RESIDENTIAL FLOOD RISK
AND KNOWLEDGE ASSESSMENT
IN THE TUCSON METROPOLITAN AREA

by

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ABSTRACT

This research explores the challenges of reducing arid land flood risk among a diverse and growing community, plus reveals how population demographics can play a role in determining vulnerability to flooding. Communities make an effort to become more resilient when natural disasters occur. Ideally, these efforts will lessen the physical and economic impacts during and after subsequent events. For the Tucson Metropolitan Area (TMA), a major push to build resilience was initiated after a 1983 flood event. Those efforts proved successful, reducing damage and recovery time when other major floods hit the area. However, homes remain in high risk flood areas and data show Hispanic homeowners may be the most vulnerable to flooding in the TMA. But, data also indicate all homeowners, no matter their race or cultural heritage, in high risk areas may be able to better afford flood insurance, which is a policy supplemental to home insurance. Plus, survey results show homeowners may be more likely to accept personal responsibility for the financial impacts of floods as compared to an earlier study also completed in the TMA. Tailored education efforts addressing why a homeowner would choose or not choose a flood insurance policy could increase the number of policies in force, which potentially builds personal resilience, while also strengthening the community's ability to withstand the impacts of the next big event.

CHAPTER 1
INTRODUCTION

"What river?"
"It never rains in Arizona."

These statements were responses to a 1977 flood risk survey conducted in the Tucson Metropolitan Area (TMA), part of the arid inland western United States in the state of Arizona. The comments highlight the challenges of communicating the severity and risk of flooding in arid lands, where rainfall is irregular, streamflow is ephemeral and in some areas flash floods form quickly with little to no warning. Downpours from storms located miles away can flood a normally dry stream channel in a matter of minutes, sweeping away anything and everything in its path.

To cope with this threat, metropolitan communities in the region seek ways to become more resilient when flood events hit hard. Flood risk resiliency is defined in this research as the ability to recover from a major flood event without significant financial assistance from resources outside the community. For the TMA, a major push to build resilience was initiated after a 1983 flood event, which inundated, and even swept away, infrastructure, businesses and homes. As will be seen, by employing a combination of structural defenses and nonstructural measures, the community progressed in resiliency leading to less damage and disruption to daily life and business during and after subsequent events. But, while the community as a whole became more resilient, individual homeowners continued to bear the full brunt of the financial consequences of flooding if their property was damaged. The average homeowner's policy does not cover flood damage, and flood insurance policies must be purchased separately from home insurance with the vast majority in the U.S. written through the federal National Flood Insurance Program (NFIP). With low participation in NFIP, there remains a gap in resilience for individual homeowners.

A homeowner's decision to purchase or not purchase a flood insurance policy can vary because of social and cultural factors, as well as socioeconomic status, age, gender, education and other demographic influences. While there are numerous reasons for low participation in the federal flood insurance program, cost is a major factor for many. Historically around the world and in the U.S., poorer populations have lived in high risk flood areas, making the purchase of a flood insurance policy prohibitive. However the opposite was found in the TMA. Through GIS analysis of demographic and flood zone data, this research indicates higher income households are generally found in known flood plains, as compared to areas outside these flood plains. Simply put, TMA households in high risk areas may be better able to afford flood insurance coverage. But, the ability to afford coverage does not mean a homeowner will purchase it. An understanding of their risk may play an important role in their choice to carry or not carry flood insurance.

Based on a survey distributed in the TMA and targeting residents in higher flood risk areas, this research found homeowners continue to minimize or misunderstand flood risk, which supports previous research both in the TMA and around the U.S. However, the data also appeared to show homeowners were more likely to accept personal responsibility for the financial impacts of floods as compared to an earlier survey also distributed in the TMA. These findings potentially indicate that because homeowners in the TMA may be better able to afford the additional cost of flood insurance, tailored education and outreach programs addressing factors that could influence their choice to purchase coverage could increase the number of policies in force. The survey results also identified trusted sources for this information through which officials can better communicate flood risk and flood insurance options. When armed with knowledge distributed through trusted sources, homeowners can make an informed choice to purchase or not purchase flood insurance. If a homeowner choose to add this additional policy to protect their home, they potentially build resilience against the monetary impacts of the flood threat and contribute to their own resilience, while also strengthening the community's ability to withstand the impacts of the next big event. Because, when it comes to natural disasters, it is not a matter of 'if', but 'when' it will happen.

Goals and Objectives

The overall goals of this research are to investigate flood risk resilience in the TMA at the community-wide level and at the level of individual homeowners, plus examine the factors that influence resilience at these different levels. Specific objectives are 1) to review the effectiveness of flood risk resilience efforts in the TMA since a major flooding event in 1983, 2) to identify populations especially vulnerable to flood risk at the homeowner level in the TMA, 3) to gain a better understanding of the level of knowledge that property owners in these vulnerable populations have about flood risk and flood insurance, 4) to examine how that knowledge could influence their choice to carry (or not carry) a flood insurance policy and 5) to compare and contrast approaches to flood resiliency in the TMA with an example of actions taken elsewhere.

In Chapter 2, some background is presented on the unique nature of arid land flood risk and the motivation for this research. The concept of flood risk resilience is discussed and defined in Chapter 3. Chapter 4 describes the 1983 flood event and how reaction to that event contributed to an effort to increase flood risk resilience in the TMA in the face of future disasters. Chapter 5 explores the evolution of flood zone mapping efforts in the United States and the western U.S. The data and analysis presented in Chapters 6 and 7 make up the original research conducted for this PhD. An analysis of TMA flood zone demographics is in Chapter 6. Chapter 7 assesses flood risk knowledge and perception of the TMA population. In Chapter 8, a comparison is made between flood risk approaches in the TMA and a similar geographic location, El Paso, Texas. A summarizing discussion, conclusions and future research recommendations can be found in Chapter 9.

CHAPTER 2
ARID LAND FLOOD RISK

Modern European settlement of the U.S. took place in the east within a temperate climate that welcomed pioneers with reliable sources of water. Rivers, streams and creeks ran year-round. As with waterways in their home countries or countries of their recent ancestors, flooding posed challenges to their growing communities. While large-scale flood events were devastating, their chance that they might happen was understood, based on prevailing weather and climate. An unusually snowy winter typically meant high water levels in the spring as snow and ice melted away. The persistence of summer downpours saturated the ground, increasing the threat of flooding. In general, it took days, weeks, even months for the conditions to culminate into a flood.

As settlers moved west and southwest, including Arizona, they encountered fewer perennial streams and a preponderance of sandy stream beds which stayed dry for weeks, months or even years at a time. Knowledge of large-scale flood events was minimal without written records that could be understood by new settlers. As the population expanded so did the misunderstanding of flood risk, and the danger was often underestimated.

As relocation and settlement in Arizona continued into the 20th and 21st centuries, comments such as “What river?” and “It never rains in Arizona” were common. Even for areas where flood risk was better known, a single large flow event can reshape the natural landscape through erosion and deposition (Baker 1988, Kresan 1988). When the landscape is changed, nature adjusts accordingly, shifting flood risk from one area to another. Add people and structures to the equation and you have a potentially deadly and certainly expensive disaster started by nature but created by people.

Study Area

The study area for this research is the City of Tucson and its surrounding metropolitan area, otherwise known as the Tucson Metropolitan Area (TMA) in this study. Located in southeastern Arizona, the TMA lies roughly 60 miles north of the Arizona-Mexico border in the Sonoran Desert and is part of the Basin and Range physiographic province where mountain ranges are separated by relatively flat alluvial valleys or basins. The city itself is located in a basin surrounded by four mountain ranges: the Santa Catalina Mountains, Rincon Mountains, Santa Rita Mountains and Tucson Mountains. Creeks and streams within these mountains drain toward the TMA. However, some of this water never reaches the desert floor as channeled streamflow because it filters into the ground or evaporates into the dry desert air. All of the creek and riverbeds that cross the TMA and located on the desert floor are dry for the much of the year. Water flowing in these channels is generally observed only after a storm event or during snowmelt in the surrounding mountains, making these ephemeral streams, rather than perennial waterways.

In the TMA, there are five main waterways (Figure 2.1). The westward-flowing Tanque Verde Creek and northeastward-flowing Pantano Wash join to form the Rillito River, which flows west to join the Santa Cruz River. The Canada del Oro Wash joins the Santa Cruz river slightly downstream of the Rillito-Santa Cruz junction. The northward-flowing Santa Cruz River is the largest trunk stream in southern Arizona with headwaters near the Mexican border, south of the TMA. It was once a perennial waterway, but is now dry much of the time. Portions of all these waterways, and some of their smaller tributaries, are characterized by arroyo-like, steep-sided banks, which can collapse when undercut by fast-moving floodwaters.

The TMA is semi-arid with an average annual rainfall of 11.59”. Three different types of flood-producing weather occur seasonally in southern Arizona. It is mostly during these periods that brief, but sometimes powerful, flows occur in the area’s waterways.

One pronounced wet period is concentrated in the cool months of December, January, February and March, making up about half the annual average rain total. When large-scale winter and early spring extratropical storms from the Pacific Ocean traverse the western U.S., they sometimes track far enough south to bring rain and snow to the TMA and the surrounding mountains, occasionally resulting in prolonged and extreme streamflow. Some of these events entrain atmospheric moisture into Arizona in a concentrated, narrow plume referred to as an “atmospheric river.” These cool-season large-scale events tend to produce moderate intensity rainfall, but repeat systems can lead to large-scale flood events within larger waterways, such as the Santa Cruz or Rillito Rivers, flowing for days or weeks at a time. Snowmelt at higher elevations can also contribute to water flowing in contributing tributaries, compounding high flows if prolonged rain events occur on top of that melt. One of the largest and most prolonged flood events on record in streams across the state of Arizona – and in the TMA – was produced by a series of extratropical storms that occurred in the early winter months of 1993 (House 1993, McHugh 1995, Osmolski and Karim 1996, House and Hirschboeck 1997, UCAR 2003).

Figure 2.1 TMA waterways labeled on Enhanced Thematic Mapper plus (ETM+) aboard the Landsat-7 satellite, October 24, 2001 (NASA 2001)

A second pronounced wet period occurs in the summer, when the other half of the annual average rain total of the TMA falls in the months of July, August and

September and originates from small scale and/or isolated convective thunderstorms that are common during the seasonal weather pattern referred to as the North American Monsoon (NAM). The NAM pattern advects tropical moisture into the TMA, primarily from subtropical areas of the eastern North Pacific Ocean, the Gulf of California and tropical regions of Mexico. In the TMA, NAM-related storms typically begin developing in late June or early July, and the months of July and August are, on average, the two wettest months of the year. Rain from these monsoonal convective storms can be intense with rain rates of one or more inches per hour over a limited area and can trigger flash floods in small streams and waterways, especially in areas where land-use change and impervious surfaces from urban development have increased runoff. Even in areas of undeveloped desert, flash flooding is common because of sparse vegetation cover and soil with reduced porosity due to soil crust. Intense convective storms are generally isolated and short-lived with temporal scales of minutes to hours. The resulting flooding can occur quickly, but often subsides quickly as water drains into larger waterways. Although quick to rise and recede, in steep-sided arroyo channels these flow events can cause thousands of dollars in damage if water flow undercuts or erodes the banks and undermines nearby structures. During the NAM, organized groups of convective storms, referred to as mesoscale convective systems, can also affect the TMA and its surrounding mountain ranges and impact larger areas of 10 to 100 kilometers over longer periods producing rain rates of up to one inch or more per hour. These events typically flood channels for slightly longer periods and over larger areas than isolated convective storms. In an extreme case of summer convective monsoon rainfall in July 2006, a multi-day event involving nocturnal mesoscale convective complexes, combined with an atmospheric moisture influx from the remnants of a tropical storm, caused record flooding, slope failures and debris flows in canyons and streams that drain the Santa Catalina Mountains to the north of the TMA (Griffiths et al. 2009).

As the atmospheric set-up favoring the NAM breaks down in September, storms and rain totals generally taper off. However, occasionally during the NAM, and especially late in the season and into the fall months of October and November, a third type of flood-producing weather pattern sometimes occurs when tropical cyclones form in the warm waters of the eastern North Pacific Ocean off the west coast of Mexico. Under certain conditions, tropical cyclones and related storms can contribute significant amounts of rain to the annual total. Enhanced or prolonged periods of convective precipitation can occur in the TMA during these events when moisture influxes from the remnants of dissipating hurricanes or tropical storms are entrained into southern Arizona. While these tropical cyclone enhanced rain events do not occur every year, they are important runoff producers and have been responsible for some of the largest flood totals on record in southern Arizona. In late September and early October of 1983, an influx of moisture from Tropical Storm Octave, dissipating off the west coast of Mexico, contributed to one of the most damaging flood events ever recorded in the TMA, leading to the highest peak on record in the Santa Cruz River and many other locations (Beal 1983, Saarinen et al. 1983, Baker 1984, Hirschboeck 1988, House and Hirschboeck 1997).

Flood Risk Mapping Challenges in the TMA

The Federal Emergency Management Agency (FEMA) designated flood risk areas along major waterways in Tucson and surrounding areas and produced flood zones maps to estimate flood insurance premiums for the TMA in 1982. The extreme tropical cyclone related flood described above occurred the following year,1983, and devastated many areas throughout the TMA, including some areas outside of the previously mapped flood zones. In certain locations during the 1983 flood, instead of inundation of the land surface by floodwaters, erosion along the banks of the channels simply wiped away the flood zones, moving sediment from the collapsed bank downstream (Baker 1984). This erosion also undermined structures along the banks, which then collapsed into the rushing water. In the downstream areas where the sediment was eventually deposited, flood levels increased due to the deposition on the river bed.

The events associated with the 1983 flood highlight some of the challenges involved in the mapping of flood risk in an area like the TMA and will be addressed further in Chapter 4, but they illustrate how difficult pinpointing the limits of flood risk for any area can be. The paucity of precipitation and sustained streamflow in arid lands, along with spatial and temporal limitations in streamflow data, make flood risk mapping especially challenging for this environment. Add to this differing methods of estimating the statistical probability of flooding frequency and the results can vary widely even at one location (Boughton and Renard 1984, Eychaner 1984, Paretti et al. 2014).

Historic streamflow data in the U.S. may go back 100 to 200 years, even less in the more recently settled inland western U.S. (Potter et al. 1999). In the TMA, data in the USGS database extend back over 100 years for only two of 82 gauges (USGS 2017a). Of those 82, only 28% had data collected since the most recent turn of the century. The limited quantity of long term data could impact streamflow analysis efforts (Perrin et al. 2007). Complicating the issue of data collection is the ephemeral nature of arid land waterways. This also creates challenges for the statistical computation of flood probabilities because in some streams, gauges may not record any values at all for months or years.

Extending the data into the future poses another challenge. Streamflow gauges cost money to purchase, install and maintain. In 1998, the Appropriations Committee of the U.S. Congress expressed concern about the streamflow gauge network maintained by the USGS. The USGS reported the reduction of reliable data for flood forecasting was directly related to the challenges of funding the network. Congress responded by funding the National Streamflow Information Program (NSIP) to alleviate some of the budget issues the USGS was facing in maintaining gauges. By providing federal funds for gauge installation and maintenance, the NSIP reported an estimated over $1 million in savings in Arizona (USGS 2007). However, the National Water Information System (NWIS) webpage states the current 230 active stations across the country are funded through partnerships between the USGS and interested agencies, not the federal government (USGS 2017b). This means gauges are still subject to cuts in funding as partners pull out of joint efforts to keep these gauges up and running (Yeskis 2017).

The local authority for flood control in the TMA, the Pima County Regional Flood Control District (PCRFCD), also maintains a series of gauges called Automated Local Evaluation in Real Time (ALERT), most of which are in the TMA, the county's population center (PCRFCD 2016a). ALERT is a national partnership between the NWS, flood control districts and other relevant entities. City and county entities own and operate ALERT gauges, while the NWS offers technical support. Efforts are made to continue the reliability of data transmitted, but the gauges are subject to budget issues within the county or city maintaining them.

Available gauge data, even with the limitations outlined above, are used to estimate flood risk. A recurrence interval is calculated using flood frequency analysis to determine the statistical probability of a flood of a given size occurring in any year[1]. The standard for this analysis across the U.S. was set forth in 1967 in the U.S. Water Resources Council's Bulletin No. 15 with updates in 1976, 1977 and 1981 (IACWD 1981), and most recently in 2018 with the release of Bulletin No. 17C (England et al. 2018). The original publication, plus each of these updates, focuses solely on statistical analysis of available data for specific points. As in any statistical procedure, there are underlying assumptions in flood frequency analysis that can impact the results or their interpretation. These include flow measurement errors, randomness of events, mixed populations, watershed changes and stationarity issues related to climate variability and change.[2] These limitation have long been recognized. For example, manuals outlining statistical methods include disclaimers such as "there is no procedure or set of procedures that can be adopted which…will accurately define the flood potential of any given watershed" (IACWD 1981 pg. 1). The manuals also encourage further study of flood risk factors for specific watersheds when warranted. As an example of such further study with applications for the TMA, Paretti et al. (2014) used data from over 320 Arizona stream gauges and applied new statistical approaches (related to Bulletin 17C) with good results that performed better than earlier methods. Other work of relevance to the TMA includes that of Hirschboeck (1988, see also Merz et al. 2014) and Zamora-Reyes (2014) which focuses on the three types of flood-producing storms in Arizona (noted earlier), and the resulting heterogeneity of the flood events these storms produce in Arizona watersheds. Their results have implications for how flood risk might be affected by climate variability and change, both now and in the future.

While no analytical approach for estimating the probability of extreme floods is flawless, hydrologists continue to work towards more accurate and reliable estimates of the likelihood of large floods in order to provide reliable maps of flood risk areas for both communities and homeowners.

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[1] For an explanation of recurrence intervals see https://water.usgs.gov/edu/100yearflood.html

[2] See Hirschboeck (1988), Wright (2007) and Bulletin 17C (England et al. 21018) for a discussion of these assumptions.

Climate Change Impacts

"Stationarity is dead." With this bold statement (Milly et al. 2008) addressed the role of climate change as a critical factor in creating uncertainty in future estimates of hydrologic variability. Whether the cause is anthropogenic climate change or natural variability in the climate system, flood risk in a given area is likely to change over time. The outlook for Arizona's climate, based on the variability seen in past records and modeling results for the future, points to overall drier conditions in the winter with greater uncertainty for the NAM (IPCC 2013). Drier conditions impact the amount of water stored in the soil, which may reduce the role of antecedent soil moisture in flood risk estimation for the future. The severity of the TMA events of 1983, 1993 and 2006 were all enhanced by antecedent soil moisture conditions. However, an increase in precipitation intensity is also projected for the future and any increase in short duration, high intensity precipitation will also impact flood risk. Currently in the TMA, short duration, high intensity convective rainfall events tend to occur over minutes to hours and are localized, generally causing flooding in smaller channels or streams, eventually draining into major waterways if the flows are large enough. While these flows may not reach the levels observed in the major streams during the 1983, 1993 and 2006 events, flooding on these smaller waterways can still cause significant damage. In 2010, a short duration, heavy rain event in the Tanque Verde Creek watershed on the eastside of the TMA flooded approximately two dozen homes in one neighborhood (PCRFCD 2016c). An investigation by PCRFCD found water levels that reached 36 to 38 inches on some of the properties.

In a warmer world, the threat of flooding from these short duration extreme precipitation events remains a concern. As average global temperatures increase, so does the atmosphere's capacity to hold moisture in the form of water vapor. According to the Clausius-Clapeyron relationship, for every 1°C increase in temperature the water-holding capacity of the atmosphere increases 7% (IPCC 2007). Simply put, there is more moisture available for precipitation with increased average global temperatures. In theory, this would increase extreme precipitation events, but more research and longer data sets are needed to determine if there is a trend.

The definition of an extreme precipitation event can vary from one region to another and from one research study to another. An inch of rain pouring down over the hard-packed desert could bring a flash flood to arid land arroyos. An inch of rain over the porous soils of the Midwest, U.S. may cause little more than puddles on the roadways. Extreme events are defined against data from the region or location (Osterkamp and Friedman 2000). Some studies set the limit of extreme events at measurements above the historic 95th or 98th percentile (IPCC 2013, Kennedy 2014); while others studies use recurrence interval thresholds (Kunkel et al. 1999, Kunkel et al. 2012) in addition to other statistical methods.

Globally, IPCC (2013) states it is "likely that since 1951 there has been statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases." Trends, both regionally and seasonally, are not consistent across the world with some areas even seeing "statistically non-significant or negative" trends (IPCC 2013). Natural variability (e.g. El Nino/La Nina, Pacific Decadal Oscillation) can also play a key role in precipitation extremes over years to decades at a time, making it difficult to assess if climate change is impacting these data.

In the continental U.S., Kunkel et al. (2012) found between 1908 and 2009 there was a statistically significant upward trend in extreme precipitation events for some regions. However, the Southwest, which included Arizona, Utah, Colorado and New Mexico, did not show a trend. An earlier study analyzing data between 1931 and 1996 even showed a slight downward trend in extreme precipitation events for southern Arizona, although this was not statistically significant (Kunkel et al. 1999).

How and if extreme precipitation events for Arizona will shift with climate change is unclear. In regional climate model (RCM) simulations, Dominguez et al. (2012) found a projected increase in the intensity of extreme precipitation events during the winter for the western U.S., including Arizona, but data analyzed by Rivera and Dominguez (2015) suggest there is no "strong evidence" of increased intensity for extreme precipitation events over Arizona, even as cool season atmospheric rivers, which transport moisture from the ocean to land, showed increased water vapor. NAM thunderstorms and influxes of tropical moisture during autumnal months are more often the source of extreme precipitation for Arizona (Ralph et al. 2014). Focused on Southeast Arizona, including the Tucson area, Zhang et al. (2012) concluded that a significant increase in the frequency and intensity of extreme precipitation events would accelerate soil erosion with climate change. While the historic data do not show a significant change in intensity or frequency of extreme precipitation events, some forecast models continue to indicate a positive trend in the future due to climate change.

Defining flood risk in an arid land, like the TMA, is challenging given all the factors previously stated. Communicating the complexity of that risk is perhaps an even more imposing task. But, building resilience is essential to the social and economic stability of a community. The next chapter defines how resilience to the impacts of flooding is approached in the TMA.

CHAPTER 3
FLOOD RISK RESILIENCE

For natural disasters, such as flood events, it is not a matter of ‘if’ an event will occur but ‘when’. In arid lands, water is often a welcome and celebrated sight. Allowing that water to move through the ecosystem is valuable for both people and nature. But when there is too much of a good thing, flooding can take lives, damage infrastructure and destroy personal property. With each new event, a cycle of flooding, damage, recovery and rebuilding occurs. Communities try to break that cycle through planning and mitigation, working to accommodate rather than eradicate risk (Mileti 1999, Zundzewicz 1999, El-Masri and Tipple 2002, Moldan et al. 2012). The goal is to decrease risk, plus reduce the time necessary for recovery and the cost for rebuilding when the next event occurs. By doing so, the community builds resilience. But, what defines a resilient community? And, how does a community measure the success or failure of resilience efforts?

Resilience is simply defined as the capacity to recover quickly from a difficulty. Instead of attempting to dominate every facet of risk, resilience is bolstered through developing countermeasures (Mileti 1999, Folke et al. 2002). These countermeasures need to increase the strength and flexibility of a community during a disaster and not be fragile (Godschalk 2003). If breakdowns occur during a disaster, it could impact a community’s ability to cope with the effects (Scheuer et al. 2011). For example, during a major flood in event in the TMA in 1983, access was limited to some areas within the community due to widespread damage to bridges and roads, directly impacting response and recovery efforts (Pima County Dept. of Transportation and Flood Control District 1985b).

Mileti (1999) interprets resilience as a community’s ability to “withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life and without a large amount of assistance from outside the community.” While that may be an ideal, the process by which resiliency can be achieved is not straightforward. There is no one-size-fits-all solution. There are unique social, physical and financial aspects that contribute to resiliency for a geographic area (Kundzewicz 2001, Godschalk 2003, National Research Council 2012). Plus, development, climate change, politics, economics and more can influence efforts to reduce vulnerability and increase resilience (Holling et al. 2002, Kundzewicz 2001, Gersonius et al. 2010). A comprehensive plan addressing these each of these factors can contribute to resiliency (Basiago 1999, Tobin 1999, Lozano 2008).

National Research Council (2012) defines resiliency to disasters as “the ability to prepare and plan for, absorb, recover from or more successfully adapt to actual or potential adverse events.” Absorb and adapt stand out as describing potential tools in building resiliency, including in the two main approaches to mitigate flood risk - structural defenses and non-structural measures (Kundzewicz 2001).

Structural defenses are engineered, such as dams, bank protection and retentions basins. These alter the environment in order to protect societal and economic interests within a community and are designed to absorb the physical stresses of a flood. While structural defenses are an important part of reducing vulnerability, it is clear there are limits to their effectiveness. Structural defenses built to reduce risk at one level but not a greater one (i.e. 100-year versus 500-year flood[3]) could lead to more severe damage beyond the threshold to which they are designed to protect. The nature of arid lands adds a layer of difficulty in designing and building effective structural flood control. With heavy rain events a rarity, there may be no records of major flooding. Plus, channels are often not well-defined in the basins of the arid western U.S., where sediment transported from surrounding mountains during past flows spreads out across the desert floor as the flow rate slows. There is also limited knowledge about how water moves through that sediment, which could influence flood risk (Hydrologic Engineering Center 1993). Another challenge is designing physical barriers to account for a shift in risk over time due to climate change, development and more (Mileti 1999, National Research Council 2002). A flood risk management approach that takes into account non-stationarity is necessary to accommodate potential future changes in the system (Merz et al. 2010, Sayers et al. 2012). Planners and engineers can, and often do, account for a level of uncertainty, but in reality there will always be a gap in protection because addressing every single scenario is not fiscally possible.

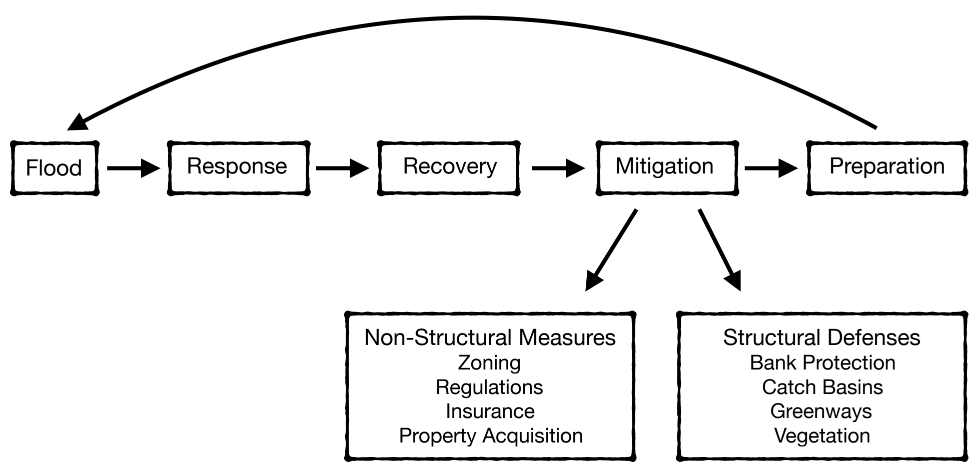
To fill the gaps in protection, a community can also employ non-structural measures, which may allow more flexibility in strengthening resilience (Kundzewicz 1999, Ryu et al. 2017). These include zoning, regulation and insurance. However, non-structural measures can be heavily influenced by politics and economics, weakening

[3] See https://water.usgs.gov/edu/100yearflood.html for an explanation of 100-year and 500-year floods

efforts to protect the community. In the TMA, disagreement between local officials and builders regarding the thresholds of zoning ordinances along waterways was a direct contributor to severe damage during a major flood event in 1983 (Saarinen et al 1984).

For this research, flood risk resilience is measured by the community's ability to recover from a major flood event without significant financial assistance from resources outside the community. Often times, many of the efforts to increase this resilience come after a flood event exposes weaknesses in the system. Serra-Llobet et al. (2016) outline how these weaknesses are addressed post-event and in preparation for the next big event, moving from response to recovery to mitigation then preparation for the next event (Figure 3.1). Response and recovery efforts are reactive to a flood event and include rescue efforts, plus emergency relief. Mitigation and preparation are proactive. Preparation includes warning systems and emergency plans, which are focused on protecting lives. Mitigation efforts are aimed at protecting assets, such as infrastructure, homes and businesses. While each step in the cycle is represented by ways to reduce vulnerability, it is mitigation that is the best chance to increase resilience from a financial perspective.

Figure 3.1. Flood risk management cycle with mitigation examples. Adapted from Serra-Llobet et al. 2016.



In Chapter 4, this research takes a look at how the TMA made an effort to build financial resilience through mitigation after a major flood event in 1983. The focus is both non-structural measures and structural defenses. Resilience is measured against the impacts of subsequent flood events when flows in the major waterways rivaled, and even surpassed, that of 1983.

CHAPTER 4

HISTORICAL REVIEW OF THE 1983 TUCSON METROPOLITAN AREA FLOOD

In October 1983, a natural disaster hit Arizona, including the TMA. A historic precipitation event filled normally dry desert waterways. Stream banks collapsed taking buildings, bridges, roads and power poles with them. Floodwaters spread out over desert lowlands and into neighborhoods. Up to 10,000 people were evacuated from their homes, 400 rescued and 14 killed statewide (Beal 1983, Peirce and Kresan 1984). The flooding was so severe that the National Weather Service deemed this event as the top weather story of the 20th century for the TMA (Tucson NWS 2014).

Much was learned from this flood event, but how that knowledge was used determines if the community strengthened resilience to the impacts of future events. The following is a review of the 1983 event and an analysis of mitigation efforts, both structural and non-structural, to determine if the TMA can recover from a major flood event without significant financial assistance from resources outside the community. These efforts are measured against major flood events in 1993 and 2006 with flows rivaling, and even breaking, those of 1983 in some waterways.

The objectives in this chapter are to determine whether post-1983 flood structural defenses and/or non-structural measures contributed to a more flood risk resilient TMA. In exploring these objectives, the following research questions will be addressed: 1) What impact did the 1983 flood have on flood control management plans in the TMA?, 2) What structural defenses and non-structural measures were put into place after the event? and 3) Did changes made to the flood control efforts in the TMA after the 1983 flood event lead to a more resilient community?

Weather and Climate Conditions Leading to the Flood of 1983

The October 1983 flooding was a direct result of a combination of three factors: a wet monsoon, an autumnal weather disturbance and a surge of moisture from a tropical storm. This trio turned major waterways running through the TMA into torrents of damaging, even deadly, floodwaters. The amount of water running through these waterways remains some of the top, if not the top, flows on record.

The 1983 NAM was an exceptionally wet one. From June 15 through September 30, the Tucson International Airport measured 10.50” of rain (Table 4.1). The NWS ranks it as the fourth wettest monsoon on record, with data extending to 1895 (Tucson NWS 2014). Over 81% of rain that fell during the 1983 NAM came during the last two months, August and September.

Month	1983 Rain Total	Average Rain Total	Difference from Average (1981 to 2010)	Percentage of 1983 Total
June (15-30)	0.00”	0.15”	-0.15”	0.00%
July	1.98”	2.25”	+0.27”	18.86%
August	4.24”	2.39”	+1.85”	40.38%
September	4.28”	1.29”	+2.99”	40.76%
NAM Total	**10.50”**	**6.08”**	**+4.42”**	**100.00%**

Table 4.1. 1983 Monsoon Monthly Rain Totals. Average rain total based on the 30-year average from 1981 to 2010.

In late September 1983 a tropical depression formed off the west-central coast of Mexico (NOAA n/d). On September 28, this disturbance became Tropical Storm Octave. The track then took the storm northwest, towards the center of the Baja Peninsula in Mexico. Octave weakened into a tropical depression just two days later and dissipated by October 2 off the west coast of Mexico. Lingering deep tropical moisture associated with the storm then moved into Arizona. Figure 4.1 shows the placement of the storm on October 1, 1983, plus the stream of clouds, indicating tropical moisture, flowing from the storm and over Arizona.

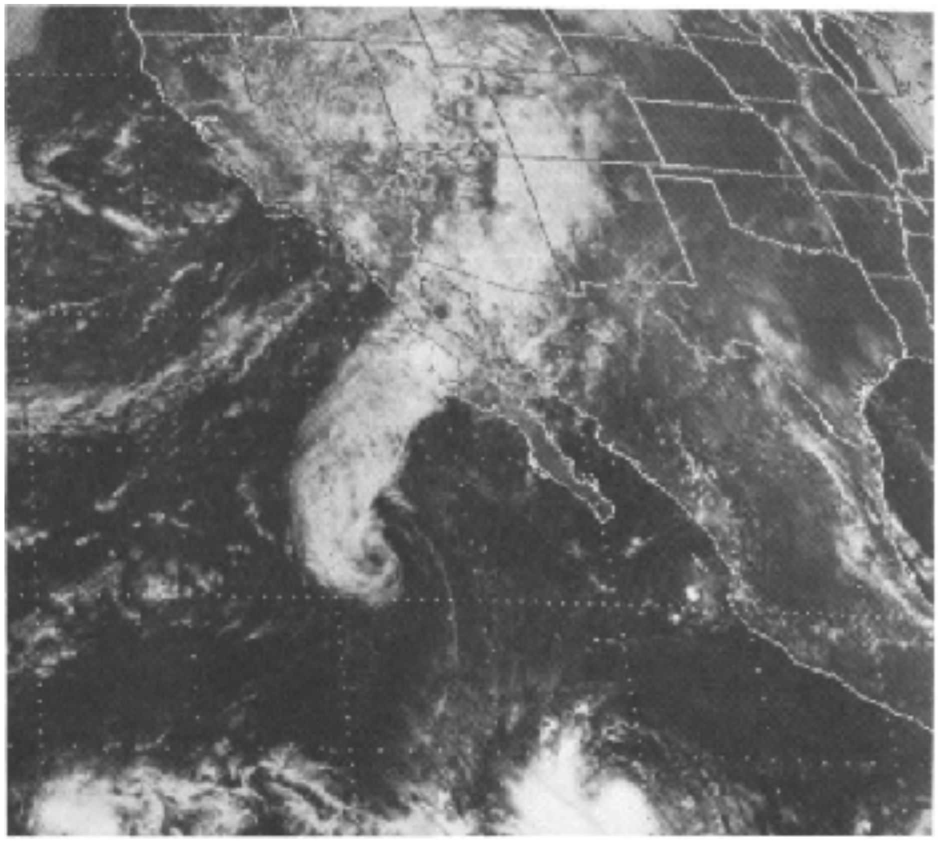


Figure 4.1. October 1, 1983 National Environmental Satellite Data and Information Service image from Geostationary Operational Environmental Satellite (GOES) of Tropical Storm Octave and associated moisture (Roeske et al. 1989).

The moisture from Tropical Storm Octave was funneled into Arizona between an area of High pressure anchored to the southeast of the state, plus an area of Low pressure forming in a trough dropping down the west coast of the continental U.S. (Figure 4.2). The southwesterly airflow between the counter-clockwise circulation of the Low and clockwise circulation of the High also moved impulses of atmospheric energy embedded in the leftover tropical moisture from Octave over Arizona. These impulses provided the atmospheric lift needed to sustain a heavy and prolonged rain event over Arizona from September 28 through October 3. The area of Low pressure weakened on October 2 as the trough began to push inland. The trough pulled off to the northeast, finally returning drier westerly flow to Arizona by October 3. However, a second, less-organized area of Low pressure lingered over Southern California and the east Pacific Ocean (off the California and Baja Peninsula coastlines) for a few more days before deteriorating and moving over Arizona on October 8. Even as this low moved inland drier conditions prevailed and the additional rain did not add to the flooding from the heavier precipitation earlier in the month.

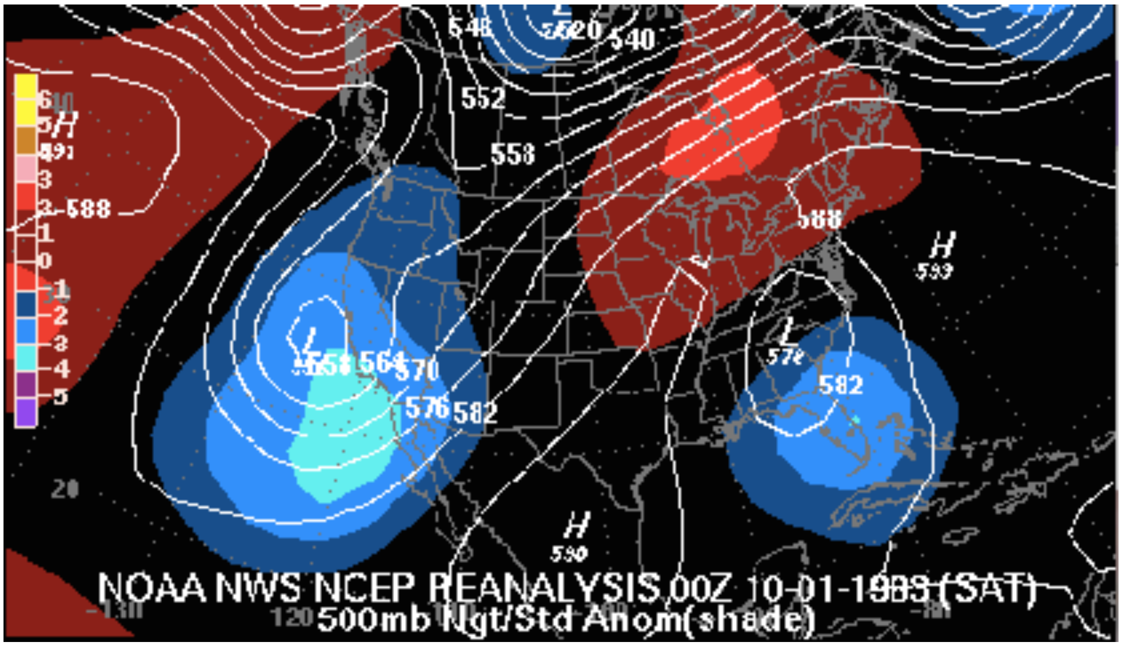


Figure 4.2. 500 mb Heights and Standard Anomalies (NOAA 2016).

Between September 28 and October 3, the Tucson International Airport received 6.71” of rain, while Mt. Lemmon, the highest peak of the Santa Catalina Mountains located north of downtown Tucson, received 9.90” of rain (Table 4.2). Runoff from Mt Lemmon drains into the TMA watershed. These two gauges did not measure additional rain totals on October 4, but some rain gauges across Arizona did measure rain on that day. However, the amounts did not add much to the already substantial numbers measured in area rain gauges. The bulk of the rain fell in southeast Arizona and the northern state of Sonora, Mexico (Figure 4.3).

Month	Day	Rain Total	Rain Total
September	28	0.31”	0.90”
	29	1.02”	0.71”
	30	0.48”	0.00”
October	1	2.96”	5.10”
	2	1.21”	2.84”
	3	0.73”	0.35”
6-day Total		6.71”	9.90”

Table 4.2. Daily Rain Totals in the TMA.

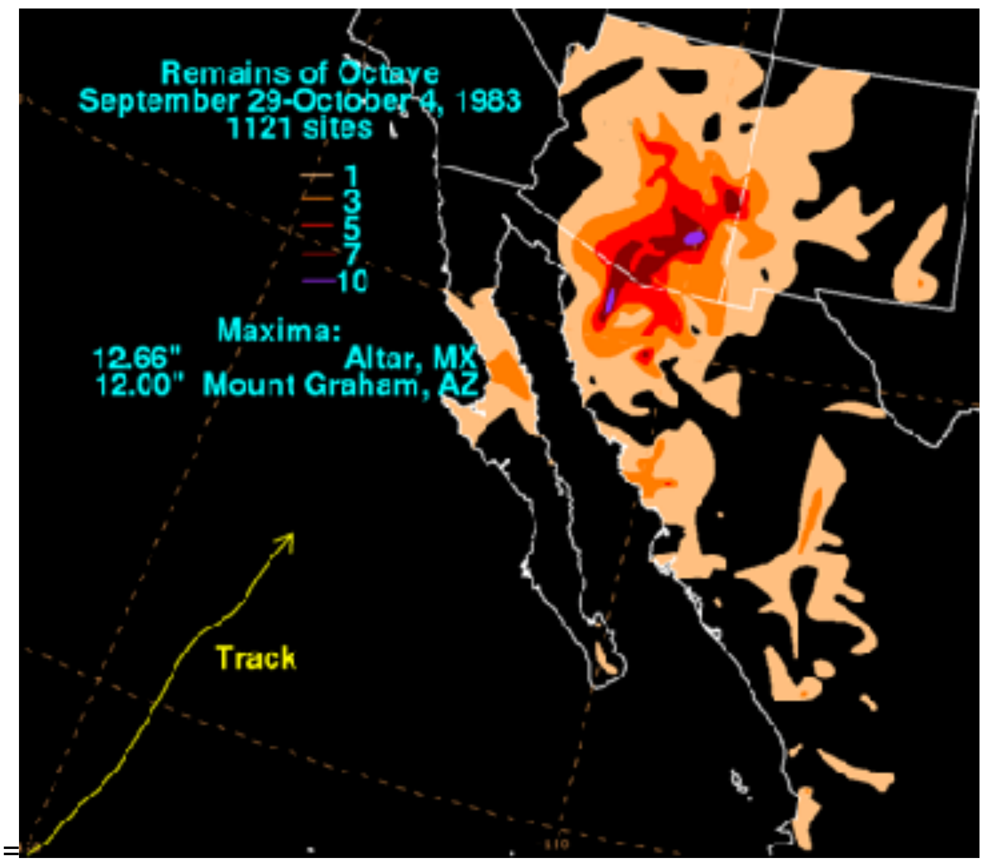


Figure 4.3. Tropical Storm Octave rain totals (Roth n/d).

Table 4.3 shows the Peak Streamflow during the 1983 event versus Estimated 100-year Flood Discharge from Saarinen et al. (1984). While the Rillito River remained below the estimated 100-year flood discharge, the Santa Cruz River at both Congress Street and Cortaro Road, which is just north of where the Rillito River runs into the Santa Cruz River, topped out above the estimated 100-year flood discharge. One study completed prior to the 1983 event had even lower 100-year flood estimates for the Santa Cruz River (Boughton and Renard 1984). The flows in the Santa Cruz River remain record-setting through present day with U.S. Geological Survey (USGS) data dating back to 1915 at Congress Street and 1940 at Cortaro Road (USGS 2017b). The Rillito River streamflow at Flowing Wells set a new record on July 31, 2006 with 39,000 cfs.

Waterway	Peak Streamflow (cfs)	Estimated 100-year Flood Discharge (cfs)
Rillito River @ Flowing Wells Rd.	29,700	32,000
Santa Cruz River @ Congress St.	52,700	30,000
Santa Cruz River @ Cortaro Rd.	65,000	40,000

Table 4.3. Peak Streamflow versus Estimated 100-year Flood Discharge in 1983 (Saarinen et al. 1984).

Post-event, there was some debate over whether the 1983 flow exceeded a 100-year flood discharge (Boughton and Renard 1984, Kresan 1988). A 100-year discharge means there is a 1% chance of a flood of that magnitude happening in any given year at that point[4]. However, varying methods of statistical analysis can lead to different 100-year flood discharge estimates (Boughton and Renard 1984, Eychaner 1984, Paretti et al. 2014). Plus, when the 100-year flood discharge is determined it assumes the channel is stable. Ephemeral stream channels located in alluvial basins in arid and semi-arid

[4] For a review of the what a 100-year discharge means see https://water.usgs.gov/edu/100yearflood-basic.html

areas, such as the TMA, are highly reactive to large flows. Bank erosion and sediment transport can dramatically alter the stream channel, changing the flood risk of the surrounding land during and following a high discharge event. In addition, the population of the TMA increased from 265,700 when original flood plain mapping occurred in the 70s to over 600,000 by 1983 (Kresan 1988). This population growth meant development in the TMA could impact runoff patterns, channel structures, vegetation coverage and more (Baker 1984, Eychaner 1984, Reich 1984). Reich (1984) analyzed streamflow data back to 1915 of the Santa Cruz River at Congress Street in Downtown Tucson. Larger floods were more common in the latter half of the data set. Reich (1984) references land-use changes, including development south of Tucson where open desert once allowed floodwaters to spread out and soak into the desert but now channeled that water flow into the city as a possible cause for this change.

Impacts of the 1983 Flood

Statewide, at least 14 people died in storm-related accidents (Beal 1983). Pima County Dept. of Transportation and Flood Control District (1985a) reported 221 injuries across Arizona, most of which were in Pima County and the county adjacent to the north, Pinal. An estimated 600 people were evacuated from their homes in Pima County (Pima County Dept. of Transportation and Flood Control District 1985b). About 10,000 people were left homeless (Devine 2003).

For all of Arizona, the Red Cross reported 26,000 homes were affected by flooding, of which 1411 were significantly damaged and 833 destroyed or sustained major structural damage (Beal 1983). Around 18% of those homes destroyed were in the Santa Cruz River basin in the TMA (Pima County Dept. of Transportation and Flood Control District 1984b). Additionally, 19 businesses had major damage with another 22 experiencing minor damage (Pima County Dept. of Transportation and Flood Control District 1985a). Much of the damage was caused from fast moving water undercutting or eroding banks. Peirce and Kresan (1984) reported up to 5 acres of land eroded away in some areas. In one spot along the Santa Cruz River in Marana, the channel was 3 times wider compared to measurements just two years earlier (Roeske et al. 1989).

Damage to bridges heavily impacted travel in the TMA. A total 35 of 42 bridges over major waterways were closed at one point. All bridges, except one, spanning the

Santa Cruz River were damaged or partially washed away (Saarinen et al.1984, Tucson NWS 2014). Six of those bridges open to travel during the flooding were built to stricter regulations put in place in 1979 by the newly formed PCRFCD (Pima County Dept. of Transportation and Flood Control District 1985a). Immediately after the flooding, the cost of “detour mileage, congestion and accidents” was estimated up to $600,000 per day (Pima County Dept. of Transportation and Flood Control District 1985a). This number decreased as repairs were made to roads and bridges re-opened to traffic.

High flow eroded the streambed and uncovered previously buried pipes that transported sewage, water and natural gas (Pima County Dept. of Transportation and Flood Control District 1983a, Peirce and Kresan 1984). In some cases these pipes broke, disrupting service for water and natural gas, creating even more dangerous conditions for residents and first responders (Pima County Dept. of Transportation and Flood Control District 1985b). Two sewage treatment plants along the Santa Cruz River were also damaged (Pima County Dept. of Transportation and Flood Control District 1985b).

Prior to the 1983 flood, bank protection along major waterways was a mix of four different kinds of engineering; riprap, unsorted debris, wire-fence revetment and soil-cement revetment (Saarinen et al. 1984). Riprap consists of a layer of boulders placed on the face of the bank, while unsorted debris was made up of available materials, both natural and manmade, dumped on the stream bank. These materials included crushed rock, demolition debris and even old vehicles (Saarinen et al.1984). A revetment is a retaining wall, built to protect an embankment. The wire-fence revetment was a wire enclosure filled with rocks and boulders. The soil-cement revetment was a newer type of engineering that protected the bank with 8% to 15% Portland cement mixed with the natural bank material (Saarinen et al. 1984).

On one stretch of the Santa Cruz River analyzed post-flood, 80% of the bank protected by riprap showed undercutting or recession (Saarinen et al 1984). For wire-fence revetments, issues related to bank erosion generally occurred only behind the start and terminus of these structures. In some cases the wire-fence structure remained in place while the entire bank eroded away behind it (Saarinen et al 1984). The 1983 flood was the first big event to test newly placed soil-cement revetments. This type of bank protection experienced only minor issues during the flood with no major failures (Baker 1984, Peirce and Kresan 1984, Saarinen et al 1984). But, like the wire-fence revetments, the soil-cement structures also experienced erosion at the start and terminus. Along the Rillito River, erosion around a soil-cement revetment led to the collapse of several townhomes.

According to Saarinen et al. (1984), there was “severe erosion” where bank protection, no matter what kind, terminated at the natural bank along Rillito and Santa Cruz Rivers. That same study determined 40 meters (about 131 feet) of bank erosion along one stretch of the Santa Cruz River was “directly related” to the upstream bank protection. In another area, erosion around piecemeal bank protection cut into an old sanitary landfill (Saarinen et al. 1984). Refuse spilled into the floodwaters (Pima County Dept. of Transportation and Flood Control District 1985b). Along the Pantano Wash, residential property was damaged due to erosion around revetments put in place to protect a bridge (Saarinen et al 1984). In some areas bank protection failure occurred as the floodwaters scoured away sediment beneath the structure. Saarinen et al (1984) found the depth of the channel increased by 2 to 3 meters (about 6.5 to 10 feet) in some waterways. The result of this sediment removal was a collapse of bank protection.

In one area, vegetation proved to be an effective form of bank protection. Bosques are riparian habitats usually found adjacent to waterways in the desert Southwest. The bosques are combination of low trees, often mesquite, plus shrubs and herbaceous plants in the understory. The root system of the bosque plants prevents or slows erosion during high discharge events. Where vegetation was in place along the waterways, erosion was either not visible or minimal (Saarinen et al 1984).

The high flow also undermined electrical structures. Saarinen et al (1984) counted 28 high-voltage electric towers damaged or destroyed, along with 13 low-voltage electric poles damage or destroyed along the Santa Cruz River. Damaged high-voltage poles in and along the Rillito River were not counted in a post-flood survey, but there were also reports of impacts in this area (Saarinen et al 1984).

Most of the overland flood damage was limited to Marana, where the Santa Cruz River spread out over 4 to 5 miles (Beal 1983, Peirce and Kresan 1984). Portions of Interstate 10 in this area were covered with floodwaters and railroad shipping was stalled due to high water (Roeske 1989). One state official flew over the area and is quoted as saying “it looked like the Mississippi Delta” (Beal 1983). Marana farmland was also impacted with farmers losing crops already in the ground and washing away topsoil needed for the next planting. Wet fields hampered recovery efforts, delaying or canceling the fall planting for some farmers (Beal 1983). Flood damage was compounded in the Marana area because of all the erosion upstream in the Santa Cruz and Rillito Rivers. Sediment transported from this erosion was deposited as the water spread out and the flow slowed. This led to aggradation, which in turn led to more severe damage from inundation as the water level rose with the deposition of sediment (Saarinen et al 1984).

President Ronald Regan declared Pima County a federal disaster area just days after the rain stopped. It was one of many counties in Arizona facing rebuilding and recovery as floodwaters receded. According to Beal (1983), this designation meant about 75% of the cost to repair state roads, bridges and public works facilities would come from federal disaster relief funds. However, smaller roads maintained by the cities, townships and counties were not funded with this money. Neither was the damage to private businesses and individual homes.

To cover the cost of repairs to public infrastructure Pima County voters approved a $63.8 million bond dedicated to repairs scheduled to be completed in the 4 years following the event (Saarinen et al 1984). The approval of the bond also brought matching funds of $41.9 million from federal, state and other sources (Pima County Dept. of Transportation and Flood Control District 1985a). Combined, the total was nearly $106 million dollars, which equaled nearly $270 million in 2018 dollar values. These funds were used to repair public infrastructure, which means the loss of private property is not included in this estimate. Crop losses in Pima County were estimated at $10 to $15 million. However, the impact to farming may have climbed as high as $100 million since livestock and equipment needed replacing, plus repairs were needed to irrigation structures, farmland and wells (Beal 1983).

The 1983 flood proved Tucson wasn't ready to handle another disaster of this magnitude without major changes. Recommendations to improve engineering and regulate against future flood risk were quick to come from the Pima County Department of Transportation and Flood Control District. After the floodwaters receded, 28 consultants and companies were tapped for a comprehensive report on the damage and what changes were needed to increase resilience in the face of another disaster (Pima County Dept. of Transportation and Flood Control District 1985a). Recommendations from this group included updating building and regulation standards for bridges, new bank protection, plus a buy-out program for flood-prone lands and improved access to rural areas where people were stranded due to high water.

Two other post-analysis reports, Saarinen et al. (1984) and Baker (1984), made a series of recommendations to improve disaster preparation and response in the TMA. Saarinen et al. (1984) stressed that data collection and communication systems needed to be improved, most notably between local, state and national agencies. Baker (1984) pointed to the lack of long term hydrological data as a weak spot. However, the instantaneous peak flow record for the USGS gauge at Tucson was an exceptionally long one, dating back to the early 1900s. Baker has long advocated that hydrologists include paleoflood evidence of extreme flooding that is recorded in the landscape to augment gauged records and supplement traditional flood frequency analysis[5].

Post-Flood Response

Once flood waters receded and the damage became more apparent, the public wanted action to prevent a repeat. The 1983 flood event changed the way the community viewed flood risk and that gave local officials an impetus to make changes quickly. Plans to improve infrastructure and restrict development were quickly outlined by local officials to show action was being taken. While structural defenses were designed and built over time, some of the non-structural measures were put into place within weeks and months of the flooding.

Prior to this historic flooding and erosion, a computer model was designed by Day and Weisz (1976), which analyzed the economic impact of flood control works and land development along a stretch of waterway in the TMA. This same stretch of waterway was one of the areas impacted by the 1983 flood. The research was driven by the fact that “flood control agencies have very little authority over local land use…” (Day and Weisz 1976). Simply put, the agencies working to protect people and development had little to no say in how the land was protected from flooding because parcels that could be impacted were owned by a variety of entities, many of whom had different visions that didn’t necessarily have flood control as part of the plan for development or use. Saarinen et al. (1984) point out that this lack of oversight is what drew some to Arizona and away from areas where higher levels of regulations may have hampered

[5] For an overview see Kochel and Baker (1992), Paleoflood Hydrology, *Science* 22 Jan 1982: Vol. 215, Issue 4531, pp. 353-361

plans for development. While Day and Weisz (1976) could never have planned for the 1983 flood event, their research seemed to foreshadow the coming clash of land development and flood damage.

Floodplain Zoning

In 1974, Pima County was the first in Arizona to adopt a flood plain zoning ordinance. The City of Tucson followed suit in 1980. These ordinances were adopted to meet the basic requirements for flood insurance eligibility and were generally considered weak (Saarinen et al. 1984). In the following years, officials and experts advocating for stronger zoning ordinances clashed with realtors and builders, who did not want additional restrictions. One expert suggested a new ordinance contain a setback of 1000 feet from current stream banks to ensure building safety (Saarinen et al. 1984). The two sides eventually did negotiate a stronger ordinance, which was adopted by the City of Tucson in 1982. The 1982 ordinance setbacks were set at 100 feet for commercial and industrial structures, as well as rental properties; for owner-occupied homes, the setback became 300 feet (Saarinen et al. 1984).

Even after the new ordinance's adoption, property owners and builders continued to resist setback limitations. To obtain permission for one construction project close to the banks of the Rillito River, a builder signed a release statement absolving the City of Tucson and Pima County of any blame or legal recourse if flooding damaged the proposed office building. This office building was later damaged in the 1983 flood with a portion of it falling into the water after bank erosion undermined the structure. The damage from the 1983 flooding proved increased setbacks were needed.

With the flood damage fresh in the minds of taxpayers, within a week of the flooding the Pima County Board of Supervisors passed an 18-month moratorium on rezoning and construction in the floodplain (Saarinen et al. 1984). Pima County flood control officials were able to put new setbacks in place by 1985 (Kresan 1988). These setbacks required new structures be 500 feet away from the edge of a waterway. Plus, any construction within 1000 feet of the bank required a river mechanics or similar study before consideration for approval.

Currently, the PCRFCD regulates any floodplain on a watercourse with peak discharge greater than 100 cfs during a 100-year flood (PCRFCD 2016c). At that rate of flow, it would take about 24 hours to fill an Olympic-sized swimming pool. This means even smaller waterways in the TMA are regulated by PCRFCD. Depending on the 100-year flood discharge, setback limitations can range from 25 feet for washes with lower discharges to the 500 feet limit set in 1985 for larger washes, such as the Santa Cruz River and Rillito River (PCRFCD 2016c).

Land Acquisition

Removing people from living in the floodplain was another nonstructural option. In response to the 1983 event, Pima County approved the Floodprone Land Acquisition Program (FLAP) (PCRFCD 2016c). Initially, the sole purpose of this program was to purchase homes damaged by the 1983 event. Pima County Dept. of Transportation and Flood Control District (1985a) recommended the county acquire five specific areas where flood damage occurred, plus some smaller additional locations. Over the years the program continued to purchase homes in floodprone areas, but funds were also used to buy undeveloped land along waterways and in the upper reaches of watersheds. Through 2007, the PCRFCD purchased over 9000 acres of land in high risk areas (Meltzer 2007). Most homes purchased through FLAP were built before 1972, prior to stricter floodplain regulations in Pima County (Meltzer 2007). The program continues today with purchases based primarily on available funds and a review of how the property is linked to the severity of the flood risk and proximity to other public lands (PCRFCD 2016c). However, FLAP can only purchase land from willing sellers. The program does not force homeowners into selling the land or use eminent domain.

Flood Insurance

Flood insurance was newly available to residents in the TMA through the National Flood Insurance Program (NFIP), but the number of polices-in-force was low. Beal (1983) reported that perhaps only perhaps 5% of the damage was covered by flood insurance, which is a separate policy from homeowner’s insurance. The low amount of coverage included business and renter’s policies, as well as individual flood insurance policies. This number was not unexpected.

McPherson and Saarinen (1977) conducted in-person interviews with residents of the newly mapped TMA 100-year flood zones using a survey instrument to gather information about perception of flood risk and flood insurance. McPherson and Saarinen (1977) findings suggest "residents appreciated the risk for the floodplain as a whole, but do not recognize the danger in their own neighbourhood." Only a small percentage said they would purchase flood insurance. Most residents also pointed to the government as the entity responsible for solving the problem with an emphasis on technological or engineering solutions. Findings suggested individuals were not taking action to protect their personal property from flood damage. In addition, Saarinen et al. (1984) found that the growing population included an influx of newcomers who were unfamiliar with the flood risk and may have assumed that the possibility of a large-scale flood event would be rare in an arid lands environment. This may have also contributed to the dearth flood insurance coverage in place during the 1983 event.

Furthermore, flood insurance is separate from the average homeowners policy, and that means an additional cost to the homeowner. Participation in the NFIP Community Rating System (CRS) can decrease the cost of flood insurance for individuals and businesses. A community acquires points linked to 18 activities meant to reduce the flood threat (FEMA 2016b). These activities are organized into four categories, which are Public Information, Mapping and Regulation, Flood Damage Reduction and Flood Preparedness. The more points a community acquires, the lower the CRS ranking, which leads to a higher discount on NFIP premiums. Pima County, plus some of the municipalities within, have met some level of CRS standards, which rank 1 through 10, with 10 being the lowest score and 1 the highest. As of October 1, 2016, Pima County held the second most favorable ranking of all participating communities in Arizona, with only Maricopa County (where Phoenix is located) holding a better ranking by one point (FEMA 2016b). In fact, less than a dozen of municipalities out of the hundreds that participate in the CRS hold a better ranking than Pima County (FEMA 2016b). The City of Tucson, the largest municipality within Pima County holds a ranking one point less favorable than Pima County. In August of 2016, the city adopted the first Floodplain Management Plan (FMP) with a major focus on improving their CRS rank (City of Tucson 2016).

In the years since, PCRFCD has made efforts to educate residents about their flood risk. With today's technology, residents have the ability to research their flood risk and flood insurance options from their home computers, tablets, laptops or SmartPhones. Pima County hosts an interactive software program where residents can view Digital Flood Insurance Rate Maps (DFIRMS) (PCRFCD 2016b). However, these maps show only the high-risk areas determined by FEMA, and not those mapped by local jurisdictions. For example, PCRFCD mapped additional flood zones on smaller waterways draining into the larger FEMA-mapped waterways. These additional flood zones are not shown on DFIRMS and individuals may have to travel to PCRFCD headquarters in order to view the information. In addition, PCRFCD provides information only for unincorporated areas within the county. Since 1984, the state of Arizona allowed incorporated jurisdictions to enforce their own floodplain management regulations. All 5 incorporated jurisdictions in Pima County chose to do so (PCRFCD 2016c). This means those jurisdictions may have had additional information valuable to residents, but not readily available in a digital format. For example, the City of Tucson defers to PCRFCD for flood zone information in much of their online paperwork (City of Tucson 2017). The City of Marana posted digital images of paper maps showing flood zones on their website, but does not provide links to the interactive maps maintained by the PCRFCD (City of Marana 2017). The process of determining flood risk remains complicated for residents, who may not know where to look for reliable information.

Structural Solutions

While these programs were generally useful as nonstructural flood protection measures, structural flood control remains an essential part of curbing risk during future events. One important change that came out of this historic flooding was a shift in bank protection engineering. First, no matter the type of bank protection, it became apparent that more was needed. This included extending the existing network of bank protection by connecting segments to prevent erosion upstream and downstream of the existing structures. Baker (1984) reported in a post-analysis study “piecemeal bank protection generates greater channel instability than does no protection at all.” Second, engineers focused on installing soil-cement because it was the only type of bank protection that fully withstood the 1983 floodwaters. In the year following, soil-cement became the primary bank protection installed in Pima County (Peirce and Kresan 1984).

Another structural solution, building a continuous wall of protection along major waterways, would have been a challenge. While the ingredients for the soil-cement mixture were readily available, installation was not as straightforward. Pima County required a cemented bank be installed below the depth of possible scour, which often meant digging 8 to 10 feet into the streambed (Pima County Dept. of Transportation and Flood Control District 1985a). In addition, the height of the soil cement needed to exceed the accepted 100-year surface water level by one foot, resulting in a structure could be 15 to 20 feet high (Kresan 1988). With a mix of private and county- or city-owned land along the banks, payments for installation were also an issue. If the private land parcel was in a zone classified as the Pima County Improvement District, the county would cover 50% of the construction cost, but if the private land was outside of that zone the landowner was responsible for 100% of the cost. Public acquisition of the private land was an option but costly. The U.S. Army Corps of Engineers (USACE) estimated land acquisition could cost up to $3 million per mile (Saarinen et al. 1984). In 2018 dollar values, that cost is nearly $7.6 million per mile. Because of this expense, the USACE said the current value of structures along the waterways did not justify the cost of protection (Saarinen et al 1984). However, based on the 1983 flood damage, piecemeal bank protection wasn't an ideal solution and an effort needed to be made, regardless of cost. Over the years, as funds became available and projects approved, bank protection expanded to 75 miles by 2007 (Maits and Hendricks 2007). Installation continues today.

Other Engineering Options

In addition to bank protection, other engineering options included slowing waterflow from smaller washes into larger washes by increasing flood storage areas, which included expanding riparian habitats and constructing detention basins. Pima County Dept. of Transportation and Flood Control District (1985a) stressed the importance of preserving and creating these areas, especially with the channelization that occurs with the installation of bank protection or cement lined streambeds. Flood peak volumes increase downstream when flood storage areas are reduced due to development or channelization.

Detention/retention basins were in place to protect parts of the growing city prior to the 1983 event. A 1945 flood that killed 10 people led to the construction of a channel to funnel water away from Davis-Monthan Air Force Base on the southside of the TMA and into the Santa Cruz River south of downtown (Pima County Board of Supervisors 2013). Subsequent flooding issues along this channel led to the TMA's first detention basin in 1966. Designated the Ajo Detention Basin, this area became the focus of restoration project completed in 2002. The main focus of restoration was creating a system by which to harvest runoff for the purpose of watering fields at the nearby sports complex. During that process, PCRFCD also created trails lined with educational signs, plus expanded the riparian habitat, which served as a refuge for wildlife in an urban area. Similar restoration projects were investigated on six other existing detention basins (Postillion et al. 2007). While water-harvesting for turf purposes was not economically feasible at these other locations, there was the benefit of expanding riparian habitats and green space for recreational activities. In addition, PCRFCD and the City of Tucson adopted a revised Stormwater Retention/Detention Manual in December 2015. While these regional detention basins are effective, the manual also stressed the importance of smaller-scale basins, such as road embankments, small basins adjoined to parking lots, and neighborhood parks or recreation areas (PCRFCD 2015). Requirements for commercial and residential development retention/detention and discharge flows are outlined in detail in that document.

Vegetation was also used to stabilize banks, plus reduce the amount of sediment deposition downstream from erosion. Undeveloped banks with sufficient vegetation experienced little to no erosion during the 1983 event (Saarinen et al 1984). Figure 4.4 shows the location of riparian projects by the PCRFCD through 2016, which are scattered across the entire eastern half of Pima County, which encompasses the TMA. "The Loop"[6] project is a direct outcome of the PCRFCD's efforts to connect riparian areas and maintain a greenway along waterways. Currently, The Loop is a 100-mile paved path along major waterways, including the Rillito River, Santa Cruz River, and Pantano Wash, where people can run, walk, bicycle, and even ride horses along some stretches. In many areas, this path is lined by a mesquite bosque habitat. The PCRFCD maintains most of the pathway and flood control facilities along The Loop, even when it extends into other jurisdictions like the City of Tucson (PCRFCD 2016c). The Loop is slated for continued expansion to a total of 131 miles.

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[6] See The Chuck Huckleberry Loop http://webcms.pima.gov/government/the_loop/

Figure 4.4. Riparian Habitat Projects (PCRFCD 2016c).

Due to flooding cutting off parts of the county in 1983, the Pima County Dept. of Transportation and Flood Control District (1985a) proposed better access to remote areas. New or improved infrastructure could be used by public welfare officials and NGOs when providing future assistance, plus allow residents in these areas to safely evacuate if needed. Additionally, better access to remote locations gave people in these areas increased employment and educational opportunities with less hazardous travel routes. Pima County Dept. of Transportation and Flood Control District (1985a) concentrated initial updates in ten areas at an estimated cost of $9.3 million. Improvements continue as the population of the TMA expands. At present, Pima County lists four active projects with another six in the design phase (PCRFCD 2016c). These more recent projects are funded from 1997 and 2004 bonds approved by voters.

Rainwater Harvesting

To alleviate flooding issues on roads and smaller waterways (plus reduce the amount of potable/drinking water for use in landscaping), many communities in the TMA promote rainwater harvesting. Some of this activity involves Green Stormwater Infrastructure (GSI) projects. In a 2015 GSI cost-benefit study along one wash on the Southside of the TMA, the data showed for every one dollar spent on GSI there would be two to four dollars in community benefit, including reduced cost of flood damage in future events (Watershed Management Group 2015). The City of Tucson also adopted a Green Streets policy, which requires new roadway projects to capture at least 1/2" of runoff (multiplied by the project area) in a nearby basin, planted with native grasses, shrubs and trees (Wittwer 2013). In addition, the Rainwater Harvesting Ordinance took effect 2010 for Pima County and the City of Tucson. It requires landscapes at all new commercial development to use at least 50% of harvested rainwater versus irrigated water (Letcher and Huckleberry 2009). While this was mostly done to save drinking water from going to irrigation purposes, it also has the benefit of reducing flood risk in local washes. While these projects are beneficial, there is along way to go before the municipalities are able to replace old infrastructures to make their systems compliant with the newer regulations and concepts.

Subsequent Major Flood Events: Has Anything Changed?

Major flood events in the 1990s and 2000s provided a test of the changes that had been made in flood protection efforts after the 1983 flood. The extreme flood events of winter 1993 and July 2006 were introduced in Chapter 2 but will now be addressed in more detail.

The Winter 1993 Event. Much of Arizona experienced flooding during the winter of 1992/93. Upper atmospheric conditions favored a southerly winter storm track, which allowed low-pressure systems from the polar region to interact with the sub-tropical jet stream. This funneled warm, moist air into Arizona resulting in three months of above-average rain totals for much of the state, including the TMA (House 1993, House and Hirschboeck 1997). Over the course of two weeks in January, periods of heavy rain over already saturated ground led to flooding that lasted two weeks in normally dry waterways (PCRFCD 2016c). For all of Arizona, damage estimates reached nearly $230 million in 1995 dollar values, which is over $380 million in 2018 dollar values (UCAR 2003). For Pima County, public infrastructure damage was estimated at $13.9 million, which is about $23 million in 2018 dollar values (Osmolski and Karim 1996).

In the TMA, no lives or homes were lost during this flooding, and the only loss of structures was a business' horse barns along the Rillito River (PCRFCD 2016c). While there were no reports of homes damaged by flooding, new flow records were set for Sabino Creek near the Recreation Area Dam and for Tanque Verde Creek at Sabino Canyon Road (McHugh 1995). High flows were also recorded in the Rillito and Santa Cruz Rivers, but the peaks were not as high as in 1983. As is typical of many winter flood events produced by one or more large scale storm systems, the water in the streams flowed for a longer period of time: a factor of weeks in 1993 versus hours or days in 1983.

Post-event studies attributed lower damage estimates from the 1993 event to the expansion of bank protection, FLAP, increased standards for bridge design and improved floodplain management (Osmolski and Karim 1996, Hansen et al 2011). One area where damage was reminiscent of the 1983 events was erosion immediately upstream of five bridges over the Santa Cruz River. Scouring at bridge piers and abutments also occurred.(Osmolski and Karim 1996). The Tucson NWS (2014) also reported that thousands of people along the Rillito River were stranded as water washed over roads making some routes impassable.

After the 1993 flooding, Pima County expanded soil-cement bank stabilization upstream of the bridges and added structures to direct flow around bridge abutments (Osmolski and Karin 1996). Two new structural flood control projects were also put into place to protect these structures from future flooding. One project was soil-cement pavement lining the bed of the wash around the piers and abutments. This reduced the amount of sediment washing away at the base of these structures. The other project used a newer technology, which employed a series of permeable panels made up of synthetic nets. These panels acted as a spur, redirecting water away from a bank where significant erosion occurred during the flood. The spurs reduced the flow velocity with the hope of eliminating erosion during future high flows (Osmolski and Karim 1996).

The July 2006 Event. In late July 2006, another flood event hit the TMA. Atmospheric conditions that included moisture influx from remnants of Tropical Storm Emilia, a stalled upper level low pressure system, monsoonal convective thunderstorms and a series of nocturnal mesoscale convective complexes led to rainfall that poured down over the Santa Catalina mountains and other southeast Arizona mountain ranges for 5 consecutive days (Griffiths et al. 2009). Rain-soaked hillsides collapsed, which created damaging debris flows. Rain gauge amounts from Sabino Canyon in the Santa Catalina mountains were estimated to have recurrence intervals of 1000- to 1200-year (Magirl et al. 2007, Webb et al. 2008, Griffiths et al. 2009). While much of the material in the debris flows remained in canyons, water flowed out of the canyons and into waterways crossing the desert floor. A new flood of record was measured in six Pima County waterways, including the Pantano Wash and Rillito River (PCRFCD 2007).

Infrastructure in the Sabino Canyon Recreation Area, which is part of the Coronado National Forest, was heavily damaged by debris flows and flooding. Around $4 million was needed to repair that damage (Beal 2008). City of Tucson (2016) reported 40 homes and businesses were damaged and one destroyed by flooding. Collectively, the damage estimate was over $1.3 million. A debris flow coming out of a nearby canyon blocked the channel causing water to flood into nearby homes. More homes were flooded as water moved out of canyons and onto the desert flood. Water in the Rillito River reached bankfull and overflowed in the Midtown area, however, the amount of damage from this overflow was not significant. Much of the flooded area was now part of The Loop, which was designed to be a buffer against floodwaters reaching private property while offering a place for public recreation. However, sediment accumulation was so great in one area along the Rillito River that water backed up into a subdivision, although no homes were reported damaged. Homes on the west side of the TMA were not so lucky. Along a creek draining from the Rincon Mountains, 35 homes experienced flood damage (PCRFCD 2007). Additionally, a cement plant and gravel pit were flooded as water moved out of the Rillito River and into the Santa Cruz River. Downstream in Marana, 80 families were evacuated one morning as a precaution, but most returned home in the evening when water started to recede and it became apparent the flood threat to their homes had subsided. While there were some reports of personal property damage in this area, there was no documentation of damage to the actual homes (Tucson Local Media 2006). Floodwaters did damage the irrigation system of a nearby farm. The cost of repair was estimated at $300,000 to $500,000 (Quinn 2006).

Damage to public infrastructure from the 2006 event was estimated at over $500,000 (not including the Sabino Canyon damage) and included repairs to washed out parts of the Catalina Highway, which winds its way from the desert floor to the highest peaks of the Santa Catalina Mountains. Within the waterways, deposition and erosion impacted the carry capacity of future flows. FEMA cleared $8 million of emergency funds to address these issues (PCRFCD 2007).

Around the TMA, roads built through normally dry channels were closed as water drained away. Some individuals ignored the danger and drove into the water. Numerous swift water rescues were reported from people driving into the water and the car stalling. City of Tucson (2016) estimated 100 vehicles were flooded. After the flooding, Pima County was one of five Arizona counties that received $13.6 million in federal disaster declaration funds.

During a post-flood interview, a division manager at PCRFCD said “we would have been annihilated” had the measures taken after the 1983 event never been put into place (Meltzer 2007). Soil-cement bank protection once again proved successful. Hansen et al. (2011) reported less than one percent, 225 feet of 10.8 miles, of soil-cement was damaged in this event. This was due to scour beneath the toe depth of the structure, which highlights the importance of burying many feet of the soil-cement bank protection below the current streambed.

Erosion and deposition again caused issues in the Santa Cruz and Rillito Rivers, as well as the Pantano Wash. With the funding from FEMA, engineers were able to immediately address some of the issues. Of the $8 million received from FEMA to restore the carrying capacity of these waterways and stabilize erosion, $3 million was used before the fiscal year closed.

Debris flows posed a new threat. While the danger was known to geologists, the size and number which occurred during the 2006 event was unexpected (Pearthree and Youberg 2006). Over 250 debris flows in the Santa Catalina Mountains were recorded from the 2006 event, along with dozens in other mountain ranges. While debris flows have been linked to areas previously burned during wildfires, the 2006 flows were not in areas impacted by recent fires. This led geologists to reassess the threat to homes, buildings and infrastructure. As the city expands into the foothills and more structures, roads and infrastructure are built, the threat of debris flows needs to be taken into account. The 2006 debris flows results revealed that, given the right environmental conditions, the geomorphic processes associated with these flows can be active on a scale larger than previously thought.

Creating more accurate maps was a major focus of PCRFCD during this year. While the 2006 flooding did not impact efforts already underway, the event highlighted the continued need for updating the maps on a regular basis. As PCRFCD moved from paper to digital maps, officials realized there were “inconsistencies in the accuracy of local and federal maps” (PCRFCD 2006). This was due to a difference in map projections used by the county and FEMA when creating maps. Projections are used in mapping to represent the curved surface of the Earth, which is in 3-D, on a flat 2-D map. This can cause some distortion of the surface on the 2- D map. In GIS software, projections are used to link the data together. If the projection methods don’t match, flood zones could be placed in the wrong areas, falsely increasing risk for some homes while not representing the elevated risk of flooding for others. To make the necessary corrections, PCRFCD gave engineering firms working on map updates open access to the FEMA data with both local and federal projections. By doing so, PCRFCD claimed in their 2005/2006 annual report “local reviews have become more accurate and FEMA’s map processing time has been reduced” (PCRFCD 2006). At the time, PCRFCD was the only known community in the country to provide this service (PCRDCD 2006).

After the July 2006 flooding, four homes were purchased through FLAP (PCRFCD 2007). These homes were built prior to the stricter floodplain building regulations that were put in place after the 1983 event. Owners of two of these homes were rescued from their roofs because they had no time to evacuate with the quick rise in water.

Discussion

“This was the flood our children and grandchildren will be told about time and again as we warn of the awful power of the normally dry rivers” (Beal 1983). This statement rings true with tributes and comparisons to the 1983 flood event in TMA local news reports decades later. Even with subsequent high flows in some TMA waterways, the 1983 event continues to rank at the top of historical floods because the dramatic damage and disruption to life area-wide has never been repeated. However, the record flow numbers in the event itself were challenged, and even broken in some washes, in 1993 and 2006. Mitigation efforts put into place after the 1983 event were a direct contributor to reducing the impacts of these subsequent flood events.

Structural flood control projects, such as bank protection, proved effective. With even larger flows in the Rillito River in 2006 compared to 1983, the damage was minimized due to the cement-soil bank protection installed during the intervening years. However, as with any physical structure, upkeep is important to maintain the level of protection. Preventative maintenance falls by the wayside during times of “financial constraint” (McDuling et al. 2014). While in the short-term this may save money, the long-term implications are clear. It costs less to maintain an asset rather than return it to good condition after deterioration (McDuling et al. 2014). As is the case with much of the rest of the country, Pima County, the City of Tucson, and surrounding municipalities were hit hard in the 2008 recession (Pima County 2015). It is not clear what long-term impacts this could have on the community.

Adding to the difficulty in assessing personal risk, developers may use engineering to remove buildings from 100-year flood zones when developing in high-risk areas. One neighborhood on the northwest side of the TMA was removed from the 100-year floodplain prior to development due to engineering efforts (Pima County Communications Office 2008). In this case, flood risk was minimized but not erased. Some homes in the neighborhood are still in a 500-year flood zone (PCRFCD 2017). If a home is in this flood zone, the owner and realtor are not required to disclose that information at the time of sale. This may leave a homeowner unknowingly at a higher risk than they would prefer.

As larger waterways have been successfully engineered for flood control, smaller waterways generally remain untouched. This is especially true for those waterways not mapped for flood risk, which have an estimated base flood peak discharge of less than 100 cfs and/or those washes on private property. While widespread damage is not likely along smaller washes, damage like that seen in 2006 with 40 homes flooded along a wash exiting mountains to the east of the TMA, shows the need to support continued efforts to map flood risk.

Regardless of how large or small a waterway, continued advancements in computer software and computational power gives engineers increased information about how runoff could impact an area. FEMA released a loss and risk assessment software package called HAZUS in 1997 with the latest update issued in 2017 (FEMA 2017). Engineers with the PCRFCD and the City of Tucson use this, plus additional updated software, to better understand the threat of flooding (City of Tucson 2016). But, constant review is necessary. Risk changes with each flood as erosion, aggregation and degradation occurs, even in minor flow events. These changes can add up over time, shifting flood risk along the waterway.

Even with progress in flood risk research and risk reduction made since the 1983 event, the knowledge of how this risk is influenced across multiple disciplines is still developing. Merz et al. (2014) writes “it is noted that a richer understanding of floods requires considering the interplay of climate, geology, topography, vegetation (biology) and humans. Experience, methods and data from a variety of scientific disciplines (e.g. meteorology, climatology, palaeohydrology, geography, economics) and from practitioners (e.g. insurance, disaster management and water authorities) need to be integrated.” Research in each of these areas continues to advance as datasets extend over time, new ones are developed and advancements in technology are applied to data collection and analysis.

As for non-structural measures, a myriad of regulations are now in place for development on mapped floodplains. As technology has advanced and knowledge of the flood risk became more expansive, so have the regulations meant to protect the public. FLAP is an effective program, but the money needed for purchasing damaged homes is not always available. FLAP is funded through general obligation bonds and the District tax levy, which means funds must be available prior to purchase. This could limit the amount of property that may be purchased in the event of another major flood (PCRFCD 2016c).

Overall, local officials created a more resilient community following the 1983 event. Disruption in normal day-to-day activities was not repeated during and following subsequent events, and the financial cost of the damage was lower than in 1983. While financial assistance from outside the community was still needed to recover, resiliency can be found in the reduced need for help from these resources. However, that’s for the community as a whole. What about homeowner’s impacted by the floodwaters? While fewer homes were damaged or destroyed due to the improved structural and non-structural efforts by the community, affected homeowners still bore the full brunt of the financial consequences unless flood insurance policies were in place. With low participation in NFIP, the main source of flood insurance coverage in the U.S., homeowners remain vulnerable and financial resiliency is not achieved. Potential reasons on why there is low participation is explored more fully in Chapter 4. By increasing flood insurance policies, homeowners impacted by flood events would build personal financial resilience and contribute to the efforts to make the TMA a more resilient community as a whole.

CHAPTER 5
ESTABLISHING FLOOD ZONES AND FLOOD INSURANCE

Floodplains and flood zones, while related, are two different entities. Every waterway has a floodplain because every waterway can possibly overflow into the neighboring land. However a flood zone is strictly a manmade designation of risk. Flood zones are defined by flood risk over a specific geographic area. In the U.S., that risk is determined by Federal Emergency Management Agency (FEMA) or other local, state and federal government agencies. FEMA flood zones designations establish flood insurance premium rates in the National Flood Insurance Program (NFIP). In general, the idea behind these rates is ‘the higher the risk, the higher the premium’.

Evolution of the NFIP

Until the early 1900s, flood protection was mainly a local or state government issue. While there was some federal aid in the 1800s to control floods, most federal waterway projects were focused solely on improving navigation. It was only after major flooding between 1907 and 1913 on the Mississippi and Ohio Rivers, plus in the Northeast U.S., that the federal government began seriously looking at a national flood protection program (Arnold 1988). This helped lead to the Flood Control Act of 1917, which appropriated funds for flood control on the Mississippi and Sacramento Rivers, as well as some of the tributaries of the Mississippi River. While this act covered a limited number of waterways, according to Arnold (1988) it “established important precedents and frameworks” for future legislation regarding flood control. The 1917 legislation was the first to focus on both navigation improvement and flood control instead of solely the former.

In the decade following the Flood Control Act of 1917, the Corps of Engineers focused mostly on levees as the form of flood control. Another large flood on the Mississippi River in 1927 proved this approach was flawed as thousands of acres of land were inundated with floodwaters when levees failed. This flood, plus another smaller but devastating flood in New England, then led to the Flood Control Act of 1928. This act appropriated $325 million dollars for additional flood control which included engineering beyond levees, plus protected the federal government from being held liable for flood damage.

A political debate on national flood control efforts continued within the federal government during the years following the Flood Control Act of 1928 as economic losses and human casualties from flooding continued to grow. This all led to the Flood Control Act of 1936, which made flood control a national priority on all major waterways, not just the ones listed in the 1917 and 1928 acts. According to the Flood Control Act of 1936 floods "constitute a menace to national welfare" and improvements to the waterways were approved for funding with federal dollars only if the benefits outweigh the costs (74th Congress, 2nd Session 1936).

While many engineering projects were put into place to control floods after 1936, damage did not cease. Mounting costs meant more federal aid was handed out after large floods in following years, but there was no major movement for additional flood control efforts until the mid-60s.

In 1965, Hurricane Betsy struck the Gulf Coast. Storm surge flooded parts of New Orleans, plus other coastal areas in Louisiana and Alabama. The storm did so much damage it earned the nickname "Billion Dollar Betsy" because it was the first billion dollar natural disaster in the United States. This historic weather event, along with another round of flooding in the upper Mississippi River basin, ignited the debate for flood insurance. A report in 1966 titled "Insurance and other programs for financial assistance to flood victims" recommended a federal insurance program be created. This was in lieu of a private industry alternatives due to a "lack of past industry interest" (89th Congress, 2nd Session 1966). This report was influential in drafting the National Flood Insurance Act of 1968.

The National Flood Insurance Act of 1968 created a federally-backed insurance policy available only to properties in Special Flood Hazard Areas (SFHA). This program was named the National Flood Insurance Program (NFIP). According to FEMA, a SFHA is "land area covered by the floodwaters of the base flood" (FEMA n/d). A base flood is also commonly known as the 100-year flood. Statistically, a base flood means there is one percent chance of the flood being "equaled or exceeded in any given year" (FEMA 2003). The Federal Insurance Administration (FIA), which is part of the U.S. Department of Housing and Urban Development (HUD), was created to manage the NFIP.

NFIP was to be funded completely from the premiums collected. However, the purchase of flood insurance was voluntary. This resulted in low program participation, even as the cost of flood damage continued to mount in subsequent years. Short on funds from premiums collected, federal tax dollars were tapped to cover claims by policyholders (GAO 2015). To increase participation and the financial stability of NFIP, Congress passed the Flood Disaster Protection Act of 1973. This mandated flood insurance coverage when buyers used a federally-backed loan to purchase or improve property in the SFHA.

When NFIP was created, flood insurance could only be purchased through agents working with the Federal Insurance Administration (FIA), which manages the NFIP. This meant a limited number of agents were available to assist with writing policies. In 1983, the federal government created the Write-Your-Own Program (WYOP). Select private insurers could now write policies for future home and business owners with no increase on premiums for their services. NFIP premiums are set by the federal government and can only be changed by that entity. The WYOP allowed a greater number of agents to assist homeowners in acquiring flood insurance.

In 1993, claims on flood losses drained NFIP reserves. It was determined that low participation in NFIP from homes in SFHAs directly resulted in the monetary deficit (King 2008). Many of these homes were required to purchase flood insurance under the Flood Disaster Protection Act of 1973. However, enforcement of this mandate was weak. The National Flood Insurance Reform Act of 1994 strengthened compliance for properties purchased through a federally-backed home loan in an effort to re-build NFIP reserves. In 1993, the Federal Insurance & Mitigation Administration (FIMA) was also formed. FIMA took over management of NFIP and was the first agency to focused on reducing or eliminating risk of property damage, rather than simply react to it when it occurred (FEMA 2018a).

A decade later Congress passed the National Flood Insurance Act of 2004, which also addressed ongoing compliance issues. However, the main point of this act was to work towards solving the repetitive loss problem (FEMA 2016c). A growing number of insured properties experienced two or more losses within a 10-year time frame (OIG 2009). Congress approved funds to aid property owners with mitigation to reduce the losses, including purchase of the property and converting it to open space. Properties were pre-selected for this program.

In 2012, the Biggert-Waters Flood Insurance Reform Act was passed by Congress. To ensure the NFIP remained fiscally sound, premium rates were adjusted to reflect flood risk (FEMA 2016c). Previously, some of the premiums paid by property owners in high-risk areas were subsidized to keep the cost of the policies down (Sarmiento and Miller 2006). This change in premium cost to reflect risk lead to steep increases for some high-risk properties, making the coverage unaffordable for some homeowners. To ease the financial burden, the Consolidated Appropriations Act of 2014 ceased some rate increases until concerns over cost could be addressed (FEMA 2016c). That same year the Homeowner Flood Insurance Act repealed parts of the Biggert-Waters Flood Insurance Reform Act in an effort to keep the cost of premiums reasonable for homeowners in high-risk areas, while also adding an annual surcharge to all policyholders to increase funding for NFIP (FEMA 2016c).

Even with the recent changes to strengthen the financial accountability of the NFIP, funding remains a concern. The U.S. Government Accountability Office issued a High Risk Report on the program in 2015 stating "it likely will not generate sufficient revenues to repay the billions of dollars borrowed from the Department of the Treasury to cover claims from the 2005 and 2012 hurricanes or potential claims related to future catastrophic losses" (GAO 2015). Additionally the existence of the program is periodically threatened by the need for Congressional reauthorization. If the program is not renewed by Congress when needed, tens of thousands of home closings could be threatened each month, plus current homeowners may not be able to renew policies making them financially vulnerable to flood damage (FEMA 2018b).

Because of these issues with NFIP funding, it could be argued that NFIP does not contribute to resilience as it is defined in Chapter 2, but instead hinders it. Insurance is an important tool in protecting against risk. A person pays a premium for an insurance policy and the insurer agrees to pay that person in the event of loss, damage, theft or medical treatment, depending on the type of policy. To sustain itself, the insurer needs to cover normal operating expenses and the cost of payouts with the pool of money created by premiums. Because taxpayer dollars, in addition to premiums, currently fund NFIP, it could be interpreted that the funds provided are sourced from resources outside the community. While this is a valid argument, this research is focused on what individual homeowner's can do to build resilience and is operating under the assumption that the program will be self-sufficient at some point in time, even if that is not likely based on current conditions.

Mapping Flood Risk

After initial floodplain mapping by the USACE in the 1960s and 1970s to determine NFIP flood zones, there were only occasional updates, additions or changes to flood zone maps. With advances in mapping and risk assessment technology, plus land-use change and population growth, many maps were not informative for the current state of flood risk. This lack of updated data became a noticeable issue in places like the coastal plains of North Carolina. In 1999, two hurricanes soaked the state in as many weeks, prompting widespread flooding over the eastern third of the state. Over 4000 of the roughly 7000 homes destroyed from this flooding were un-insured or underinsured (NOAA 2000). This was a direct result of unknown risk due to outdated flood zone maps. Flood zone map updates showed the old maps to be off by up to 10 feet in some areas (Douglas 2004). As a result, many homeowners simply didn't know the true risk of flooding to their property.

Across the nation, an analysis of flood zone maps showed similar problems. Skinner (2005) reported "over 70% of the maps are more than 10 years old; many of the floodplains depicted on them where hand-drawn and are difficult to update." It was clear there needed to be a widespread update to flood zone maps. To prioritize an update, the U.S. Congress funded Flood Map Modernization (FMM) from fiscal years 2003 to 2008.

Flood Map Modernization addressed three key points in updating NFIP maps - (1) reflect development and/or natural changes to the environment, (2) use current data and technology to identify flood hazards and (3) show actual risk, encourage responsible floodplain management and increase flood risk awareness (FEMA 2015). Plus this program essentially transformed most maps into a digital format, allowing the public and professionals to easily, and at no cost, access the data with Geographic Information Systems (GIS) software. These new maps are called Digital Flood Insurance Rate Maps (DFIRMS). Updated mapping continues today with FMM transitioning into an new program called Risk MAP in 2009 (FEMA 2010).

NFIP in the TMA

In the TMA flood zone maps were first created by the Corps of Engineers in 1973 (McPherson and Saarinen 1977) (Figure 5.1). At this time, the flood zones were mapped for only the major waterways, considered to be the Tanque Verde Creek, Pantano Wash, Rillito River and Santa Cruz River. The Tanque Verde Creek and Pantano Wash drain from the east side of the TMA and flow into the Rillito River, which meets up with the Santa Cruz River on the northwest side of the TMA. The Santa Cruz River stretches from the Arizona/Mexico border and northward along the west side of the TMA. These are all ephemeral waterways, meaning water generally only runs through these channels after extreme precipitation events.

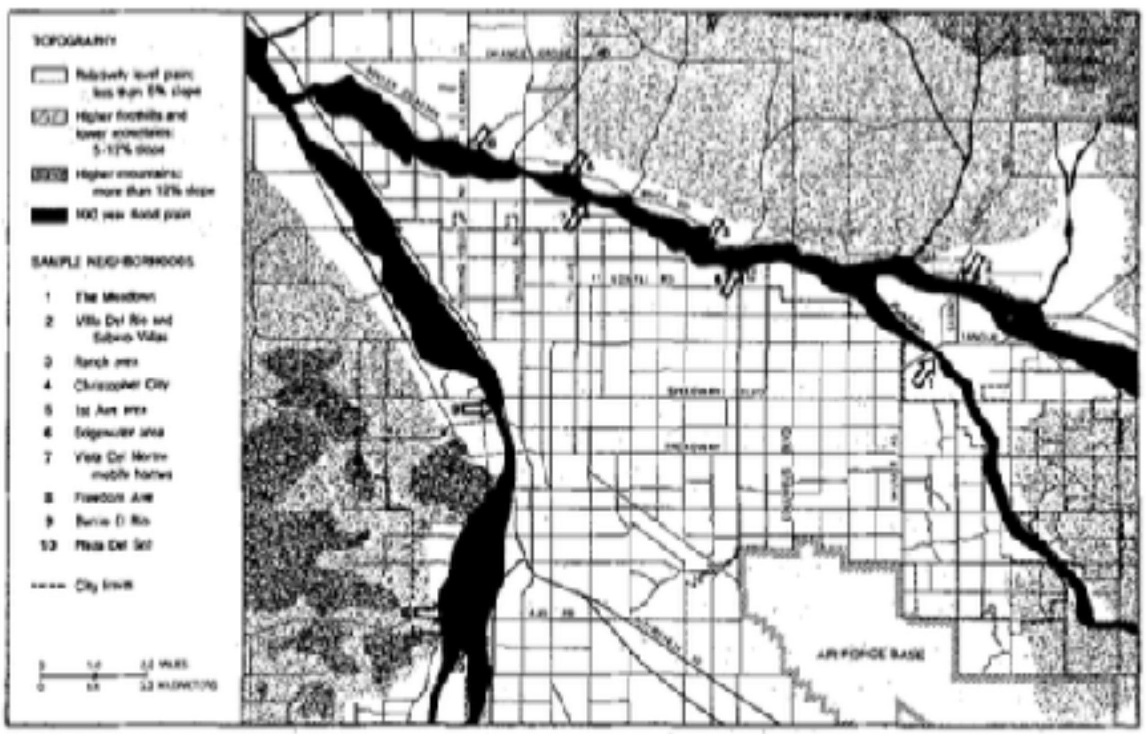

Figure 5.1. 1973 map of SFHAs in the TMA (McPherson and Saarinen 1977).

While some additional mapping was completed in next three decades, it wasn't until the FMM program was implemented that a widespread update of NFIP maps was completed in the TMA. The new DFIRMS went into effect in June of 2011. Figure 5.2 is a timeline indicating how flood control and NFIP progressed across the nation and in the TMA, plus major flood events that influenced flood control.

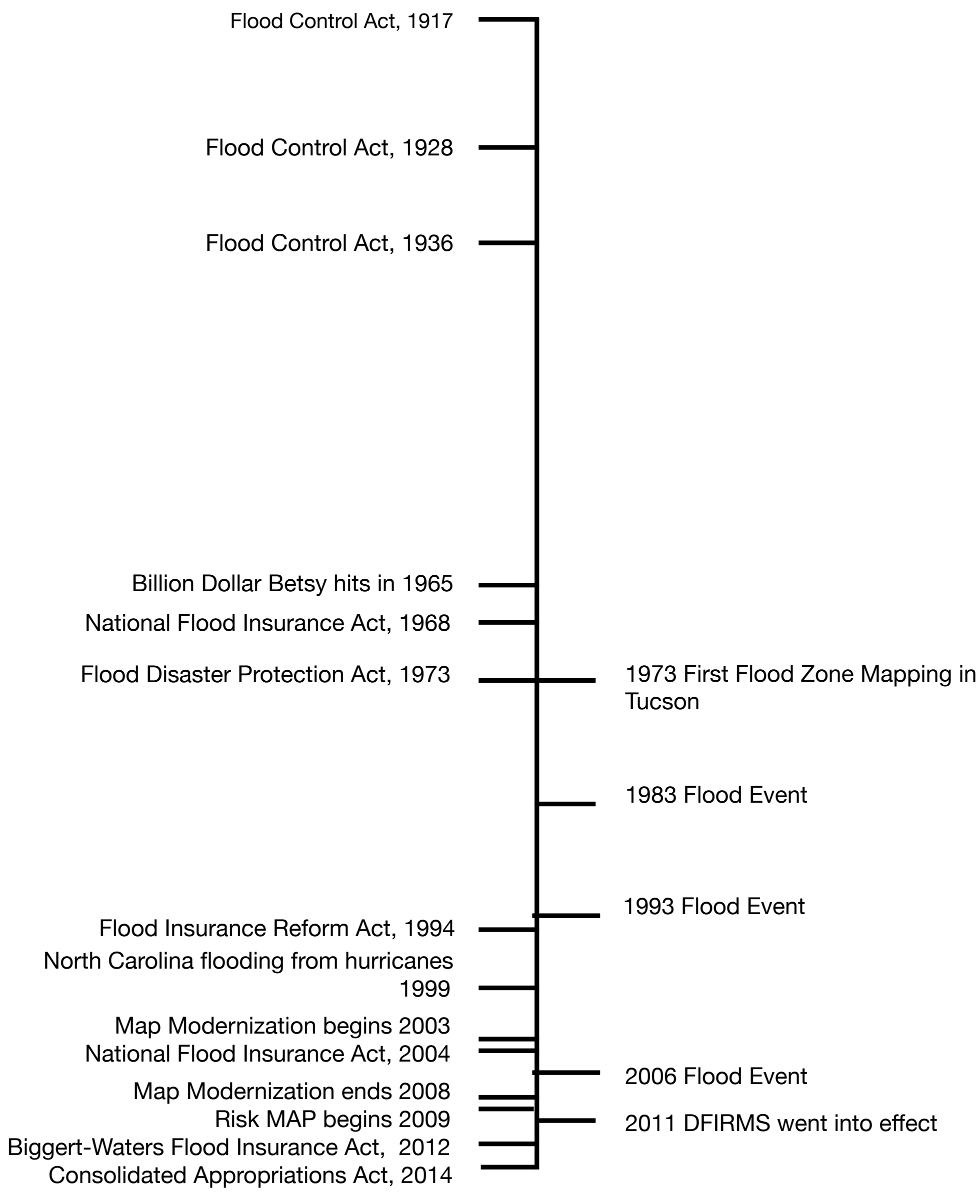

Figure 5.2 Timeline of national and Tucson flood events, flood related legislation and flood plain mapping efforts

There are many miles of smaller creeks, streams and arroyos that drain into these major waterways. Each one of these smaller waterways poses a flood risk as well. To define flood risk along these smaller waterways, the county authority for flood control mapped two additional flood zones - Special Studies and Sheet. The Special Studies flood zones are additional 100-year floodplains in the TMA. Sheet flood zones are broad areas of possible inundation that are not associated with a defined stream channel. Information on these flood zones is available to the public through the county, but these flood zones are not recognized by the NFIP. This allows homeowners at risk of flooding in these smaller-scale waterways to purchase flood insurance at a discounted rate.

In Pima County, including the towns of Marana, Oro Valley and Sahuarita, plus the city of Tucson, 4787 NFIP polices were in-force as of November 30, 2014 (FEMA 2015) (Table 5.1). The city of Tucson, these towns, plus other municipalities and unincorporated areas of eastern Pima County, make up the TMA. The numbers include policies held by homeowners, renters and business owners. Keeping this in mind, this is still a low number compared to the single-family residences with at least a portion of their property within a known flood zone. According to data analyzed in Chapter 5 from the Pima County Assessors Office, as of November 26, 2014, 208,073 single-family residential properties of 5 acres or less were located in the TMA. Of these, 21554, or 10.36%, are all or partly located in a known flood zone as determined by FEMA or the country flood control authority. If all NFIP policies in force were for single-family residential properties 5 acres or less, that means only 20.22% of properties located in a known flood zone would be protected financially against flood damage. It is important to note the NFIP data cited above does not differentiate what kind of policies are in effect. The list includes business and renter coverage, as well as coverage purchased by homeowners. This means the numbers for NFIP policies in force are likely lower for the single-family residential properties 5 acres or less located, at least partially, in a flood zone.

Location	Policies In-Force	Insurance In-Force	Written Premium In-Force
Pima County	2439	$555,162,400	$1,744,672
City of Tucson	1819	$388,691,100	$1,690,655
Town of Marana	299	$78,836,900	$173,368
Town of Oro Valley	187	$49,480,000	$71,953
Town of Sahuarita	43	$11,547,900	$17,385
Total For All Locations	4787	$1,083,718,300	$3,698,033

Table 5.1. NFIP Policy Information as of November 30, 2104 (FEMA 2015).

NFIP Low Participation Factors

NFIP has notoriously low participation, not just in Tucson but in other regions across the U.S. as well (McPherson and Saarinen 1977, Blanchard-Boehm et al. 2001, Kousky and Kunreuther 2009). As a result, the program is partly subsidized by taxpayers, instead of self-sustaining with payments from premiums (Archer 2015). In a report contracted by FEMA, Sarmiento and Miller (2006) found the average annual cost to taxpayers is between $48 and $125 for damage to residences in SFHAs. Increased premiums could make up for part of this monetary discrepancy, but then the cost of insurance may become an issue for some homeowners, causing them to drop coverage. This was one of the reasons portions of the Biggert-Waters Flood Insurance Reform Act was repealed just two years after it was passed by Congress. Another solution is to put more insurance policies into effect. However, this is easier said than done because there are numerous reasons why people do not acquire flood insurance coverage. Blanchard-Boehm et al. (2001) list three main reasons that explain why people choose not to purchase flood insurance. These reasons are the psychological defense, varying degrees of perception and economics and are explored below. A fourth reason, also explored in this work, is a lack of knowledge about NFIP.

The psychological defense often includes the ‘normalcy bias’, which is the ‘it can’t happen to me’ mentality (Omer and Alon 1994, Valentine and Smith 2002). People fail to prepare for a disaster because they cannot mentally picture the event happening to them. In disaster preparedness, this can lead to increased vulnerability when an event, such as a major flood, occurs because people underestimate the the probability (Omer and Elon 1994). In a Tucson flood risk study, McPherson and Saarinen (1977) found that while the majority of respondents indicated an appreciation for the risk of living in a floodplain, a lower percentage related that risk to their specific neighborhood. The sample population for McPherson and Saarinen (1977) were residents of the SFHA along the Rillito River, recently mapped by the U.S. Corps of Engineers prior to the study. Even though these residents recognized they lived in a high risk area, they didn't mentally translate that into a flood impacting their lives.

Also related to the psychological defense is a belief the government will provide the funds necessary for recovery (McPherson and Saarinen 1977, Blanchard-Boehm et al 2001). McPherson and Saarinen (1977) found most people surveyed believe the city, state and county governments were responsible for solving the problem, not the individuals themselves. In a more recent survey, two-thirds of adults in 10 states, including Arizona, said the "national government needs to do more to address extreme weather impacts" (Civil Society Institute 2012). While government entities, such as FEMA, do provide some relief during disasters, it is not often enough to rebuild a home not covered by flood insurance. Instead many uninsured homeowners can apply for low-interest loans through the U.S. Small Business Administration (SBA 2015). However, these options are only available in areas declared a 'disaster' by the federal government and not for smaller scale events (FEMA 2015). Federal disasters are declared through a process outlined in the Robert T. Stafford Disaster Relief and Emergency Assistance Act, passed by Congress in 1988. The Governor of the affected state makes a request for assistance through the local FEMA or Emergency Preparedness (EPR) office. After review of the request, plus damage assessments by state and local officials, the U.S. President may issue a disaster declaration. This opens up federal funding for response and recovery efforts. However, these loans are capped at $40,000 for contents and $200,000 for construction to replace what is lost or damaged (FEMA 2016a). Simply put, the government is not going to rebuild your house. The simple step of better communicating the limitations of government funding during and after a natural disaster could increase the number of policies-in-force. Soane at al. (2010) found homeowners were more likely to purchase flood insurance if they perceived themselves as financially responsible for the damage over government agencies. Blanchard-Boehm et al. (2001)

suggested homeowners may be more “cautious and prudent” if they were more aware of the constraints of disaster declarations. A clear understanding of the financial limitations of government assistance, as well as addressing the normalcy bias, could be key in increasing NFIP participation.

Perception is perhaps the most complicated reason behind a homeowner’s choice to purchase or not purchase flood insurance since it is highly variable depending on the individual’s beliefs and experiences. Asnar and Zannone (2008) define risk as an “expected loss due to a negative event”. Among individuals, the amount of losses expected can vary significantly because perception of the risk is also highly variable. Living in a flood-prone area doesn’t necessarily translate to an awareness of that risk. Presented with the information, some individuals may be deterred from taking action or simply dismiss the data if it doesn’t fit in their current mental picture. Slovic (1987) found individuals use “mental strategies, or heuristics” to make sense of an uncertain world. Heuristics are informal problem solving techniques based on an individuals experience, beliefs, feelings, knowledge, or a combination of these and possibly more factors, including social and cultural influences (Slovic 1987, Gough 2000, Leiserowitz 2006, Drobot et al 2007, Ruin et al 2007, Coles 2008, Raaijmakers et al. 2008, Siegrist and Gutscher 2008, Whitmarsh 2008, Costa-Front et al. 2009, Figueiredo at al 2009, Spence et al. 2009, Kahan et al 2010, Soane et al 2010, Weber 2010).

Numerous studies indicate experience does raise awareness of the flood danger (McPherson and Saarinen 1977, Brilly and Polic 2005, Drobot et al. 2007, Ruin et al. 2007, Siegrist and Gutscher 2008, Spence et al. 2009, Petrolia et al. 2012). Brown and Hoyt (2000) found the number of NFIP policies positively correlated with flood losses in the previous year. However, Ruin et al. (2007) stresses the “recency, frequency, and intensity” of that experience is a factor on the level of awareness. For some people, flood experience led to less worry about future flooding (Blanchard-Boehm et al 2001, Soane et al. 2010). Theories behind this finding include a lack of control over the flood risk, meaning they feel helpless in the event of a flood, or that the flood experience only caused minor damage or inconveniences instead of major impacts (Blanchard-Boehm et al 2001, Siegrest and Gutscher 2008, Soane et al 2010). Overall, predicting how an individual will perceive their risk, post-flood, could be as unpredictable as the flood itself.

Specifically to Tucson, the arid land environment may have an effect of “lulling people into a sense of false security” (McPherson and Saarinen 1977). When responding to survey questions relating to the flood threat, McPherson and Saarinen (1977) quoted respondents as saying “What river?” and “it never rains in Arizona”. Determining if this is still the perception of flood risk in the TMA could improve targeted communications efforts about flood insurance and the financial protection it offers to homeowners.

The cost of coverage is often cited as the reason for homeowners to forego flood insurance (McPherson and Saarinen 1977, Brown and Hoyt 2000, Petrolia et al. 2012). Annual premiums for homes in an SFHA could reach into the thousands. For homes outside of that designation, annual premiums range from $48 to $425 (FEMA 2016). Some studies indicate homeowners not required to purchase flood insurance for loan approval will purchase reasonably priced flood insurance policies (Blanchard-Boehm et al. 2001, Brilly and Polic 2005). Determining what is a reasonable price may be dependent on household income. Here in the United States, lower-income households are generally tied to race and cultural backgrounds, specifically Black/African American and Hispanic (Pilon 2002). With a large Hispanic population in the TMA, it becomes important to identify how household income, plus flood plain habitation, varies between race and cultural groups.

When analyzing home values the evidence is mixed on the degree of impact flooding and flood-risk have on those numbers. Some studies show a decline in value for all homes in areas impacted by flooding, regardless of damage, often occurs immediately following a flood event (Tobin and Montz 1994, Bartsova et al 1999, Yeo 2003, Bin and Landry 2011). However, this effect seems to be mostly temporary, with prices rebounding over time in many locations (Tobin and Montz 1994, Bartsova et al. 1999, Yeo 2003, Bin and Landry 2011). Plus, while the recency of flood events negatively impacts home value, floodplain designation in areas not recently impacted does not (Yeo 2003). Based on the research above, it appears the health of the housing market could be impacted on how quickly repair and rebuilding occurs within a community impacted by a major flood. By purchasing a flood insurance policy, funds for rebuilding and recovery may be more readily available to these homeowners versus ones that did not purchase a policy to cover the financial impacts of damage.

While Blanchard-Boehm et al. (2001) list the above three reasons for low participation in NFIP, a fourth reason is lack of knowledge. For homeowners outside SFHAs, where flood insurance is not a condition of federally-backed loans, numerous studies indicate a lack of knowledge about NFIP could be contributing to the low participation numbers (McPherson and Saarinen 1977, Blanchard-Boehm et al 2001, Chivers and Flores 2002). Blanchard-Boehm et al. (2001) even wrote "risk-averse homeowners, not mandated to buy coverage, would in fact buy flood insurance if they were simply more aware of the program and level of cost." Establishing what homeowners currently know about NFIP and the limited of home insurance coverage then becomes a key starting point from which to design flood risk and flood insurance communications efforts.

A lack of knowledge about the 100-year flood descriptions remains a challenge for researchers and communicators. Two common descriptions of the 100-year flood are the '1% chance of flood in any given year' and '26% chance of flood over 30 years'[7]. The latter description is used when relating risk to homeowners because this is a common time period for loans.

Bell (2007) notes neither of these descriptions are adequately tested for levels of threat perception among the public. After testing these terms among community members in the Northeast U.S., Bell (2007) recommended further research into how these two definitions are perceived by the public.

Knowing what causes low participation is only the first step in tackling the issue of increasing the number of policies-in-force. Officials also need to know what trusted sources people look to for flood risk information. With this knowledge, officials can work with these trusted sources to open the flood risk conversation, which may lead to better protection against risk and creating a less vulnerable population.

Research shows people are more accepting of information from experts who share their personal values or views on a subject (Raaijmakers 2008, Whitmarsh 2008, Kahan et al. 2010). Local media generally ranks high as a communication platform for gathering information about flood warnings and flood-related information (Brilly and Polic 2005, Knocke and Kolivras 2007). However, the media's inclusivity of the entire population may not make it an ideal platform to communicate flood risk to individual homeowners. Instead, homeowners associations or similar groups that formally or

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[7] The equation for these calculations reads $J_k = 1 - (1 - p)^N$ where J_k is the probability a flood of an identified return period, which is identified as p, will occur during a specific number of years, which is identified as N. For a 100-year flood return period over 1 year the equation reads $J_k = 1 - (1 - 0.01)^{1}$. After calculating, $J_k = 0.01$. For a 30 year time period the equation reads $J_k = 1 - (1 - 0.01)^{30}$. After calculating, $J_k = 0.2602$. During a 30-year time frame, if a home is located in a high risk area, considered to be the 100-year flood zone, the probability of a flood of that magnitude happening during that time is 26.02%.

informally govern neighborhoods could be a more efficient mode of communication (Drobot et al. 2007, Terpstra at al. 2009). Ikeda (1982) found when warnings of a disaster were communicated through neighborhood associations about half the people chose to evacuate, versus 36% when information was disseminated through alternate sources, including local mass media. By working with these targeted groups, Terpstra et al. (2009) argues it could increase the "frequency of thought, discussion, and passive information receipt that will promote the adoption of household hazard adjustments."

For homebuyers, it is the real estate agents or realtors that are on the forefront of information dissemination. However, it appears this professional group may not be actively communicating flood insurance options. Chivers and Flores (2002) found 60% of homeowners were informed their home was in a SFHA at the closing. A closing is the final step in the home-buying process when the title of the property is transferred to the buyer, which means this information was not disclosed by the previous owner, real estate agent or realtor earlier in the buying process. Some of these buyers indicated knowledge of this flood risk could have impacted their choice to buy a home or the price initially offered to purchase a home (Chivers and Flores 2002, Knocke and Kolivras 2007). Since price could be impacted, it is a possible reason why the previous owner, real estate agent or realtor did not reveal the SFHA designation earlier in the process. However, numerous studies found home values are not impacted by flood zone designation over the long-term and a drop in value after a flood event is only temporary (Tobin and Montz 1994, Bartsova et al 1999, Yeo 2003, Bin and Landry 2011). With this data, real estate agents or realtors may be more willing to discuss flood insurance with potential homeowners. If this group is a trusted source for flood risk information, including them in the flood risk conversation could increase homeowner's knowledge about programs available to protect their investment.

CHAPTER 6

FLOOD ZONE DEMOGRAPHICS IN THE TUCSON METROPOLITAN AREA

With flooding, accurately identifying who is at risk and who is vulnerable can be challenging. Areas unmapped or under-mapped for flood risk can severely impact the known severity of the threat. And while records of historic flooding give an initial impression of at-risk populations, a written account is simply not available for every location. In arid lands, where flooding may be a rare occurrence, a major event may not have happened since modern-day settlement. Plus, vulnerability is not simply linked to the physical environment, but also to social, economic and political factors (Cardona 2003, Eakin and Luers 2006). These factors can influence individual and collective behaviors, which can then impact mitigation efforts aimed at creating a more resilient, less vulnerable population (Gough 2000, Raaijmakers et al. 2008, Figueiredo et al. 2009).

Being vulnerable to flood impacts isn't solely tied to geography, but also to wealth. According to the United Nations, poorer populations are at a higher risk of being impacted by flooding across the globe (Pilon 2002) (Figure 6.1). Here in the United States, Sarmiento and Miller (2006) found more low-income populations live in high-risk areas as compared to middle-income households because there was more affordable housing in the high-risk areas. However, that same study found high-income households were also found to be at a greater risk as compared to middle-income households (Sarmiento and Miller 2006); but higher-income households are less vulnerable because they have the financial means more readily available for a quick recovery (Masozera et al. 2007).

In the United States, lower-income households are generally tied to race and cultural backgrounds, specifically Black/African American and Hispanic (Figure 6.2) (Pilon 2002). According to the U.S. Census Bureau's 2010 census, 41.9% of the City of Tucson population identifies as Hispanic or Latino, while 5% identifies as Black of African American (U.S. Census Bureau 2011). Because the Hispanic or Latino population makes up a major part of the City of Tucson numbers, the research highlighted in Chapters 5 and 6 only focus on identifying risk within the Hispanic or Latino population and the non-Hispanic white population.

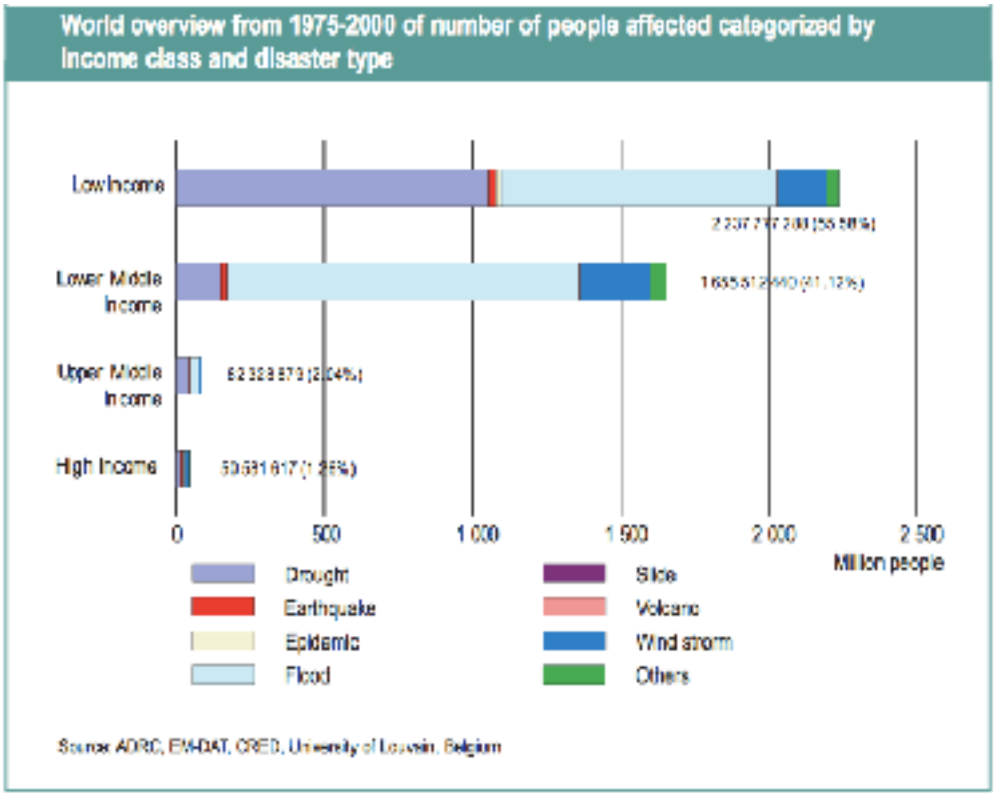


Figure 6.1. World overview from 1975-2000 of number of people affected categorized by income class and disaster type (Pilon 2002).

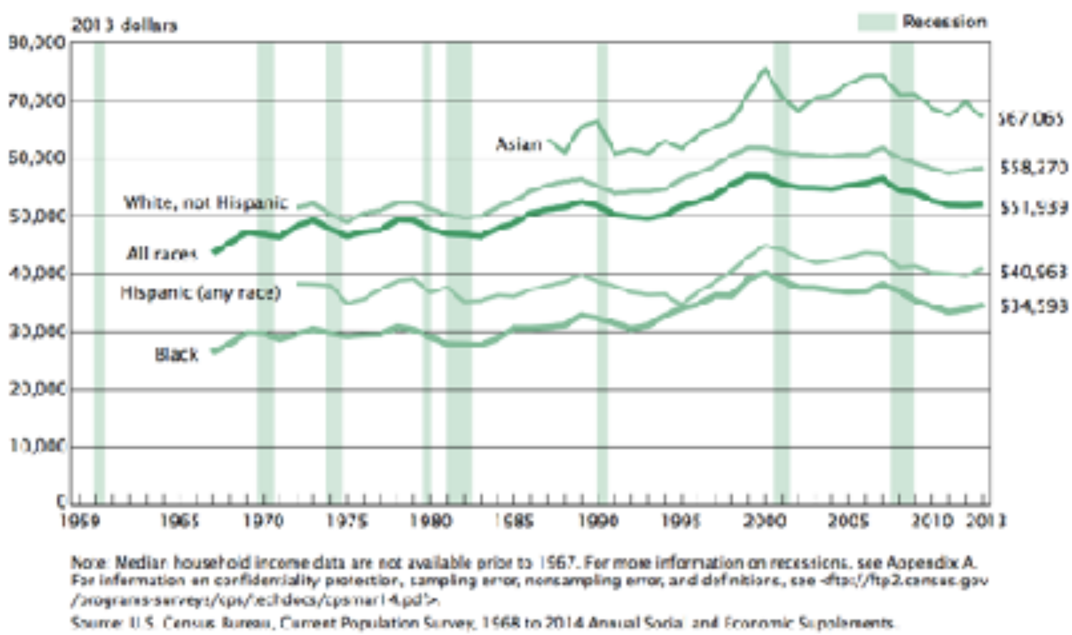


Figure 6.2. Real Median Household Income by Race and Hispanic Origin: 1967 to 2013 (DeNavas-Walt and Proctor September 2014).

Using GIS software, demographic data from the U.S. Census Bureau and property value estimates from the local county Assessor's Office were combined with flood zone maps in the TMA. The purpose of this analysis is to identify the populations vulnerable to flooding in the TMA.

Objectives

1. Combine flood zone maps with U.S. Census and county assessor's data to gain insight about vulnerability within the community at a hyper-local level.
2. Analyze data from various flood zones in the TMA to determine the impact of local mapping efforts versus FEMA mapping efforts to quantify flood risk.
3. Determine how race, cultural, and socioeconomic backgrounds vary within and between flood zone classifications and non-flood areas.
4. Create a base of knowledge by which to measure future changes in flood zone habitation.

Research Questions

1. Does local flood plain mapping add to the knowledge of flood risk in the TMA?
2. What, if any, difference is there in the property values between the TMA and flood zones inside the TMA, plus areas outside the flood zones in the TMA?
3. What is the diversity of the population for the Tucson Metropolitan Area (TMA), flood zones inside the TMA, plus areas outside flood zones in the TMA?
4. What, if any, difference is there in the household income between the TMA and flood zones inside the TMA, plus areas outside flood zones in the TMA?

Study Area

The study area was determined by 32 of the zip codes that make up the Tucson Metropolitan Area (TMA). These zip codes are the most densely populated in Pima County, Arizona (Table 6.1). The majority of flood plains in this area are associated with ephemeral streams, which do not run year-round but instead only run during and immediately following precipitation events.

85658	85710	85719	85747
85701	85711	85730	85748
85704	85712	85737	85749
85705	85713	85741	85750
85706	85714	85742	85755
85707	85715	85743	85756
85708	85716	85745	85757
85709	85718	85746	

Table 6.1. Zip Codes.

Data

Flood zone data were acquired from Pima County GIS. Four flood zone classifications were analyzed in this study. Two are defined by NFIP and two are defined by PCRFCD (Table 6.2). In this study these are labeled as NFIP 100-year, NFIP 500-year. PCRFCD Special Studies, and PCRFCD Sheet.

NFIP 100-year is also known as SFHA on FEMA's DFIRMS. These flood zones indicate mapped flood plains with a 1% chance of flooding in any given year and all start with Zone A, which is sometimes followed by other letters or numbers to further define flood risk (Table 6.3). NFIP 500-year is listed as X-Shaded by FEMA. It must be noted that for water to reach the NFIP 500-year levels, the water must first flood the NFIP 100-year area. However, for research purposes in this study the NFIP 500-year indicates the mapped flood plains between the outer delineation of the NFIP 100-year and the line that indicates a 0.2% chance of flooding in any given year.

PCRFCD mapped additional flood plain areas in Pima County, which do not appear on DFIRMS. This additional flood plain mapping is not recognized by FEMA, but instead is meant to be "used in conjunction with NFIP maps" according to the PCRFCD (PCRFCD 2016c). These additional flood zones are called Special Studies and Sheet.

Special Studies flood zones are additional 100-year flood plains. Sheet flood zones are areas where there isn't a defined channel, but surface water runoff depths of 6" or more are possible over a broad area (PCRFCD 2016b).

Flood Zone Data	Description
NFIP 100-Year	Known as the Special Flood Hazard Area (SFHA); 100-year flood plains as determined by Digital Flood Insurance Rate Maps (DIFIRMS) issued by FEMA. Designated as Zone A* (*additional letters further define the flood zone) on NFIP maps for Pima County.
NFIP 500-Year	500-year floodplains as determined by DFIRMS issued by FEMA. Designated Zone X-Shaded on NFIP maps for Pima County.
PCRFCD Special Studies	Select 100-year flood plains mapped by PCRFCD; not shown on DFIRMS.
PCRFCD Sheet	Sheet floodplains; type of surface water runoff occurring over a broad area and is not associated with defined stream channels; according to PCRFCD depths of 6" or more are possible in locally mapped areas; not shown on DFIRMS

Table 6.2. Flood Zones Analyzed In This Study.

Zone A	Areas with a 1% annual chance of flooding and 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown in these zones.
Zone AE	The base flood plain where base flood elevations are provided.
Zone AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations are derived from detailed analyses and show at selected intervals within these flood zones.
Zone AO – Alluvial Fan 1	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these flood zones.

Zone AO – Alluvial Fan 2	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these flood zones.
Zone AO – Alluvial Fan 3	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these flood zones.
Zone AO – Alluvial Fan 4	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these flood zones.
Zone AO 1	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
Zone AO 2	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
Zone AO 3	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 265 chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
X-Shaded	Areas of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods.

Table 6.3. NFIP Flood Zone Designations and Definitions

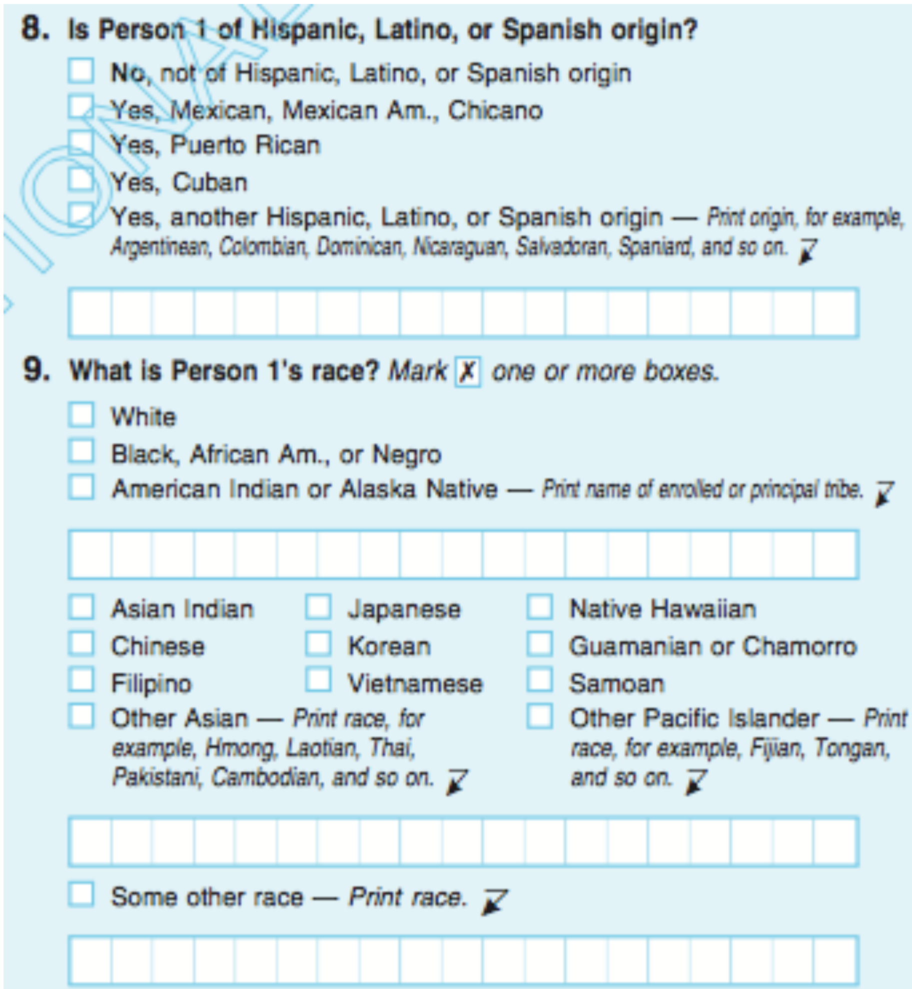
TFCV of parcels was obtained from the Pima County Assessor's Office and Pima County GIS. Only land parcels with a Property Use Code indicating Single Family Residential (5 acres of less) according to the Arizona Department of Revenue were analyzed in this study. Data updates range from 2006 to 2014. The data was downloaded on November 26, 2014. (*Note: periodic data updates by Pima County following the download used in this study could alter future work.*)

The U.S. government conducts a nationwide poll of the population every ten years known as the U.S. Census. In this study, U.S. Census population data from 2000 and 2010 were analyzed. Three population categories were used in this study. For the purposes of this research, these populations are called All, Hispanic and Non-Hispanic White (Table 6.4).

'All' includes the population of all races, ancestry, or ethnicity. It represents the entire reported population of the study area during the U.S. Census. Hispanic is not defined as a race but as a "heritage, nationality group, lineage, or country of birth of the person or the person's parents or ancestors before their arrival in the United States" (U.S. Census Bureau 2011). The Hispanic population in this study includes people who specified Hispanic, Spanish or Latino origin. This encompasses the sub-categories Mexican, Puerto Rican, Cuban or another Hispanic, Latino, or Spanish origin (U.S. Census Bureau 2011). The Non-Hispanic White population is made up of people that marked "not of Hispanic, Latino, or Spanish origin" but also specified race as White (U.S. Census Bureau 2011). Figure 6.3 shows questions 8 and 9 on the 2010 U.S. Census form, which asks about origin and race. The questions are similar, if not the same, to the ones asked on the 2000 Census form.

Population Title	Description	U.S. Census Bureau Identifier
All	All races, ancestry, or ethnicity	P0020001
Hispanic	Any person that marked Hispanic or Latino	P0020002
Non-Hispanic White	Any person that mark Not Hispanic or Latino and also marked race as White	P0020005

Table 6.4. U.S. Census Population Data.



8. Is Person 1 of Hispanic, Latino, or Spanish origin?
- No, not of Hispanic, Latino, or Spanish origin
- Yes, Mexican, Mexican Am., Chicano
- Yes, Puerto Rican
- Yes, Cuban
- Yes, another Hispanic, Latino, or Spanish origin — *Print origin, for example, Argentinean, Colombian, Dominican, Nicaraguan, Salvadoran, Spaniard, and so on.*

9. What is Person 1's race? *Mark* ☒ *one or more boxes.*
- White
- Black, African Am., or Negro
- American Indian or Alaska Native — *Print name of enrolled or principal tribe.*
- Asian Indian
- Chinese
- Filipino
- Other Asian — *Print race, for example, Hmong, Laotian, Thai, Pakistani, Cambodian, and so on.*
- Japanese
- Korean
- Vietnamese
- Native Hawaiian
- Guamanian or Chamorro
- Samoan
- Other Pacific Islander — *Print race, for example, Fijian, Tongan, and so on.*
- Some other race — *Print race.*

Figure 6.3. Questions from 2010 Sample Census Form (U.S. Census Bureau 2011).

Note in Figure 6.3 that people who mark themselves as “No, not of Hispanic, Latino, or Spanish origin” are then given a choice in the following questions to mark what race they consider themselves to be. This means the All population numbers should be roughly the same as the sum of the Hispanic and Non-Hispanic data. Non-Hispanic White is only the portion of Non-Hispanic that marked ‘White’ for race.

Population data were analyzed at the Census Block level, which the U.S. Census Bureau defines as “the smallest level of geography you can get basic demographic data for, such as total population by age, sex, and race” (U.S. Census Bureau 2011). Census Block boundaries can change each census period, but generally are not drastically different than the previous U.S. Census. These Census Blocks are created by an automated computer process, which determines visible and non-visible features as the outer boundaries and are not limited by population numbers that may be found within the

Census Block. The boundaries create a polygon, which can be uploaded into GIS mapping software for analysis.

Median Household Income (MHI) data comes from the American Community Survey (ACS), which is separate from the decadal U.S. Census but is also administered by the U.S. Census Bureau. The ACS is a yearly survey meant to give “communities the current information they need to plan investments and services” (U.S. Census Bureau 2011). About 1 in 38 households per year are invited to take the ACS. The ACS is measured at the Census Block Group level with MHI only available in the 5-year estimates data. Census Block Groups are the smallest level of geography available for the ACS and are one step up in size from the individual Census Blocks. These Census Block Groups are made up of multiple Census Blocks and have a minimum of 600 people or 240 housing units. The maximum is 3000 people or 1200 housing units. The 2006 to 2010 5-year estimates were used in this study.

The MHI “includes income of the householder and all other people 15 years and older in the household, whether or not they are related to the householder” and is the “Median Household Income In The Past 12 Months” (U.S. Census Bureau 2011). MHI is the point where half the population has an income below that level and half above that level. The U.S. Census notes this median is “based on the income distribution of all households, including those with no income” (U.S. Census Bureau 2011). Because of the smaller sample size in the Census Block Groups in the ACS compared to the Census Blocks in the decadal U.S. Census, the Margin of Error (MOE) can be large for MHI. The ACS MOE is calculated by the U.S. Census Bureau from the 90% Confidence Interval.

In this study, MHI was calculated for the All, Non-Hispanic White and Hispanic populations. Table 6.5 lists the populations used in the study for MHI estimates, plus the U.S. Census Bureau identifier.

Population Title	Description	U.S. Census Bureau Identifier
All	Median Household Income In The Past 12 Months	B19013
Non-Hispanic White	Median Household Income In The Past 12 Months (White Alone Not Hispanic Or Latino Householder)	B19013H
Hispanic	Median Household Income In The Past 12 Months (Hispanic Or Latino Householder)	B19013I

Table 6.5. US. Census Median Household Income Data.

Methods

Esri's ArcMap 10.0 in ArcGIS was used for data processing. Additional statistical analysis was done in Microsoft Excel.

Flood zones were analyzed in ArcMap to determine the area of each individual flood zone and the total area for all flood zones added together. Additionally, the data was analyzed for the entire TMA and for areas in the TMA outside flood zones. The names used in this study for these areas of analysis are labeled in Table 6.6.

Name	Description
TMA	Entire area covered by the 32 selected zip codes
Non-Flood	Area of the TMA not covered by a flood zone
NFIP 100-Year	Known as the Special Flood Hazard Area (SFHA); 100-year flood plains as determined by Digital Flood Insurance Rate Maps (DIFIRMS) issued by FEMA. Designated as Zone A* (*additional letters further define the flood zone) on NFIP maps for Pima County.
NFIP 500-Year	500-year flood plains as determined by DFIRMS issued by FEMA; in this study, these begin at the edge of the NFIP 100-year flood zones to the line that delineates the 500-year flood plain from areas of lower risk beyond it; designated Zone X-Shaded on NFIP maps for Pima County.
PCRFCD Special Studies	Select 100-year flood plains mapped by PCRFCD; not shown on DFIRMS.
PCRFCD Sheet	Sheet flood plains; type of surface water runoff occurring over a broad area and is not associated with defined stream channels; according to PCRFCD depths of 6” or more are possible in locally mapped areas; not shown on DFIRMS
Flood Zones Combined	All four flood zones areas combined into a single area

Table 6.6. Areas of Analysis.

Any parcel that wholly or partially overlapped the flood zone was included in the calculations for that flood zone. Some properties overlapped multiple flood zones. When this was the case, each property was included in the individual flood zones analysis but only once in the Flood Zones Combined analysis. It must be noted that if a property is partially located in a flood zone, structures on these properties may or may not be located in the flood zone.

The Area Proportion Method was used to determine population estimates for All, Hispanic, and Non-Hispanic White. For each flood zone a Population Density was first determined for each of the populations. The Population Density was calculated by dividing the Census Block population by the total area of each Census Block that overlapped at least a portion of the flood zone. In some cases, the U.S Census Bureau or Pima County GIS already completed this calculation. If this data was not already calculated, the author did so before determining the estimated area population. Only the area of each Census Block that overlapped the flood zone was used to create the estimated population living in the high-risk areas. Using the Area Proportion Method, the population numbers do not come out to whole numbers, but instead are estimated to two decimal points.

MHI was calculated for the TMA, the Non-Flood area, each Census Block Group that fully or partially overlaps a flood zone and the total area of all flood zones added together. Both the mean and the median MHI were calculated.

Results

The TMA study area covers a total of 983.99 mi^2. NFIP and PCRFCD flood zones combined cover 189.24 mi^2, which is 19.23% of the TMA land (Table 6.7). The NFIP 100-year makes up the majority of the flood zone coverage with 104.11 mi^2 or 10.58% of the TMA. The second and third largest flood zone areas are the PCRFCD flood zones with Sheet covering 42.50 mi^2 and Special Studies covering 40.39 mi^2. These make up 4.32% and 4.10% the TMA. NFIP 500-year covers the smallest area with 16.75 mi^2, which is 1.70% of the TMA.

AREA	Area mi^2	% Area
TMA	983.99	100%
Non-Flood	794.74	80.77%
NFIP 100-Year	104.11	10.58%
NFIP 500-Year	16.75	1.70%
PCRFCD Special Studies	40.39	4.10%
PCRFCD Sheet	42.50	4.32%
Flood Zones Combined	189.24	19.23%

Table 6.7. Study Area Breakdown.

There was some overlap between flood zones (Table 6.8). The greatest amount of overlap is found between the PCRFCD Special Studies and the NFIP 100-year, plus 500-year flood zones. The overlap between NFIP 500-year and PCRFCD Special Studies amounts to 3.70% of the land area for the NFIP 500-year and 1.15% of the land area for the PCRFCD Special Studies. The NFIP 100-year and PCRFCD Special Studies overlap is the largest at 13.23 mi^2, which is 12.71% of the total land area for the NFIP 100-year and 32.76% of the total land area for the PCRFCD Special Studies. Total overlap of all flood zones was 14.50 mi^2. According to Hendricks (2015), this overlap is simply because the PCRFCD wants to err on the side of caution when completing additional mapping in or adjacent to high-risk areas defined by the NFIP.

Flood Zones	**Area Overlap mi^2**	**% Area Overlap**
100-year & 500-year	0.0000016	Negligible Overlap
100-year & Sheet	0.023	0.02% of 100-year 0.05% of Sheet
100-year & Special Studies	13.23	12.71% of 100-year 32.76% of Special Studies
500-year & Special Studies	0.62	3.70% of 500-year 1.15% of Special Studies
500-year & Sheet	0.00	No Overlap
Special Studies & Sheet	0.63	1.56% of Special Studies 1.48% of Sheet
Total Flood Zone Overlap	14.50	7.12%

Table 6.8. Overlap of Flood Zones.

Because there is some overlap, all flood zones were linked together in one layer to streamline analysis. This one layer was then used to analyze the following data in this study and is labeled as Flood Zones Combined. By using one layer to represent all flood zones, the risk of counting the data multiple times if the data is found in more than one flood zone is reduced or eliminated.

Table 6.9 shows the number of properties found in the TMA. The NFIP 500-year flood zone, which covers the smallest area of all the flood zones, has the largest number of homes compared to the three other individual flood zones.

Zone	Number of Properties	% of TMA
TMA	208073	100.00%
Non-Flood	194140	93.30%
NFIP 100-year	7425	3.57%
NFIP 500-year	10846	5.21%
PCRFCD Special Studies	2761	1.33%
PCRFCD Sheet	2637	1.27%
Flood Zones Combined	21554	10.36%

Table 6.9. Number of Properties.

Table 6.10 shows the Minimum, Mean, Median, Maximum and Total TFCV for the TMA, Non-Flood, all individual flood zones and Flood Zones Combined. The Mean and Median TFCV was higher in the NFIP 100-year, PCRFCD Special Studies and All Flood Zones Combined compared to TMA TFCV. However, the NFIP 500-year showed a lower Mean and Median TFCV as compared to the TMA TFCV. The PCRFCD Sheet showed a lower Median than the TMA TFCV but a slightly higher Mean. The total TMA TFCV of was over $35.7 billion, with over $3.7 billion of that in a flood zone.

Zone	Minimum	Mean	Median	Maximum	Total
TMA	$500.00	$171,696.34	$131,561.00	$5,271,250.00	$35,725,371,997.00
Non-Flood	$500.00	$173,837.78	$132,817.00	$5,271,250.00	$33,748,866,868.00
NFIP 100-year	$500.00	$202,128.55	$153,418.00	$1,847,867.00	$1,500,804,505.00
NFIP 500-year	$500.00	$138,388.78	$119,812.00	$1,847,867.00	$1,500,964,756.00
PCRFCD Special Studies	$8,250.00	$313,297.11	$287,656.00	$1,916,408.00	$865,013,312.00
PCRFCD Sheet	$21,480.00	$172,039.47	$126,130.00	$923,963.00	$453,668,088.00
Flood Zones Combined	$500.00	$173,573.88	$131,772.00	$1,916,408.00	$3,741,211,414.00

Table 6.10. TFCV.

Table 6.11 indicates the percent of TFCV difference for Non-Flood, all individual flood zones and Flood Zones Combined from the TMA TFCV. Most notable is the Special Studies Median TFCV, which is over double that of the TMA and 82.47% greater than the Mean of the TMA.

Zone	Mean	Median
Non-Flood	1.25%	0.95%
NFIP 100-year	17.72%	16.61%
NFIP 500-year	-19.40%	-8.93%
PCRFCD Special Studies	82.47%	118.65%
PCRFCD Sheet	0.20%	-4.13%
Flood Zones Combined	1.09%	0.16%

Table 6.11. % Difference from TMA TFCV.

Table 6.12 shows the percent of TFCV for Non-Flood, all the individual flood zones and Flood Zones Combined compared to the TMA. Unsurprisingly, the vast majority of TFCV is found in Non-Flood areas. However, 10.47% of TFCV is at least partially located in a flood zone.

Zone	Total
Non-Flood	94.47%
NFIP 100-year	4.20%
NFIP 500-year	4.20%
PCRFCD Special Studies	2.42%
PCRFCD Sheet	1.27%
Flood Zones Combined	10.47%

Table 6.12. % of Total TFCV for as compared to the TMA.

Because there was a large range with TFCV data, the Margin of Error (MOE) was also large. Figure 6.4 is a box-and-whisker plot. The blue box indicates the range between the first and third quartiles of the TFCV data for the group listed. The whiskers show the maximum and minimum TFCV.

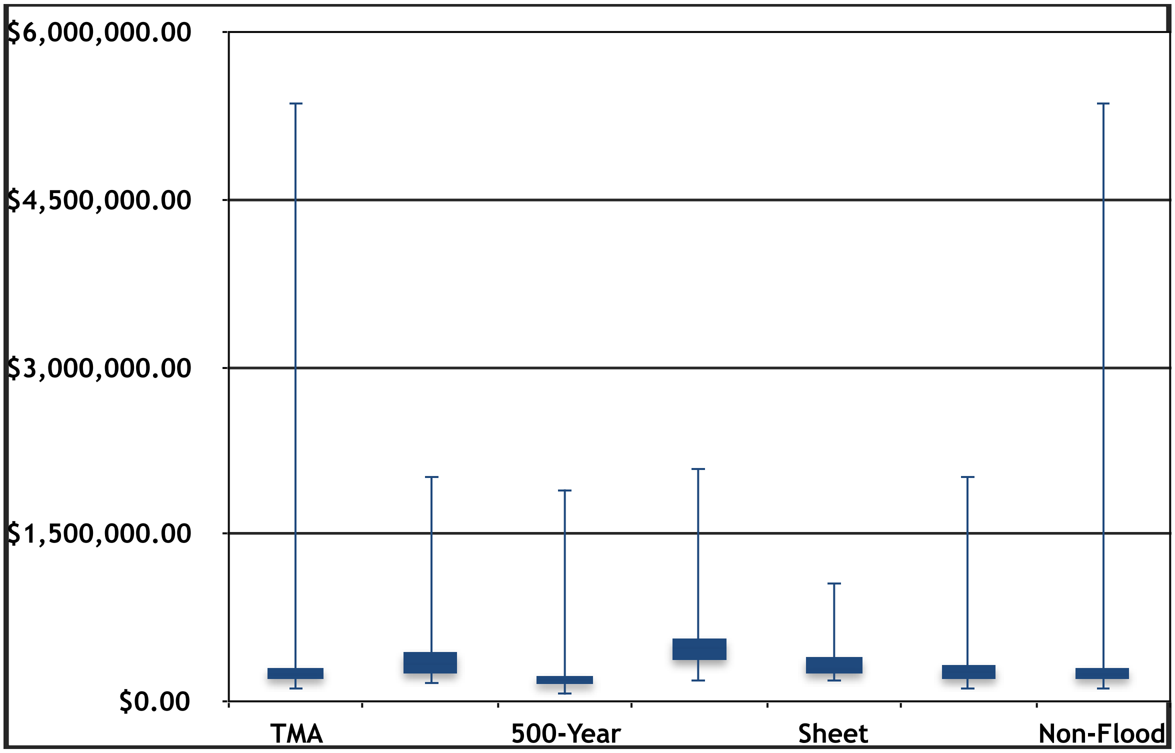


Figure 6.4. Box-and-Whisker Plot indicating the range of TFCV for each of the areas analyzed in this study. The blue box indicates the range between first and third quartiles. The maximum and minimum values are indicated by the ends of the whiskers.

There were 13,772 Census Blocks wholly or partially in the TMA in the 2010 census and 10,944 in the 2000 census (Table 6.13). The number of Census Blocks in the NFIP flood zones is higher than the number in the PCRFCD flood zones. However, the 2010 percent of Census Blocks in flood zones is lower than the percent in 2000 for all the individual flood zones and Flood Zones Combined (Table 6.14). Note the Non-Flood zone number of census blocks is larger than the TMA number of census blocks in 2000 (Table 6.13). Some of the flood zones transected a single census block. When the flood zone area was removed from the map, it split some census blocks into two or more units. This caused the census block numbers to be artificially high in some of the zones analyzed.

Area	2000	2010
TMA	10944	13772
Non-Flood	11224	13637
NFIP 100-year	2674	2916
NFIP 500-year	1557	1669
PCRFCD Special Studies	612	704
PCRFCD Sheet	574	618
Flood Zones Combined	5870	6366

Table 6.13. Number of Census Blocks.

Area	2000	2010
Non-Flood	102.56%	99.02%
NFIP 100-year	24.43%	21.17%
NFIP 500-year	14.23%	12.12%
PCRFCD Special Studies	5.59%	5.11%
PCRFCD Sheet	5.24%	4.49%
Flood Zones Combined	53.64%	46.22%

Table 6.14. Percent of Census Blocks Compared to Total in TMA.

The All population from the 2010 U.S. Census for the TMA was 852215.84 persons (Table 6.15). This is a 10.17% increase over the 2000 U.S. Census, which recorded a population of 765583.22. In those ten years the Hispanic population increased by 24.72% (Table 6.16). There was a drop in Non-Hispanic White between 2000 and 2010 (Table 6.17).

Census Year	All	% Change
2000	765583.22	--
2010	852215.84	10.17%

Table 6.15. U.S. Census Population Estimates of the TMA.

Census Year	Hispanic	% Change
2000	231502.94	--
2010	307507.16	24.72%

Table 6.16. U.S. Census Hispanic Population Estimates of the TMA.

Census Year	Non-Hispanic White	% Change
2000	466759.60	--
2010	458606.19	-1.78%

Table 6.17. Non-Hispanic White Population of the TMA.

Table 6.18 shows the percent of Hispanic and Non-Hispanic White compared to the All population of the TMA for 2000 and 2010. Hispanic made up 30.24% of the All population in 2000 and grew to 36.08% by 2010. The Non-Hispanic White population shows a drop in percentage between 2000 and 2010.

Census Year	Hispanic	Non-Hispanic White
2000	30.24%	60.97%
2010	36.08%	53.81%

Table 6.18. Percent of Population Hispanic, Non-Hispanic and Non-Hispanic White compared to All Population.

Table 6.19 shows the estimated 2000 population for All, Hispanic and Non-Hispanic White in Non-Flood, each individual flood zones and Flood Zones Combined. Table 6.20 shows the percentage of the Hispanic and Non-Hispanic White populations compared to the All population for Non-Flood, each individual flood zones, and Flood Zones Combined. The NFIP 100-year, 500-year and Flood Zones Combined show a greater percentage of Hispanics live in these areas as compared to the Non-Flood area. The percentage of Hispanics living the PCRFCD Special Studies and Sheet was lower than the Non-Flood area. The Non-Hispanic White flood zone population shows the opposite. The percent of this population in the NFIP 100-year and 500-year, plus the Flood Zones Combined, is lower than the percent of the population living in Non-Flood areas, with the PCRFCD Special Studies and Sheet showing a higher percentage.

Flood Zone	All	Hispanic	Non-Hispanic White
Non-Flood	675487.12	203704.01	413462.46
NFIP 100-year	40514.75	12469.24	22326.28
NFIP 500-year	29106.99	9838.85	16999.59
PCRFCD Special Studies	7517.05	1652.18	5442.31
PCRFCD Sheet	15698.16	4279.66	10695.78
Flood Zones Combined	90096.10	27798.93	53295.27

Table 6.19. Estimated 2000 Population in Flood Zones and Non-Flood area.

Flood Zone	Hispanic	Non-Hispanic White
Non-Flood	30.16%	61.21%
NFIP 100-year	30.78%	55.11%
NFIP 500-year	33.80%	58.40%
PCRFCD Special Studies	21.98%	72.40%
PCRFCD Sheet	27.26%	68.13%
Flood Zones Combined	30.85%	59.15%

Table 6.20. Estimated Percent Hispanic and Non-Hispanic White 2000 Populations in Flood Zones Compared to All Population for each flood zone.

Table 6.21 and Table 6.22 are the same as Table 6.19 and Table 6.20, except the data are for 2010 U.S. Census. The percent of the Hispanic population living in the NFIP 100-year and 500-year, as well as Flood Zones Combined, was once again higher than the percent of this population in the Non-Flood area. The percent of Hispanic population living in PCRFCD Special Studies and Sheet was lower than in the Non-Flood area. The Non-Hispanic White population showed a higher percentage located in the PCRFCD flood zones as compared to the Non-Flood area. The opposite was found for the NFIP flood zones and Flood Zones Combined, which showed a lower percentage of population as compared to the Non-Flood area.

Flood Zone	All	Hispanic	Non-Hispanic White
Non-Flood	744849.65	267305.75	403396.88
NFIP 100-year	49590.75	18530.55	23933.99
NFIP 500-year	35313.41	13872.71	17771.56
PCRFCD Special Studies	8941.96	2866.52	5526.44
PCRFCD Sheet	17228.32	5790.25	10594.05
Flood Zones Combined	107366.19	40201.41	55207.48

Table 6.21. Estimated 2010 Population in Flood Zones.

Flood Zone	Hispanic	Non-Hispanic White
Non-Flood	35.98%	54.16%
NFIP 100-year	37.37%	48.26%
NFIP 500-year	39.28%	50.33%
PCRFCD Special Studies	32.06%	61.80%
PCRFCD Sheet	33.61%	61.49%
Flood Zones Combined	37.44%	52.42%

Table 6.22. Estimated Percent Hispanic, Non-Hispanic and Non-Hispanic White 2010 Populations in Flood Zones Compared to All Population for each flood zone.

Table 6.23 indicates the percent of the All population in each flood zone for both the 2000 and 2010 census. In 2000, 11.77% of the population lived in Flood Zones Combined. That grew to 12.60% in 2010. There was also growth in the NFIP 100-year, NFIP-500 year and PCRFCD Special Studies flood zones. However, there was a decline in the percentage for the PCRFCD Sheet flood zone, as well as the Non-Flood area.

Flood Zone	2000	2010
Non-Flood	88.23%	87.40%
NFIP 100-year	5.29%	5.82%
NFIP 500-year	3.80%	4.14%
PCRFCD Special Studies	0.98%	1.05%
PCRFCD Sheet	2.05%	2.02%
Flood Zones Combined	11.77%	12.60%

Table 6.23. Percent of All population in flood zones and Non-Flood areas compared to the TMA All population.

Table 6.24 indicates the percent change of each population within Non-Flood, each individual flood zone, plus Flood Zones Combined from 2000 to 2010. Each area showed a population increase, with the exception of PCRFCD Sheet and Non-Flood for the Non-Hispanic White population. Across the board, the largest increases are in the Hispanic population.

Flood Zone	All	Hispanic	Non-Hispanic White
Non-Flood	9.31%	23.79%	-2.50%
NFIP 100-year	18.30%	32.71%	6.72%
NFIP 500-year	17.58%	29.08%	4.34%
PCRFCD Special Studies	15.94%	42.36%	1.52%
PCRFCD Sheet	8.88%	26.09%	-0.96%
Flood Zones Combined	16.09%	30.85%	3.46%

Table 6.24. Percent Population Change within each flood zone classification, plus Non-Flood areas between 2000 to 2010.

Both the Mean and Median were calculated from MHI data. Tables 6.25, 6.26 and 6.27 list the Mean and Median MHI for the TMA, all individual flood zones, plus Flood Zones Combined for the All, Hispanic and Non-Hispanic White populations. Table 6.28 shows the difference for the Hispanic population MHI from the All and Non-Hispanic White populations for the TMA, Non-Flood areas, each individual flood zone and Flood Zones Combined. Table 6.29 indicates the Hispanic MHI percent difference from the Hispanic TMA MHI for Non-Flood, each individual flood zone and Flood Zones Combined.

Overall the Hispanic Mean and Median MHI is lower than the All and Non-Hispanic White populations for each of the areas analyzed (Table 6.28). The Non-Hispanic White Mean and Median MHI for each of the areas analyzed is higher than the All Mean and Median, with the exception of the Median for PCRFCD Special Studies. Within only the All and Non-Hispanic White populations, the Mean and Median MHI is higher for Non-Flood, each individual flood zone, plus Flood Zones Combined compared to the TMA All and Non-Hispanic White populations (Tables 6.25, 6.27). Within the Hispanic Population the Mean and Median MHI is lower than the TMA Hispanic population for NFIP 100-year and 500-year, but higher in Non-Flood, PCRFCD flood zones and Flood Zones Combined (Tables 6.26, 6.29). For Non-Flood areas, the Mean and Median MHI is lower than each of the individual flood zones, plus the Flood Zones Combined for the All and Non-Hispanic White populations (Tables 6.25, 6.27). However, the Non-Flood area Hispanic population shows a lower Mean and Median MHI compared to PCRFCD flood zones and Flood Zones Combined, but a higher Mean and Median MHI than the NFIP flood zones (Table 6.26).

Zone	Mean	Median
TMA	$48,947.12	$42,745.00
Non-Flood	$49,100.10	$43,251.00
NFIP 100-year	$50,916.21	$44,604.50
NFIP 500-year	$51,528.92	$43,438.50
PCRFCD Special Studies	$73,373.51	$73,750.00
PCRFCD Sheet	$57,746.43	$56,287.00
Flood Zones Combined	$51,754.36	$46,250.00

Table 6.25. Mean and Median MHI for All.

Zone	Mean	Median
TMA	$47,442.75	$37,980.50
Non-Flood	$47,611.89	$38,176.50
NFIP 100-year	$47,200.64	$37,937.50
NFIP 500-year	$46,952.93	$36,719.00
PCRFCD Special Studies	$66,787.12	$61,482.50
PCRFCD Sheet	$56,764.59	$54,500.00
Flood Zones Combined	$48,134.73	$39,271.00

Table 6.26. Mean and Median MHI for Hispanic.

Zone	Mean	Median
TMA	$51,391.17	$46,471.00
Non-Flood	$51,514.15	$46,484.00
NFIP 100-year	$53,317,43	$48,527.00
NFIP 500-year	$54,210.99	$48,967.00
PCRFCD Special Studies	$75,033.21	$72,750.00
PCRFCD Sheet	$61,348.70	$60,459.00
Flood Zones Combined	$54,125.97	$49,744.50

Table 6.27. Mean and Median MHI for Non-Hispanic White.

Zone	Difference Mean From All	Difference Median From All	Difference Mean from Non-Hispanic White	Difference Median From Non-Hispanic White
TMA	-$1504.36	-$4764.50	-$3948.42	-$8490.50
Non-Flood	-$1488.22	-$4975.50	-$3902.27	-$8307.50
NFIP 100-year	-$3715.57	-$6667.00	-$6116.79	-$10,589.50
NFIP 500-year	-$4575.99	-$6719.50	-$7258.06	-$12,248.00
PCRFCD Special Studies	-$10,813.42	-$12,687.00	-$12,473.12	-$11,687.00
PCRFCD Sheet	-$981.85	-$1787.00	-$4584.11	-$5959.00
Flood Zones Combined	-$3487.03	-$6736.00	-$5858.64	-$10,260.50

Table 6.28. Difference for Hispanic population from the Mean and Median All and Non-Hispanic White MHI for the TMA, Non-Flood, Flood Zones Combined and each individual flood zone.

Zone	Mean	Median
Non-Flood	100.36%	100.52%
NFIP 100-year	99.49%	99.89%
NFIP 500-year	98.97%	96.68%
PCRFCD Special Studies	131.86%	160.77%
PCRFCD Sheet	119.65%	143.49%
Flood Zones Combined	101.74%	104.04%

Table 6.29. Percent difference from the TMA Hispanic MHI and the Hispanic MHI in each individual flood zone, Flood Zones Combined and Non-Flood categories.

This data was at the Block Group level, which means fewer people were surveyed as compared to the decadal U.S. Census. Because of this, there is a large MOE. Figure 6.5 is a Box-and-Whisker Plot showing the range of MHI for each of the areas analyzed in this study.

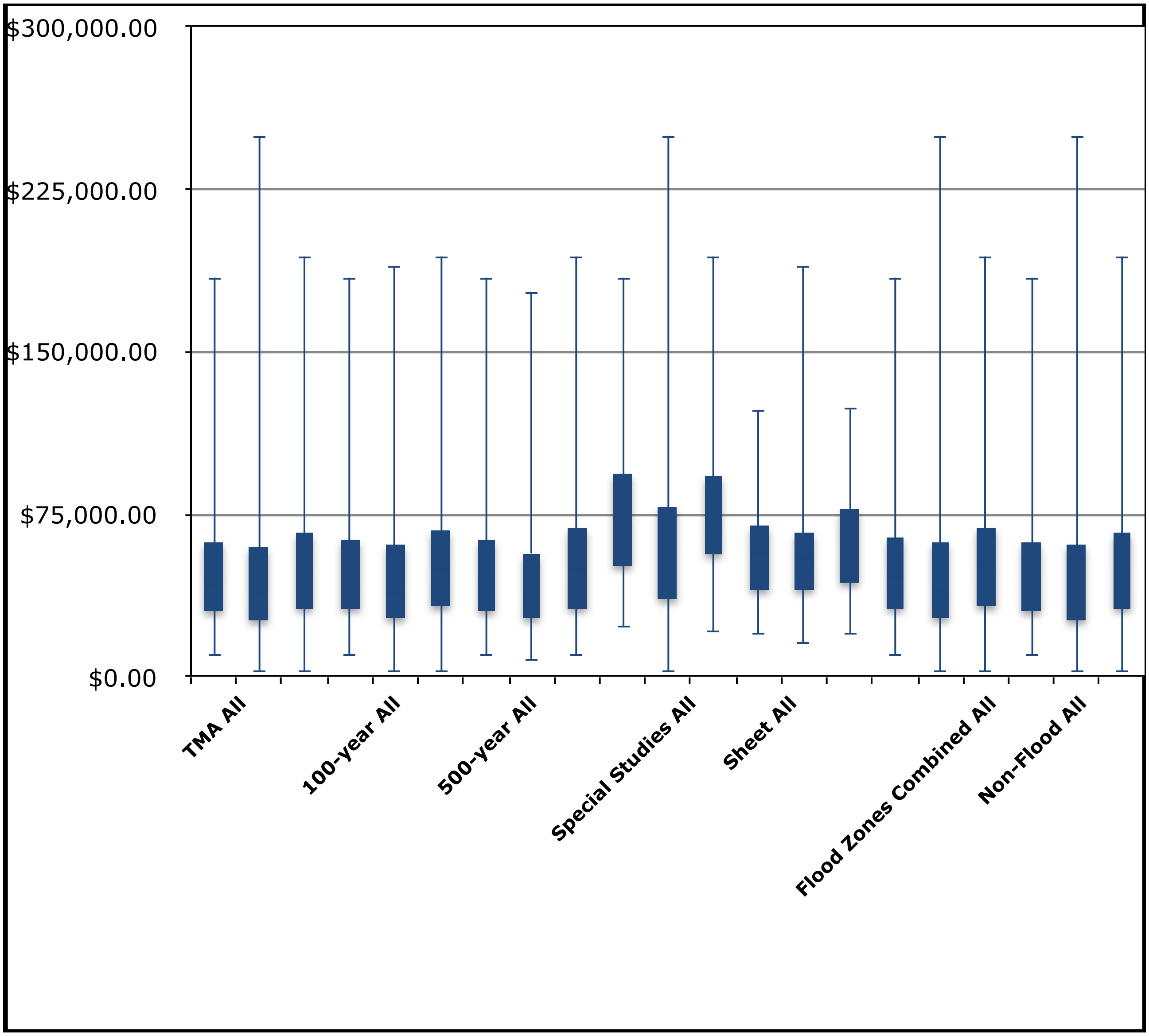


Figure 6.5. Box-and-Whisker Plot showing the range of MHI for each of the areas analyzed in this study. The blue box indicates the range between first and third quartiles. The Maximum and Minimum values are indicated by the ends of the whiskers.

Discussion

In this study of the TMA, four different flood zone classifications were analyzed. These zones make up the majority of high-risk flood areas in the TMA. Two of these zones are defined by the Federal Emergency Management Agency (FEMA) and account for about 12% of the TMA (Table 6.7). The other two are locally mapped flood zones by the Pima County Regional Flood Control District (PCRFCD), where the TMA is located, and make up over 8% of the land (Table 6.7). Subtracting overlap between the PCRFCD and FEMA flood zones, over 19% of the TMA is located in a mapped flood plain (Tables 5.7, 5.8). While it is unclear if the total land area in flood zones is unusually high compared to other cities and towns, even those in the Southwest U.S., one thing is clear through this research: thousands of people live in these areas, raising the risk they could be impacted by high water.

In the TMA, over 21,000 thousand single-family residential homes on 5 acres or less were found to be located in at least one of these mapped flood plains (Table 6.9). The estimated total value of these properties was over $3.7 billion dollars. One each of the FEMA and PCRFCD flood zones showed higher values for these properties as compared to non-flood areas and TMA as a whole (Table 6.10). The PCRFCD flood zone property values were significantly higher at 82.47% and 118.65% of the TMA values (Table 6.11). Generally, the other two flood zones showed lower values, but the difference from the TMA values was not as large (Table 6.11). Property values can vary widely depending on a variety of factors. Because of this, the margin-of-error for these data was very high (Figure 6.2). In addition, for this study, only a portion of the land for each property needed to be in the flood zone to be included. It was unclear if structures were located in these higher-risk areas. However, if the land floods within the delineation of a flood zone, there is always a chance that water could reach farther outside the area of mapped risk. This makes purchasing flood insurance prudent for some homeowners near, but not necessarily inside, one of these mapped areas. Because flood insurance means paying an additional premium separate from a normal home insurance policy, homeowners need to budget for the extra expense, which could be problematic for lower-income households.

Traditionally, lower-income households and minorities are considered to be at a greater risk of flooding compared to wealthier counterparts (Pilon 2002, Sarmiento and Miller 2006). These households are more vulnerable to the impacts of flooding since they may not have the means to recover from the losses (Masozera et al. 2007). In the Tucson Metropolitan Area (TMA), the largest minority population, Hispanic, does have a higher percentage of flood zone occupation compared to the total population and non-Hispanic white population. However, those households did not necessarily have lower incomes than their counterparts outside of the flood zones.

According to the 2010 census numbers, over 12.60% of the TMA population possibly resides in one of these mapped flood plains (Table 6.20). That amounts to over 107,000 people (Table 6.23). Although recently updated and additional flood plain mapping raises awareness of flood risk in the TMA, these new mapping efforts may not have much impact the decision to move into or continue living in these areas. Between the 2000 and 2010 census, the overall population increased in all flood zones (Table 6.23). However, it must be pointed out that the updated FEMA maps were put into effect in 2011, after the 2010 census. Plus the PCRFCD local flood zone maps accessible through a GIS mapping program date back to only 2009. Flood zone awareness could have been limited to older mapping efforts leading up to the decadal census update in 2010. With increased education efforts by PCRFCD about flood risk in the following years, an analysis of 2020 census numbers should be considered as an update to this study to determine if efforts to reduce risk are impacting flood plain occupation.

The data show the Hispanic population is growing in the flood zones at a greater rate than other segments of the population. In the Hispanic population as a whole there was an increase of 24.72% between 2000 and 2010 (Table 6.16). The percent of increase for this population was higher than that number in each of the four flood zones, but lower in the non-flood area of the TMA during this time (Table 6.24). While the non-Hispanic white population of the TMA dropped between 2000 and 2010 (Table 6.17), there was increased growth in the two flood zones determined by FEMA and in one of PCRFCD flood zones (Table 6.24). However, the percentage of growth in non-Hispanic white was much lower than the Hispanic population.

Overall, the Hispanic population had a lower household income as compared to the total population and non-Hispanic white population (Table 6.28). However, comparing the household incomes within this population, it appears those households located in the PCRFCD flood zones have a higher income than the non-flood area Hispanic households by about $9,000 to $19,0000 (Table 6.26). Only the FEMA flood zones showed lower Hispanic household income compared to non-flood area households. However, the difference was lower, about $400 to $650. In contrast, the total and Non-Hispanic White populations consistently had higher household income for all four of the flood zones as compared to the non-flood area (Tables 6.25, 6.27). While globally, and even in some areas of the U.S., poorer populations occupy high-risk flood areas (Pilon 2002, Sarmiento and Miller 2006), it generally appears the opposite is true for the TMA.

Additional research is necessary to determine why this is the case. However, it could be related to the desire to live in a greenway with taller trees and thicker plant growth than in areas away from water sources where there is little plant cover to protect against the strong desert sun. For this privilege, homeowners may be willing to pay a higher price for property, which may in-turn lead to wealthier households that could afford this expense. With higher income households as compared to non-flood areas, flood zone homeowners may be in a better position to afford flood insurance, which would reduce their financial risk if and when damage occurs.

CHAPTER 7

FLOOD RISK AND FLOOD INSURANCE PERCEPTION AND KNOWLEDGE IN TUCSON METROPOLITAN AREA RESIDENTS

In many cases more than one of the factors outlined in Chapter 5 - psychological defense, perception, economic, lack of knowledge and trusted sources - needs to be addressed before homeowners, including those living in high risk areas, may consider purchasing a flood insurance policy. Identifying how age, gender, race and cultural backgrounds, socioeconomic status, education, flood experience and floodplain habitation currently influence an individual homeowner's decision to purchase or not purchase flood insurance and their perception of flood risk is a critical first step in designing potentially impactful education programs about NFIP. With low participation in NFIP extending into the TMA, an increase of policies-in-force could help to boost the financial stability of the program, while also diminishing the vulnerability and strengthening the resilience of the community to flood damage. By protecting themselves through NFIP, homeowners build resilience against the monetary impacts of the flood threat.

For the TMA, race and cultural factors may be an especially important part of designing flood risk and flood insurance communication because of a large minority population. As noted in chapter 5, cultural backgrounds can impact heuristics, which can then influence a homeowners choice to purchase or not purchase flood insurance. According to the U.S. Census Bureau's 2010 census, 41.9% of the City of Tucson population identifies as Hispanic or Latino, with Non-Hispanic White making up much of the rest of the population (U.S. Census Bureau 2011). In addition, data indicate that across the U.S., the Hispanic population generally has lower household incomes than the Non-Hispanic White population (Pilon 2002). Plus, lower income households are more commonly found in high-risk flood areas, as compared to middle-income households (Sarmiento and Miller 2006). With cost often cited as a factor for not purchasing insurance, these lower income households could forgo the purchase of a flood insurance policy, making them more vulnerable to the impacts of flooding (McPherson and Saarinen 1977, Browne and Hoyt 2000, Petrolia et al. 2012). Educating households about the costs of varying levels of coverage could lead to some homeowners purchasing a policy.

To better understand what influences homeowners in the TMA chose or not chose to purchase flood insurance, a survey instrument was designed to gather demographic data, in addition to information about flood insurance, flood risk knowledge and trusted sources.

Objectives

1. Determine flood risk and flood insurance knowledge of homeowners in the TMA.
2. Determine trusted sources for flood risk information for homeowners in the TMA
3. Determine reasons for homeowners in the TMA purchasing or not purchasing flood insurance,.
4. Determine if age, socio-economic, education, race or cultural factors influence any of the first 3 objectives.
5. Determine if flood risk knowledge and perception has remained consistent or changed from the themes that emerged in a previous Tucson survey of flood zone residents.

Research Questions

1. Does age, gender, socioeconomic, education, race, or cultural factors influence a homeowner's flood risk knowledge?
2. Does age, gender, socioeconomic, education, race, or cultural factors influence a homeowner's decision to purchase flood insurance?
3. Does floodplain habitation influence a homeowner's flood risk knowledge?
4. Does floodplain habitation influence a homeowner's decision to purchase flood insurance?
5. What are the trusted sources for flood risk and flood insurance information?
6**.** Has flood risk knowledge and perception evolved compared to themes which emerged from a previous survey of flood zone residents in Tucson?

Multivariate analysis of select variables was done to determine if relationships existed between the data gathered. Some questions in the survey instrument were based on responses and themes in McPherson and Saarinen (1977). You may remember from Chapter 5 that McPherson and Saarinen (1977) was a flood risk study targeting residents in a TMA SFHA. While the survey instrument was not available, the responses and themes reported in McPherson and Saarinen (1977) were used to structure select questions and responses for this study. The responses to these questions were compared and contrasted with findings of McPherson and Saarinen (1977).

Methods

This research was approved by an Institutional Review Board under the University of Arizona Human Subjects Protection Program.

In the survey, there are four different question classifications as defined by Patton (1990) and listed in Table 7.1. Classification questions gather demographic and background data on the person being surveyed. Behavioral questions focus on what a person does or has done when faced with a decision or situation that requires action. Knowledge questions measure what a person knows or does not know about a subject. Finally, perception questions gather information about how people interpret information presented to them.

Question Type	Description	Example
Classification	Aims to identify the characteristics of the person being interviewed	Demographic data; Do you rent or own your home?; What is your age?
Behavioral	Aims to discover what a person does or has done	What is your reason for not purchasing flood insurance?
Knowledge	Aims to determine what factual information a person has about a certain subject	Does an average home insurance policy cover flood damage from natural causes?
Perception	Aims to understand the cognitive and interpretive processed of people	How many floods do you expect in 100 years of time?

Table 7.1. Types of questions asked of the participants (Patton 1990).

Most questions were closed, versus open, using qualitative and quantitative data. This allowed respondents to quickly answer a series of questions, limiting the time committed to taking the survey and encouraging participation (Gummer and Roman 2015). Data gathered was further classified as nominal, ordinal or ratio levels of measurement. In some closed questions 'Other; *Please specify'* was included as a choice. According to Bird (2009), adding this option minimizes "the limitations closed questions can pose to participants". Open questions, plus responses to 'Other, *Please specify*', were analyzed, but the data was not coded. Instead, these answers were used to enhance the findings of the closed questions, identify potential issues that could be investigated in follow-up research, and determine if additional themes emerged from answers given.

McPherson and Saarinen (1977) designed a survey using open-ended questions. In-person interviews were conducted with residents of the 100-year flood zone in Tucson as determined by the U.S. Army Corp of Engineers in 1973. A total of 162 respondents completed the survey. Responses and themes reported in McPherson and Saarinen (1977) were compared and contrasted with data in this survey.

Validity of the survey questions was measured against the study objectives and research questions. The survey included questions about home ownership, flood experience, general perception of flood risk, flood information sources, flood insurance knowledge and basic demographic data. The survey was pre-tested by the Arid Lands Resource Sciences (ALRS) department students and faculty. Minor changes made prior to public distribution were based on feedback from the pre-test.

The boundaries of the study area for survey distribution were determined by 32 zip codes that make up most of the Tucson Metropolitan Area (TMA), as identified in chapter 5. Demographic data analyzed in chapter 5 was also used to determine survey parameters and as a comparison to the data collected.

The survey was available online through the University of Arizona's Qualtrics survey software account. At a 95% Confidence Level with a 5% Margin of Error, 384 completed surveys were needed reflect the target population. To represent the diversity of the population, 36.08% need to be from the Hispanic population. To represent the number of people living in the flood zones, 12.60% needed to be located in a known flood zone. Of those that live in a flood zone, 37.44% needed to be Hispanic with 52.42% Non-Hispanic White. To increase the possibility of meeting these numbers, procedures for distribution targeted culturally diverse neighborhoods, plus neighborhoods that were at least partly located in or near a known flood zone.

In the first round of distribution, Neighborhood Association boundary data was acquired from Pima County GIS. In the TMA, 93 Neighborhood Associations boundaries were analyzed to determine if a percentage of the neighborhood land area was part of a flood zone. Neighborhood Associations with over 10% of land in a known flood zone were considered for this study. The presence of known flood zones does not infer structures are located in that flood zone. It simply means a portion of the Neighborhood Association boundary lies within a known flood zone. Of the 93 Neighborhood Associations, 40 met the criteria. The data were filtered further to determine if the neighborhood showed a Hispanic population of 33% or higher. Half of the 40 Neighborhood Associations met the second criteria. Contact information from the 20 selected Neighborhood Associations was then acquired from the City of Tucson (City of Tucson 2015). Exploratory e-mails were then sent to the contacts to gain permission for survey distribution (Table 7.2). From that list, two agreed to distribute the survey through e-mail. Additional Neighborhood Associations on the list may have distributed the survey by e-mail, but did not notify the principle investigator. Plus, recipients could forward the e-mail message and survey link to people outside of their neighborhood.

Amphi	Barrio Kroeger Lane	Flowing Wells	**Mountain View**
Arroyo Chico	Barrio San Antonio	Las Vistas	Santa Cruz Southwest
Barrio Anita	Campus Farm	**Menlo Park**	Santiago Hills
Barrio Blue Moon	El Presidio	Midvale Park	Silverbell Terrace
Barrio Hollywood	El Rio Acres	Miles	Silvercroft

Table 7.2. List of Neighborhood Associations contacted for survey distribution. Bold type indicates Neighborhood Associations which communicated with the principle investigator about distributing the survey through e-mail.

To increase survey participation, another round of distribution was done through Nextdoor.com (Table 7.3). Homeowners can register online to be part of this social network, which connects people living within a specific neighborhood, plus surrounding neighborhoods. The selected neighborhoods are listed in Table 9. Each of these neighborhoods border a Tucson waterway, including the Alamo Wash, Arroyo Chico, Pantano Wash, Pima Wash, or Rillito River.

Casa Adobes II	Ellen Townsend	River Road Estates	Terra Del Sol
Cholla Manor	Manana Vista/Yale Estates	Rosemont West	Willshire Heights
Cloud Ridge	Oracle Heights/Casa Adobe	Sewell	
Colonia Del Valle	Palmdale	Sun River	

Table 7.3. Nextdoor.com Neighborhoods contacted for survey distribution.

Each of the neighborhoods targeted for distribution were located in Tucson, Flowing Wells, or Casa Adobes as defined by the 2010 Census, Geographic Level, Place (U.S Census Bureau 2010b). In these areas, the number of females was slightly higher than males, with 50.76% of the population female and 49.24% male (Table 7.4). Over 45% of the population was between the ages of 35 and 64 (Table 7.5).

Sex	Number	Percent of Total
Male	297,077	49.24%
Female	306,253	50.76%
Total	603,330	100.00%

Table 7.4. U.S Census Male/Female data for Tucson, Flowing Wells, and Casa Adobes as defined by the 2010 Census, Geographic Level, Place.

Age	Number	Percent Total
18 & 19	23,959	5.16%
20-24	57,893	12.47%
25-34	88,244	19.00%
35-49	112,387	24.20%
50-64	105,826	22.79%
65 & over	76,038	16.38%
Total	464,347	10.00%

Table 7.5. U.S Census Age data for Tucson, Flowing Wells, and Casa Adobes as defined by the 2010 Census, Geographic Level, Place.

The U.S. Census Bureau's American Community Survey 5-year estimates from 2006 to 2010 show 25.1% of the Tucson population obtained a Bachelor's degree or higher (U.S Census Bureau 2010a). For Flowing Wells, 11.1% of residents had obtained a Bachelor's degree or higher (U.S Census Bureau 2010a). In Casa Adobes, 35.0% of residents had obtained a Bachelor's degree or higher (U.S Census Bureau 2010a).

This survey was distributed wholly through the Internet, which could result in biased or unreliable data. This could bring the validity of the findings into question.

Coverage bias is a concern since Internet access is not equally distributed through socioeconomic and demographic groups, the survey may not reach a portion of the sample population (Shonlau et al. 2011). Generally Hispanics, senior citizens (65+ years old), lower income households (earning less than $30,000), and those without a college education were less likely to have Internet access within the home (Perrin and Duggan 2016). However, these differences have been reduced in recent years, diminishing the influence of coverage bias (Perrin and Duggan 2016).

Non-response bias means there could be a difference between how respondents answered the questions versus those that did not complete the survey. To increase response rates, repeat e-mails or message were sent to the sample population. The survey instrument itself was tested for clarity of questions and kept short to limit the time commitment of respondents. In addition, confidentiality was prioritized, ensuring respondents anonymity.

If a respondent has an interest in an issue or outcome in the results of the survey, they could complete multiple surveys leading to a stakeholder bias. Because this is an informational survey and not one related to policy or regulation, stakeholder bias was not anticipated.

For those that did respond to the survey, there is no way to verify they are who they say they are or if they completed the survey multiple times. Unverified respondents could lead to unreliable data. While respondents completing multiple surveys were not anticipated, it is possible, especially with repeat e-mails or messages seeking respondents for this survey, a respondent could have completed more than one survey.

Results

A total of 65 surveys were started online. Of those, 60 were completed. Since respondents were able to proceed in the survey without marking an answer for the previous questions, the number of respondents on each question may vary slightly.

More women than men competed the survey, around 62% versus 37%, which was a higher ratio than in the target population (Table 7.4). The respondents to the survey tended to be older (Table 7.6) than the target population (Table 7.5). Respondents also tended to have completed some level of higher education with over 93% of respondents indicating some college or completion of a Bachelor’s, graduate or professional degree (Table 7.7). This was a higher percentage than the target population.

Age Range	Number of Respondents	Percentage
18 to 24 years old	0	0.00%
25 to 34 years old	4	6.67%
35 to 44 years old	8	13..33%
45 to 64 years old	14	23.33%
55 to 64 years old	15	25.00%
65 to 74 years old	15	25.00%
75 years or older	3	5.00%
Prefer not to answer	1	1.67%

Table 7.6. Responses to Question “What is your age?”

Education Level	Number of Respondents	Percentage
12th Grade or Less	0	0.00%
High School or Equivalent	2	3.33%
Some College	14	23.33%
Bachelor’s Degree	16	26.67%
Graduate or Professional Degree	26	43.33%
Prefer not to answer	2	3.33%

Table 7.7. Responses to Question “Which of the educational levels best describes the highest level of school or highest degree you have completed.”

Table 7.8 indicates the race or ethnicity of respondents. Nearly 17% of respondents marked Spanish/Hispanic/Latino, which is below 36.08% of Hispanic population estimate for the TMA for the 2010 census. The White, non-Latino population made up 75% of the respondents, which is above the 53.81% of the non-Hispanic White population in the TMA. Around 8% of respondents indicated ‘Other’ or ‘Prefer not to answer’.

Race or Ethnicity	Number of Respondents	Percentage
White, non-Latino	45	75.00%
Spanish/Hispanic/Latino	10	16.67%
Black/Afrian American	0	0.00%
American Indian	0	0.00%
Asian	0	0.00%
Other; please specify	1	1.67%
Prefer not to answer	4	6.67%

Table 7.8. Responses to Question “Which best describes your race or ethnicity?”

Because demographic data indicating age, sex, race/ethnicity, and education levels gathered in this survey differ from demographic data gathered on the target population, the sample population may not represent the target population. In addition, the number of surveys was fewer than the necessary amount needed to reliably represent the target population.

Household income was fairly evenly distributed (Figure 7.1) with levels ranging from less than $20,000 to more than $100,000. For the TMA, mean and median MHI was $48,947.12 and $42,745.00, according to the 2006 to 2010 American Community Survey. Flood zone households had a mean and median MHI at $51,746.43 and $46,250.00. About a quarter of respondents marked their household income was in the two categories where these numbers fall. The majority of the total respondents and Non-Hispanic White respondents marked MHI in the upper four categories. However, the majority of Hispanic respondents indicated MHI was in the lower 4 categories.

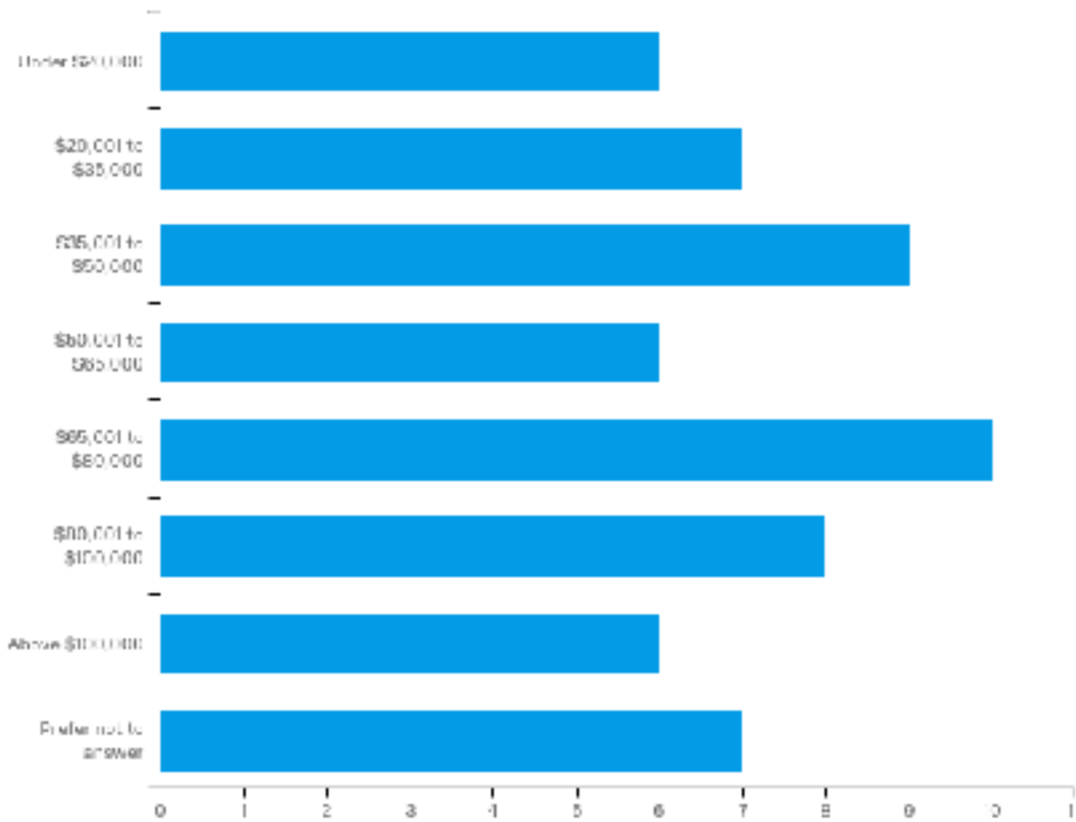


Figure 7.1. Responses to Question "Which of the categories best describes your household income in 2014."

On average, the number of years living at the current address was 11.37 and the median 8. Answers ranged from "less than a year" to 50 years. The number of people living in the home ranged from 1 to 6. The average number was 2.20 with a median of 2 people. The number of years a respondent lived in the TMA ranged from one to 80 years. Of 64 respondents, all but one indicated a numerical response. The average number of years was 31.40 with a median of 30.

Over 23% of respondents indicated they were personally affected by flooding. These respondents were asked to describe their experience. All but one of these respondents typed a response. Nearly 43% of these statements referring to the historic Tucson flooding in 1983. Other responses included references to water over roadways, poor drainage or landscape contouring, and flooding in laundry rooms.

When asked if they live in a floodplain, a third of respondents indicated 'yes' with around 46% indicating 'no' (Table 7.9). Nearly 21% indicated they did not know if they lived in a floodplain. The percentage that answered if they lived in a floodplain is higher at 33.33% than the estimated percentage of the TMA population living in a flood plain, which is 12.60% (Table 6.23).

For respondents that marked they lived in a flood zone and specified race or ethnicity, 70% were White, non-Latino, 20% Spanish/Hispanic/Latino, and 10% preferred not to answer (Table 7.10). The White, non-Latino respondent percentage is higher than the estimated target population living in a floodplain, which his 52.42%. The Spanish/Hispanic/Latino is lower at 20.00% than the estimated Hispanic population living in a floodplain, which is 37.44%.

Response	Number of Respondents	Percentage
Yes	21	33.33%
No	29	46.03%
Don't Know	13	20.63%

Table 7.9. Responses to Question "Do you live in a floodplain?"

Race or Ethnicity	Number of Respondents	Percentage
White, non-Latino	14	70.00%
Spanish/Hispanic/Latino	4	20.00%
Black/Afrian American	0	0.00%
American Indian	0	0.00%
Asian	0	0.00%
Other; please specify	0	0.00%
Prefer not to answer	2	10.00%

Table 7.10. Race or ethnicity for respondents living in a floodplain.

Over 82% of respondents indicated some level of flood risk knowledge (Figure 7.2). Of these respondents, nearly 32% of respondents marked 'Moderately knowledgable'. Over 17%, claimed "not at all knowledgeable" about flooding in their neighborhood.

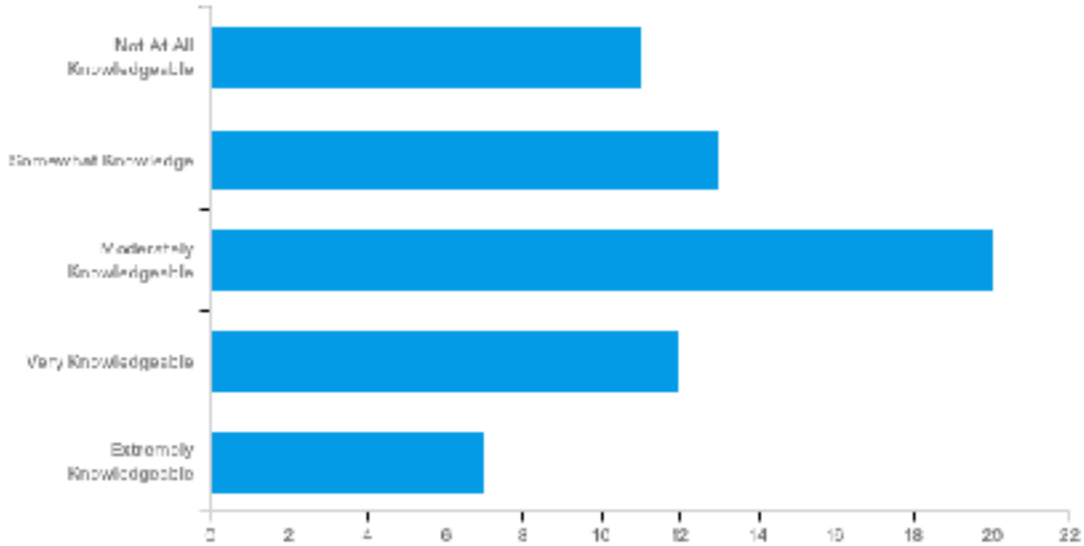


Figure 7.2. Responses to Question “How knowledgeable do you think you are about flooding in your neighborhood?”

Most respondents indicated flooding is a risk to their home in the future, with over 60% citing ‘Low risk’ (Figure 7.3). Nearly 10% of respondents said there was ‘no risk’, while over 6% said they did not know.

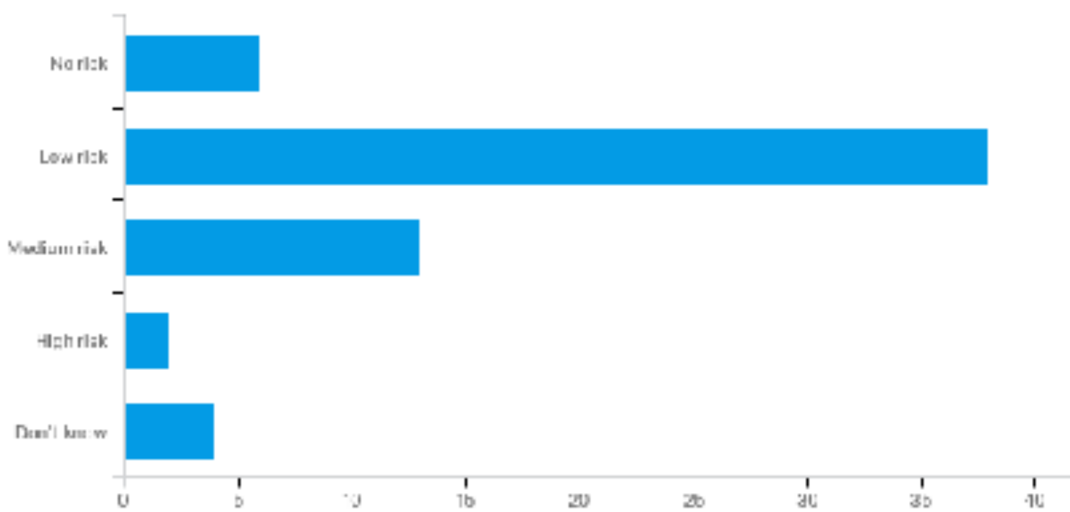


Figure 7.3. Responses to Question “In your opinion, what is the flood risk to your home in the future?”

Respondents answered a question about the 100-year flood risk definition and they were asked to check any answer that applied (Table 7.11). There were two correct answers, which where ‘1% chance of flood in any given year’ and ‘26% chance of flood over 30 years’. While these terms are commonly used to define a 100-year flood, Bell (2007) notes neither of these definitions are adequately tested for levels of threat perception among the public. After testing these terms among community members in the Northeast U.S., Bell (2007) recommended further research into how these two definitions are perceived by the public. By including two correct answers among the other possible selections in this survey, it gives future flood risk research in the TMA a base starting point at which homeowner’s perception of the 100-year flood definition can be measured against.

No respondent selected both correct answers and only about 29% of the respondents chose one of the correct answers. Around 8% of respondents chose two answers, with 80% of those selecting ‘Don’t know’ as the second answer. Nearly 24% of the respondents did select the correct answer of ‘1% chance of flood in any give year’. However, less than 5% selected the other correct answer. No one selected three answers. Over a third of respondents marked they ‘Don’t know’.

Answer	Number of Respondents	Percentage
Occurs once every 100 years	13	20.63%
1% chance of flood in any given year*	15	23.81%
26% chance of flood over 30 years*	3	4.76%
All above answers are correct	9	14.29%
None are correct	7	11.11%
Don’t know	21	33.33%

Table 7.11. Responses to Question “What defines a 100-year flood? Check all that apply.” * Indicates correct answers.

Comparing answers from Table 7.11 to how knowledgeable people think they are about flood risk (Figure 7.2) reveals around 71% of respondents who selected ‘Extremely knowledgeable’ also chose one of the correct answers. For respondents that chose ‘Very knowledgeable’, only about 8% selected a correct answer. Only 30% of respondents that ranked themselves ‘Moderately knowledgeable’ selected one of the correct answers. For respondents that marked ‘Somewhat knowledgeable’, about 23% selected one of the correct answers. Over 27% of ‘Not at all knowledgeable’ respondents marked one of the correct answers.

When asked to identify how many floods occur in 100 years time, over 65% of respondents selected ‘none’ or ‘1 or 2’ (Figure 7.4). Nearly 37% of respondents selected a higher number. Almost 16% of respondents marked they did not know.

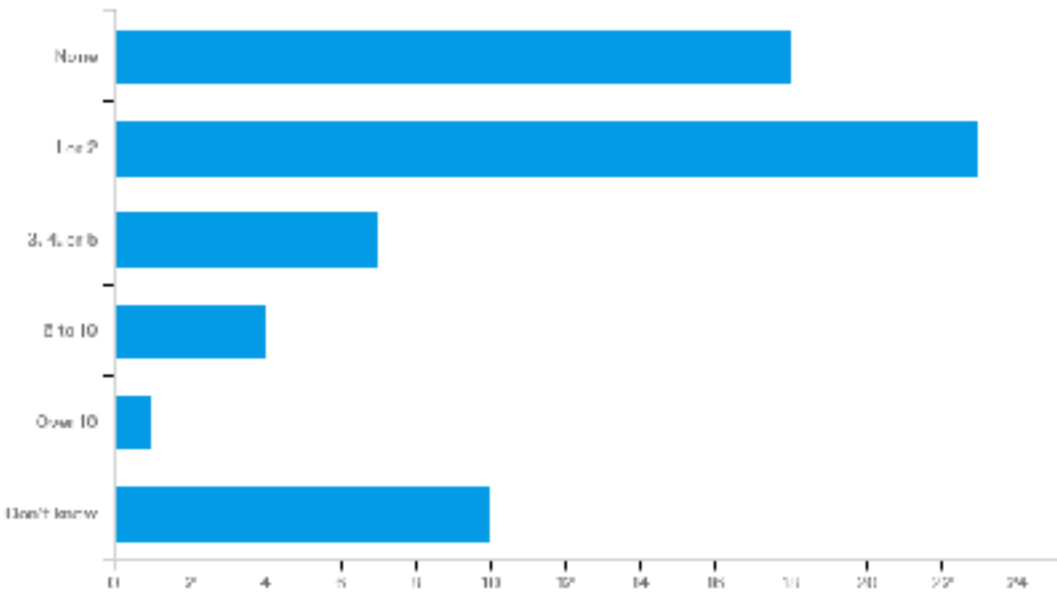


Figure 7.4. Responses to Question 11 “How many floods do you expect in 100 years of time in your neighborhood?”

Out of ten possible responses, most respondents selected one of three choices when asked what they would do first if flooding was threatening their home (Figure 7.5). Get out/flee, get out with some possessions, or sandbag property/build a flood wall was the choice for around 85% of the respondents. Nearly 7% of respondents selected ‘Other’ and were asked to specify their answer. 75% of these respondents referenced the level of severity would be a factor in taking action.

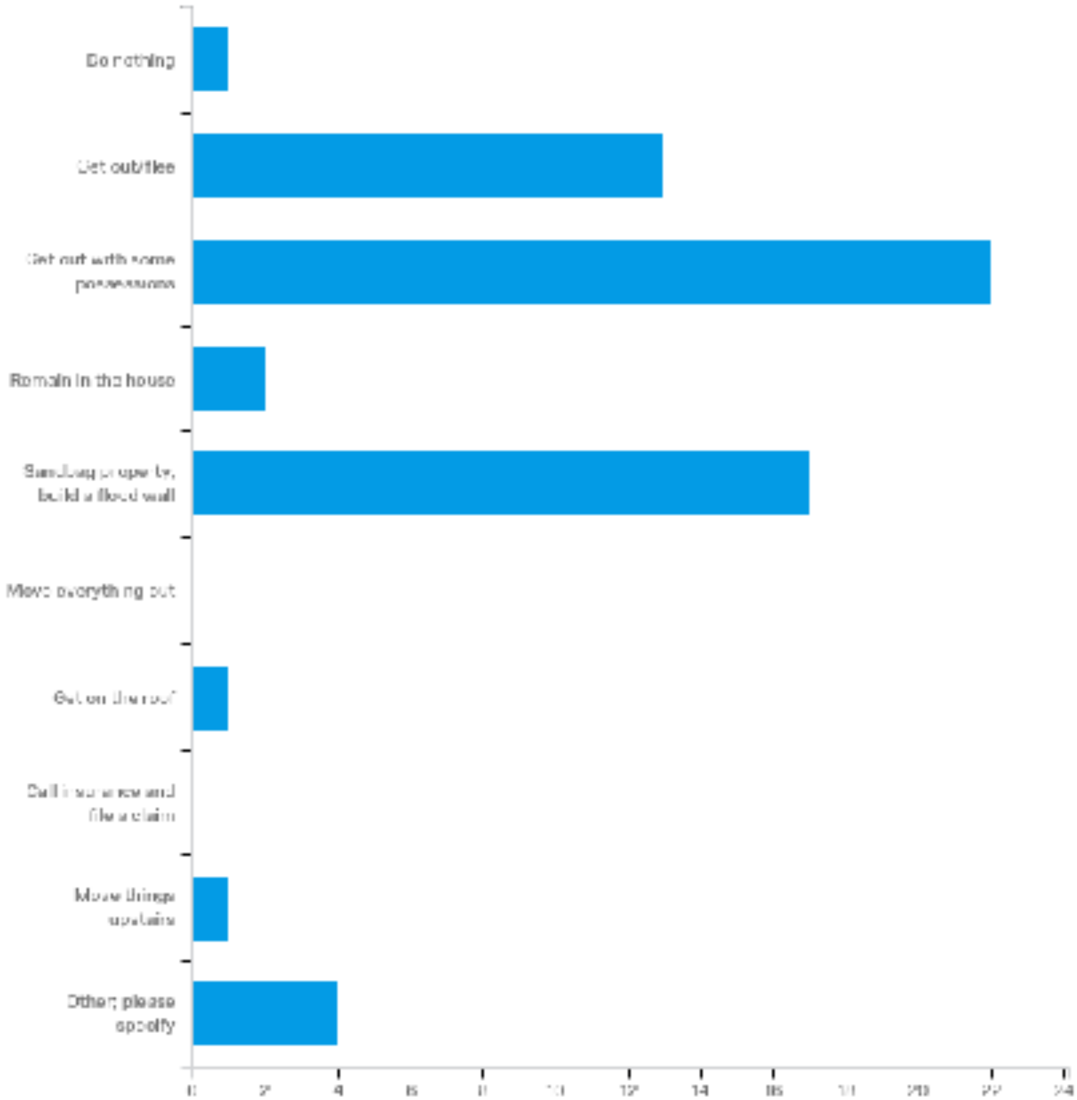


Figure 7.5. Responses to Question “If a flood is threatening your home, what is the first thing would you do in response to the risk?”

Respondents were asked who took economic responsibility for recovery and rebuilding (Figure 7.6). Nearly 38% respondents selected individual/homeowners. Around another 38%, selected insurance companies. About 8% of respondents selected ‘Other’ and were asked to specify their answer. One answered Federal Flood Insurance. Another two respondents answered they were personally responsible. One person added the “entity that approved regulations allowing structures to built in flood prone areas.” Plans are generally approved through town, city, or county government officials. Another respondent to ‘Other’ submitted the statement “if you get flood insurance, it doesn't kick in unless there is a catastrophic event. at least that's how it was explained to me."

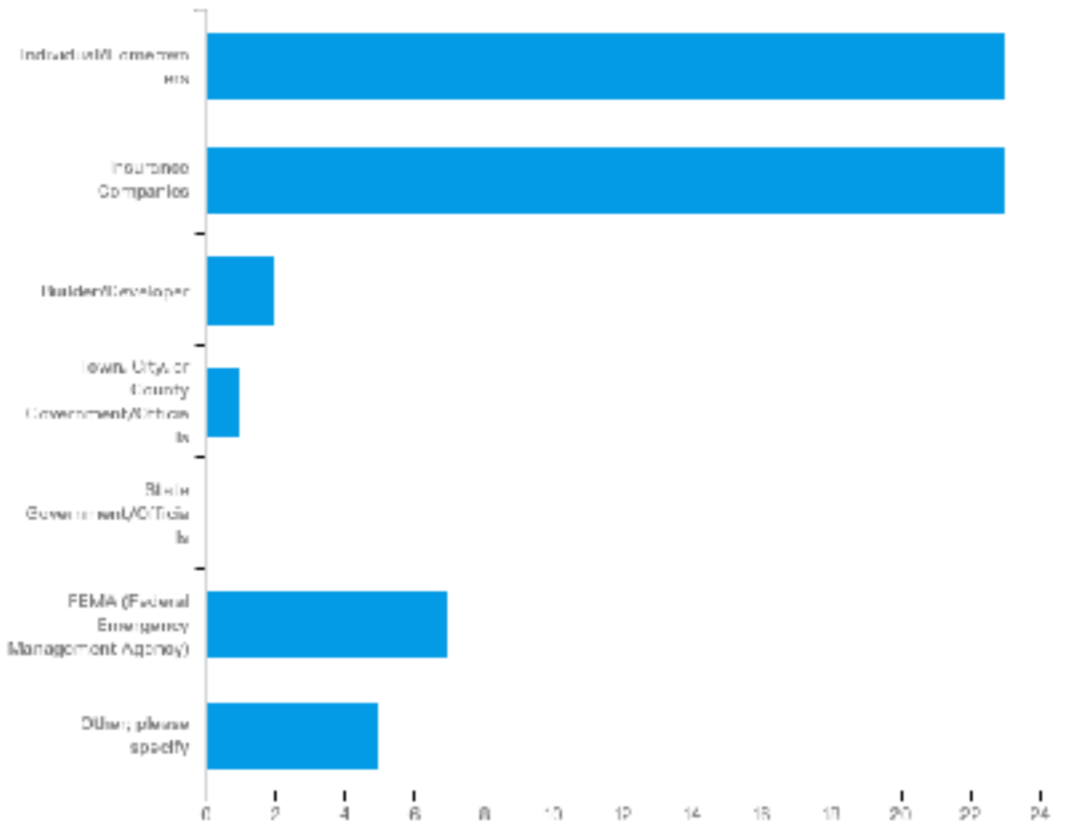


Figure 7.6. Responses to Question "If your home is flooded, who do you believe is economically responsible for recovery and rebuilding?"

Respondents were asked to check all answers that apply to the question "If your home was damaged by a flood, what steps do you believe should be taken to protect against future flood damage?" Over half the respondents selected at least one of four options (Table 7.12). One of these four selections was the option of purchasing insurance. Two of these responses referenced engineered changes. The fourth response was to provide warnings and information. Note that flood insurance and structural measures are part of mitigation and meant to protect structures, as well as lives, when another disaster hits the community. Warnings are more focused on informing people when danger is imminent so they can evacuate or stay away. In the flood cycle (Figure 3.1), warnings are part of preparation, not mitigation, and are not meant to protect homes. Nearly 7% of respondents chose ‘Other’ and were asked to specify an answer. Two of these respondents referenced rainwater harvesting. One said to “stop concreting drainage”, while another referred to the 1983 floods and government officials “accepting bribes” to approve development on flood plains.

Answer	Number of Respondents	Percentage
Build dams and improve river channels	14	22.95%
Leave river/waterway alone	8	13.11%
Zone housing out of high risk flood areas	27	44.26%
Provide warnings and information to people at high risk	32	**52.46%**
Flood proof homes through engineering on your property (e.g. build a flood wall, countour yard, raise home and outbuildings, etc)	35	**57.38%**
Government should do something about the problem	10	16.39%
Improve flood protection in the neighborhood	31	**50.82%**
Divert the water	22	36.07%
Study the problem	24	39.34%
Purchase insurance	32	**52.46%**
Don’t know	2	3.28%
Other; please specify	3	6.56%

Table 7.12. Responses to Question to “If your home was damaged by a flood, what steps do you believe should be taken to protect against future flood damage? Check all that apply.” Bold percentages indicate when more than 50% of respondents selected that choice.

Table 7.13 ranks the respondents opinion of source credibility in regards to flood danger information. Each source above 'Other" had 56 to 58 respondents. Over 25% of respondents selected four groups as 'Very Credible'. These were 'Town, City, or County Government/Officials', 'State Government Officials', 'FEMA', and the 'National Weather Service'. The National Weather Service ranked the highest in the 'Very Credible' category with 36.21% of respondents. Over 25% of respondents ranked 'Family' and 'Real Estate Agent/Realtor' as 'Not Credible'. Twenty-seven respondents chose 'Other; please specify', but only 14 of these respondents specified an answer. One of these respondents answered they didn't understand the question, while others named themselves, personal experience, NOAA, zoning boards, geologists, radio, friends, and the Army Corps of Engineers.

Group	Not Credible	Somewhat Credible	Moderately Credible	Very Credible	Completely Credible
Family	32.14%	26.79%	21.43%	16.07%	3.57%
Friends/Colleagues	16.07%	42.86%	28.57%	12.50%	0.00%
Real Estate Agent/Realtor	25.86%	37.93%	22.41%	12.07%	1.72%
Insurance Agent	15.25%	28.81%	33.90%	16.95%	5.08%
Town, City, or County Government/Officials	8.62%	15.52%	41.38%	27.59%	6.90%
State Government/ Officials	12.07%	27.59%	29.31%	25.86%	5.17%
FEMA (Federal Emergency Management Agency)	13.79%	17.24%	36.21%	27.59%	5.17%
National Weather Service	3.45%	17.24%	36.21%	36.21%	6.90%
Newspapers	13.79%	36.21%	37.93%	10.34%	1.72%
Local TV News	12.07%	29.31%	41.38%	13.79%	3.45%
National TV News	18.97%	37.93%	31.03%	8.62%	3.45%
On-line Resources	10.53%	31.58%	42.11%	10.53%	5.26%
Other; please specify	37.04%	0.00%	37.04%	14.81%	11.11%

Table 7.13. Responses to Question “How would you rate the credibility of flood danger information in relation to your home from each of the following sources?”

Over 40% of respondents marked town, city, or county government/officials as the entity with the primary responsibility of informing homeowners of the potential risk of flooding (Figure 7.7). A quarter of respondents said this responsibility belonged to the real estate agent/realtor.

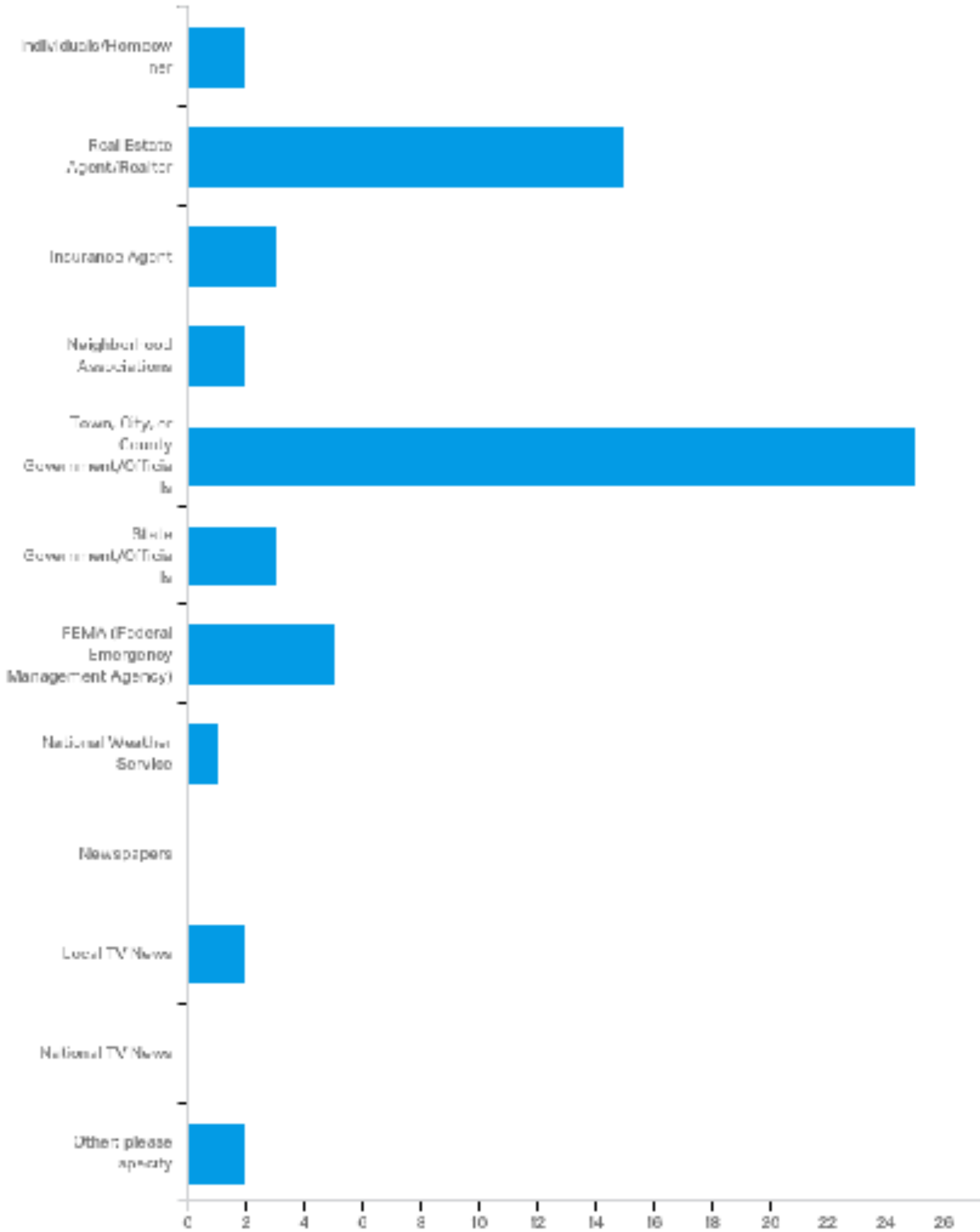


Figure 7.7. Responses to Question "Which of the following do you think has primary responsibility for informing homeowners of the potential risk of flooding?"

When asked if a standard home insurance policy covers flood damage from natural causes over 78%, of respondents correctly answered 'No'. The remaining respondents selected ‘Don’t know’, with zero respondents marking ‘Yes’. The correct answer is ‘No’.

About 17% of respondents said they have flood insurance, and 70% of respondents selected ‘No’, with around 13% ‘Don’t know’. For those respondents indicating they did have flood insurance, they were asked if the mortgage company required this coverage. Half said ‘yes’ with the other half selecting ‘no’. None said ‘Don’t know’. For the 50 respondents that marked either ‘No’ or ‘Don’t know’ in response to having flood insurance, they were asked if they would consider purchasing coverage (Figure 7.8). Of those respondents, 24% marked ‘Yes’, with 44% selecting ‘No’, and 32%, stating ‘Don’t know’. The respondents that marked ‘Yes’ to considering purchasing flood insurance were then asked what their reason was for this consideration. Over 83% referenced peace of mind. One selected a reasonable monthly payment, while another desired a payment included in the monthly mortgage statement, as is the case with most home insurance payment options, but not flood insurance outside the NFIP 100-year flood zones.

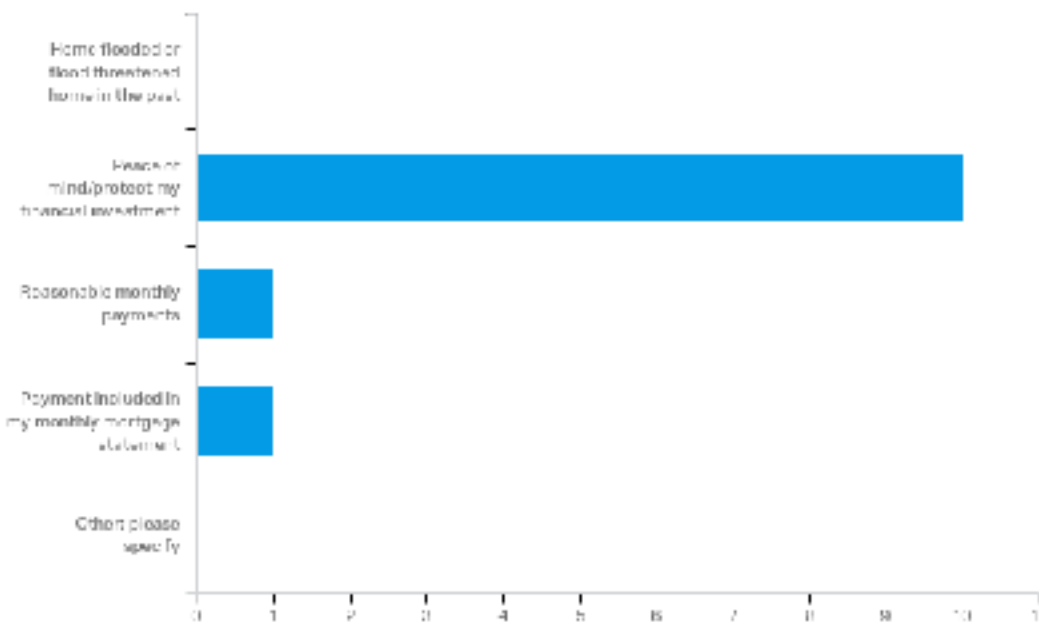


Figure 7.8. Responses to Question “What is your reason for considering the purchase of flood insurance coverage for your home?”

The 22 respondents that said they would not consider purchasing flood insurance were asked their reason behind this decision (Figure 7.9). Half of these respondents stated there is no danger of flooding. Five respondents selected ‘Other; please specify’. Three of the five respondents referenced little or low risk of flooding to their home. In addition, one ‘Other’ respondent said their reasoning was a mix of the first three answers to the question listed, and one respondent commented “insurance companies lie.”

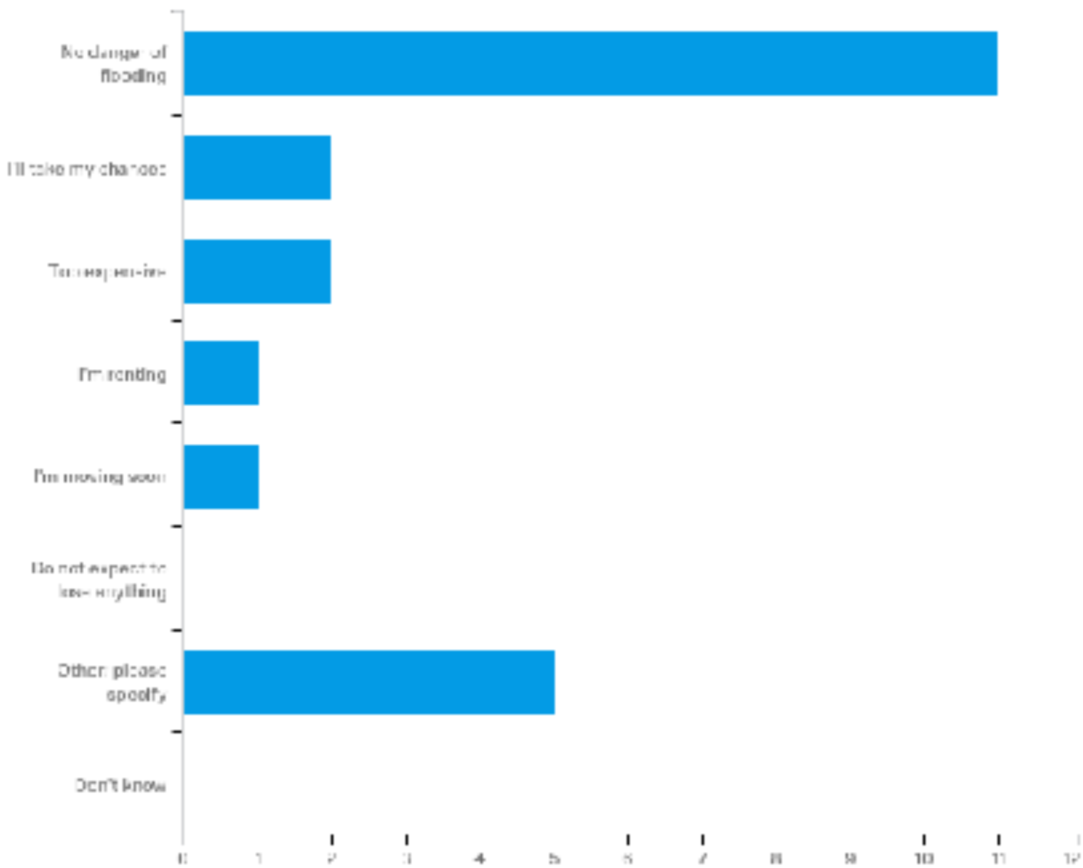


Figure 7.9. Responses to Question “ What is your reason for not considering purchasing flood insurance coverage for your home?”

All respondents were then asked what they believed was a reasonable amount to pay per month for flood insurance coverage (Figure 7.10). Over two-thirds of respondents marked below $25. There were three ‘Other’ selections with one respondent stating “the insurance company said it wouldn't have been covered even if we had insurance b/c we are not in a floodplain and there was not a catastrophic event impacting the area. Why pay?" Another respondent answered $0 to $5000, while the remaining respondent said they believe there is no threat of flooding.

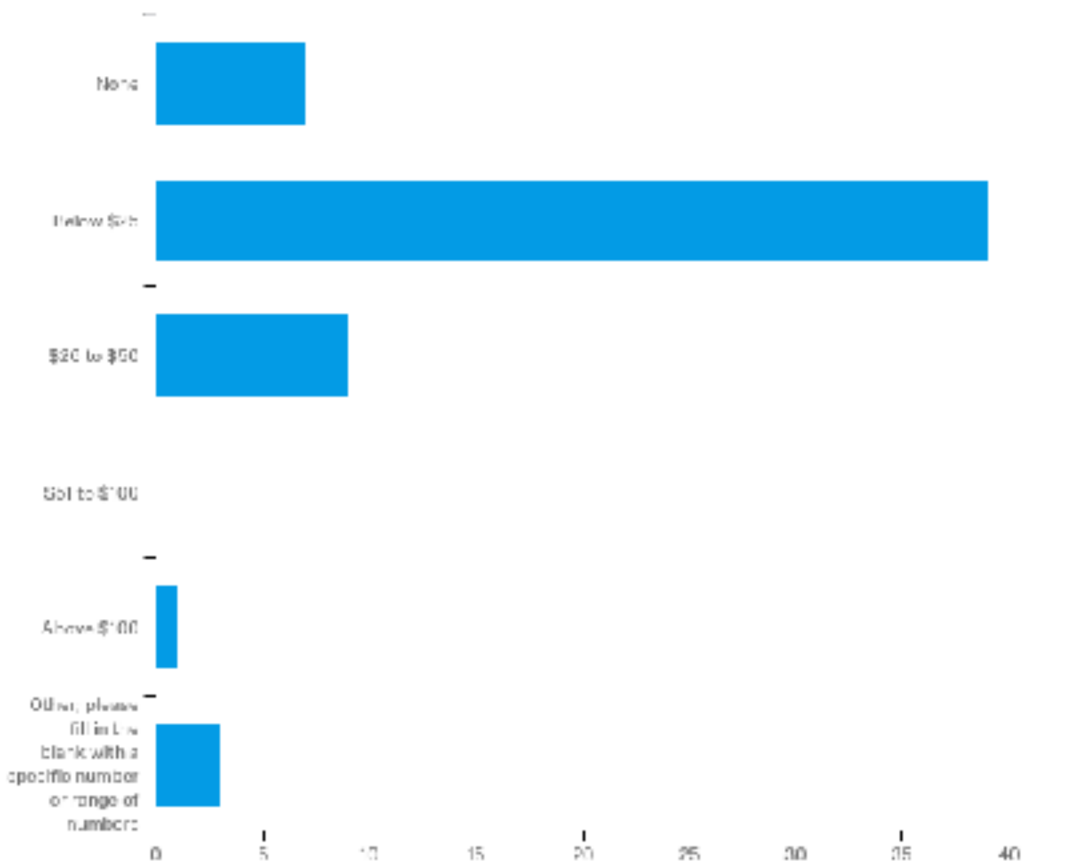


Figure 7.10. Responses to Question "Please select what you believe is a reasonable amount to pay per month for flood insurance coverage for your home."

Respondents were asked to check all that apply to the question "What sources would you use to gather information on flood insurance?" The most common selection was insurance agents, with over one-third of respondents marking family/friends, neighborhood associations, FEMA, plus town, city, county government/officials (Figure 7.11). For the respondents that selected 'Other', three specified the Internet; one specified historical flood data; and another said their landlord, who has lived in the neighborhood for a "long time."

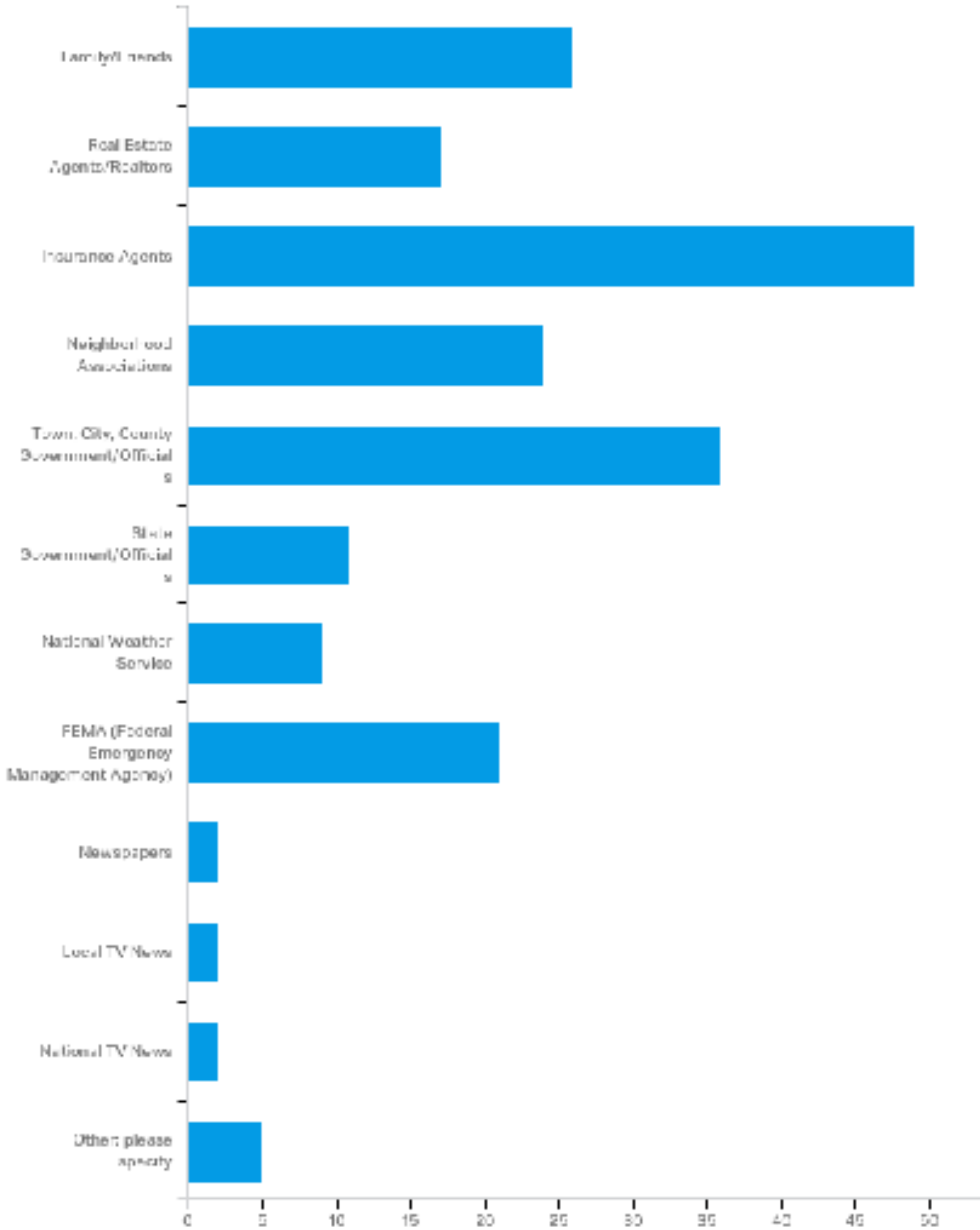


Figure 7.11. Responses to Question "What sources would you use to gather information on flood insurance? Check all that apply."

Multivariate analysis was performed on select questions to determine if there was a relationship between variables. A p-value of 0.05 at the 95% confidence interval was used to determine significance. Seven relationships between variables were found. However, some relationships may be significant by chance.

There is a relationship between the variables of the questions “Have you been personally affected by flooding?” and “In your opinion, what is the risk of flooding to your home in the future?” with a p-value < 0.05 (Table 7.14). The highest percentage of respondents that were affected by flooding ranked the risk of flooding to their home in the future at ‘medium risk’. For the respondents that indicated they were not personally affected by flooding, the highest percentage indicated their home was at ‘low risk’ of future flooding.

		Have you been personally affected by flooding?	
		Yes	No
In your opinion, what is the risk of flooding to your home in the future?	No risk	16.67% 7.14%	83.33% 10.20%
	Low Risk	10.53% 28.57%	89.47% 69.39%
	Medium Risk	46.15% 42.86%	53.85% 14.29%
	High Risk	50.00% 7.14%	50.00% 2.04%
	Don’t know	50.00% 14.29%	50.00% 4.08%

Table 7.14. Multivariate analysis of questions “Have you been personally affected by flooding?” and “In your opinion, what is the risk of flooding to your home in the future?” Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the questions “Do you live in a floodplain?” and “How knowledgeable do you think your are about flooding in your neighborhood?” with a p-value < 0.05 (Table 7.15). The highest percentage of respondents that answered either ‘Yes’ or ‘No’ to living in a floodplain, also answered they were ‘Moderately Knowledgeable’ about flooding in their neighborhood. The highest percentage of respondents that did not know if they live in a floodplain chose ‘Not at all Knowledgeable’.

		Do you live in a floodplain?		
		Yes	No	Don’t know
How knowledgeable do you think you are about flooding in your neighborhood?	Not at all Knowledgeable	27.27% 14.29%	18.18% 6.90%	54.55% 46.15%
	Somewhat Knowledgeable	15.38% 9.52%	61.54% 27.59%	23.08% 23.08%
	Moderately Knowledgeable	40.00% 38.10%	45.00% 31.03%	15.00% 23.08%
	Very Knowledgeable	33.33% 19.05%	66.67% 27.59%	0.00% 0.00%
	Extremely Knowledgeable	57.14% 19.05%	28.57% 6.90%	14.29% 7.69%

Table 7.15. Multivariate analysis of questions “Do you live in a floodplain?” and “How knowledgeable do you think you are about flooding in your neighborhood?” Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the questions “Do you live in a floodplain?” and “Do you have flood insurance?” with a p-value < 0.05 (Table 7.16). For the respondents that answered yes to living in a floodplain, 35% indicated they have flood insurance, while 50% said they did not have flood insurance and 15% said they ‘Don’t know’. The majority of respondents indicating they live outside the floodplain also stated they did not have flood insurance. Only about 11% of respondents indicating they lived outside a floodplain also indicated they purchased flood insurance. Nearly a quarter of respondents that answered ‘Don’t know’ if they live in a flood plain also answered ‘Don’t know’ if they have flood insurance.

		Do you live in a floodplain?		
		Yes	No	Don't know
Do you have flood insurance?	Yes	70.00% 35.00%	30.00% 11.11%	0.00% 0.00%
	No	23.81% 50.00%	52.38% 81.48%	23.81% 76.92%
	Don't know	37.50% 15.00%	25.00% 7.41%	37.50% 23.08%

Table 7.16. Multivariate analysis of questions "Do you live in a floodplain?" and "Do you have flood insurance?" Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the questions "In your opinion, what is the risk of flooding to your home in the future?" and "What defines a 100-year flood?" with a p-value < 0.05 (Table 7.17). The two correct answers were '1% chance of a flood in any give year' and 26% chance of flood over 30 years'. While no respondent selected the correct two responses, nearly 29% of respondents did select one of the correct answers (Table 7.11). Half of the respondents who defined the flood risk to their home as 'No Risk' selected one of the correct answers, as did half of the "High Risk' respondents. For 'Low Risk' respondents, almost 24% chose one of the correct answers, and around 38% of 'Medium Risk' chose one of the correct answers.

		In your opinion, what is the risk of flooding to your home in the future?				
		No Risk	Low Risk	Medium Risk	High Risk	Don't know
What defines a 100-year flood? Select all that apply.	Occurs once very 100 years	7.69% 16.67%	69.23% 23.68%	7.69% 7.69%	0.00% 0.00%	15.38% 50.00%
	1% chance of flood in any given year	13.33% 33.33%	60.00% 23.68%	26.67% 30.77%	0.00% 0.00%	0.00% 0.00%
	26% chance of flood over 30 years	33.33% 16.67%	0.00% 0.00%	33.33% 7.69%	33.33% 50.00%	0.00% 0.00%
	All above answers are correct	0.00% 0.00%	77.78% 18.42%	11.11% 7.69%	11.11% 50.00%	0.00% 0.00%
	None are correct	14.29% 16.67%	85.71% 15.79%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%
	Don't know	4.76% 16.67%	42.86% 23.68%	38.10% 61.54%	0.00% 0.00%	14.29% 75.00%

Table 7.17. Cross-tabulation of questions “In your opinion, what is the risk of flooding to your home in the future?” and “What defines a 100-year flood?” Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the questions “In your opinion, what is the risk of flooding to your home in the future?” and “How many floods do you expect in 100 years time in your neighborhood?” with a p-value < 0.05 (Table 7.18). Respondents that defined flood risk to their home as ‘No Risk’ or ‘Low Risk’ favored the two lowest numbered answers, which are ‘None’ or ‘1 or 2’. ‘Medium Risk’ and ‘High Risk’ respondents generally selected ‘1 or 2’ or higher number answers. Three-quarter of respondents that selected ‘Don’t know’ for risk of flooding also selected ‘Don’t know’ to the number of floods expected in 100 years time.

		In your opinion, what is the risk of flooding to your home in the future?				
		No Risk	Low Risk	Medium Risk	High Risk	Don't know
How many floods do you expect in 100 years of time in your neighborhood?	None	22.22% 66.67%	72.22% 34.21%	5.56% 7.69%	0.00% 0.00%	0.00% 0.00%
	1 or 2	8.70% 33.33%	69.57% 42.11%	17.39% 30.77%	4.35% 50.00%	0.00% 0.00%
	3, 4, or 5	0.00% 0.00%	57.14% 10.53%	14.29% 7.69%	14.29% 50.00%	14.29% 25.00%
	6 to 10	0.00% 0.00%	25.00% 2.63%	75.00% 23.08%	0.00% 0.00%	0.00% 0.00%
	Over 10	0.00% 0.00%	100.00% 2.63%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%
	Don't know	0.00% 0.00%	30.00% 7.89%	40.00% 30.77%	0.00% 0.00%	30.00% 75.00%

Table 7.18. Multivariate analysis of questions “In your opinion, what is the risk of flooding to your home in the future?” and “How many floods do you expect in 100 years time in your neighborhood?” Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the questions “Please select what you believe is a reasonable amount to pay per month for flood insurance coverage?” and “In your opinion, what is the risk of flooding to your home in the future?” with a p-value < 0.05 (Table 7.19). The majority of respondents at ‘Low Risk’, ‘Medium Risk’, and ‘Don’t Know’ selected ‘Below $25’. The majority of ‘No risk’ respondents marked ‘None’. Generally, respondents in all risk categories favored lower monthly payments, below $25 and up to $50.

		In your opinion, what is the risk of flooding to your home in the future?				
		No Risk	Low Risk	Medium Risk	High Risk	Don't know
Please select what you believe is a reasonable amount to pay per month for flood insurance coverage.	None	57.14% 66.67%	0.00% 0.00%	28.57% 15.38%	14.29% 50.00%	0.00% 0.00%
	Below $25	2.56% 16.67%	69.23% 71.14%	20.51% 61.54%	2.56% 50.00%	5.13% 66.67%
	$26 to $50	0.00% 0.00%	69.67% 17.14%	33.33% 23.08%	0.00% 0.00%	0.00% 0.00%
	$52 to $100	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%
	Above $100	100.00% 16.67%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%
	Other; please fill in the blank with a number or range of numbers	0.00% 0.00%	66.67% 5.71%	0.00% 0.00%	0.00% 0.00%	33.33% 33.33%

Table 7.19. Multivariate analysis of questions "Please select what you believe is a reasonable amount to pay per month for flood insurance coverage?" and "In your opinion, what is the risk of flooding to your home in the future?" Row Percents are on top in red. Column Percents are on the bottom in blue.

There is a relationship between the variables of the question "What is your age?" and the variable 'Online Resources' for "How would you rate the credibility of flood danger information in relation to your home from each of the following sources?" with a p-value < 0.05 (Table 7.20). The majority of respondents ranked 'Online Resources' as 'Somewhat' to 'Moderately' credible. Plus the majority of each age group, except 'Prefer not to answer' selected the first three credibility rankings, which were lower than the last remaining two choices.

		How would you rate the credibility of flood danger information in relation to your home from the following source: Online Resources				
		Not Credible at All	Somewhat Credible	Moderately Credible	Very Credible	Completely Credible
What is your age?	18 to 24 years old	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%
	25 to 34 years old	0.00% 0.00%	0.00% 0.00%	100.00% 16.67%	0.00% 0.00%	0.00% 0.00%
	35 to 44 years old	42.86% 50.00%	14.29% 5.56%	28.57% 8.33%	0.00% 0.00%	14.29% 33.33%
	45 to 54 years old	15.38% 33.33%	30.77% 22.22%	46.15% 25.00%	0.00% 0.00%	7.69% 33.33%
	55 to 64 years old	0.00% 0.00%	66.67% 55.56%	6.67% 4.17%	20.00% 50.00%	6.67% 33.33%
	65 to 74 years old	7.14% 16.67%	21.43% 16.67%	57.14% 33.33%	14.29% 33.33%	0.00% 0.00%
	75 years or older	0.00% 0.00%	0.00% 0.00%	100.00% 12.50%	0.00% 0.00%	0.00% 0.00%
	Prefer not to answer	0.00% 0.00%	0.00% 0.00%	0.00% 0.00%	100.00% 16.67%	0.00% 0.00%

Table 7.20. Multivariate analysis of questions “How would you rate the credibility of flood danger information in relation to your home from the following source: Online Resources?” and “What is your age?” Row Percents are on top in red. Column Percents are on the bottom in blue.

Besides the questions highlighted in Table 7.20, there were no significant correlations between survey questions relating to sources of information, flood insurance, or flood risk knowledge and the demographic data of age, socio-economic, education, race, and cultural factors.

Responses to “In your opinion, what is the flood risk to your home in the future?” (Figure 7.3) were compared to the themes that emerged out of the responses to a similar open-ended question in McPherson and Saarinen (1977) (Table 7.21). In McPherson and Saarinen (1977) around 20% of respondents indicated there was no risk of flooding. In this survey nearly 10% of people answered there was no risk of flooding. However, it is unclear if the respondents of this survey live in a 100-year flood zone, as in McPherson and Saarinen (1977). The majority of respondents in both surveys ranked flood risk to their homes as ‘Low risk’ and ‘Medium risk’.

Answer	Percentage	Percentage McPherson and Saarinen (1977)
No risk	9.52%	20.4%
Low risk	60.32%	50.6%
Medium risk	20.63%	18.5%
High risk	3.17%	1.9%
Don’t know	6.35%	8.6%

Table 7.21. Responses to “In your opinion, what is the flood risk to your home in the future?” versus themes for responses in McPherson and Saarinen (1977)

Responses to “How many floods do you expected in 100 years of time in your neighborhood?” (Figure 7.4) were compared to the themes that emerged out of the responses to a similar open-ended question in McPherson and Saarinen (1977) (Table 7.22). In McPherson and Saarinen (1977), 72% of respondents answered ‘none’ or ‘1 or 2’. In this study, only around 44% of respondents selected these same answers. Around 33% of respondents to this survey selected ‘Don’t know’ versus the lower percentage in McPherson and Saarinen (1977) of 14.2%.

Answer	Percentage	Percentage McPherson and Saarinen (1977)
None	20.63%	24.5%
1 or 2	23.81%	47.5%
3, 4, or 5	4.76%	11.1%
6 to 10	14.29%	3.1%
Over 10	11.11%	0.6%
Don't know	33.33%	14.2%

Table 7.22. Responses to “How many floods do you expect in 100 years of time in your neighborhood?” compared to responses to a similar question in McPherson and Saarinen (1977).

Responses to the question “If a flood is threatening your home, what is the first thing you would do in response to the risk?” (Figure 7.5) were compared to the themes that emerged out of the responses to a similar open-ended question in McPherson and Saarinen (1977). In this study, about 57% of respondents selected ‘Get out/flee’ or ‘Get out with some possessions’. In McPherson and Saarinen (1977), nearly 53% of respondents that answered the question also said they would “get out”. However, McPherson and Saarinen (1977) point out over half of their respondents did not provide any answer to the question, implying they “had probably not considered the possibility seriously.”

Responses to the question “If your home is flooded, who do you believe is economically responsible for recovery and rebuilding?” (Figure 7.6) were compared to the themes that emerged out of responses to an open-ended question in McPherson and Saarinen (1977). Over 75% of respondents in McPherson and Saarinen (1977) referenced city, state, and/or county government, and only 7% mentioned the individual. McPherson and Saarinen (1977) stated “few people feel that the individual has any responsibility to protect themselves.” In this survey, only about 2% of respondents selected ‘Town, City, or County Government/Officials’. None selected ‘State

Government/Officials'. In contrast, nearly 38% of respondents selected 'Individual/ Homeowners'. The same percentage selected 'Insurance Companies'. It must be noted these questions may have been worded differently, resulting in very different responses.

Responses to the question "If your home was damaged by a flood, what steps do you believe should be taken to protect against future flood damage? Check all that apply" (Table 7.12) were compared to the themes that emerged out of responses to a similar open-ended question in McPherson and Saarinen (1977). The exact wording of this question is unknown, but McPherson and Saarinen (1977) referenced "adjustments that should be made" when discussing responses and it appears only one answer was recorded per respondent, if the respondent answered at all. In McPherson and Saarinen (1977), over half of respondents selected a "technological fix" of either 'Building dams and channelize' or 'Flood protection, storm sewers'. While over half of respondents chose similar technological fixes in this study, 'Purchase insurance' and 'provide warnings and information to people at high risk' were also selected by over half of respondents (Table 7.12). While 'Purchase insurance' was not listed in the themes found by McPherson and Saarinen (1977) for this topic, respondents were asked about their intent to purchase flood insurance. The majority, over 65%, answered no, while nearly 15% said yes, around 17% said maybe, and almost 3% said they didn't know.

Responses to the question "What is your reason for not considering purchasing flood insurance coverage for your home?" (Figure 7.9) were compared to the themes that emerged out of responses to a similar open-ended question in McPherson and Saarinen (1977). In McPherson and Saarinen (1977), about 54% of respondents said there was "no danger" with nearly 15% citing "too expensive". In this study, 50% of respondents that answered this question selected 'No danger'. The selection with the second highest number, at around 23%, was 'Other; please specify'. Four of the five referenced low risk in their answer. In addition, around 9% of respondents selected 'Too expensive' and the same number selected 'I'll take my chances'.

Discussion

The sample population may not represent the target population. Demographic data indicating age, sex, household income, race/ethnicity, and education levels gathered in this survey differs from demographic data gathered on the target population. In addition, the number of surveys was fewer than the necessary amount needed to reliably represent the target population. This brings the robustness of the data into question. While inferences can be made and patterns may emerge, increasing the response rate of this or future surveys could expand the findings of this research and determine if the results are valid. That being said, respondent answers did reveal some themes about flood risk and flood insurance knowledge, as well as trusted sources for information relating to these topics.

As with numerous other studies, the findings in this study indicate experience does raise awareness of the flood danger (McPherson and Saarinen 1977, Brilly and Polic 2005, Drobot et al. 2007, Ruin et al. 2007, Siegrist and Gutscher 2008, Spence et al. 2009, Petrolia et al. 2012). Respondents who specified they were affected by flooding tended to choose a higher risk level for potential future flooding than those that were not personally affected (Table 7.17). However, all respondents, regardless of their flood experience, may still be minimizing risk or misunderstanding sources of flood damage to their homes, possibly both, when deciding to purchase or not purchase a flood insurance policy. The majority of respondents recognize a standard home insurance policy does not cover flood damage from natural causes. While a third of respondents acknowledged they live in a floodplain (Table 7.9), only around 17% of respondents claimed to have a flood insurance policy. Of the respondents with flood insurance, half said they were required to have it as a condition of their loan and the other half did not. This means only about 8% of respondents chose to carry flood insurance on their home voluntarily.

These results are not unexpected. Ruin et al. (2007) found the level of awareness was impacted by “recency, frequency, and intensity” of the flood experience. Some studies found flood experience led to less worry about future flooding (Blanchard-Boehm et al 2001, Soane et al. 2010). Lack of control over the flood risk or the flood experience only caused minor damage were proposed as potential reasons for these findings (Blanchard-Boehm et al 2001, Siegrest and Gutscher 2008, Soane et al 2010). In this study, respondents who indicated they were personally affected by flooding were asked to describe their experience. Only five of 14 responses cited their home was impacted by flooding, and just one of these responses indicated significant damage and the loss of pets to the flooding. That respondent also indicated they did not live in a floodplain, but voluntarily purchased flood insurance. Further investigation into what level of flood impact could push a homeowner to purchase insurance may prove useful if and when an event occurs. With data showing a rise in flood insurance policies immediately after an event (Browne and Hoyt 2000), knowing what kind of damage or impact can motivate homeowners into paying a premium could increase participation in the NFIP. In this case, timing of the information could be a key element of an education program.

Half of the respondents who said they would not consider flood insurance marked 'No danger of flooding' as the reason. Each of these respondents also claimed to have and an increased level of flood risk knowledge (Somewhat, Moderately, Very, and Extremely). Given these results, plus those discussed in the above paragraph, respondents may not fully comprehend the risks which come with arid land weather events. In an arid land environment, like the TMA, it is not unusual for a home to sustain damage simply from a heavy downpour when water could not drain away quickly enough from the property. As a result, even those homes outside a mapped flood zone could sustain flood damage. Determining what type of weather and climate conditions people perceive as a flood threat may provide insight into why homeowners choose not to carry flood insurance, even when they acknowledge their home insurance policies do not cover this type to damage.

Relating the 100-year flood to accurate descriptions of probability remains a challenge. If people misunderstand or underestimate the probability, this can lead to a more vulnerable community (Omer and Elon 1994). Bell (2007) asked community members in flood impacted areas about their perception of terms commonly associated with a 100-year flood. The result was a recommendation for further research into how these descriptions were perceived by the public. Two of the descriptions in Bell (2007) were'1% chance of flood in any given year' over '26% chance of flood over 30 years'. Both of these descriptions are statistically accurate. In this survey, the question 'What defines a 100-year flood?' (Table 7.11) listed these two descriptions, among other choices. Respondents could 'check all that apply' to the question. No respondent selected both correct answers and only about 29% of respondents selected one of the correct answers. The majority of the respondents who selected one of the correct answers chose '1% chance of flood in any given year' over '26% chance of flood over 30 years'. Respondents may be more accustomed to the first definition over the second. However, the use of the second definition as a more common phrase for flood risk could be impactful since many mortgages are set at 30 years. A 26% chance of flooding over those 30 years is over a 1-in-4 chance a home could flood during the loan period. Further investigation into how this knowledge gap between the terms officials use when describing 100-year for flood risk and how the public perceives this information could be used to design future flood risk communication efforts. By including the two descriptions in this survey, it gives future flood risk research in the TMA a base starting point at which homeowner's perception of the 100-year flood definition can be measured against.

Numerous studies indicate a lack of knowledge about the NFIP could be contributing to low participation (McPherson and Saarinen 1977, Blanchard-Boehm et al 2001, Chivers and Flores 2002). With this in mind, results from this study suggest educating homeowners about the NFIP could increase participation in the TMA. About a quarter of the respondents who did not have flood insurance said they would consider it, with another 32% marking they don't know if they would consider it. Many respondents answered they would consider the additional insurance coverage for 'Peace of mind, protect my financial interest' (Figure 7.8). These results suggest respondents may not fully understand what options are available within the NFIP.

Affordability of flood insurance remains an important factor for increasing NFIP participation. While cost is often cited as a reason for not carrying a policy on the home (McPherson and Saarinen 1977, Browne and Hoyt 2000, Petrolia et al. 2012), some studies found homeowners would consider a policy if they perceived the cost as reasonable (Blanchard-Boehm et al. 2001, Brilly and Polic 2005). In this survey, over two-thirds of respondents marked 'Below $25' as a reasonable amount for monthly insurance payments (Figure 7.10). Even those respondents who ranked risk of flooding to their home at medium to high favored lower monthly payments (Table 6.19). Outside the SFHA, rates range from $4.00 to $39.50 per month for residential properties depending on the level of coverage selected (NFIP 2016). These numbers are roughly in-line with what respondents in this study consider a reasonable cost for a flood insurance premium. Education efforts which focus on communicating the numbers to homeowners could increase the number of flood insurance policies in effect. In addition, it may be useful to pay policies out of escrow, rather than requiring a lump sum once a year. Policies required by the lender are paid in this way, however policies-in-effect not required by the lender are not necessarily included in escrow and are only included at the "lender's discretion" (FloodSmart.gov 2016). By paying through escrow, the monthly payments will add up to the required one-year premium fees and decrease the one time, and potentially larger impact, on the homeowner's finances.

Correlations between demographic data from classification questions and data from behavioral, knowledge and perception questions were examined as well. Numerous studies found individuals use informal problem solving techniques, called heuristics, to assess the risk and benefits of a situation (Slovic 1987, Gough 2000, Leiserowitz 2006, Drobot et al 2007, Ruin et al 2007, Coles 2008, Raaijmakers et al. 2008, Siegrist and Gutscher 2008, Whitmarsh 2008, Costa-Font et al 2009, Figueiredo at al 2009, Spence et al. 2009, Kahan et al 2010, Soane et al 2010, Weber 2010). These mental strategies can be influenced by social and cultural factors, as well as socioeconomic status, age, gender, education, and other demographic data. While only one correlation was found in this study (Table 6.20), the small sample size could have negatively impacted results. To increase confidence, expanding the sample size is recommended in future work, potentially testing the same questions with the larger sample.

Communicating flood risk through trusted sources could enhance education efforts regarding NFIP options. Research shows individuals are more accepting of information from experts who share their personal values or views on a subject (Raaijmakers 2008, Whitmarsh 2008, Kahan 2010). Respondents in this study ranked the National Weather Service (NWS) highest for credible sources (Table 6.13). While the NWS is responsible for disseminating watches, warnings, and on-going flood threats, traditionally the agency does not give out information about the federal flood insurance program managed by FEMA. Since the NWS credibility ranks highest and they are also part of a federal agency, FEMA could potentially partner with the NWS to further inform the public about the NFIP. However, two different U.S. departments oversee these agencies (FEMA by the Department of Homeland Security and the NWS by the Department of Commerce). As a result, the mission and objective of these two entities need to be considered before a partnership is formed.

With real estate agents and realtors working closely with homebuyers, these professional groups may be best suited to introduce the topic of flood insurance. However, it appears they are not active participants in the flood risk conversation. Chivers and Flores (2002) found buyers were often informed a property was in a SFHA during the final step in the home-buying process, and not earlier by the seller or the real estate agent/realtor. Educating real estate agents and realtors about NFIP and how the various options could protect their client's investment opens another pathway of communication for flood risk. Addressing credibility issues may be a key first step. The findings in this study suggest real estate agents and realtors are not a highly trusted source for flood risk information (Table 7.13). Since insurance agents rank higher in credibility than real estate agents or realtors, these professionals may be in a better position to inform potential homebuyers about flood insurance options. With most loans requiring proof of insurance at closing, buyers are in contact with these professionals while purchasing a home. Plus, over half of respondents said they would 'Purchase insurance' to protect against flood risk (Table 7.12) and over 81% said they would go to insurance agents to gather information about flood insurance (Figure 7.11). However, since flood insurance and home insurance are two different policies, not all insurance agents are educated in or licensed to write flood insurance policies. This means not all home insurance agents can adequately inform homebuyers of their flood insurance options. For one respondent, it appears misinformation from the insurance company did cause confusion. After stating there was flood damage to a portion of the home, the respondent wrote "the insurance company said it wouldn't have been covered even if we had insurance b/c we are not in a floodplain and there was not a catastrophic event impacting the area." The respondent may be referring to a Federal Disaster Declaration, which opens up federal funds to assist with recovery. However, individual flood insurance policies are paid out on a case-by-case basis. A Federal Disaster Declaration is unrelated to that process.

Select questions in this survey were based off themes which emerged from a previous flood risk survey completed in Tucson by McPherson and Saarinen (1977). The findings suggest respondents of this survey may be more aware of the flood danger than in the previous survey, possibly reflecting education efforts over the last four decades by the local flood control agency, county, city, or towns. However, the data indicates respondents in this survey continue to minimize the danger. Both surveys had around 50% of respondents select 'no danger' as the reason for not considering flood insurance.

Respondents to this survey were more likely to accept personal responsibility for the financial impacts of flood damage recovery through either themselves or insurance policies than the respondents in McPherson and Saarinen (1977). Plus, over half of respondents in this survey chose 'Purchase insurance' as an option to protect against future flood damage (Table 7.12). This is in contrast with the findings of McPherson and Saarinen (1977), which found over 65% of respondents would not purchase federal flood insurance policies. McPherson and Saarinen stated "few people feel that the individual has any responsibility to protect themselves.” Instead, most of the McPherson and Saarinen (1977) respondents believed the city, state, and county governments were responsible for solving the problem, not the individuals themselves. While that was the case forty years ago, the findings in this survey suggest individuals may now be more willing to consider flood insurance policies to protect against possible future damage.

CHAPTER 8

FLOOD CONTROL COMPARISON: TUCSON METROPOLITAN AREA TO EL PASO METROPOLITAN AREA

Flooding is a challenge in arid land urban areas other than the TMA. El Paso, Texas is 300 miles east of Tucson. With a comparable population size, climate and desert geography, the El Paso Metropolitan Area (EPMA) faces similar flood threats to the TMA. The two share a commonality in major employers, with military bases and major universities located in both metropolitan areas. Even the major cities in these metropolitan areas, Tucson and El Paso cover roughly the same square miles. And in both, it took a major flood event to change the course of flood management.

Established in 1978, PCRFCD is the main agency addressing flood control measures in the TMA. While some of the cities and towns making up the TMA have their own agencies and people with expertise in this subject, many defer to PCRFCD.

As the population of the TMA grew in the decades following the creation of PCRFCD, this one central agency's approach to flood control allowed the city to expand while addressing flood risk at the same time. While early efforts of PCRFCD to regulate waterways were met with pushback from developers, the major 1983 flood event, discussed in Chapter 3, mitigated that pushback. PCRFCD was able to put non-structural measures, such as stricter regulations, into place for development in and along desert waterways and prioritize larger structural flood control measures to better protect people, homes and businesses. The updated regulations, along with engineering projects, have reduced flood risk in many neighborhoods across the TMA. This was proven when an event of even greater magnitude was measured in some of the waterways in 2006 with little damage reported post-flood.

In the EPMA, a major flood also changed the way flood risk was addressed. But this event happened in July 2006. Rain totals not seen since 1881 were measured in the City of El Paso, plus the Rio Grande River defining the southern border of the county exceeded its banks for the first time in nearly 50 years (Brock 2006). Damage estimates in the City of El Paso were $200 million to homes and businesses with another $100 million to the stormwater system (KVIA 2016). One major difference between the TMA and the EPMA is the Rio Grande. The TMA does not have a major perennial river, while the EPMA does. Flood control measures along the Rio Grande are overseen by the The

U.S. International Boundary Water Commission (USIBWC), a federal agency. Separate from the damage in El Paso, an estimated over $280 million to repair and restore infrastructure, plus clean-up the river (Brock 2006). For the purposes of this comparison between the TMA and the EPMA, the focus will be on the arroyos criss-crossing the EPMA, draining into the Rio Grande. City and county authorities have oversight for flood control measures along these arroyos, similar to the TMA.

The EPMA 2006 flood event brought attention to the lack of a widespread flood control policy as the city expanded. According to a post-event report, “other fiscal priorities meant that maintenance had been neglected and the city had grown without an overall plan or construction of projects to improve the system and provide a greater level of protection” (Community Advisory Committee 2009). It is a statement that could have been applied to the TMA in 1983. With successful flood control during subsequent large-scale events, the lessons learned in TMA could have been applied to the EPMA, just half a days drive from one city center to another. Unfortunately for the EPMA, this did not occur. It took the major event in 2006 to change the course of flood control.

Unlike in Pima County, even today there is no central agency for structural flood control projects in El Paso County. Most of the efforts have been done through the City of El Paso. Two years after the 2006 EPMA event, the city council designated stormwater management to the Public Service Board of the El Paso Water Utility (EPWU). This is in contrast to PCRFCD, which is part of the Pima County Public Works Department and separate from other water-related entities within the county and those operated by the City of Tucson. While the City of Tucson does have a Floodplain Administration office through the Tucson Department of Transportation, many flood control projects within the city are completed by PCRFCD. The decision to make the EPWU the local agency for flood control may have originated out a lack of experience within other local government entities and departments. The utility supplies about 90% of the municipal drinking water in El Paso County and had some expertise in stormwater management in addition to water resource management. The main reason may have been financial. The EPWU was well-established and maintained a superior bond rating, meaning it had the credit needed to obtain loans and the reputation essential to secure voter-approved bonds (EPWU 2018).

In 2009, EPWU released the Stormwater Mater Plan (SMP), which was in direct response to the 2006 event. The SMP is a comprehensive review of existing structural stormwater drainage systems in the EPMA, plus recommendations for additional infrastructure. These recommendations came out of community feedback, technical evaluations and infrastructure assessments. The estimated cost for the improvements identified in the SMP was $650 million (Community Advisory Committee 2009). Like PCRFCD projects, the EPWU stormwater infrastructure improvements are funded through bonds approved by the voters, which doesn't eat into the annual budget of these agencies. However, operations and maintenance are on-going and part of the annual budget. The most recent budget reports for EPWU were between $6.6 and $6.9 million. PCRFCD's most recent yearly budgets range from $15 to $20 million. While the difference could be due to many factors and a comprehensive fiscal review is outside the scope of this research, PCRFCD did have over a 20 year head-start on infrastructure improvements over the EPWU. Simply put, PCRFCD may have much more infrastructure in place that needs yearly maintenance versus EPWU. Another reason could be the division of responsibility month EPWU and other local governmental authorities, such as the El Paso Water Control and Improvement District and El Paso County Public Works. Moving into the future, a question does need to be asked - does EPWU need to expand their stormwater budget to accommodate operation and maintenance of the new projects? If that question isn't addressed, the EPMA could find themselves in a similar situation decades down the road with crumbling infrastructure unable to accommodate large flows.

In response to the damage from the 1983 flood event, PCRFCD initiated an on-going buy-back program for homes in flood plains, especially those with repeat damage, when funds are available. During that time and in the following decades, there were no major relocation programs for residents in flood plains. The buy-outs were mostly voluntary. Officials in the EPMA took a different approach, and it's one that proved controversial.

As outlined in Chapter 5, generally higher income households are found in TMA flood zones. In the EPMA, the story is similar on the westside of the city, but near the central business district to the east some of the poorest households in El Paso were found in a high risk area (Collins 2010). Post-flood, this dichotomy led to two different approaches to non-structural flood control. The poorer neighborhoods affected by the flooding were colonias, known as wildcat subdivisions in Arizona. According to the U.S. Department of Housing and Urban Development (HUD), colonias "lack adequate water, sewer, or decent housing, or a combination of all three" (HUD 2018). Rather than repair and rebuild, plus invest in new structural flood control projects to protect these residents, the city of El Paso chose to buy-out properties in the colonias, demolishing homes and relocating homeowners (Collins 2010). While homeowners may have been compensated for the structure, their loss of personal belongings plus the difficulty in finding adequate housing elsewhere proved to be a hurdle residents had to deal with during the city's attempt to reduce the risk of repeat damage.

Only 18% of low-income damaged homes had flood insurance through FEMA, while 100% of the high-income homes carried the coverage (Collins 2010). Outdated risk maps and engineering failures contributed to much of the damage in low-income areas, but the risk seemed to be better known in the high-risk areas with all damaged homes either choosing or required to have NFIP coverage. As a result, buyouts were not a priority in high-income residential areas, even with the risk of repeat damage in the future. However, the city did take steps to protect some undeveloped land in these areas. In one affluent neighborhood, property owners agreed to an additional fee to buy back land marked for development in an adjacent arroyo (Collins 2010). This deal was facilitated by the city, and the creation of this green space likely increased property value for the existing homeowners.

While there have been efforts since 2006 to update flood control measures in the EPMA, a December 2016 status review of flood risk for the county stated "without appropriate flood control regulations, these growing areas will have greater problems in the future" (Maidment and Tarboton 2016). The 'growing areas' are the outskirts of El Paso in SFHAs. Desert scrubland, which slowed water flow allowing some water to soak into the ground was replaced with paved roads, parking areas, homes and businesses, raising flood risk downstream. That same report recommended flood control measures, both structural and non-structural could be implemented to protect the areas from future flooding. Even after the lessons learned in 2006, it appeared development was still occurring without significant plans for flood control.

It is a problem also seen in the TMA. While the TMA had a head start in flood control with the 1983 event, the work never ends. In the 2017 Pima County Multi-Jurisdictional Hazard Mitigation Plan, dozens upon dozens of projects or actions related to mitigation are listed (Pima County Office of Emergency Management 2017). Not only are both of these counties working to stay ahead of development, protecting current and future residents from the flood threat, but they are dealing with a shifting climate, which is another factor influencing flood risk.

Counties are responsible for flood zone mapping in both the TMA and the EPMA, and both areas have updated to DFIRMS. However, finalizing flood plain maps remains a challenge in the EPMA due to levees along the river, which are maintained the USIBWC. In some areas the levees may not provide adequate protection according to the NFIP regulations. Certifications are required by NFIP to ensure the levees can handle a 100-year event. In areas where certification is lacking, flood zone maps can't be finalized, leaving residents in areas of potentially unknown risk. This limbo can also impact development efforts as property owners don't know if they need to adhere to building and zoning regulations related to higher risk flood zone areas. While the USIBWC has worked to raise levees in some areas to provide the needed certification, sedimentation in the river remains an issue. Deposition of sediment raises the riverbed and reduces the amount of freeboard required by NFIP to certify the levee. After the 2006 EPMA flood event, the USIBWC estimated $250 million was needed to build up the levees and dredge the river. The USIBWC commissioner at the time said "that's not feasible, but the commission should be able bolster the levees within six to nine months to bring them within FEMA compliance for about $500,000." While dredging may be the best long-term solution, federal budget limitations can prevent this from happening at regular intervals in the Rio Grande bordering the EPMA. Even today, over a decade after the 2006 EPMA flood event, FEMA's interactive online flood zone mapping tool, shows a large portion of flood zones have not been finalized in the EPMA due to levees not meeting NFIP regulations (RiskMap6 2018).

The lack of flood control planning before 2006 and the continued issues with levees along the Rio Grande show in the CRS ranking. As explained in chapter 3, the lower the CRS score on a scale of 10 to 1, the higher the discount for NFIP policy holders. The City of El Paso holds a score of 9, while the county does not participate. Contrast that to Pima County, with holds a score of 5 and the City of Tucson a 6. The residents of Pima County and the City of Tucson receive a higher discount on NFIP premiums because of the higher score, which recognizes the systematic efforts of these local entities to reduce flood risk.

Both the TMA and EPMA learned a hard lesson about flood control when major events hit. For the TMA that was in 1983. For the EPMA it was 2006. Flood control plans developed in the TMA after the 1983 flood event proved successful based on reduced damage during subsequent major events in 1993 and 2006. When hit with a major flood event in 2006, the EPMA also took a reactive stance to flood control, recognizing a lack of planning as a major contributor to the resulting damage. But while the TMA flood control has now been tested twice, the EPMA has yet to experience a repeat event. Only time will tell if the measures put into place after 2006 will successfully prevent widespread damage from the next major flood.

CHAPTER 9

CONCLUSIONS AND FUTURE RESEARCH RECOMMENDATIONS

Resiliency strengthens a community's and an individual's ability to face and overcome a challenge. These challenges come in many forms. From social and political unrest to economic and environmental disasters, one thing is certain; there has always been, and will always be, challenges to face in this ever-changing world. In 1983, the TMA faced one of these challenges in a historic and deadly flood event that not just inundated, but also wiped away, homes and businesses, plus disrupted travel and severely damaged infrastructure. After the 1983 TMA flood event, there was a widespread effort to make the community more resilient in the face to future events.

In this study, resiliency is measured by the community's ability to recover from a major flood event without significant financial assistance from resources outside the community. After the 1983 event, both structural and nonstructural flood control measures were put into place to protect infrastructure, businesses and homes from future floods. In 1993 and 2006, these measures proved effective, when flows in some TMA waterways rivaled, and even broke, the 1983 numbers. Damage was less severe and travel within the community was not markedly hampered by infrastructure failures, allowing most people to go about their day-to-day business unaffected by the flooding. But, while efforts to build resilience seemed to decrease the financial impacts of flooding, the community continued to accept outside assistance when there was a need. Federal funds were once again used to repair damaged infrastructure after subsequent events, as well as some smaller floods.

However, a fully resilient TMA may never be possible through structural defenses and nonstructural measures. Nature is in constant flux. Rainfall patterns can shift due to climate change or natural variability in large-scale ocean oscillations, which impact weather and flood risk for a number of years to decades at a time. Plus, flood risk changes as the landscape is altered by both human and natural elements. With all of this comes uncertainty, which can undermine efforts to make the community resilient to flood risk over the long-term.

Nor is complete resilience necessarily desirable for a community. Staying connected to networks outside the community could allow access to resources and skills otherwise not present within the community. Plus, natural disasters are rare. When these events occur, few people may have the knowledge and expertise to manage response and recovery effectively and efficiently. Additionally, lessons learned from previous disasters may be lost as the keepers of that knowledge leave the community or retire. It is simply not beneficial for communities to isolate themselves and remove all connections to potential aid and assistance.

As a community strengthens resilience, property owners are in the position to gain financial resilience through flood insurance policies, the majority of which are written through NFIP. But, it cannot be overlooked the the current financial status of NFIP is, at least partially, funded through taxpayer dollars instead of insurance premiums. Based on the definition of resilience in this study, money received from NFIP could be considered as outside resources. While a valid point, the value NFIP provides in building personal financial resilience cannot be overlooked. The program protects homeowners from potential financial ruin if flooding significantly damages their home. If a large number of homes are damaged, the entire community could be impacted through lost productivity, a loss of tax dollars, even lower population numbers as people move away instead of rebuilding and more. By increasing policies-in-force through individual homeowners, a community could build resilience collectively through individual policies.

However, there is notoriously low participation in NFIP across the United States. Work to identify which populations are at a higher-risk of the flood threat, plus how these populations view flood insurance options and how that could impact NFIP participation, may be needed to better target efforts to increase insurance coverage.

To better identify populations at risk in the TMA, local mapping efforts by officials in Pima County, Arizona expanded known flood zones by dozens of miles. These areas include thousands of privately-owned properties. Data within these recently mapped areas, plus updates to flood zones mapped decades ago by the federal government, showed the population that occupies these properties may be in a better position to purchase insurance, increasing their financial resilience if flood damage occurs. In general, higher income households reside within each of these flood zones. However, the population with the lowest household income analyzed in this study, Hispanic, showed greater growth between 2000 and 2010 into these flood zones, as compared to the total population and the non-Hispanic White population. Because of these factors, the Hispanic population may be the most vulnerable to the impacts of flooding in the TMA.

Increasing policies-in-force could be as simple as communicating flood insurance options and clarifying risk. While the results of this research indicate homeowners continue to minimize or misunderstand flood risk, they were also more likely to accept personal responsibility for the financial impacts, as compared to an earlier survey also completed in the TMA. However, a homeowner's decision to purchase or not purchase a policy can vary because of social and cultural factors, as well as socioeconomic status, age, gender, education and other demographic data. Tailored education and outreach programs addressing these factors, in addition to working through identified trusted sources of information, could increase the number of flood insurance policies in force. By doing so, homeowners can build resilience against the monetary impacts of the flood threat, contributing to their own personal financial stability and strengthening the community's ability to with withstand the impacts of the next big event. Because when it comes to natural disasters, it is not a matter of 'if', but 'when'.

Future Research

Results from this study could be used to develop targeted educational efforts that will better communicate the options homeowners have in regards to flood insurance. By developing communication plans that better adhere to the beliefs and values of a diverse population, more property owners may select flood insurance as an option to protect what is likely the biggest investment of their lives, their house. Plus, there is a lack of databases by which to measure the effectiveness of such programs. This study provides a base of information by which to measure current and future efforts.

Future research assessing flood risk and flood insurance knowledge of local home insurance agents, in addition or realtors and real estate agents, could determine if there is a widespread knowledge gap about flood risk and flood insurance among the professionals dealing directly with home buyers. Additionally, it may be beneficial to investigate why there is low credibility for flood risk information from real estate agents and realtors among the public. The assessments could be used to develop a flood risk and insurance education program for these professionals groups, which are often required to complete a set number of professional development hours each year.

Additional research possibilities also include a similar analysis of the 2020 census numbers to determine if flood plain occupation is changing in relation to the past census numbers. Additionally, a study on why TMA home values and household incomes are generally higher in flood zones, compared to non-flood areas could expand this work.

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APPENDIX A

MULTIVARIATE ANALYSIS LIST

X indicates multivariate analysis between question data.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1																															
2																															
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23					X		X		X																						
24																															
25												X	X	X	X	X	X	X		X	X	X	X	X							
26												X	X	X	X	X	X	X		X	X	X	X	X							
27					X		X					X	X	X	X	X	X	X		X	X	X	X	X							X
28																															
29																															
30												X	X	X	X	X	X	X		X	X	X	X	X							
31												X	X	X	X	X	X	X		X	X	X	X	X							

APPENDIX B

SURVEY INSTRUMENT

1. Do you rent or own your home?
   a. Rent
   b. Own

2. How many years have you lived at your current address?

3. How many people live your home (including yourself)?

4. How many years have you lived in the Tucson metropolitan area?

5. Have you been personally affected by flooding?
   a. Yes
   b. No - *If you answered No please skip to question 7*

6. If you answered yes to question 5, briefly describe how you were personally affected by flooding.

7. Do you live in a flood plain?
   a. Yes
   b. No
   c. Don't know

8. How knowledgeable do you think you are about flooding in your neighborhood?

Not at All Knowledgeable	Somewhat Knowledgeable	Moderately Knowledgeable	Very Knowledgeable	Extremely Knowledgeable
1	2	3	4	5

9. In your opinion, what is the risk of flooding to your home in the future? *Circle one*
   a. No risk

b. Low risk
c. Medium risk
d. High risk
e. Don't know

10. What defines a 100-year flood? *Circle all that apply*
    a. Occurs once every 100 years
    b. 1% chance of flood in any given year
    c. 26% chance of flood over 30 years
    d. All above answers are correct
    e. None are correct
    f. Don't know

11. How many floods do you expect in 100 years of time in your neighborhood?
    a. None
    b. 1 or 2
    c. 3, 4, or 5
    d. 6 to 10
    e. Over 10
    f. Don't know

12. If a flood is threatening your home, what is the first thing would you do in response to the risk? *Circle only one*
    a. Do nothing
    b. Get out/flee
    c. Get out with some possessions
    d. Remain in the house
    e. Sandbag property, build a flood wall
    f. Move everything out
    g. Get on the roof
    h. Call insurance and file a claim
    i. Move things upstairs
    j. Other; *Please Specify*

13. If your home is flooded, who do you believe is economically responsible for recovery and rebuilding? *Circle only one*

a. Individuals/Homeowners
b. Insurance Companies
c. Builder/Developer
d. Town, City, or County Government/Officials
e. State Government/Officials
f. FEMA
g. Other; *Please Specify*

14. If your home was damaged by a flood, what steps do you believe should be taken to protect against future flood damage? *Circle all that apply*

a. Build dams and improve river channels
b. Leave river/waterway alone
c. Zone housing out of high flood risk areas
d. Provide warnings and information to people at high risk
e. Flood proof homes through engineering on your property (e.g. *build a flood wall, contour yard, raise home and outbuildings, etc)*
f. Government should do something about the problem
g. Improve flood protection in the neighborhood
h. Divert the water
i. Study the problem
j. Purchase insurance
k. Don't know
l. Other: *Please Specify*

15. How would you rate the credibility of flood danger information in relation to your home from each of the following sources?

	Not Credible At All	Somewhat Credible	Moderately Credible	Very Credible	Completely Credible
Family	1	2	3	4	5
Friends/Colleagues	1	2	3	4	5

Real Estate Agent/Realtor	1	2	3	4	5
Insurance Agent	1	2	3	4	5
Town, City, or County Government/Officials	1	2	3	4	5
State Government/Officials	1	2	3	4	5
FEMA (Federal Emergency Management Agency	1	2	3	4	5
National Weather Service	1	2	3	4	5
Newspapers	1	2	3	4	5
Local TV News	1	2	3	4	5
National TV News	1	2	3	4	5
Online Resources	1	2	3	4	5
Other; *Please Specify*	1	2	3	4	5

16. Which of the following do you think has primary responsibility for informing homeowners of the potential risk of flooding? *Circle only one*

a. Individuals/Homeowner
b. Real Estate Agent/Realtor
c. Insurance Agent
d. Neighborhood Associations
e. Town, City, or County Government/Officials
f. State Government/Officials
g. FEMA
h. National Weather Service
i. Newspapers
j. Local TV News
k. National TV News
l. Other; *Please Specify*

17. Does a standard home insurance policy cover flood damage from natural causes?

a. Yes
b. No
c. Don't Know

18. Do you have flood insurance?

a. Yes
b. No - *If you answered No please skip to question 20*
c. Don't Know – *If you answered Don't Know please skip to question 20*

19. If you answered Yes to question 18, are you required by your mortgage company to purchase flood insurance coverage?

a. Yes
b. No
c. Don't Know

Please skip to question 23

20. If you answered No or Don't Know to question 18, would you consider purchasing flood insurance coverage for your home?

a. Yes - *If you answered Yes, please skip to question 21*
b. No - *If you answered No, please skip to question 22*
c. Don't Know - *If you answered Don't Know, please skip to question 23*

21. If you answered Yes to question 20, what is your reason for considering the purchase of flood insurance coverage for your home?

a. Home flooded or flood threatened home in the past
b. Peace of mind/Protect my financial investment
c. Reasonable monthly payments
d. Payment included in my monthly mortgage statement
e. Other: *Please Specify*

Please skip to question 23

22. If you answered No to question 20, what is your reason for not considering purchasing flood insurance coverage for your home?

a. No danger of flooding

b. I'll take my chances
c. Too expensive
d. I'm renting
e. I'm moving soon
f. Do not expect to lose anything
g. Other: *Please Specify*
h. Don't know

23. Please select what you believe is a reasonable amount to pay per month for flood insurance coverage for your home.

a. None
b. Below $25
c. $26 to $50
d. $51 to $100
e. Above $100
f. Other *Please fill in the blank with a specific number or range of numbers*

24. What sources would you use to gather information on flood insurance? *Circle all that apply*

a. Family/Friends
b. Real Estate Agents/Realtors
c. Insurance Agents
d. Neighborhood Associations
e. Town, City, or County Government/Officials
f. State Government/Officials
g. National Weather Service
h. FEMA
i. Newspapers
j. Local TV News
k. National TV News
l. Other; *Please Specify*

25. Are you:

a. Male
b. Female
c. Prefer not to answer

26. What is your age?
   a. 18-24 years old
   b. 25-34 years old
   c. 35-44 years old
   d. 45-54 years old
   e. 55-64 years old
   f. 65-74 years old
   g. 75 years or older
   h. Prefer not to answer

27. What best describes your race or ethnicity?
   a. White, non-Latino
   b. Spanish/Hispanic/Latino
   c. Black/African American
   d. American Indian
   e. Asian
   f. Other; please specify
   g. Prefer not to answer

28. What is the primary language spoken within your home? *Please move onto the next questions if you prefer not to answer.*

29. Please list any other languages spoken within your home. *Please move onto the next questions if you prefer not to answer or do not speak any other languages in your home.*

30. Which of the educational levels best describes the highest level of school or highest degree you have completed.
   a. 12th Grade or Less

b. High School graduate or equivalent
c. Some college
d. Bachelor’s degree
e. Graduate or Professional degree
f. Prefer not to answer

31. Which of the categories best describes your household income in 2014?
    a. Under $20,000
    b. $20,001 to $35,000
    c. $35,001 to $50,000
    d. $50,001 to $65,000
    e. $65,001 to $80,000
    f. $80,001 to $100,000
    g. Over $100,000
    h. Prefer not to answer

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