Vulnerability Index, and Census Tracts were analyzed. The social vulnerability index was used to determine socially vulnerable areas in Pinellas county. The complete Pinellas County social vulnerability index created by the CDC is shown in figure 30. The darker blue areas on the map below indicate the areas found to be the most vulnerable overall including variables like socio-economic data, housing composition, ethnicity and transportation. Figure 31 breaks down the four categories to individually show what areas are most vulnerable in those aspects.

Figure 30. Social Vulnerability of Pinellas County (CDC)
Below is a GIS map created to show where these areas determined to be socially vulnerable intersect those areas in evacuation zones. This shows where the socially vulnerable and geophysically vulnerable overlap. The social vulnerability index is represented by the varying shades of blue as shown above, and the evacuation zones are represented by colors
purple, green, yellow, orange and red. With red being evacuation zone A, those first to evacuate.
The social vulnerability index was made transparent to show where the vulnerabilities were both represented and the areas that had social vulnerabilities and were also in an evacuation zone are represented by the maroon polygons in figure 32.

**Figure 32. Overlay of social vulnerabilities and geophysical vulnerabilities (GIS)**
2.4.2 Survey Data Collection

These areas determined to be both socially and geophysically vulnerable were the target locations for the distribution of the survey instrument (see appendix A). The survey consisted of 23 items and several components including, household socio-demographics, resource assessment, and past and future evacuation decisions. The survey was distributed in public areas known to have abundant foot traffic. These included major shopping centers like Target, Publix, and Walmart. Three separate locations were used as distribution sites to make the surveys more random and to increase the sample size. The surveys were administered over two days with three teams, consisting of graduate and undergraduate students from the University of South Florida summer Research Experience for Undergraduates Program, surveying in three different locations.

The areas selected for the surveys are represented as squares labeled 1, 2 and 3 in the evacuation zone map (Figure 33). Square 1 is in the East Clearwater area, square 2 is in the St. Petersburg area, and square 3 is Pinellas Park. The red areas represent zone A, orange zone B, and yellow zone C. These locations were chosen due to their proximity to an A, B, or C evacuation zone. Students conducting the survey approached any Pinellas County residents, willing to take the time to answer the survey questions, which generally took about ten minutes to complete. To participate in the survey, the person had to be a resident of Pinellas county during the time of Hurricane Irma and had to be over the age of 18. During the process, many residents who lived through the experience of Hurricane Irma, were very willing to share their stories and experiences, even though the surveys were distributed nine months after impact. To
avoid issues with literacy, our surveyors read the survey to the participant and marked the survey tool for them.

To address the research questions regarding evacuation, the survey included categorical and short answer questions addressing their evacuation decisions for Hurricane Irma, including reasons why they chose to evacuate or not. A Likert scale measure was included to rate what information sources they relied on the most to make their evacuation decisions. Questions were included to determine if peoples’ future evacuation decisions have been affected by Hurricane Irma. A Likert scale was included for residents to rate how the various threats during a hurricane influenced their decision to evacuate. The inclusion of this question will help determine if people perceive storm surge as a major threat during a hurricane.

![Figure 33. Areas chosen for evacuation surveys (Pinellas County Emergency Management)](image)
2.4.3 Statistical Data

Once the surveys were coded and cleaned, multiple analyses of the data were performed using the statistical program SPSS version 25. To find if any significance association exists between two variables, such as different demographics and evacuation decision, or evacuation decisions past and future, or storm surge if storm surge has an influence on evacuation decisions, a Pearson’s Chi- Square test was performed.

The data for the study were provided from the 234 surveys that were completed. Residents could choose not to answer questions, so some variables were left blank leading to some missing data points. The different demographics represented by those who participated in the survey is as follows. Of those surveyed, 31.2 percent were male, and 67.7 percent were female. The average age of responders was 45 years old. Many different ethnicities were represented, with the majority, 70 percent being white. Out of the residents surveyed, 26.9 percent reported someone in the household having a disability. Of those surveyed, 40 percent had a college degree. Others had some college or a high school diploma. The average annual household income was $40,000-49,999. The average length of time of residency in Florida was 26.5 years.

The demographics of Pinellas County provided by the US Census Bureau shows the county having 52% females, 82% are white, 9.8% have a member of the household with a disability, 30 % have at least a bachelor’s degree, and the median household income is $48,968 (US Census 2010).

Even with three different locations chosen for the survey distribution many people from multiple zip codes participated. Table 1 shows the distribution and frequency of different zip codes. Figure 34 shows a map of the different zip codes and their locations in Pinellas County.
along with the evacuation zones represented by the colors red, yellow, orange and green. The five zip codes that were most abundant are outlined in light blue and shows that all of them are in an area that has a possibility of flooding.

Table 1. Count of zip codes represented by survey participants

![Histogram of evacuation zip codes](image)

Figure 34. Counties with highest number of participants in survey
CHAPTER THREE

ANALYSIS

Using a simulation similar to the worst-case scenarios discussed by Weisburg and Zheng and Lin and Emanuel, a SLOSH map was created. The map created, figure 35, shows a simulation of what the storm surge for a category 5 hurricane moving north at 10 mph over Pinellas county during high tide would be like. The blue flags show the tide levels in feet. It can be seen that most of Pinellas County experiences minimal to extreme flooding, with only those areas well above sea-level remaining dry.

Figure 35. SLOSH model of category 5 hurricane (SLOSH)
The three cities used for the survey, Clearwater, Pinellas Park, and St. Petersburg would all experience flooding. The populations for these cities respectively; 107,685, 49,079, and 244,769. That’s a total of 401,533 residents that live in these three cities, 43 percent of Pinellas County’s population. The residents not in the storm surge zones, would also be impacted, due to road closures and would find themselves cut off from resources and emergency help.

3.1 Demographics

A total of 234 residents participated in the survey. Of those 234, 145 or 62% made the decision to stay home or in their local area within the same evacuation zone, only 64 residents or 27.4% decided to leave the area and 25 residents or 10.7% chose to go to a shelter. To answer the question if demographics affected resident’s decisions to evacuate of not, a Chi-Square analysis using SPSS 25 was created comparing evacuation decision to demographic information. First, table 2, comparing gender and evacuation status was created. Table 2 shows the Chi-Square test results. According to the tests, gender, education level, and annual household income did have a significant association with evacuation status.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-Squared Value</th>
<th>Significance between variables (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation status &amp; Gender</td>
<td>10.267</td>
<td>.036</td>
</tr>
<tr>
<td>Evacuation status &amp; Ethnicity</td>
<td>9.672</td>
<td>.289</td>
</tr>
<tr>
<td>Evacuation status &amp; Education</td>
<td>15.250</td>
<td>.018</td>
</tr>
<tr>
<td>Evacuation status &amp; Annual</td>
<td>28.542</td>
<td>.027</td>
</tr>
<tr>
<td>Household Income</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In terms of percentages, table 3 shows 98 out of the 157 or 62.4% of women surveyed chose to stay home or their local area. Of the men surveyed, 44 out of 73 or 60.3% chose to stay home or in local area. The percentage of women who chose to evacuate was 30.6% and 21.9% of men decided to leave the area.

Table 4 shows the comparison of ethnicity with evacuation decision. The majority of all the ethnicities represented made the decision to stay home or in their local area. However, there was no significance between the ethnicity of the resident and their decision to evacuate. The ethnicities represented included, white residents, 97 out of 164 or 59.1%, African American residents, 30 out of 39, or 76.9%, Latino’s 9 out of 13 or 69%, Asian Pacific Islander, 3 out of 7 or 42.9%, and other 4 out of 8 or 50%. Whites did have the highest percentage of residents leave the area compared to the other ethnicities, however it is acknowledged that the numbers of some other ethnicities in this study are lower.
Highest education level was another demographic determined by the survey. The results are shown in table 5. Of the 65 with a high school diploma or GED, 40, or 61.5% decided to stay home or in local area. Likewise, those with some college and those with college degrees who decided to stay home or local area, were 65.1% and 63.8% respectively. The percentages for those deciding to evacuate were high school diploma/GED, 21.5%, those with some college, 23.1%, and those with a college degree 32.2% Again, according to the Chi-Squared test, there was a significance between education level and evacuation decision.
The last demographic determined by the survey was annual household income. From table 6, the majority of almost all income brackets chose to stay home or in their local area. Most people, regardless of income decided to ride out the storm in their own houses or at a friend or family’s house nearby, but there was a significance according to the Chi-Squared analysis between annual household income and evacuation decision.
According to these residents interviewed for this survey, some of the demographic variables like gender, education level and annual household income did have a significant association to their evacuation decisions.

### 3.2 Evacuation Decisions

The decision to evacuate can be a difficult decision to make. Mandatory evacuations do not ensure that everyone evacuates who should, as many people still decide to remain in their homes. With the SLOSH scenario created for this study, the residents in all types of evacuation zones would experience flooding of some degree. Deciding to stay in their homes could cost them their lives. Table 7 shows the comparison of evacuation types with the evacuation decisions. The chart shows that only 41 of the 92 residents in the mandatory evacuation zone left the area and 16 out of the 92 went to a shelter outside of the evacuation zone. Only 18 of the 97 residents in the voluntary evacuation zones left the area and 6 of the 97 went to a local shelter outside of the evacuation zone. Even though mandatory evacuations are called, many people in this case, preferred their own homes regardless of the dangers instead of trying to leave the area.

#### Table 7. Evacuation status vs evacuation zone type (SPSS)

<table>
<thead>
<tr>
<th>Evacuation Status</th>
<th>Evacuation Zone Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mandatory</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Shelter outside evac zone</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Home or Local Area</td>
<td>35</td>
<td>73</td>
</tr>
<tr>
<td>Left area</td>
<td>41</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>97</td>
</tr>
</tbody>
</table>

To understand what affected evacuation decisions for these residents, different questions were asked. One of the first sections of the survey included a Likert scale to rate how much the resident relied on different forms of media to inform their decision, with 0=not relied on at all
and 4=relied on the most. The results are displayed in Table 8. The most relied on source for evacuation decisions was the local media, or local news stations, followed by national media. The least relied on source was print media followed by radio broadcasts.

Table 8. Role of Media on Evacuation Decision (SPSS)

A Chi-Squared analysis was also performed comparing the evacuation status to the type of media to see if there was a significant association between the two. Table 9 shows the results of each of the tests. The $p$-values for all of the variable comparisons except, government officials were greater than .05, indicating the only significant association between media and evacuation status for this group of residents was government officials.

After determining what types of media, the residents were more likely to follow, what type of social relationships affected evacuation decisions was also determined with a Likert scale with the same type of rating. The results in Table 10 shows that the residents participating in this
survey did not rely heavily on any relationships to make their decisions according to the percentages.

**Table 9. Evacuation status and media sources Chi-Square analysis**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-Squared Value</th>
<th>Significance between variables (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation status &amp; National media</td>
<td>7.986</td>
<td>.435</td>
</tr>
<tr>
<td>Evacuation status &amp; local media</td>
<td>4.778</td>
<td>.781</td>
</tr>
<tr>
<td>Evacuation status &amp; electronic media</td>
<td>8.747</td>
<td>.364</td>
</tr>
<tr>
<td>Evacuation status &amp; print media</td>
<td>7.692</td>
<td>.464</td>
</tr>
<tr>
<td>Evacuation status &amp; radio broadcasts</td>
<td>7.162</td>
<td>.519</td>
</tr>
<tr>
<td>Evacuation status &amp; government officials</td>
<td>15.846</td>
<td>.045</td>
</tr>
</tbody>
</table>

**Table 10. Role of relationships on evacuation decision**

[Bar chart showing the role of different relationships on evacuation decision.]

61
A Chi-Squared analysis was also completed on each of the relationship variables compared to evacuation status to see if there was any significance (p<.05). Table 11 shows the results from this analysis. From this analysis, no significant association exists between the evacuation status of these residents and their social connections.

**Table 11. Evacuation status and social relationships Chi-Squared analysis**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-Squared Value</th>
<th>Significance between variables (p&lt;.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation status &amp; family nearby</td>
<td>6.747</td>
<td>.564</td>
</tr>
<tr>
<td>Evacuation status &amp; family far away</td>
<td>11.521</td>
<td>.174</td>
</tr>
<tr>
<td>Evacuation status &amp; neighbors</td>
<td>5.088</td>
<td>.748</td>
</tr>
<tr>
<td>Evacuation status &amp; friends nearby</td>
<td>8.515</td>
<td>.385</td>
</tr>
<tr>
<td>Evacuation status &amp; friends far away</td>
<td>5.604</td>
<td>.691</td>
</tr>
</tbody>
</table>

Residents who participated in the survey were also asked if there were any other reasons why they decided to evacuate or stay at home or in their local area. Some of the reasons for evacuating included; worried about damage, living on the bottom floor of apartments, wanting to avoid power outages, and keeping family safe. Reasons for not evacuating included; did not live in an evacuation zone, felt like their structure would be safe, did not want to leave pets, and did not believe the storm would be that bad.

To determine if their decision to evacuate for Hurricane Irma will impact their future decisions to evacuate for other major hurricanes threatening to impact Pinellas County, a Chi Square test was run using their evacuation status for Irma and the decision to evacuate for the
next major hurricane as the variables. Table 12 shows the results from the Chi- squared test and based on these results, it can be stated that there was a significant association between evacuating for Hurricane Irma and evacuating in the future ($\chi^2(1) = 16.63, p < .0001$). Surprisingly, even with the trials and tribulations people faced during the evacuation process for Hurricane Irma, this survey showed that most people would evacuate for the next major hurricane. Luckily, with the dangers of storm surge during a hurricane, evacuation is the best way to save lives. If this survey is any indication of how others in Pinellas County feel, they will leave the area, instead of risking being stranded due to storm surge, or risking their lives.

**Table 12. Evacuation status vs evacuation decision for next hurricane**

The actual number of residents from this study who would evacuate for the next major storm are shown in the table 13. Though the majority of these residents answered that they would evacuate for the next hurricane, 36.3% still said no. If we applied that percentage to the entire population of Pinellas county, that would be just under 300,000 residents that would stay behind and risk being in danger of storm surge. The reasons why they would choose to evacuate are included in table 14. The survey participants were able to choose from flooding, wind damage,
safety issues, power outages, and they were able to add in any other reasons why they would evacuate. The other reasons people gave included; avoiding damage to car, food and water shortages, living on ground level of buildings, and keeping family members safe.

Table 13. Percentages of evacuation decisions (SPSS)

<table>
<thead>
<tr>
<th>Valid</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>85</td>
<td>36.3</td>
</tr>
<tr>
<td>Yes</td>
<td>145</td>
<td>62.0</td>
</tr>
<tr>
<td>Total</td>
<td>230</td>
<td>98.3</td>
</tr>
<tr>
<td>Missing</td>
<td>999</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>234</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 14. Reasons why residents will evacuate for next hurricane (SPSS)
The residents who decided to stay home instead of evacuating were also asked to choose reasons why, including transportation, pets, family members, disabilities, damage to house, looting, finances, and the option to add in any other reasons. The results are represented in the table 15. According to the graph, the highest percentage of people said they would stay home because of their pets, which means these residents were not aware that many shelters allowed pets. Better communication about shelters could save lives. Some of the other reasons included, being through many hurricanes where nothing happened, it’s more fun to stay home since it’s like camping, money issues, and house is well prepared.

**Table 15. Reasons why residents will not evacuate for next major hurricane (SPSS)**

![Pie chart showing reasons for not evacuating](image)

The final part of the survey was for the resident to add any other comments about their evacuation experience during Hurricane Irma and the following are some of the quotes taken straight from the surveys.

“First storm to actually scare me, since it was at first a category 5”

“Brutal, but did not lose power.”
“Didn’t leave mainly because of work, preparing for future storms now, buying a generator.”

“Evacuate! Safe, better than sorry.”

“Good response after the storm.”

“Hurricane centers could have done a better job, shelters giving mixed signals.”

“It was horrible, house fire caused after the storm from power pole falling on house.”

“People need to pay attention to the news, and young people need watch news more.”

“Power nightmare, 9 days without power, no ice, no gas.”

“Shelters need to provide better food, need more reliable generators, need better sleeping arrangements, terrible experience at shelter, lack of transportation so had to bike there, because I don’t have a car.”

### 3.3 Storm Surge Perceptions

To determine if people perceive storm surge to be a threat and if it has any influence on their evacuation decisions, a section of the survey addressed this question. This section included a Likert scale where they could rate how each type of storm threat, influenced their decisions 0=not influenced at all and 4=influenced the most. The different threats of the storm included storm surge flooding, strong wind, flooding from rain, size of storm, and tornadoes. The tables (16-20) below show the results for this section of the survey.

The percentages represented in the graphs above show that size of storm and strong winds influenced residents’ decisions the most, much like in the study by Senkbeil et.al. (2018). In regard to storm surge, people were split with 30% not influenced at all and 31% influenced the most. According to these responses, storm surge does not seem to have much influence on evacuation decisions. To show there was no significance between storm surge threat and evacuation decision a chi square test was run on the two variable and the results below show there was no significance between the two $\chi^2(1) = 14.661, p > .05$). Unfortunately, as in the case
of Hurricane Ike in 2008, if people decide to only evacuate for the size of a storm or the strength of wind, they could still experience devastating storm surge and risk losing their life.

Table 16. Influence of storm surge on evacuation decision

<table>
<thead>
<tr>
<th>Storm Surge Flooding influenced decision</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not influenced</td>
<td>30</td>
</tr>
<tr>
<td>Influenced a little</td>
<td>20</td>
</tr>
<tr>
<td>Influenced</td>
<td>10</td>
</tr>
<tr>
<td>Influenced a lot</td>
<td>10</td>
</tr>
<tr>
<td>Most influenced</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 17. Influence of strong winds on evacuation decision

<table>
<thead>
<tr>
<th>Strong Winds Influenced</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not influenced</td>
<td>10</td>
</tr>
<tr>
<td>Influenced a little</td>
<td>20</td>
</tr>
<tr>
<td>Influenced</td>
<td>30</td>
</tr>
<tr>
<td>Influenced a lot</td>
<td>20</td>
</tr>
<tr>
<td>Most influenced</td>
<td>40</td>
</tr>
</tbody>
</table>
Table 18. Influence of flooding from rain on evacuation decision

<table>
<thead>
<tr>
<th>Flooding from Rain influenced</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Influenced</td>
<td></td>
</tr>
<tr>
<td>Influenced a little</td>
<td></td>
</tr>
<tr>
<td>Influenced</td>
<td></td>
</tr>
<tr>
<td>Influenced a lot</td>
<td></td>
</tr>
<tr>
<td>Most Influenced</td>
<td></td>
</tr>
</tbody>
</table>

Table 19. Influence of size of storm on evacuation decision

<table>
<thead>
<tr>
<th>Size of Storm Influence</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Influenced</td>
<td></td>
</tr>
<tr>
<td>Influenced a little</td>
<td></td>
</tr>
<tr>
<td>Influenced</td>
<td></td>
</tr>
<tr>
<td>Influenced a lot</td>
<td></td>
</tr>
<tr>
<td>Most Influenced</td>
<td></td>
</tr>
</tbody>
</table>
Table 20. Influence of tornadoes on evacuation decision

<table>
<thead>
<tr>
<th>Tornadoes influenced</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Influenced</td>
<td>35</td>
</tr>
<tr>
<td>Influenced a little</td>
<td>10</td>
</tr>
<tr>
<td>Influenced</td>
<td>15</td>
</tr>
<tr>
<td>Influenced a lot</td>
<td>5</td>
</tr>
<tr>
<td>Most Influenced</td>
<td>40</td>
</tr>
</tbody>
</table>
CHAPTER FOUR

CONCLUSIONS AND FUTURE WORK

Storm surge from hurricanes is one of the most devastating natural disasters. The role storm surge plays in devastation is not always understood by the residents in the path of a hurricane. Deciding to not evacuate for a hurricane because it is not a category 4 or 5 could lead to fatalities. Evacuating for a storm can be a stressful, fearful event that many people rather not take part in. If they do evacuate for a storm and their area is spared by the storm this could lead to the decision to stay in their home or local area for the next storm that threatens. This study used the case of Pinellas County, an area of Florida both geophysically and socially vulnerable to storm surge, after Hurricane Irma to determine what factors played a role in the decision to evacuate, if their decision to evacuate or not for Hurricane Irma would affect their decision to evacuate for future storms, and if they perceived storm surge to be a major issue with hurricanes.

What this study found some demographic variables like gender, education level, and annual household income did have a significance in the evacuation decision. The only type of media to have a significant impact was government officials, and social relationships did not show any significance when making the evacuation decisions. This study also revealed that many people did not evacuate for Hurricane Irma, even under mandatory evacuation orders. However, when asked if they would evacuate for the next storm, majority of those surveyed said they would evacuate for the next hurricane. After running a Chi-Squared analysis, it was determined that the residents’ decision to evacuate for Hurricane Irma was significantly associated to their decision to evaluate for the next hurricane. When sharing their stories at the end of the survey, many
people described the power outages were terrible, and many lacked resources during this time. People who did go to local shelters, were not happy with the conditions there. After a frightful 2017 and 2018 hurricane season where people all around the nation watched as Hurricane Maria in 2017 caused massive destruction to Puerto Rico, and then in 2018 Hurricane Michael barreled through the peninsula of Florida as a very powerful category 4 storm leaving little more than remnants in its wake, it is understandable that people have a stronger sense of urgency to leave a threatened area.

Flooding due to storm surge was found to not have a significant influence on people’s decisions to evacuate, instead wind speed and size of storm were more influential. Unfortunately, if scenarios like those modeled by studies like Weisberg and Zhang or Lin and Manuel or the one created in SLOSH for this study, were ever to become reality, many people would suffer from the impacts of storm surge.

Some of the limitations of this study would be the small sample size. Having only 234 participants may not have adequately represented the population of Pinellas County. Another limitation would be length of time between the actual event and the survey. Memory decay (Stallings 2002) could have caused the participants to remember the situation differently than what actually transpired which could affect how they answered survey questions. With the surveyors in control of the survey, the participant may have not been entirely truthful with certain answers due to embarrassment. Missing data due to non-responses could have also affected the data. The rejection rate was moderately high at 40%.

This research will add to the literature on evacuation decisions, in particular for those residents who live in geophysically and socially vulnerable areas. Understanding what influences evacuation decisions can save lives. This research could also be used to help decision makers in
other areas of similar vulnerabilities. Further research into better communication during emergency situations would be beneficial for this area of Florida, since some of the residents discussed not knowing if shelters would accept pets or which ones were even open or available. Performing a similar study after a longer period of inactivity would determine if these residents in vulnerable areas would still choose evacuation for the next storm or with a major hurricane as a distance memory would choose to stay in the comfort of their own home. Other studies could discuss the economic impact storm surge from a hurricane would have in Pinellas County, or the other hazards that this area could face in the event of a major hurricane making landfall.
CHAPTER FIVE

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Appendix A:
Hurricane Evacuation Decision Making and Risk Perception Survey

Hello, my name is _______ and I’m part of a research team from the University of South Florida in Tampa. We are conducting a survey of Florida Residents about their hurricane experiences. Your answers will be kept completely confidential. That means we will never reveal your personal identity, but instead will report all information gathered in group form. You are under no obligation to participate in the survey and may stop answering questions at any time.

WERE YOU LIVING IN PINELLS COUNTY AT THE TIME OF HURRICANE IRMA IN 2017? (If YES, continue. If NO – state the survey is only for Pinellas County residents, thank you)

1. Would you like to continue with the survey?       [  ] Yes
                                               [  ] No

(If YES, continue. If NO, stop and thank individual, then RECORD THE NO RESPONSE of those 18 or older).

2. What is your age? ____________
    under 18  (DO NOT CONTINUE THE SURVEY, only participants 18 or older)

The first set of questions are about your previous evacuation experiences with hurricanes. By evacuation we mean, leaving the geographic area that was threatened by the storm. This does NOT include staying in a local shelter still in the storm area.

3. With regards to Hurricane Irma in 2017, did your household
    [  ] Go to a shelter outside of evacuation zone
    [  ] Stay at home or in your local area
    [  ] Leave the area threatened by Hurricane Irma, but did not go to a shelter

4. Did your household leave the area threatened by any hurricanes between 2004 and 2016?
    [  ] Yes
    [  ] No
    [  ] DK

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5. Not counting Hurricane Irma, what was the LAST hurricane you remember evacuating for?
____________________________

The next set of questions are about your hurricane evacuation decision.

6. When did you decide to evacuate or not for Hurricane Irma e.g. Day of, or 2 days before?
____________

7. What is the City and Zip you were at when you made your decision to evacuate or not?
CITY: _______________ ZIP:_____________

8. Have you moved since Hurricane Irma?
[ ] No
[ ] Yes, new City: _______________ Zip:_____________

9. On a scale of 0-4, with 0 being Not relied on at all & 4 being relied on the MOST, please rate the following hurricane information sources on how much you RELIED on it in your decision to stay or go.

<table>
<thead>
<tr>
<th></th>
<th>NOT relied on at all</th>
<th>Relied on only a little</th>
<th>Relied on</th>
<th>Relied on a lot</th>
<th>MOST relied on</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Media</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. Weather Channel, CNN, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Media</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. Local news or cable shows)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic Media</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. Internet news and weather websites)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIST websites used most:</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Print Media</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. Newspapers)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Radio broadcasts</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. AM, FM, Satellite)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Government Officials</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(e.g. Emergency managers, elected officials, etc)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family nearby you</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(within 50 miles away)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
10. If you left the threatened area with Hurricane Irma, did anyone in your household evacuate with you and why? ________________________

11. If you did not leave the threatened area with Hurricane Irma, did anyone in your household stay with you and why? ________________________

12. Did anyone outside your household stay with you or evacuate with you? If so who (i.e. what relationship do they have to you: relation (what?), neighbor etc)? ________________________

13. If you have pets, did that influence your decision to evacuate or not? __________

14. Which evacuation zone were you living in at the time of Irma?
[ ] Zone A
[ ] Zone B
[ ] Zone C
[ ] Zone D
[ ] Zone E
[ ] None
[ ] Don’t know

15. Which type of evacuation zone were you living in at the time of Irma?
[ ] Mandatory
[ ] Voluntary
[ ] None
[ ] Don’t Know

16. If you were in an area that received an evacuation order did you follow that order?
[ ] Yes
[ ] No
17. What do you understand ‘Hurricane Warning’ to mean? Choose one answer.

<table>
<thead>
<tr>
<th>A hurricane could possibly impact the area in 24 hours or less</th>
<th>A hurricane is expected to impact an area in the next 36 hours.</th>
<th>The anticipated onset of tropical-storm-force winds are expected within 36 hours.</th>
<th>Don’t Know</th>
</tr>
</thead>
</table>

18. Please rate the following questions regarding your friends and family on a scale of 1-4, where 1 is strongly disagree and 4 is strongly agree.

<table>
<thead>
<tr>
<th>Most of my friends know each other</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>My good friends also know my family members</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>My neighbors come to my parties</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I send my neighbors holiday cards</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>At work, I meet completely different people than during leisure time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I do not easily ask for help when I need it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I can’t expect my neighbors to help me with serious problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I can’t expect my colleagues to help me with serious problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Before I trust someone, I have to be sure of his/her intentions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

19. Please rate how the following influenced your decision to evacuate or not for Hurricane Irma. 0 didn’t influence at all, 4 influenced most.

<table>
<thead>
<tr>
<th>Flooding from storm surge</th>
<th>NOT influenced me at all</th>
<th>Influenced only a little</th>
<th>Influenced a lot</th>
<th>MOST Influenced me</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong winds</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Flooding from rain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
20. Had Pinellas County received a direct hit, here is what could have happened. *(Show visual of the storm surge impact to the current location).*
Would you have made the same decisions?
[ ] No, because ________________________________________________________________
[ ] Yes, because ________________________________________________________________

21. Will you choose to evacuate the next time there is a major hurricane forecasted to impact your area?
[ ] YES
[ ] NO

If no, why? Check all that apply:

[ ] Transportation issues
[ ] Pets
[ ] Family members
[ ] Disabilities
[ ] Risk of damage to house
[ ] Risk of looting
[ ] Finances
[ ] Other reasons: ________________________________________________________________

If yes, why? Check all that apply:

[ ] House may flood
[ ] Wind damage may occur
[ ] Safety
[ ] Power outage issues
[ ] Other reasons: ________________________________________________________________

22. These couple of questions will help us gather some demographic information for the study. Again, please remember that this information will remain confidential and will not be linked back to you.
<table>
<thead>
<tr>
<th>Does anyone in Hshold have a disability?</th>
<th>[ ] Yes</th>
<th>[ ] No</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long have you lived in FL?</td>
<td>_____ weeks</td>
<td>_____ months</td>
</tr>
<tr>
<td>Have you ever lived in another state that was impacted by hurricanes?</td>
<td>[ ] Yes</td>
<td>[ ] No</td>
</tr>
<tr>
<td>If so, how long were you there?</td>
<td>HOW LONG?</td>
<td>____________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>[ ] Male</th>
<th>[ ] Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnicity</td>
<td>[ ] African American</td>
<td>[ ] Latino</td>
</tr>
<tr>
<td>Education (highest completed)</td>
<td>[ ] &lt; HS grad</td>
<td>[ ] HS Grad/GED</td>
</tr>
<tr>
<td>Annual Household Income</td>
<td>[ ] &lt; $20k</td>
<td>[ ] $20k - $29,999</td>
</tr>
</tbody>
</table>

23. Is there anything else you would like to tell us about your Hurricane Irma experience?

*Thank you for your time!*

Data Collector Initials: ________________
Appendix B:
List of Figures and Images Fair use Arguments

Figure 2: Public domain, educational use (www.NOAA.gov)
Figure 3: Public domain, educational use (www.NOAA.gov)
Figure 4: Public domain, educational use (www.usgs.gov)
Figure 5: Public domain, educational use (www.NOAA.gov)
Figure 6: Public domain, educational use (www.NOAA.gov)
Figure 7: Public domain, educational use (state of Florida archives)
Figure 8: Public domain, educational use (FEMA.gov)
Figure 9: Public domain, educational use (FEMA.gov)
Figure 10: Public domain, educational use (SLOSH.org)
Figure 11: Educational use, research
Figure 12: Public domain, educational use (NOAA.gov)
Figure 13: Public domain, educational use (National Geographic)
Figure 14: Public domain, educational use (National Geographic)
Figure 15: Public domain, educational use (NOAA.gov)
Figure 16: Educational use, research
Figure 17: Educational use, research
Figure 18: Public domain, research
Figure 19: Public domain, educational use (National Geographic)
Figure 20: Educational use, research
Figure 23: Public domain, educational use (NHC.gov)
Figure 24: Public domain, educational use (Pinellas.gov)
Figure 30: Public domain, educational use (CDC.gov)
Figure 31: Public domain, educational use (CDC.gov)
Figure 33: Public domain, educational use (Pinellas County)
Appendix C
IRB Document

August 26, 2016
Jennifer Collins, PhD
School of Geosciences
4202 E Fowler Ave
NES 107
Tampa, FL 33620
RE: Exempt Certification
IRB#: Pro00027740
Title: Evacuation Behavior Measured at Time of Expected Hurricane Landfall: An Assessment of the Effects of Social Networks
Dear Dr. Collins:

On 8/26/2016, the Institutional Review Board (IRB) determined that your research meets criteria for exemption from the federal regulations as outlined by 45CFR46.101(b):
(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
(i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

As the principal investigator for this study, it is your responsibility to ensure that this research is conducted as outlined in your application and consistent with the ethical principles outlined in
the Belmont Report and with USF HRPP policies and procedures.

Please note, as per USF HRPP Policy, once the Exempt determination is made, the application is closed in ARC. Any proposed or anticipated changes to the study design that was previously declared exempt from IRB review must be submitted to the IRB as a new study prior to initiation of the change. However, administrative changes, including changes in research personnel, do not warrant an amendment or new application.

Given the determination of exemption, this application is being closed in ARC. This does not limit your ability to conduct your research project.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Vice Chairperson

USF Institutional Review Board