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A Methodological Approach for Pricing Flood Insurance and Evaluating Loss Reduction Measures: Application to Texas

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This research by the Wharton Risk Management Center and CoreLogic® aims at better understanding flood risk in the United States and the role that public and private insurance can play in providing financial coverage and reducing losses from this risk to residents in areas subject to water damage from floods and hurricanes. We discuss a methodology for assessing risks, measuring the costs and benefits of a selected number of loss reduction measures and comparing different pricing methods with those used by the National Flood Insurance Program (NFIP). We believe the methodology developed in this study will be of interest to key stakeholders and can be generalized for other states in the United States.

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Table of Contents

Figures

Tables

Chapter 1

Executive Summary

Introduction

If the natural disasters of recent years are any indication of what America will face in the future, it is time to recognize that our country has entered a new era of weather-related catastrophes. Because of increased population and more exposed assets in hazard-prone areas, one should expect more devastating and costly natural disasters in the coming years. Changes in climate patterns are likely to exacerbate this trend, bringing sea level rise, increased flooding from more intense hurricanes, and coastal erosion.

Hurricane Irene, which made landfall in mid-Atlantic and Northeast states in August 2011, is the latest reminder of our vulnerability to natural disasters. This hurricane claimed more than 50 lives and caused losses in the $7-to-10 billion range. Preparedness for the disaster was remarkable, indicating that some important lessons were learned following Hurricane Katrina in 2005. But if Hurricane Irene had not weakened, and if the required evacuation in cities had not taken place on a weekend, the human and economic impact could have been much higher.

As Hurricane Irene moved north along the coast in August 2011, the nature of the damages also changed from mainly wind in the Carolinas to coastal and inland flooding in northern states. Families who had flood insurance will soon be indemnified and be able to quickly repair or rebuild their house. From past experience, however, we know that many residents did not have flood insurance. Either they mistakenly thought that losses from flooding were covered by their homeowners' policy and/or they perceived the risk of flooding to be below their threshold level of concern so they did not feel they needed flood insurance. Some may also have decided not to purchase flood insurance because of budget constraints during difficult economic times: the cost of coverage competed against expenses that had higher priority.

These uninsured victims are likely to need and demand disaster assistance. This dynamic process is not specific just to Hurricane Irene; over the period of 1950–2010, two-thirds of Presidential disaster declarations were flood-related.[1] A significant portion of flood-related damage can be reduced if protective mitigation actions have already been taken. However, for reasons similar to not purchasing flood insurance, many individuals do not invest in these flood mitigation measures voluntarily.[2]

Background on Residential Flood Risk Insurance in the United States

In the United States, coverage for flood damage is explicitly excluded in homeowners' insurance policies. Since 1968 flood insurance has been available through the federally managed National Flood Insurance Program (NFIP) because insurers contended at the time that the peril was uninsurable by the private sector for the following reasons: (1) only particular areas are subject to the risk, so adverse selection would be a problem; (2) risk-based premiums would be so high that few property owners would be willing to purchase coverage; (3) flood losses could be catastrophic and cause insolvencies of some insurers; (4) there were no standards or building codes for construction

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[1] Michel-Kerjan and Kunreuther (2011). Reforming Flood Insurance, *Science*, 333, July 22.

[2] Kunreuther, Meyer and Michel-Kerjan (in press). Overcoming Decision Biases to Reduce Losses from Natural Catastrophes. In E. Shafir (ed.), Behavioral Foundations of Policy, Princeton University Press.

in and near flood-prone areas; and (5) the level of sophistication in hazard assessment and mapping was quite limited in the 1960s, compared to what it is today.

The NFIP has grown substantially over its 43 years of operation and today provides insurance to 5.6 million policyholders across the country in exchange for $3.3 billion in premiums paid in 2010. The program now covers more than $1.2 trillion in assets (a 250 percent increase since 1990, corrected for inflation).[3] In November 2011, the program was renewed for one month, until December 16, 2011. On December 23, 2011, President Obama extended it through May 30, 2012, as part of the FY2012 omnibus appropriations bill.

The NFIP's goals with regard to setting premiums differ from those of a private insurance company because the NFIP does not expect to make a profit. Its rates do not reflect the market's cost of capital nor the need to set aside a large reserve to handle truly catastrophic losses since it can borrow from the government if it faces a deficit. Moreover, properties built before flood maps were established are offered subsidized rates. (New structures are charged the full-risk premium based on their location in specific flood zones determined by FEMA, with the exception of those properties eligible for grandfathered rates.)

Under this pricing strategy, NFIP insurance rates are not necessarily risk-based for a given residence (probabilistically defined), so prices can be "too high" for some and "too low" for others, as is indicated in this report. The NFIP does not necessarily aim at fiscal solvency in a given year, but at collecting enough premiums to cover the operating expenses and losses associated with the historic average loss year. Unfortunately, between 2005 and 2008 a series of catastrophic flood events occurred in Louisiana and Texas that were much more devastating than the average annual flood losses. The NFIP was thus forced to borrow $19.3 billion from the U.S. Treasury to cover the deficit produced by these disasters. As of December 15, 2011, the outstanding debt from claim payments and accrued interest cost stood at nearly $17.8 billion.

Improving Flood Insurance: Focus of the Report

In the past few years there have been calls for reform of the NFIP from experts, insurers and reinsurers, local, state and federal government bodies, and from Congress.[4] A major difficulty in judging the validity of the proposed reforms, however, is that they typically provide a conceptual vision without an in-depth quantitative analysis of the pros and cons of the proposed strategy, how it will impact different stakeholders and how it compares with the status quo. Notably, Congress and the President renewed the NFIP twelve times (sometimes for only one month) between 2008 and 2011, without ordering in-depth analyses. (Several bills now do, but none have become legislation, yet.)

During the past two years, the Federal Emergency Management Agency (FEMA) has worked openly at proposing several reform options as well. One option under consideration is to end the NFIP and to privatize flood insurance. At this time, we do not necessarily believe that full privatization of flood insurance is practically feasible. For flood insurance to be entirely privatized, a number of policy issues must be addressed. These include but are not limited to: the ability of insurers to charge rates reflecting risk predicated on probabilistic modeling in a highly regulated market, special treatment being given to those who cannot afford risk-based premiums, a strategy for transitioning existing NFIP policies into the private market, the management of high-risk repetitive loss locations, data sharing and accurate mapping. Until at least these and possibly other issues are addressed, primary insurers are unlikely to want to sell flood insurance on the scale the NFIP does today. Many of these points are discussed in more detail in the final section of the report.

While the NFIP faces challenges that must be addressed, the program continues to provide enormous benefits to millions of Americans. Nevertheless, we feel it is possible to envision an increased role for private insurers to sell flood insurance as a *complement to*, and potentially in competition with, the NFIP; if this dual source of flood insurance supply were tailored to residential demand, this could significantly increase the number of homeowners with flood coverage. More people would be covered when they suffer water damage from the next flood or hurricane, thus reducing the need for federal relief to be paid by all taxpayers. This would be a positive change, as demonstrated by the recent debate over federal relief for the flood victims of Hurricane Irene.

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[3] Michel-Kerjan (2010). Catastrophe Economics: The National Flood Insurance Program. *Journal of Economic Perspectives*, 24(4): 165–86.

[4] The Wharton Risk Center has been at the forefront of studying flood insurance and possible reform options of the NFIP; findings from previous studies can be obtained upon request.

As this report shows, technology has radically improved since the 1960s, allowing insurers to more accurately assess flood risk. Four decades of claims from the NFIP provide insurers with important historical data as inputs to assessing future flood risks. This reduces many of the barriers previously considered as such by the insurance industry. Moreover, the conventional wisdom—that insurers will always price individual flood policies at much greater premiums than the NFIP because they would require higher loading cost—is incorrect. Our findings show that there are potential market opportunities for insurers, as well as societal value, in increasing the overall supply of flood insurance.

This report importantly provides the aforementioned missing quantitative analysis of flood risk, utilizing a catastrophe risk model to ascertain the probabilistic flood risk at the single-family residence level. The report is organized as follows. ***Chapter 2*** describes the operation of the NFIP, and provides a financial analysis of the program from 2001-2009 based on the Wharton Risk Center's access to NFIP accounting records. It also highlights challenges the program currently faces. ***Chapter 3*** discusses the rationale for choosing Texas for this study, specifically the counties of Travis and Galveston, and how one builds a flood catastrophe risk model. Texas has the second highest number of NFIP policies-in-force of all states in the nation (Florida being the highest), and is exposed not only to significant *riverine flooding* but also to *storm surge related flooding* from hurricanes and tropical storms. Hurricane Ike in 2008, a Category 2 hurricane at landfall, triggered the second largest NFIP payment sum in the history of the program (after Hurricane Katrina), with $2.6 billion in flood insurance claims (2008 prices). The majority of those claims were filed by policyholders in several Texas counties, including $1.3 billion in Galveston County alone. ***Chapter 4*** examines alternative flood loss scenarios (including worst cases) and implements a methodology for determining risk-based *insurance premiums* required to cover these expected losses at a given location. ***Chapter 5*** compares these risk-based premiums with the prices currently charged by the NFIP for the counties of Galveston and Travis in Texas as a pilot case. ***Chapter 6*** quantifies the costs and benefits of individual risk reduction measures to homes in these two Texas counties. ***Chapter 7*** concludes and discusses future research.

Main Findings

Worst-Case Scenarios

The analysis throughout this study focuses on two counties: Galveston and Travis (which includes the city of Austin); together they total 1.3 million residents and rank among the most flooded counties in Texas during the period of 1960-2009. For Galveston County, the worst-case scenario (calculated as a storm-surge flood event with a 10,000-year occurrence) is a $2.3 billion loss to residential properties. This translates into 17 percent of the county's $14 billion single-family residence property values exposed to some flood hazard. The worst-case scenario for riverine flood in Galveston would be $825 million in residential loss; that is 6 percent of this same total county exposure. In Travis County, the worst-case scenario (a 10,000-year flood event) is an $890 million loss to residential properties from riverine flood, or 7.4 percent of the county's $12 billion in single-family residence property values exposed to some flood hazard risk.

Quantification of the Pure Premium

The *pure premium* is defined as the expected average annual loss over a 10,000-year period of time across thousands of possible scenarios. It is generated by the CoreLogic and Swiss Re flood models which are currently used in the industry to assess and manage the inland and coastal flood risk associated with trillions of dollars of residential and commercial exposure around the world. It does not include the cost of marketing the insurance policy, claim adjustment or any other cost faced by a public or private insurer in selling flood insurance.

For Travis County, the study results indicate that the pure premium per $1,000 of exposure is more than 12 times lower on average than in Galveston County, illustrating a significant disparity in flood risks between coastal and inland counties. The analysis is also undertaken to correspond with the existing FEMA-defined flood zones (see appendix of Chapter 2 for definitions). For Travis, pure premium per $1,000 of exposure for residences in the high risk A zone is more than 3 times higher on average than for those in the moderate risk X500/B zones, and nearly 78 times greater on average than for those in the low risk X/C zones. However, for Galveston, the pure premium per $1,000 of exposure range across flood zones is not nearly as large: the high risk A zone pure premium per $1,000 of exposure is 1.5 times greater on average than residences in the moderate risk X500/B zones and 4 times greater on average than those in the low risk X/C zones. The mean pure premium for Galveston's high risk A zone is similar to that for residences in the coastal high risk V zones.

According to the FEMA flood zone classifications, V and coastal A zones are the only areas subject to some level of storm-surge flood risk. However, our probabilistic model-based results identify a significant amount of storm-surge exposure and risk outside of the V and coastal A zones in Galveston County. For example, in the Galveston X500 and X flood zones, there is $3.1 billion of property exposure at risk to storm-surge only.

Several conclusions can be drawn from the above analyses. First, there is substantial variation in flood exposure (and hence pure premiums) between coastal and inland locations within zones of similar risk classification. For instance, homes in the designated moderate risk X500/B zones in Galveston are exposed to a flood risk 2.5 times greater than residences in X500/B zones in Travis. Second, there is substantial variation of flood risk within a given coastal or inland county: the range of average values between high and low risk are much wider in Travis than in Galveston County. Third, FEMA characterizes only an average flood risk in a given zone without indicating the variance across properties. Finally, the model results indicate a significant amount of storm-surge exposure outside of the V and coastal A zones. These findings highlight the importance of undertaking a microanalysis of the exposure of residents to riverine flood and storm surge to determine the pure premium associated with a given home. All told, similarly classified FEMA flood zones in different parts of the country can have significantly different flood exposure; thus, one cannot simply average the risk in a given flood zone.

Would Private Insurance Charge More or Less Than Existing NFIP Premiums?

We then compared the premiums generated by the CoreLogic and Swiss Re probabilistic flood models with NFIP premiums from the database FEMA provided to the Wharton Risk Center.

- **Unloaded premium comparison.** The unloaded NFIP premiums were determined by subtracting the administrative cost and fees the program pays to participating insurers and agents. These costs translate into a 50 percent loading charge on the NFIP premiums. The current unloaded NFIP premiums are “too high” in some areas and “too low” in others relative to the probabilistic flood model results. For example, in Travis County, the NFIP on average *underprices* the risk in A zones (high risk) and *overprices* the risk in the X500 and X zones (moderate and low risk) compared to the probabilistic model results in these zones. By not charging enough in the Travis County high risk zone, and overpricing in the moderate and low risk zones, the NFIP may be fostering adverse selection. More specifically, residents who are high-risk are likely to purchase insurance while many homeowners who live in a low risk area will not want coverage because insurance is too expensive relative to the true risk. If this behavior occurs, it can lead to fiscal insolvency.

  In Galveston County, our findings reveal that the NFIP on average *underprices* the flood risk in the A, X500 and X zones by not charging enough against the risk of storm surge in these areas compared to the probabilistic model results in these zones. On the other hand, NFIP premiums are higher than what the probabilistic loss model predicts in V zones. This pricing policy can have important implications for the financial balance of the program for Texas. To illustrate this point, Galveston County has only about 3,000 policies in V zones; however, there were 20,000 claims for Hurricane Ike’s related storm surge flooding in 2008 in the county, potentially 85 percent of which were underpriced because they were in the A, X500 and X zones.

- **Loaded premium comparison.** We undertook comparative analyses between the full premium charged by the NFIP (that is what residents actually pay) and what would be charged by private insurers if they applied a loading cost of 50, 100, 200, and 300 percent on top of the pure premium to reflect expenses such as taxes, cost of capital, dividends to their shareholders as well as correlation between risks (i.e., wind and water in coastal areas). To our knowledge, this type of comparison has not been undertaken in earlier studies of flood insurance.

  In flood zones where the NFIP underprices the risk on average relative to the probabilistic model results, such as the A zones in Travis and Galveston Counties, the price discrepancy between private insurance premiums with high loading costs and NFIP full premiums will be magnified over the unloaded premium comparisons. However, for those areas where the NFIP overprices the risk on average, relative to findings from the probabilistic model, such as the Travis County X500 and X zones and the Galveston County V zones, we find that in general, a private insurer’s loading factor of 200 percent must be applied for private insurers to charge more than the NFIP.

  To the extent that a private insurer has a relatively lower loading factor (for example, in the case of most riverine exposure), there are targets of opportunity for that insurer to actively sell flood insurance today. This could increase take-up rates and ensure that more individuals are effectively covered against floods.

Evaluating the Cost Effectiveness of Flood Loss Reduction Measures

The analysis of the cost effectiveness of flood loss reduction measures (i.e., mitigation) reveals that they can have an enormous impact. For a 100-year event, elevating all existing houses by two or eight feet would reduce the total losses from riverine flood in Travis County by 40 percent or 89 percent, respectively. For a 100-year storm surge event, elevating all existing houses by two or eight feet would reduce the total losses in Galveston County by 16 percent or 64 percent, respectively. Elevation is more effective in reducing future losses from riverine flooding than for storm-surge flooding. Combining all possible future scenarios through the probabilistic flood model, the average annual reduction in expected flood losses when all homes are elevated by eight feet is 92 percent in Travis and 82 percent in Galveston. Providing 100-year flood protection to all homes (for example, installing individual home floodwalls) reduces flood losses by 62 percent in Travis and 28 percent in Galveston.

We analyzed the benefits of elevating existing homes in relation to the cost, using discount rates of 0 percent, 5 percent, 10 percent, and 15 percent and time horizons of 1, 5, 10 and 25 years. The benefit-cost analysis undertaken for 89,000 homes in Galveston and 226,000 in Travis County reveals that on average, dollar savings associated with these significant loss reductions are not enough to balance the costs for a homeowner to want to undertake such measures for existing construction. The primary factor responsible for this economically unfavorable result is the relatively high cost of elevation to existing structures. For example, elevating a 2,000 square foot wood-frame home with a crawlspace by two feet would cost $58,000. Still, there are some specific examples where elevation is economically worthwhile, suggesting that mitigating existing houses could be cost effective if done selectively. FEMA's five hazard mitigation grant programs are designed to include the option of elevating existing structures where it is cost effective to do so. This is likely to be the case for structures with their lowest floor below the base flood elevation. Elevation costs for new construction would be significantly lower than for existing construction, which could make mitigation of new homes much more appealing.

Note that we have calculated only the direct economic benefits stemming from elevation and not considered other direct benefits, such as reduced fatalities and injuries or reduced damage to infrastructure and the environment. Nor have we looked at the indirect economic benefits such as the savings to the government in the costs of permanently relocating residents.

Conclusions

This report provides the first systematic analysis of the potential for private flood insurance to complement the current NFIP operation so as to increase the number of homeowners who have proper coverage, and thus reduce the need for post-disaster federal relief. Our findings show that current NFIP pricing does not always reflect local conditions so that some properties are being undercharged while others are paying premiums that are greater than the actuarial risk. Those findings also reveal that private insurers could cover some of the risk at premiums below those currently charged by the NFIP.

Of course, the decision by primary insurers to sell flood insurance also depends on other factors that have not been studied here, such as their ability to charge rates reflecting risk in a highly regulated market and the possible correlation or diversification of flood risk with wind exposure from hurricanes or other risks in an insurer's portfolio.

Mitigation also can play a critical role in reducing exposure to future floods, which translates into lower flood insurance premiums if rates reflect risk. Our analysis reveals, however, that risk reduction measures for existing homes could be expensive and are normally not cost-effective except for certain homes in flood-prone areas. These findings suggest the need for a holistic approach to mitigation such as implementing land-use restrictions or community based-mitigation efforts in addition to individual measures.

We look forward to continuing this research effort across many of these fronts in order to provide further value to both Congress and the Office of Management and Budget at the White House as they decide upon reforming flood insurance, and to the insurance industry and other stakeholders to reconsider the insurability of flood risk and how to reduce America's exposure to future floods.

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Chapter 2

Overview of Flood Insurance in the U.S.[5]

Chapter 2 Summary

This chapter describes the operation of the National Flood Insurance Program (NFIP), which provides most of the residential flood insurance coverage in the United States. We highlight how the program has grown in recent years to provide insurance to 5.3 million policyholders across the country for $3.3 billion in yearly premium revenue, now covering more than $1.2 trillion in assets (a 250 percent increase since 1990, corrected for inflation).

We also discuss some of the challenges facing the program, notably its current $17 billion deficit. An open question now being debated in the U.S. Congress is how this deficit will be paid over time.[6] A large part of this deficit was due to the failure of the levee system in New Orleans, over which the NFIP had no control. Still, this deficit also highlights the fact that the NFIP charges premiums that reflect only the average annual year loss, failing to account for the potential occurrence of truly catastrophic events. Moreover, a large proportion of NFIP policyholders receive a subsidized rate because their residence was built before FEMA flood maps were established.

For these reasons, it is important to determine what the real annual expected loss would be if all probable scenarios of catastrophic flooding were included in flood insurance pricing; that is, the calculation of the "***pure premium***" (excluding any subsidy or administrative cost being loaded into the cost of insurance). This aspect has been missing from the ongoing debate about the reform of the program; one often hears the term "risk based premiums," but definitions of what "risk-based" actually means vary among insurers and reinsurers, the NFIP, Congress and consumers. We illustrate this point by conducting a pure premium analysis in subsequent chapters of this report.

Another related challenge is that many flood risk maps are very outdated. Considerable efforts are now being made, with billions of dollars spent in recent years, to digitalize and update many of these maps. Paradoxically, **this modernization process has met strong opposition**. Specifically, while according to FEMA more people have been reclassified as being out of high flood-risk areas than being in as a result of this new zoning, those who are now obligated to purchase flood insurance have been successful in petitioning against these new risk classifications to the extent that Congress is now considering postponing this insurance requirement for several years.[7]

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[5] This chapter is based on Michel-Kerjan (2010), Michel-Kerjan and Kousky (2010), and Michel-Kerjan, Lemoyne and Kunreuther (2011).

[6] HR. 1309, which passed the House of Representatives in July 2011, proposes that a study be undertaken on ways this deficit could be repaid over a 10-year period.

[7] As introduced in HR.1309.

Within the spectrum of natural hazards, floods are of particular concern: during the 20th Century in the United States, they accounted for the most lives lost and the most property damage of all natural disasters (Perry, 2000). Over the period 1953-2010, about two-thirds of U.S. Presidential disaster declarations were related to losses from riverine floods and storm damage from hurricanes (Michel-Kerjan and Kunreuther, 2011).

In the United States, a standard multi-peril homeowners' insurance policy is normally required as a condition for a mortgage. These policies cover damage from fire, wind, hail, lightning and winter storms, among other common non-catastrophe perils. Coverage for flood damage resulting from rising water is explicitly excluded in homeowners' insurance policies, but such coverage has been available since 1968 through the federally managed National Flood Insurance Program (NFIP). This chapter provides an overview of the history of the program, its current scope and some of the challenges it currently faces. We conclude by highlighting some of the options that have been proposed to reform this program, which now covers $1.2 trillion in assets.

2.1 A Brief History of the National Flood Insurance Program (NFIP)

The National Flood Insurance Program (NFIP) was ultimately developed due to a widespread belief among private insurance companies following the Mississippi floods of 1927 and continuing through the 1960s that this peril was uninsurable. It was argued in the United States that floods could not be insured by the private sector alone because: (1) only particular areas are subject to the risk, and as such, adverse selection would be a problem; (2) risk-based premiums would be so high that few property owners would be willing to purchase coverage; (3) flood losses could be catastrophic and cause insolvencies of some insurers (Overman, 1957; Gerdes, 1963; Anderson, 1974); (4) there were no standards or building codes for construction in and near flood-prone areas; and (5) the level of sophistication in hazard assessment was quite limited in the 1960s compared to what it is today. (Progress made in the field of catastrophe modeling, GIS and risk map digitalization in the past 20 years has been very significant and has improved the risk assessment process considerably, thereby challenging previous assumptions that flood risk should still be considered uninsurable by the private sector. We will address this element later in the chapter.)

This lack of coverage by the private sector led the federal government to provide significant relief to victims of Hurricane Betsy in 1965. Discussion took place about the role that the federal government could play in developing some form of public insurance coverage, which led to the creation of the NFIP in 1968 (Kunreuther et al., 1978). It was thought that a government program could potentially be successful because it would have funds to initiate the program, pool risks more broadly, subsidize existing homeowners to maintain their property values while charging actuarial rates to new construction, and tie insurance to land-use changes that might lower risks. The program would also have the capacity to spread losses over time by borrowing money from the federal government to compensate for a deficit, something private insurers cannot do (see Michel-Kerjan, 2010 for an analysis of the first 42 years of operation of the program between 1968 and 2009). Thus, the main goal of the NFIP was to provide flood insurance to those in hazard-prone areas with the understanding that there might still be truly exceptional events for which the program would have to borrow money from the federal government. This aspect of the program is important to bear in mind when quantifying flood risk. Our view is that it is important to include the potential for all possible extreme events in any insurance pricing mechanism to provide the policyholder with a signal of the true exposure s/he faces, and to allow the insurer to break even financially over the long term.

In communities where local governments enact flood management regulations that follow FEMA requirements, property owners are eligible to buy flood insurance from the NFIP. To encourage further mitigation, the NFIP has established the Community Rating System (CRS), a voluntary program that rewards communities undertaking mitigating activities with lower premiums. The cost of flood insurance is determined by the federal government, which manages the program. The length of the contract is also determined by the government; it is currently one year.

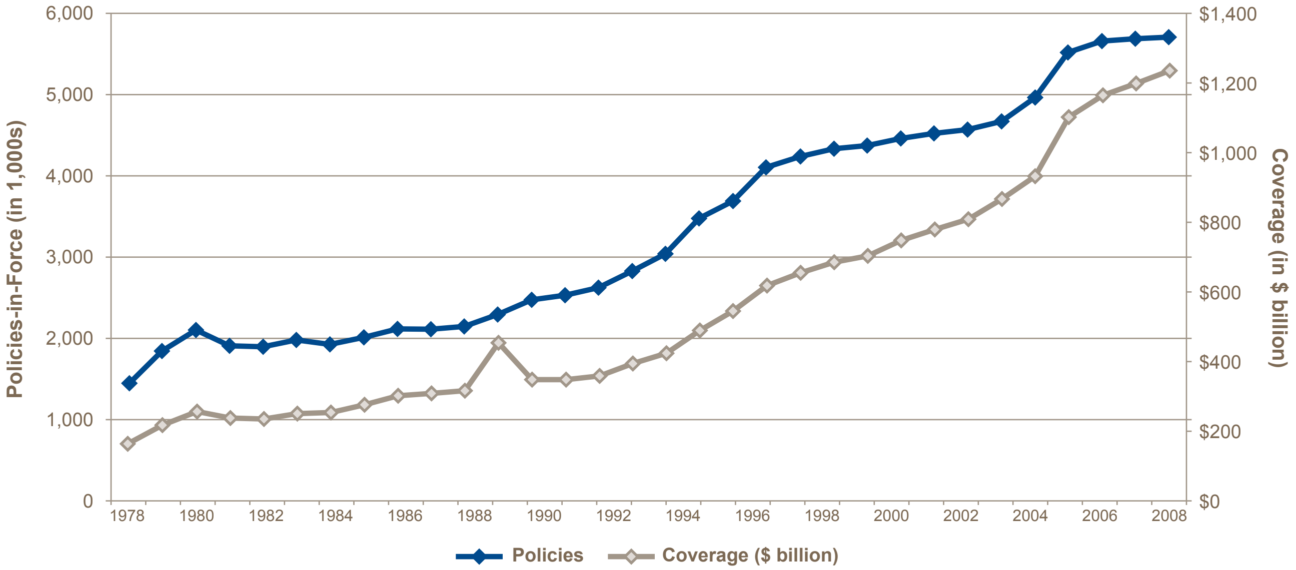
The majority of NFIP policies are written through the Write-Your-Own (WYO) Program, which allows participating property/casualty insurance companies to write and service NFIP's standard one-year flood insurance policy. The insurance companies bear no risk and are compensated for writing policies and settling claims; the Federal Emergency Management Agency (FEMA), which runs the program under the U.S. Department of Homeland Security, benefits from the private industry's marketing channels and the presence of private insurers in participating communities. Nearly all flood policies issued today by the NFIP are written by 90 companies that write flood insurance policies through the WYO program.

The NFIP provides insurance up to a maximum limit for residential property damage, now set at $250,000 for building coverage and $100,000 on contents coverage. Some additional coverage is offered by private insurers above the current $250,000 maximum building-coverage limit covered by the NFIP for residential property owners, even though this represents a relatively small portion of the market today.

2.2 Scope and State Distribution

The combination of three elements — flood experience, tighter requirements and risk awareness campaigns — has resulted in a significant increase in the number of NFIP's policies-in-force over time. Originally, the purchase of flood insurance in the United States was not mandatory by law, since it was thought that mortgage lenders would require this new flood insurance in order to protect their assets. However, financial institutions did not require the insurance and few homeowners purchased coverage voluntarily during the first few years of the program. The Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994 were enacted in the wake of major flooding events, mandating federally-regulated mortgage lenders to require flood insurance for properties acquired or developed in high risk areas (so-called "special flood hazard areas") under the threat of sanctions. Another significant jump in demand for flood insurance occurred right after the seven major hurricanes that hit the Gulf Coast in 2004 and 2005, resulting in major storm surge inland.

The lower line in Figure 2.1 shows the total value of property insured under the National Flood Insurance Program. This is calculated as the sum of the limits minus deductibles on all policies, in 2009 prices. This value was $165 billion in 1978, $348 billion in 1990, and $703 billion in 2000. Between 2001 and 2009, the **total exposure** increased by another 75 percent, reaching **$1.23 trillion** at the end of December 2009. This level has remained stable since. As of December 2010, there were 5.65 million NFIP policies-in-force nationwide which generated more than $3.3 billion in premiums (average annual premium per policy of $593 nationwide).



Source: Michel-Kerjan (2010)

Figure 2.1 Evolution of the Number of NFIP Policies-in-Force and Coverage, 1978–2009

In addition to the requirement that all property in flood-prone areas must have flood insurance if they have a federally insured mortgage, the increase in insured value is due to two other factors. First, policyholders have purchased more flood insurance to protect their assets. Inflation-corrected data show that the average quantity of insurance per policy almost doubled over 30 years, from $114,000 in 1978 to $217,000 in 2009. Second, there has been a large population increase in exposed areas such as coastal states, which now account for a very large portion of the NFIP portfolio (see Table 2.1). For instance, according to the U.S. Bureau of the Census, the population of Florida has more than doubled over the past forty years: it was 6.8 million in 1970, 13.0 million in 1990 and was nearly 18.5 million in 2009. Over the same period, the number of flood insurance policies-in-force in Florida increased by more than seven times.

However, the NFIP does not play the same role in every state; highly populated coastal states have the largest number of flood insurance policies as would be expected. In particular, two states — **Florida** and **Texas** — represent more than 50 percent of the entire NFIP policies-in-force; approximately 70 percent of all policies are in five states — Florida, Texas, Louisiana, California, and New Jersey.[8] The distribution among the top states remains nearly the same when the dollar value of the coverage-in-place is used instead of the number of policies as the measure of the quantity of insurance. The top five states account for more than $800 billion of flood coverage, or 71 percent of the national figure. With respect to take-up rates (defined here as the ratio of the number of NFIP policies over Census population estimates from 2000), Florida has one of the highest; Texas has a much lower rate.

Table 2.1 shows a summary of several coverage, penetration and pricing measures for the nation and the five states (ranked by the number of flood policies-in-force) as of March 31, 2010. Flood *insurance penetration* is defined in column three as the ratio number of policies-in-force in a state, compared with the number of households in that state.[9] For instance, as one would expect, flood insurance penetration is significantly higher in Florida (25 percent) and Louisiana (26 percent), where a large portion of the state is exposed to flood risk, than in California (2 percent) or Texas (7 percent). These are state-average estimates which do not show the important differences within a state, for example, exposure to flood hazard, value of the house, and demographics of the homeowner.

TABLE 2.1 SUMMARY STATISTICS FOR THE NFIP: NATION AND TOP 5 STATES

	Number of flood policies-in-force	Insurance penetration	Quantity of insurance in place ($US)	Annual premiums ($US)	Average premium per policy ($US)	Average premium per $1000 of coverage
Nation	5,629,263	4%	1,221,914,068,200	3,222,657,554	$ 572	$ 2.64
Florida	2,141,076	25%	473,469,375,500	971,566,626	$ 454	$ 2.05
% nationwide	38.03%		38.75%	30.15%		
Texas	681,425	7%	157,415,703,000	329,049,757	$ 483	$ 2.09
% nationwide	12.11%		12.88%	10.21%		
Louisiana	483,593	26%	104,544,951,700	313,139,277	$ 648	$ 3.00
% nationwide	8.59%		8.56%	9.72%		
California	276,915	2%	68,233,163,700	199,504,523	$ 720	$ 2.92
% nationwide	4.92%		5.58%	6.19%		
New Jersey	229,461	6%	50,341,159,900	186,194,962	$ 811	$ 3.70
% nationwide	4.08%		4.12%	5.78%		
Top 5 States	3,812,470	10%	854,004,353,800	1,999,455,145	$ 524	$ 2.34
% nation	**67.73%**		**69.89%**	**62.04%**		

2.3 NFIP Flood Insurance Premium Pricing Approach

Average annual loss year versus probabilistic risk assessment. The NFIP's goals with regard to setting prices differ from those of a private insurance company for several reasons: (1) the NFIP does not have to seek a profit, (2) its prices do not need to reflect the cost of capital, and (3) it does not have to be concerned with the risk of insolvency due to truly extreme events (Hayes et al., 2007). As previously discussed, certain properties are offered subsidized rates, whereas others are charged the full-risk premium. Because more than one-quarter of all policies are subsidized, the entire program cannot be actuarially sound. The goal of the NFIP's program-wide pricing strategy is thus not fiscal solvency, but the collection of enough premiums to cover the operating expenses and losses associated with the historical average loss year (Hayes et al., 2007). Because the non-subsidized policies are set at full-risk premiums, the programmatic target of the historical average loss year is achieved through setting the subsidized premiums to a level such that the combined premium of subsidized and non-subsidized policies sum to the historical average loss year.

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[8] All states have at least some NFIP policies-in-force. The states with the lowest number of policies-in-force, with less than 5,000 are: Alaska, District of Columbia, Montana, North Dakota, South Dakota, Utah, Vermont, and Wyoming.

[9] Data on the overall number of structures in flood zones across the country is incomplete and often inaccurate, which makes it difficult to determine take-up rates in flood zones for the entire country. Studies on small samples for certain specific locations reveal that about half of the relevant homes in high-risk areas had flood insurance (Kriesel and Landry, 2004, Dixon et al., 2006).

"Actuarial" risk assessment*.* "Actuarial" premiums set by FEMA are modeled first using the NFIP's Actuarial Rate Formula described in the yearly rate reviews.[10] This model is used to calculate rates for A and V zones that vary by elevation difference of the structure from the one percent flood elevation. Although the model calculates rates for a variety of floodplains within the A and V zones, the final elevation-based rates are set for each flood zone for the nation as a whole; rates for structures with the same elevation difference in similar flood zones are the same throughout the country. Rates for other zones, such as those for AO and AH zones subject to ponding and sheetflow or for X zones outside the SFHA, are derived from these modeled rates.

Consequently, the NFIP pricing mechanism builds on an actuarial approach based on modeling the full range of flood depth probabilities derived from its engineering analyses used to determine the extent of the 1 percent and 0.2 percent floodplains. It does not, however, employ a robust probabilistic approach which would look at all possible future scenarios, as has been developed in the private sector in recent years. In doing so, FEMA might be under- or overestimating some of the catastrophic events that have yet to happen and which would typically be incorporated as part of a probabilistic risk assessment. These two distinct approaches should be discussed more openly with key stakeholders so they better appreciate when the two approaches converge in FEMA's estimate and, more importantly, when and why they diverge. Undertaking such a comparison is one of the purposes of this report.

Average premiums per $1,000 of coverage. To set premiums and support local governments, the NFIP maps participating communities, designating flood risks through different flood zones. These maps are called Flood Insurance Rate Maps (FIRMs). Prices for insurance, which are set nationally by the NFIP, vary by contract (deductible and limit), flood zone, characteristics of the house and whether that house was built before the map was established (pre-FIRM; in which case it receives a subsidy, see below) or after. They do not otherwise vary by state or locality, so the numbers reported in Table 2.1 reflect the variety in flood risk by state, variation in the composition of who buys insurance, and how much coverage is bought per policy. However, the quantity of insurance coverage per policy actually does not vary much across states because of the aforementioned cap in coverage imposed by the program. It is in the $215,000–245,000 range for all five states with the most policies-in-force, with the upper end in California; as of 2010 it was $217,000 on average nationwide. A somewhat better measure of the cost of insurance than the premium per policy is the *ratio of premium over quantity of insurance purchased*, a measure discussed in much more detail in our Texas case study results. On average nationwide, homeowners pay only $2.64 per $1,000 of flood coverage. This average ratio varies from state to state and depends on the location and the characteristics of the house: on average, insurance cost in 2010 was lower in Florida and Texas ($2.05 and $2.09), and more expensive in Louisiana and New Jersey ($3.00 and $3.70).

Subsidized insurance. A building that was in place pre-FIRM—before the mapping of flood risk was completed in that area—is given a subsidized rate. Construction built after the risk mapping was made public is charged an actuarial rate. The program was structured to subsidize the cost of flood insurance on existing homes in order to maintain property values (in fairness to those residents that lived in homes that existed before the new rules were established), while charging actuarially fair rates on new construction. The expectation was that fewer policies would be subsidized over time. However, approximately one-quarter of properties are still subsidized today since the housing stock is turning over more slowly than predicted, due in part to new renovation techniques that have extended the life of buildings (Pasterick, 1998; Wetmore et al., 2006; CBO, 2007).

This pricing strategy clearly leads to important cross-subsidizations in the program. Rates are not risk-based at the local level (probabilistically defined), so prices will be "too high" in some areas and "too low" in others. The Government Accountability Office (GAO) notes that rates do not reflect local topographical conditions and finds that historical claim and premium data suggest that NFIP rates are not always reflections of the risk (GAO, 2008). Without a detailed analysis of expected losses in various locations, however, it is impossible to say if and how much the prices of NFIP policies may deviate from true risk-based rates.[11] We propose to undertake such a study in the following chapters, using two counties in Texas as a pilot.

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[10] Taken from the 2008 *Actuarial Rate Review* (Hayes and Spafford, 2008), the NFIP formula for calculating rates is:

$$\text{RATE} = \left[\sum_{\text{i-Min}}^{Max}\left(PELV_i \times DELV_i\right)\right] \times \frac{LADJ \times DED \times UINS}{EXLOSS}$$

PELV gives the probability of water reaching a certain height, relative to the base flood elevation. This is calculated for many different potential heights based on engineering and hydrological analyses. Elevations are rounded to the nearest foot. Probabilities for water depths resulting from events rarer than the 350- to 500-year event are not calculated from the engineering and hydrologic analyses because FEMA notes that it is difficult to estimate the probability of extremely rare events using these methods. The depth of water for all events rarer than the 350- to 500- year event is estimated at a catastrophic level derived from the depth of the rarest estimated probability. The NFIP model employs a number of different PELV curves to model the gamut of floodplains from flat with shallower flooding, to steep with deeper flooding. DELV gives the ratio of flood damage to the value of the property. FEMA assesses this ratio from tables that relate depth of water to damage. The tables are checked by FEMA against actual claim data. LADJ is a loss adjustment factor given as a percentage of losses. It is currently 4.12 percent and covers the cost of payment loss adjuster fees and special claim investigations. DED is the deductible offset. UINS is a factor to adjust the DELV values for the fact that most people underinsure. Finally, EXLOSS is a loading factor for insurance agent commissions and other expenses; in non-V zones it is 10 percent, and in V zones it is 20 percent.

[11] The GAO has further criticized some aspects of the NFIP pricing strategy. Some of the data used are outdated, such as estimates of flood probabilities that are from the 1980s, and some data are inaccurate, such as damage estimates that do not reflect the full amount of NFIP claim experience (GAO, 2008).

2.4 Financial Balance of the NFIP

This distinction between average year loss pricing and probabilistic risk estimate-based cost is effectively illustrated very well when examining the financial balance of the program over time. To do so, we recently undertook an in-depth financial analysis of the first 42 years of the program. We found that combining all earnings and expenses of the NFIP over this period, the cumulative total operating results of the program was such that at the end of 2004—that is, before Hurricane Katrina and the failure of the levee system which flooded Louisiana—the NFIP was facing a $1.5 billion net cumulative deficit since its inception in 1968 (in 2008 prices corrected for inflation) (Michel-Kerjan, 2010). That deficit, which had been built from rolling-over expenses from all previous years, seemed manageable given the scope of the program and the significant non-claim expenses it faced: it must be noted that about one-third of all collected premiums are used to pay for insurers and agents' fees (that is a 50 percent loading on what the program estimated to be the "right price").[12] But then came 2005.

On the positive side, collaboration between insurers and the National Flood Insurance Program enabled a large portion of the losses incurred to be settled in the months following the 2005 hurricanes. As of May 2006, with over 95 percent of the claims reported by FEMA settled, the NFIP had paid claims for about 162,000 losses for flood damage from Hurricane Katrina in Alabama, Florida, Louisiana, and Mississippi. This was an historical number of claims to process in such a short period of time. For comparison, the program processed about 30,000 claims in each of the three largest single flood events prior to Hurricane Katrina: the 1995 Louisiana flood, Tropical Storm Allison in 2001 and Hurricane Ivan in 2004. The average amount paid per claim for Hurricane Katrina flood damages, $94,800, was about three times the average paid per claim in the previous record year, 2004. A year after Hurricane Katrina, virtually all claims (99 percent) had been closed (GAO, 2006). In that sense, when put to a very severe test, the partnership between the NFIP and participating insurers worked well.[13]

On the financial side, however, claims from Hurricanes Katrina, Rita and Wilma, and other floods in 2005, pushed the program's operating budget into a deep hole. Hurricane Katrina alone generated $16.1 billion in flood insurance payments. Between 2005 and 2008 (due to claims from Hurricane Ike), the program had to borrow a total of $19.3 billion from the U.S. Treasury (King, 2009). This clearly shows the limit of a strategy consisting of pricing the risk based on only the average annual loss year and not including the potential for devastating events (at least in terms of making the program self-supporting). It will be very difficult for the program to repay this debt: total annual premiums for the program are about $3.3 billion and interest payments alone have been as high as $900 million. As of December 15, 2011, the current debt was $17.75 billion. In some sense, the debt accumulated after the 2005 losses confirms what was known since the inception of the National Flood Insurance Program: it is largely designed to be financially self-supporting, or close to it, but cannot handle extreme financial catastrophes (Wetmore et al., 2006; Michel-Kerjan and Kunreuther, 2011).[14] As Congress discusses options on the reform of the program, it is still not clear how this debt should be handled. For instance, the House bill (HR. 1309), which overwhelmingly passed in July 2011, stated that "not later than the expiration of the six-month period beginning on the date of the enactment of this Act, the Administrator of the Federal Emergency Management Agency shall submit a report to the Congress setting forth a plan for repaying within 10 years all amounts, including any amounts previously borrowed but not yet repaid."

Note that if the NFIP were able to establish a much more comprehensive probabilistic risk assessment against its entire portfolio under a series of specific assumptions, then it could be possible to find way to hedge some of its current exposure directly through private insurance, reinsurance or even alternative risk transfer instruments like catastrophe bonds. Those markets might indeed have an appetite to cover part of the NFIP if they can better estimate the full exposure (Michel-Kerjan and Kunreuther, 2011). In any event, better assessment of the risk and ways to reduce it cost-effectively are also very important.

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[12] As a simple example, assume the unloaded premium (i.e., the "right price") is $100. A 50 percent loading factor on this unloaded premium makes the total premium $150, or [$100 + (50% of $100)]. Thus, in this example, 1/3 of the $150 total premium (i.e., $50) is used to pay for insurers and agents' fees.

[13] To put things into perspective, the devastation caused by Hurricane Katrina was such that in just a few days, New Orleans' population declined from over 400,000 to near zero. Almost two years after the storm, by July 1, 2007, nearly half of these evacuees had yet to return (Vigdor, 2008).

[14] Note that we have focused here on the insurance pillar of the NFIP; the program also integrates several other elements (e.g., risk mapping, Community Rating System, risk awareness campaigns).

2.5 The Paradox of Unveiling the True Risk

As discussed earlier, one of FEMA's responsibilities is to develop appropriate flood insurance rate maps. FEMA's role is also to make sure these maps are updated regularly so exposure to the risk—which is evolving with new construction, deterioration of the environmental habitat, erosion and possibly a change in climate patterns—is measured adequately over time and communicated to those living in risky areas (GAO, 2008).

Existing flood risk maps are not as accurate as they could be because there is no uniform collection of data on the number of properties in floodplains in the United States. A study by Burby (2001) estimated that half of the country's 100,000 flood maps were at least 15 years old and noted that several reports challenged their quality. FEMA has developed a Flood Map Modernization Plan to update the maps and convert them to a digital format, but the process is still underway. While new technology allows FEMA to do a better job at evaluating flood exposure, reclassifying an area from not being in a 100-year floodplain to being in one can be correct actuarially, but difficult to implement locally.

Those who are put into high-risk zones as a result of the remapping process are likely to complain and be more vocal, resulting in media coverage to which elected officials might be sensitive. The residents living in this now-established floodplain who have a federally backed mortgage will need to purchase high-risk flood insurance, a more expensive package than low-risk flood insurance. This dynamic has resulted in political pressure on elected officials to postpone the starting date of the mandatory requirement associated with those "new maps" or to refute the scientific quality of these new maps (see for instance the provisions in section 3(a) of HR.1309, *Authority to Temporarily Suspend Mandatory Purchase Requirement*).

This might also explain why many areas have not been studied in more detail: keeping the veil of ignorance (being treated as a low risk) might be seen as a more attractive option to many, especially since undertaking very precise risk assessment can potentially be very costly. A prerequisite for a financially sounder NFIP is to increase the quality of these maps and communicate the information on the risk more effectively to the public (Chivers and Flores, 2002). Drawing up detailed flood risk maps for the entire country and appropriately updating them over time is admittedly a monumental job that may require a special appropriation by Congress to supplement the current FEMA budget for undertaking this activity.

2.6 Better Measuring the Pure Premium Will Be Key for Any Reform Option

In summary, the NFIP has grown significantly in recent years to become the largest public flood insurance program in the world. When put to the test in 2005 by Hurricane Katrina, the most devastating natural disaster in recent U.S. history, the program provided policyholders with claim payments in a timely fashion. But Hurricane Katrina also revealed that the program faces important challenges to make it more effective in the long-run. These include the following components:

- Improving the accuracy of the flood risk maps
- Continuing to increase insurance penetration and retention
- Encouraging individuals to invest in risk mitigation measures
- Reducing repetitive losses, the number of subsidized properties and operating expenses
- Strengthening financial sustainability in the face of large-scale catastrophes

In the past few years, there have been a number of calls for reform from experts in the field, insurers and reinsurers, local, state and federal government bodies, and from Congress. A major difficulty in judging the validity of the proposed reforms, however, is that they typically provide a conceptual vision without any quantitative analysis of the pros and cons of the proposed strategy, impacts on different stakeholders and comparison with the status quo. Congress and the President have renewed the NFIP twelve times (sometimes for only one month) between 2008 and 2011, without ordering in-depth analyses.

Notably, FEMA has launched a multi-year public debate about those reforms and discussed these with many stakeholders through public meetings, panels and private discussions (FEMA, 2011). As previously discussed, the House has also passed HR. 1309 that would reauthorize the program for five years and change its operation substantially. The Senate Banking Committee has introduced its own bill (S. 1940) on the Senate floor in early December 2011, and discussions will surely take place between the two chambers during the coming months. Importantly, however, the work and proposals of both the House and the Senate include a series of studies that will have to be performed after the renewal of the program, if enacted.

As highlighted in the executive summary, one option under consideration is to end the NFIP and to entirely privatize flood insurance. At this time, we do not necessarily believe that full privatization of flood insurance is practically feasible. For flood insurance to be entirely privatized a number of other issues must be addressed. These include but are not limited to: the ability of insurers to charge rates reflecting risk predicated on probabilistic modeling in a highly regulated market; special treatment for those who cannot afford risk-based premiums; a strategy for transitioning existing NFIP policies into the private market; the management of high-risk repetitive loss locations; data sharing; and accurate mapping. Until at least these and possibly other issues are addressed, primary insurers are unlikely to want to offer flood insurance on the scale the NFIP does today. Many of these points are discussed in more detail in the final section of the report.

We believe that while the NFIP faces challenges that must be addressed, it continues to provide enormous benefits to millions of Americans. Nevertheless, it is possible to envision an increased role for private insurers to sell flood insurance as a *complement to* and potentially in competition with the NFIP; if this dual source of flood insurance supply were tailored to residential demand, this could significantly increase the number of residents with flood coverage. More people would be covered when they suffer water damage from the flood or hurricane, thus reducing the need for federal relief to be paid by all taxpayers. As this report shows, technology has radically improved since the 1960s, allowing insurers to more accurately quantify flood risk. Four decades of claims from the NFIP provide insurers with important historical data, too. This reduces many of the barriers previously considered as such by the insurance industry.

This study proposes a methodological framework to evaluate how private insurers would price flood risk. We undertake this analysis in the state of Texas, which suffered severe wind and flood losses from Hurricane Ike in 2008. We focus on two specific counties which have different exposure to flood risk (storm surge and riverine): Galveston and Travis. We are also interested in better appreciating the cost and benefits of individual risk reduction measures homeowners could invest in to reduce their exposure to this hazard. We use these same counties in Texas for our mitigation analysis.

Chapter 2 Appendix: Definitions of FEMA Flood Zone Designations

Flood zones are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area.

Moderate to Low Risk Areas

In communities that participate in the NFIP, flood insurance is available to all property owners and renters in these zones:

ZONE	DESCRIPTION	STUDY CLASSIFICATION
B and X	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.	X500 / B
C and X	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.	X / C

High Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION	STUDY CLASSIFICATION
A	Areas with a 1% annual chance of flooding and a 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 within these zones.	A
AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.	
A1–30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).	
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 derived from detailed analyses are shown at selected intervals within these zones	
AO	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.	
AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A Zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.	
A99	Areas with a 1% annual chance of flooding that will be protected by a federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.	

High Risk – Coastal Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION	STUDY CLASSIFICATION
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.	V
VE, V1–30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.	

Source: Modified from:
http://www.msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

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Chapter 3

Description of the Study

Chapter 3 Summary:

This chapter provides background information on our choice of Texas for conducting this research. Texas is the second most populous state in the country with over 24 million people, and the second largest state by gross domestic product (GDP) at over $1.2 trillion. Specifically, our pilot analysis focuses on two counties in Texas, Galveston and Travis (which includes the city of Austin), totaling 1.3 million residents.

Texas is exposed to not only significant riverine flooding, but also to storm surge-related flooding as it is frequently hit by hurricanes and tropical storms. Texas also has the second greatest number of NFIP policies-in-force of all states in the nation (second only to Florida). Hurricane Ike in 2008 triggered $2.6 billion in flood insurance claims, the second largest sum of NFIP payments in the history of the program (after Hurricane Katrina), with the majority of those claims going to policyholders in a number of Texas counties including $1.3 billion in Galveston County alone (2008 prices).

Over the time period of 1960–2009, Galveston and Travis ranked as two of the most flooded counties in Texas. Over this same time period, Galveston was the Texas county most frequently hit by hurricanes and tropical storms, including being directly hit by Hurricane Ike in 2008. Both counties have significant assets under NFIP coverage today.

This chapter also provides an overview of the four main components used to create a catastrophe model:

- **Hazard**: determination of the physical riverine and storm surge flood risk (from a probabilistic perspective) specific to the geographical location
- **Exposure**: characterization of the inventory of properties at risk
- **Vulnerability**: quantification of the physical impact of flooding on properties at risk
- **(Financial) Loss**: quantification of the financial impact of flooding on properties at risk

We also provide a detailed accounting of the key data behind, and assumptions utilized, within the four components of the catastrophe model used for this study.

3.1 Focus on Texas

Texas is frequently affected by hurricanes and tropical storms, a frequency due to the state's position along the Gulf of Mexico coastline. In terms of flood risk, the state is exposed to both storm surge related flooding and to riverine flooding. Two of the most devastating flooding events occurred in 1900 and in 2008.

On September 8, 1900, Galveston was unprepared for the massive hurricane that destroyed most of the city with an estimated death toll of 8,000. It is the deadliest natural disaster ever to strike the United States to date. As a basis of comparison, Hurricane Katrina, the deadliest storm in recent years, caused approximately 1,300 deaths.

On September 13, 2008, Hurricane Ike made landfall near Galveston as a strong Category 2 hurricane. Ike's 100 mph winds, 13-foot high storm surge and 16 inches of rain destroyed thousands of homes and properties. Ike is the third costliest hurricane to make landfall in the United States in recent history (after Katrina in 2005 and Andrew in 1992). Total economic losses from Hurricane Ike were nearly $38 billion (2010 prices). Private insurers and reinsurers paid about $18 billion in claims to residents and businesses.

In addition to its geographic location and corresponding flood risk, socio-economic factors also make Texas a good candidate for our case study:

- Texas is the second most populous state in the U.S. with over 24 million residents. Approximately one-third of the Texas population lives in a coastal county, placing its coastal population sixth of the 31 states classified as having residents living in coastal counties.
- Texas is consistently one of the fastest growing states in the nation, averaging 21 percent population growth per decade since 1960 (ranking it seventh) versus an average 11.4 percent population growth per decade for the entire United States over the same timeframe. Projections for future growth relay a similar story of continued robust growth with 12 million new residents expected to be added by 2030, a 60 percent increase from 2000.
- From an economic perspective, Texas has the second largest state gross domestic product (GDP) in the U.S. at over $1.2 trillion. While ranking only 26th on a per capita income basis, it has the 5th lowest cost of living. Texas is one of the most important states in the U.S. from a socio-economic perspective, representing approximately 8 percent of both the nation's total population and total GDP (U.S. Census Bureau 2011 Statistical Abstract).

From a flood insurance perspective, Texas is important because, as shown in Table 3.1, it had in 2008 more than 578,000 NFIP policies-in-force, second largest number of NFIP policies-in-force after Florida — about 12 percent of the total policies-in-force. The majority of Hurricane Ike's $2.6 billion in flood insurance claims were filed by policyholders in a number of Texas counties. Over the period 1978-2008, the NFIP premiums paid by policyholders in Texas accounted for only 67 percent of the claims they collected during the same period. Flood insurance policyholders paid $4.5 billion in premiums but collected a larger $6.7 billion in claims, with about one-third of the premiums earmarked as fees to insurers and agents (Michel-Kerjan 2010).

Table 3.1 shows that the total NFIP insured building and content exposure net of deductibles for single-family residences[15] in Texas was over $130 billion (in 2008 prices), with 16 counties each having at least $1 billion of insured exposure, and in aggregate representing 90 percent of the total Texas single-family exposure. The state average county premium was $418, while the state average county premium per $1,000 of flood coverage was $1.85 in 2008. Consistent with some of the NFIP issues discussed earlier, we found that these top exposure counties in Texas had relatively low implied market penetration rates (number of policies per county / number of households from 2000 Census data), with over three-quarters of the top exposed counties having implied market penetration rates less than 50 percent.[16]

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[15] Single-family residences are 91.8% of total active Texas NFIP policies in 2008.

[16] Data discrepancies involving Kleberg and Nueces Counties, which has the city of Corpus Christi split between them, did not allow for determination of the implied market penetration rates in these two counties.

TABLE 3.1 TEXAS NFIP POLICY SUMMARY, 2008

Rank	Texas County	# of Policies	Total Exposure ($)	Total Premium ($)	Average County Premium	Average Premium per $1000 of Exposure	Implied Market Penetration
1	HARRIS	247,719	59,242,301,100	93,835,510	$ 379	$ 1.58	20.5%
2	**GALVESTON**	**64,694**	**13,962,212,300**	**39,066,326**	**$ 604**	**$ 2.80**	**68.3%**
3	FORT BEND	33,363	9,468,602,100	11,434,945	$ 343	$ 1.21	30.1%
4	BRAZORIA	37,678	8,761,782,300	15,394,108	$ 409	$ 1.76	46.0%
5	JEFFERSON	23,631	4,950,034,400	7,633,374	$ 323	$ 1.54	25.4%
6	MONTGOMERY	16,912	4,600,718,000	6,190,967	$ 366	$ 1.35	16.4%
7	KLEBERG	15,697	3,378,025,900	6,052,585	$ 386	$ 1.79	N/A
8	CAMERON	11,667	2,217,670,300	4,478,297	$ 384	$ 2.02	12.0%
9	HIDALGO	9,664	1,771,527,500	3,132,102	$ 324	$ 1.77	6.2%
10	CHAMBERS	7,846	1,765,350,100	2,703,585	$ 345	$ 1.53	85.9%
11	ORANGE	9,198	1,630,526,200	3,496,230	$ 380	$ 2.14	29.1%
12	NUECES	5,764	1,391,057,500	2,560,296	$ 444	$ 1.84	N/A
13	ARANSAS	5,549	1,344,082,400	2,309,798	$ 416	$ 1.72	60.8%
14	**TRAVIS**	**6,053**	**1,271,638,600**	**3,197,517**	**$ 528**	**$ 2.51**	**1.9%**
15	BEXAR	5,951	1,173,841,600	2,445,934	$ 411	$ 2.08	1.2%
16	COLLIN	4,548	1,091,953,800	2,172,637	$ 478	$ 1.99	7.9%
	TOTAL STATE	**578,552**	**130,652,172,100**	**242,052,539**	**$ 418**	**$ 1.85**	**7.9%**

We focus our Texas study on two specific counties, **Galveston** (along the Gulf of Mexico) and **Travis** (inland) (Figure 3.1), that have significant populations as well as a history of damages from both riverine and storm surge flooding.

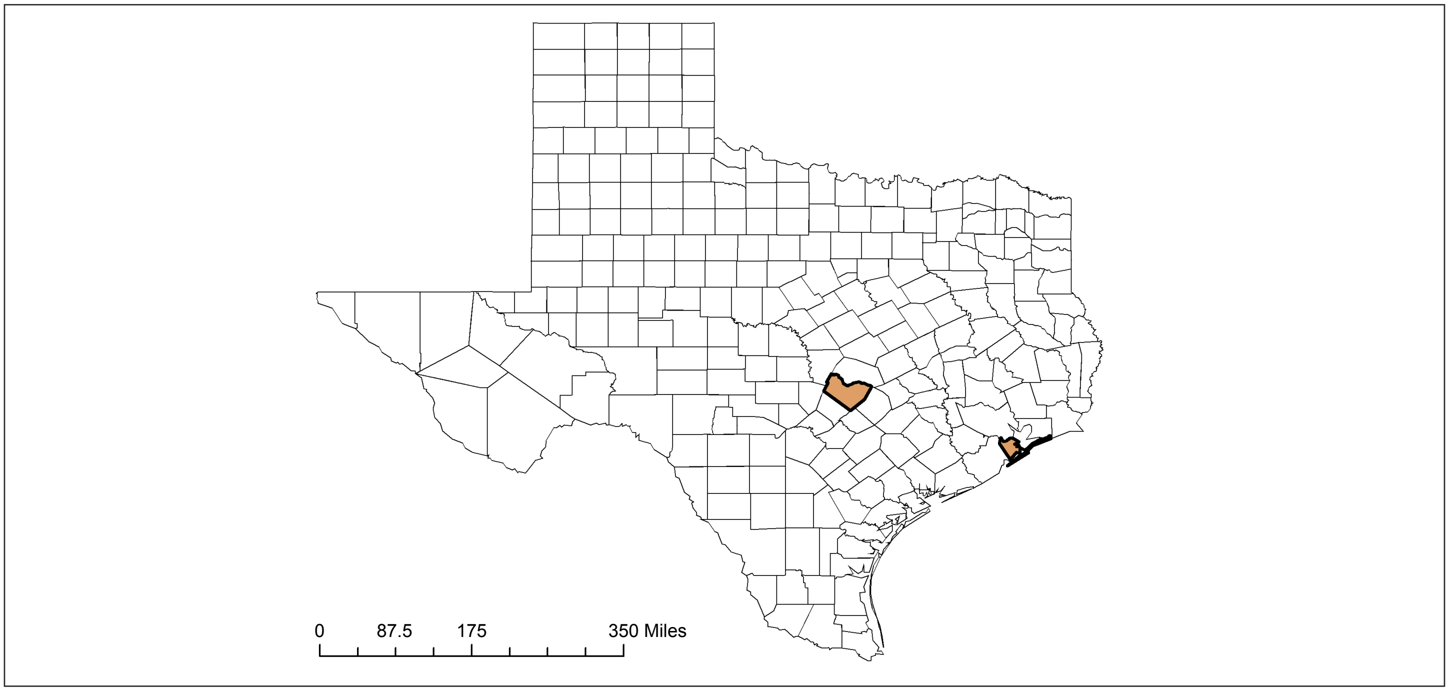

Figure 3.1 Focus of the Study: Galveston County and Travis County, TX

According to the 2009 Texas State Data Center population estimates (Texas State Data Center, 2011), these two counties combined have over 1.3 million residents total and represent 5.2 percent of the state population. Travis County is the 5th most populous county in the state with approximately one million residents, while Galveston County is ranked 16th of 254 counties. In terms of exposure of the NFIP, we see from Table 3.1 that Galveston is ranked 2nd, with nearly $14 billion in NFIP insured exposure, and Travis is ranked 14th with $1.2 billion of NFIP insured exposure. Note also that further data on eighteen Texas coastal counties from NOAA, based upon 2000 Census data (NOAA Coastal County Snapshots, 2011), has Galveston ranked second in terms of percentage of the total population located in a FEMA floodplain (33 percent) and first for the percentage of the designated high-risk populations (37 percent of the total population over age 65, and 43 percent of the total population in poverty) located in a FEMA floodplain. Galveston also ranks high based on the percentage of land converted to development within a floodplain from 2001-2006, tied for third amongst the state's eighteen coastal counties (NOAA Coastal County Snapshots, 2011).

We also collected data on the total number of events and associated property damages (adjusted to 2009 dollars) due to flooding and hurricanes/tropical storms for our two selected Texas counties from 1960-2009 from the SHELDUS database. SHELDUS is a county-level hazard data set for 18 different hazard events (including flooding and hurricanes) containing property losses that affected each county (SHELDUS, 2011). A summary of this data is presented in Table 3.2. As SHELDUS does not explicitly account for storm surge damage, we collected the database designated hurricane and coastal damage estimates as a proxy for storm surge flooding damages. Furthermore, as SHELDUS spreads the total damages per hazard event over the number of counties affected by each storm, thereby overweighting damages to some counties while underweighting others, we present only a ranking of the total damages from the data collected to give a sense of the aggregate order of magnitude of damages over time. In terms of frequency of flooding events over this time period, our two selected counties ranked in the top seven most flooded counties out of the 254, with Galveston being fifth and Travis seventh. Galveston was also the county most frequently hit by hurricanes and tropical storms over this time period. Galveston incurred the third most aggregate hurricane damage,[17] while both Travis and Galveston Counties were in at least the 72nd percentile of damages due to flooding. Clearly, Galveston and Travis are two of the most frequently hit and highly damaged counties in Texas due to either riverine or storm surge flooding.

TABLE 3.2 SUMMARY OF FLOODING AND HURRICANE FREQUENCY AND DAMAGES FROM 1960–2009 FOR GALVESTON AND TRAVIS COUNTIES

		Out of 254 Total TX Counties			Out of 254 Total TX Counties	
	# of Floods	# of Floods Rank / (Percentile)	Total Flood Property Damage Rank / (Percentile)	# of Hurricanes / Tropical Storms	# of Hurricanes Rank / (Percentile)	Total Hurricane Property Damage Rank / (Percentile)
Galveston	66	5 / (98th)	71 / (72nd)	33	1 / (100th)	3 / (99th)
Travis	62	7 / (97th)	55 / (78th)	6	73 / (71st)	80 / (69th)

Sources: calculation by the authors. Data from SHELDUS.

3.2 Catastrophe Modeling Module Overview and Texas Model Assumptions

The Role of Catastrophe Modeling in Dealing with Natural Hazards[18]

Consider a standard insurance policy whereby premiums are paid at the start of a given time period to cover losses during this interval. Two conditions must be met before insurance providers are willing to offer coverage against an uncertain hazard event. The first condition is the ability to identify and quantify, or estimate at least partially, the chances of the event occurring and the extent of losses likely to be incurred. The second condition is the ability to set premiums for each potential customer or class of customers. For our purposes we initially focus on the first condition and come back to a discussion on the second condition in the final section of the report. To satisfy the first condition, estimates must be made of the frequency of specific events and the likely extent of resulting losses. However, catastrophes

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[17] This ranking is likely understated. For example, Galveston sustained $1.3 billion of flooding damages from Hurricane Ike in 2008 but was allocated only approximately $300 million from this event in SHELDUS.

[18] This section is based on Grossi and Kunreuther (2005).

of the scale of Katrina or Ike are relatively infrequent events, therefore historical data for such extreme events is somewhat scarce. Hence, statistical techniques used by actuaries for estimating future losses that rely on a wealth of available claims data, such as from automobile accidents or house fires, are not appropriate for estimating future losses from natural catastrophes. Furthermore, the limited historical loss data cannot be easily extrapolated to estimate the economic impact of disasters because of ever-changing property and household values and costs of repair and replacement. Building materials, design and practice change along with building codes. Hence new structures may be more or less vulnerable to catastrophic events than existing ones. A probabilistic approach to catastrophe loss analysis, that is, catastrophe modeling, is the most appropriate way to handle these loss data issues as well as the abundant sources of uncertainty inherent in all natural hazard related phenomena.

The four basic components of a catastrophe model are hazard, inventory (exposure), vulnerability and loss, as depicted in Figure 3.2 and illustrated for a natural hazard such as a flood. First, the model determines the risk of the *hazard* phenomenon, which in the case of a flood is characterized by its frequency, intensity and associated water depth. Next, the model characterizes the *inventory* (or portfolio) of properties at risk as accurately as possible. This is done by first assigning geographic coordinates to a property and then determining how many structures in the insurer's portfolio are at risk from floods of different water depths from inland rivers and storm surges in coastal areas and associated frequencies.

Figure 3.2 Structure of Catastrophe Models

The hazard and inventory modules enable one to calculate the *vulnerability* or susceptibility to damage of the structures at risk. In essence, this step in the catastrophe model quantifies the physical impact of the natural hazard phenomenon on the property at risk. How this vulnerability is quantified differs from model to model. Vulnerability is typically characterized as a mean loss (or the full distribution of the losses) given a hazard level. Based on this measure of vulnerability, the financial *loss* to the property inventory is evaluated. In a catastrophe model, loss is characterized as direct or indirect. Direct losses include the cost to repair and/or replace a structure, which has to anticipate the increase in cost of material and workforce due to the demand surge in the aftermath of a major disaster. Indirect losses include business interruption impacts and relocation costs of residents forced to evacuate their homes. In our analysis we focus only on direct losses.

Based on the outputs of a catastrophe model, the insurer can construct an exceedance probability (EP) curve. For a given portfolio of structures at risk, an EP curve is a graphical representation of the probability p that a certain level of loss \$X will be surpassed in a given time period. Special attention is given to the right-hand tail of this curve where the largest losses are situated. Figure 3.3 depicts a hypothetical mean EP curve. Suppose that one focuses on a specific loss L_i. One can see from Figure 3.3 that the likelihood that losses will exceed L_i is given by p_i. The x-axis measures the loss in dollars and the y-axis depicts the annual probability that losses will exceed a particular level.

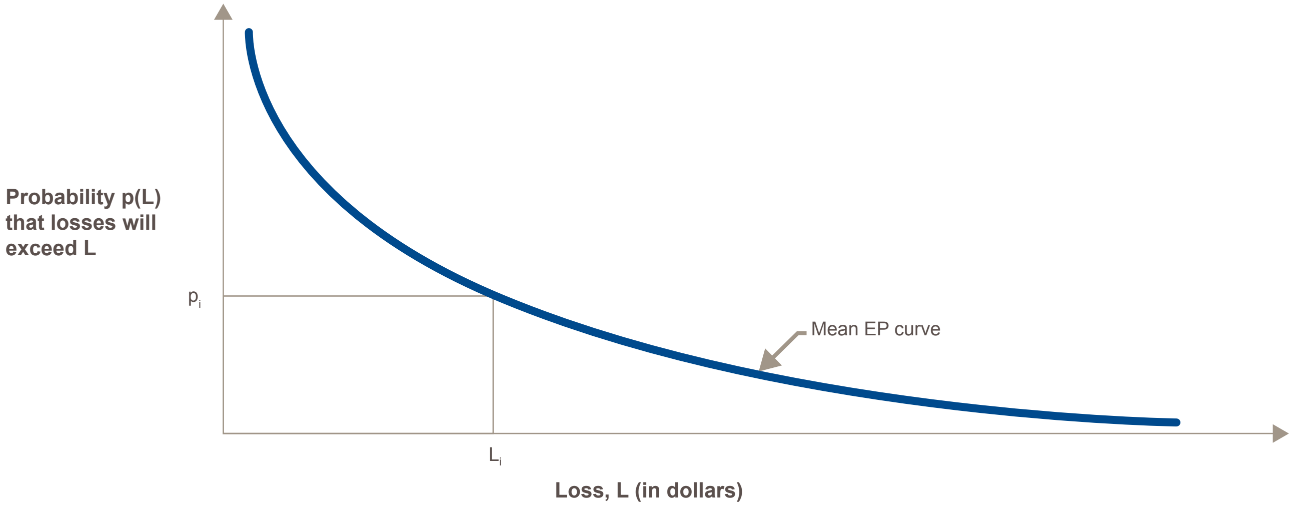

Figure 3.3 Example of Mean Exceedance Probability Curve

Given the importance of how insurers use catastrophe modeling and the EP curve to manage risk, it is essential to understand how the EP curve can be created from the loss output. For the purposes of illustration, some simplifying assumptions are made to generate an EP curve below. Suppose there is a set of natural disaster events, E_i, which could damage a portfolio of structures. Each event has an annual probability of occurrence, p_i, and an associated loss, L_i. The number of events per year is not limited to one; numerous events can occur in the given year. A list of 15 such events is listed in Table 3.3, ranked in descending order of the amount of loss. In order to keep the example simple and calculations straightforward, these events were chosen so the set is exhaustive (i.e., sum of the probabilities for all of the events equals one).

TABLE 3.3 EVENTS, LOSSES, AND PROBABILITIES

Event (E_i)	Annual probability of occurrence (p_i)	Loss (L_i)	Exceedance probability ($EP(L_i)$)	$E[L] = (p_i * L_i)$
1	0.002	25,000,000	0.0020	50,000
2	0.005	15,000,000	0.0070	75,000
3	0.010	10,000,000	0.0169	100,000
4	0.020	5,000,000	0.0366	100,000
5	0.030	3,000,000	0.0655	90,000
6	0.040	2,000,000	0.1029	80,000
7	0.050	1,000,000	0.1477	50,000
8	0.050	800,000	0.1903	40,000
9	0.050	700,000	0.2308	35,000
10	0.070	500,000	0.2847	35,000
11	0.090	500,000	0.3490	45,000
12	0.100	300,000	0.4141	30,000
13	0.100	200,000	0.4727	20,000
14	0.100	100,000	0.5255	10,000
15	0.283	0	0.6597	0
				Average Annual Loss (AAL) = $760,000

The events listed in Table 3.3 are assumed to be independent Bernoulli random variables, each with a probability mass function defined as:

$$P(E_i \text{ occurs}) = p_i$$
$$P(E_i \text{ does not occur}) = (1 - p_i)$$

If an event E_i does not occur, the loss is zero. The Expected Loss for a given event, E_i, in a given year, is simply:

$$E[L] = p_i \cdot L_i$$

The overall expected loss for the entire set of events, denoted as the average annual loss (AAL) in Table 3.3, is the sum of the expected losses of each of the individual events for a given year and is given by:

$$AAL = \sum_i p_i \cdot L_i$$

Assuming that during a given year, only one disaster occurs, the exceedance probability for a given level of loss, $EP(L_i)$, can be determined by calculating:

$$EP(L_i) = P(L > L_i) = 1 - P(L \leq L_i)$$
$$EP(L_i) = 1 - \prod_{j=1}^{i} (1 - p_j)$$

The resulting exceedance probability is the annual probability that the loss exceeds a given value. As seen in the equation above, this translates into 1 minus the probability that all the other events below this value have not occurred. The exceedance probability curve for the events in Table 3.3 is shown in Figure 3.4.

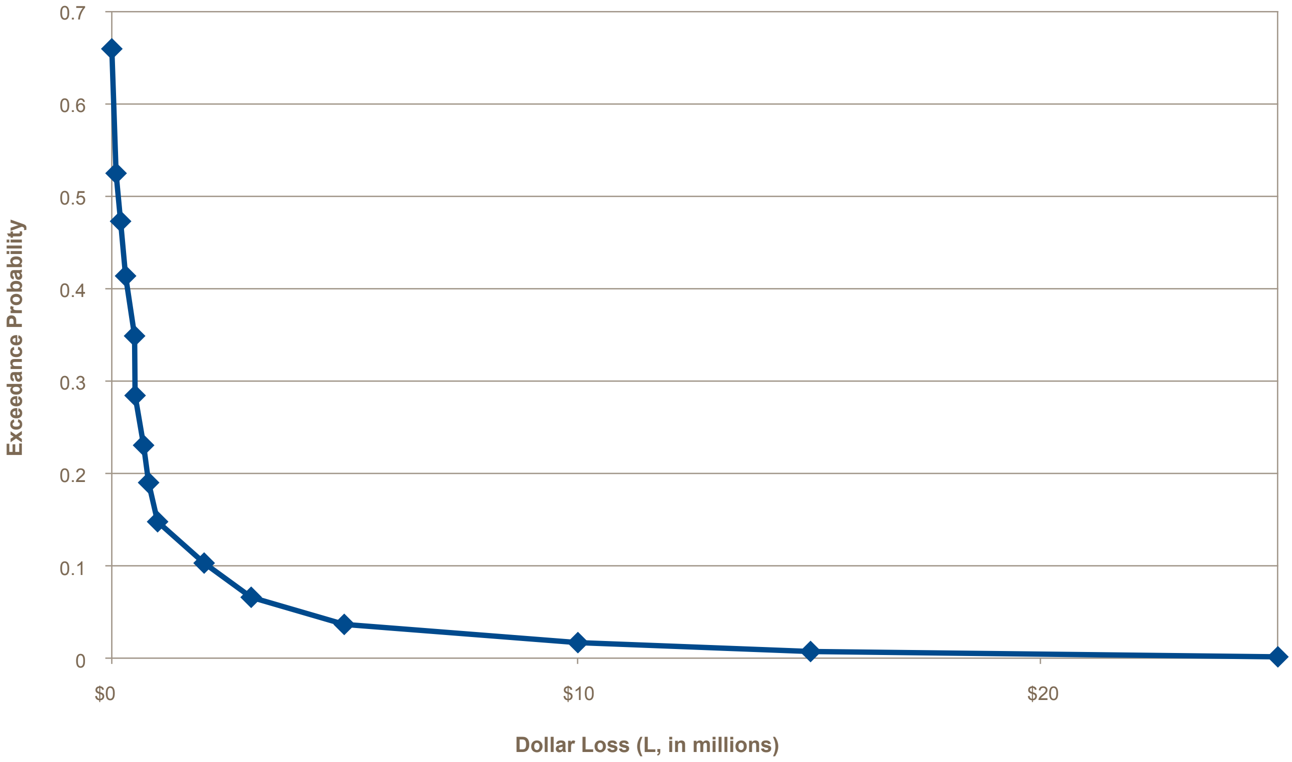

Figure 3.4 Exceedance Probability Curve

Below we describe in detail the key data behind, and assumptions utilized, within the four modules of the CoreLogic and Swiss Re flood catastrophe models used for this study. These models are used throughout the industry by numerous clients to assess and manage the inland and coastal flood risk associated with trillions of dollars of residential and commercial exposure.

3.2.1 Hazard Module[19]

Flood hazards within the CoreLogic and Swiss Re models are comprised of both **riverine flooding** as well as **hurricane related storm surge flooding** for coastal locations, where applicable. Hence, we describe the riverine hazard module and storm surge hazard module separately below. Although separate, the overall goal for each module is essentially the same, that is, to gauge the flood inundation depth at a given location due to riverine or storm surge flooding from any of the probabilistic events.

Riverine Module

The flood frequency map quantifies the probability of any given location being flooded, and is constructed via three inputs—FEMA national flood risk zone maps, United States Geological Survey (USGS) National Hydro dataset, and the USGS National Elevation dataset. Flooding probabilities are defined for each 90 x 90 meter (m) area over the entire U.S. Therefore, for any given property's latitude and longitude, the model will locate the associated 90 x 90 m area and retrieve the assigned probability value. The event return period is based upon 43 years' worth of monthly maximum discharge measurements from over 4,100 gauging stations located throughout the U.S. To get the best possible coverage of historical discharges, this dataset was extended to outlets of each of the 24,000 drainage basins the U.S. counts, using a routing methodology that uses river networks, drainage area and precipitation as input parameters. Then, Monte Carlo simulations were implemented to create an expanded probabilistic event return period set to extend the 43-year historical event return period set. These return period events have the same spatial and temporal correlations as the original ones, but unlike the original data, cover a time span of 10,000 years.

Return periods of events are defined at a ZIP code resolution. Figures 3.5a and 3.5b illustrate the event return period distribution for Galveston and Travis Counties used in our model.[20] At a given property's latitude and longitude, the riverine flood inundation water depths from a collection of flood events are computed through an empirical relationship determined by the probability of flood occurrence combined with the flood intensity (event return period). Thus, the impact of flood events on a targeted geographical area (such as a county) can be quantitatively measured by the set of varying water depths across all flooded locations. For this study, the South Central USA geographical entity was used with 100,000 probabilistic events, with each event assigned an occurrence probability of 0.0001.

There are 400,000 simulated riverine flood events with a return period greater or equal to five years in the entire U.S. Approximately 2,000 of them impacted Galveston County and approximately 5,000 of them impacted Travis County. Those flood events will be used in the loss computation. Further, from the distribution in Figures 3.5a and 3.5b, we see that if an event does impact either of these two counties, the majority of events generated are less than or equal to 100-year flood intensity (90 percent in Galveston and 87 percent in Travis). Compared to Galveston County, Travis County generally experienced stronger events with the mean and median event return period being 107- and 23-year events, respectively, versus 81-year and 19-year mean and median year events in Galveston.

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[19] This material is sourced from internal documentation provided by CoreLogic and Swiss Re.

[20] It is important to note that the event set results of the CoreLogic and Swiss Re models are not meant to be interpreted literally as the forecasted events for these counties. If CoreLogic and Swiss Re were to re-generate the event set, the outcome could be slightly different due to the random sampling.

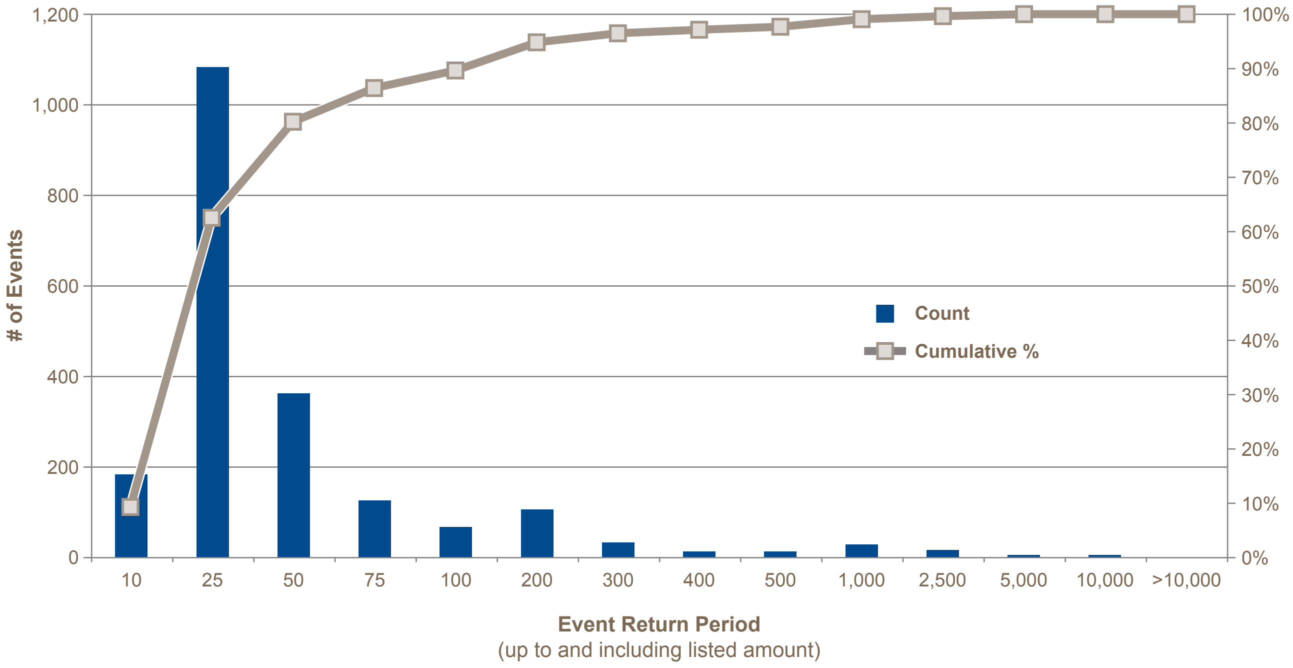


Figure 3.5a Galveston County River Event Distribution

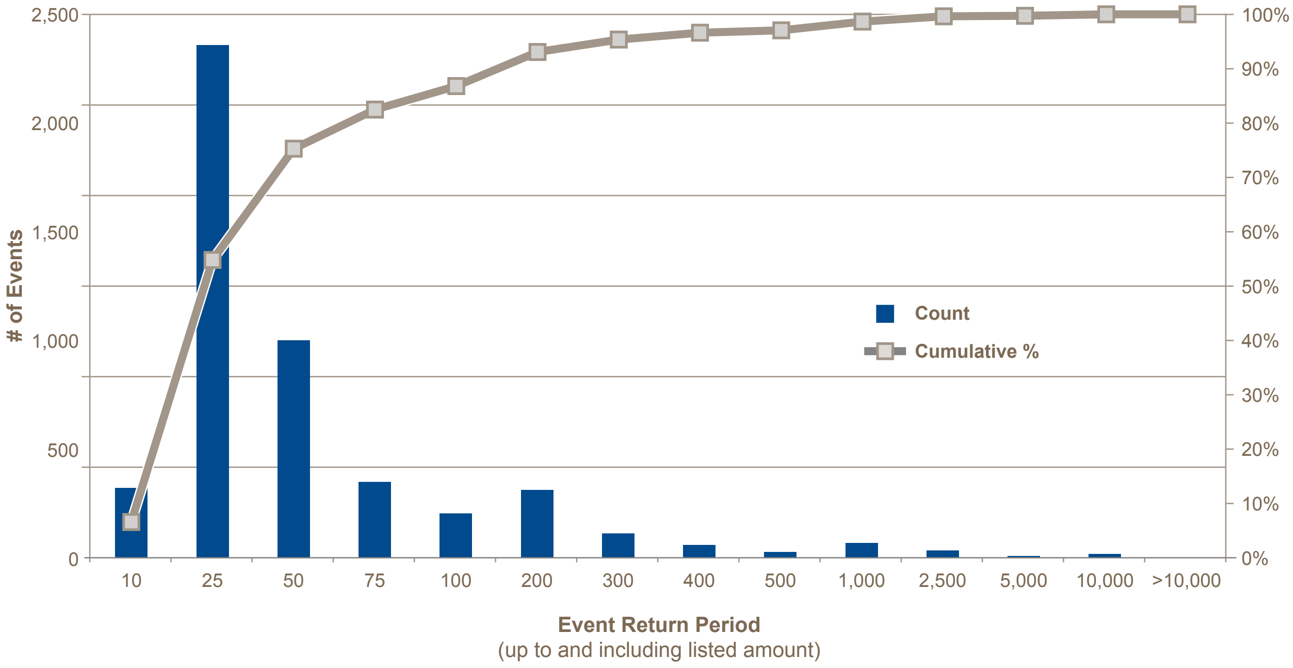
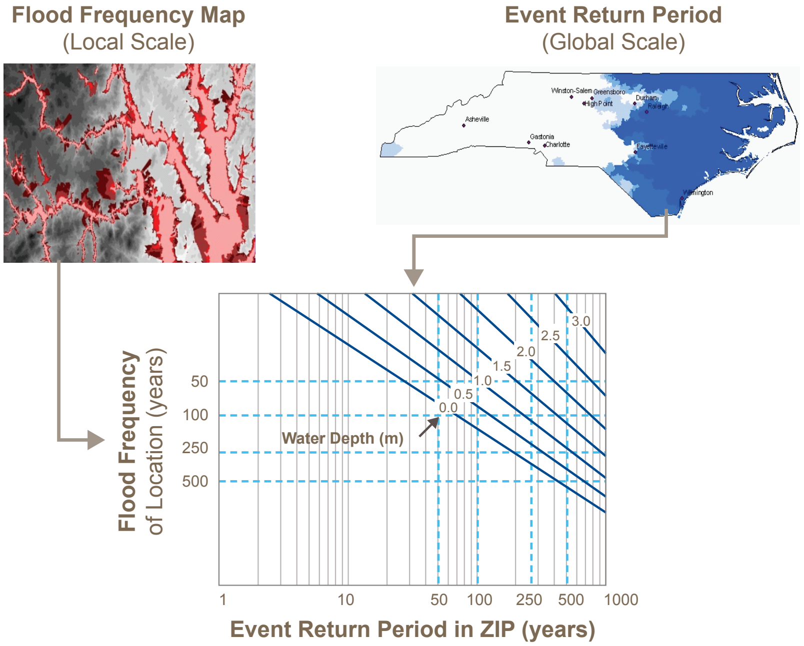


Figure 3.5b Travis County River Event Distribution

With the probability of flood occurrence in the ZIP code area and flood intensities (event return period) from the flood events that would have impact on the area, the flood depths can be determined through the empirical relationship as illustrated in Figure 3.6.



(Source: Swiss Re Internal Documentation)

Figure 3.6 Illustrative Determination of River Flood Depths

Storm Surge Module

For a given coastal location, the hurricane storm surge flood inundation water depths were computed through an empirical relationship determined by the storm surge heights (associated with hurricanes of different intensities) at different landfall locations combined with the stochastic hurricane event set defining storm surge location, frequency and intensity. Thus the resulting *storm surge flood event* was defined as the set of varying water depths across all flooded locations within the predetermined coastal geographical area. The probabilistic flood event set generated in the storm surge module contained 100,000 hurricane events based upon a 10,000-year simulation. Each event was assigned with an occurrence probability having a consideration on the impact of climate change.

A numerical coastal model was used to determine the geospatial distribution of storm surge heights generated from the five different hurricane intensity categories striking along the North Atlantic and Gulf coasts. The storm surge module then utilized maximum storm surge heights to simulate the resulting surge impact area and corresponding water depths. To produce the probabilistic hurricane event set, tropical cyclone activity covering a period of 10,000 years was simulated on the basis of statistical data and the dynamic development of tropical cyclones that have occurred in the North Atlantic and Gulf coasts over the past 150 years. The stochastic event set was generated by altering paths of the historical cyclones using a mathematical simulation process based on a Monte Carlo simulation. Over 100,000 individual storm tracks were represented by their peak gust wind footprint. Given this generated storm surge intensity from the stochastic event set, the storm surge height at a specific geographic location can be determined. Table 3.4 illustrates the distribution of the various hurricane categories for Galveston County generated in the model.[21] Approximately 1,000 of the simulated hurricane events impacted Galveston County. Nearly 70 percent of these events will be below major hurricane strength — Category 2 or below.[22]

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[21] It is important to note that the event set results of the CoreLogic and Swiss Re models are not meant to be interpreted literally as the forecasted events for these counties. If CoreLogic and Swiss Re were to re-generate the event set, the outcome could be different due to the random sampling.

[22] Although based upon purely historical hurricane data, landfall probability of one or more named storms (hurricanes) making landfall within Galveston County in any given year is 4.3% (2.6%) according to the landfall probability project (Gray and Klotzbach, http://www.e-transit.org/hurricane/welcome.html).

TABLE 3.4 HURRICANE EVENT SET; SAFFIR-SIMPSON CATEGORY SUMMARY FOR GALVESTON COUNTY

Saffir-Simpson Hurricane Category	Number of events generated in our probabilistic approach greater than or equal to category level	Cumulative %
5	108	11.1%
4	196	20.2%
3	304	31.4%
2	470	48.5%
1	969	100.0%
Total	969	

3.2.2 Inventory (Exposure) Module

The inventory of properties at risk used for the model analysis was defined as single-family residences. As a point of reference, these properties represented nearly 62 percent of the total 160,324 land parcels collected from CoreLogic for the entire Galveston County as shown in Table 3.5. The next largest group of parcels in the county were vacant parcels, which is land only and therefore would have no physical building property exposure to floods. Travis County had similar percentages of property type parcels. From these single-family residences we eliminated any properties that had a building value of $0, had less than or more than one building on the property, or those that were classified as mobile homes. In Galveston, for example, this was roughly 9,500 of the 98,636 single-family residences collected. Geographically, each single-family residence parcel was defined by its exact latitude and longitude coordinates.

TABLE 3.5 SUMMARY OF GALVESTON COUNTY TOTAL PARCELS BY PROPERTY TYPE[23]

Property Code	Property Code Definition	Count
0	Miscellaneous	7
10	Single Family Residence/Townhouse	98,636
11	Condominium (residential)	143
20	Commercial	5,686
22	Apartment	1,875
50	Industrial	146
53	Transport	5
54	Utilities	302
70	Agricultural	2,415
80	Vacant	42,690
90	Exempt	4,751
N.A.	N.A.	3,668
	Total	**160,324**

The total insured value of these single-family residences inputted into the model was the collected building value, with a conservatively assigned content assumption of 40 percent of the building value which is aligned with Swiss Re client data content percentages. Building value was provided by CoreLogic as the current market improvement value, where market improvement value equaled the residence's total market value net of the market land value with all current market values as provided by the county or local taxing/assessment authority.[24]

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[23] Parcel data collected by CoreLogic.

[24] Replacement cost values were not readily available. Also, given that there is a range of deductible values that homeowners can choose as part of their insurance policy to which the research team has not had comprehensive access, the model does not include deductible values. (Data reveal, however, that the majority of NFIP policyholders have selected a low $500 deductible; see Michel-Kerjan and Kousky, 2010.)

3.2.3 Vulnerability Module[25]

Vulnerability for flood hazards in the CoreLogic and Swiss Re models represented the relationship of water depth and mean damage ratio on standardized categories of residential properties. Figure 3.7 illustrates normalized mean damage degrees per various water depths. Multiple sources of vulnerability data were used to generate the vulnerability curves in the model. The main source of data for residential risks was the detailed NFIP loss statistics compiled between 1978 and 2002, with over 850,000 single losses. To complete the vulnerability set, engineering methods of damage assessment and expert opinion were used as well.

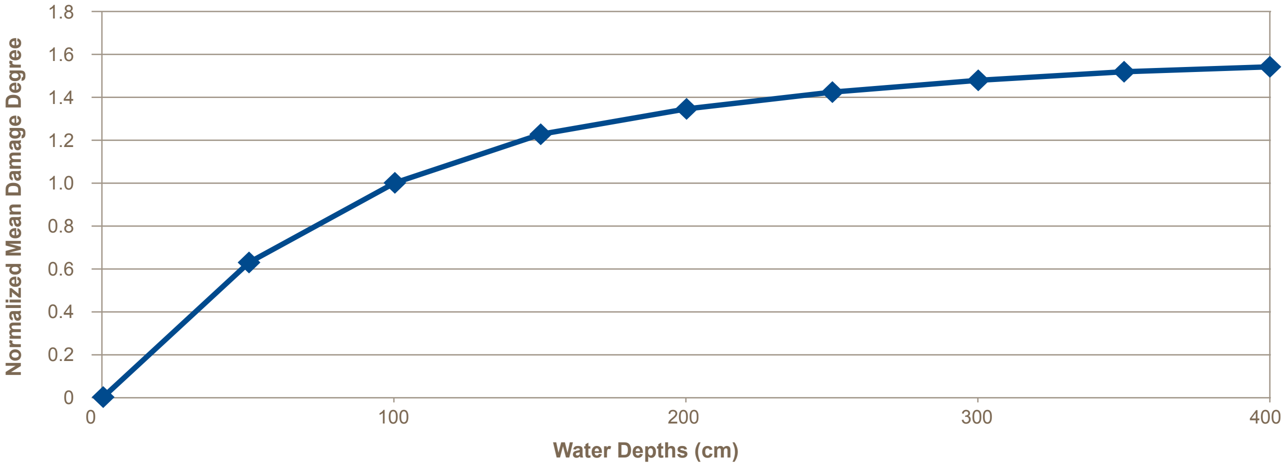

Figure 3.7 Indicative River Flood Vulnerability Curve for Mixed Residential Building Normalized to Water Depth (cm)

While there are other factors that generally characterize the vulnerability of single-family residences, such as the construction type, the number of stories in the structure and its age, these are not explicitly accounted for in our analysis. Although the number of stories or basement are not included as primary or secondary vulnerability characteristics, they are implicitly present in the curves as most were developed using actual claims for each occupancy.[26] The resulting Mean Damage Degrees therefore account for the intrinsic characteristic of the building.

Existing community flood protection measures are accounted for in two ways in the model. First, flood protection measures along streams (levees, dams, etc.) are already implicitly accounted for in the calibrated flood frequency values utilized in the model. Second, where a specific level of flood protection had already been designed and built (e.g., for existing engineered structures such as a seawall or levee) the model could be explicitly modified to account for this existing protection. In this case, flood protection could be set as either protection against 100-year or 50-year floods for riverine flooding, or similarly for Category 2 or Category 1 hurricanes for storm surge flooding.

3.2.4 Financial Loss Module

As detailed above, financial losses from the model are typically represented as EP curves and Average Annual Loss (AAL) values. In our model, only direct loss costs stemming from the building and content values were generated. Figure 3.3 illustrated a sample mean EP curve for characterizing losses and estimating AAL. While we generate similar looking single EP curves in this analysis, the event loss values used have already accounted for uncertainty through a five-point loss scheme. That is, the loss value returned per event is a weighted average of lower and higher losses with various frequencies that together sum to 0.0001, with higher losses weighted more heavily in the aggregated event loss outcome to reflect aversion to catastrophic losses. As an example, the loss associated with a particular flooding event is $15,891,925 with annual probability of 0.0001. Figure 3.8 illustrates this loss (circled) as well as the five point losses that together comprised this weighted event loss value in order to account for uncertainty in the event outcome. From the five points, the highest loss was over $43 million with annual probability of 0.00001, while the lowest loss was $127,584 with annual probability of 0.000001. In the next chapter we applied this complete probabilistic risk assessment approach to our dataset in Texas.

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[25] This material is sourced from internal documentation provided by CoreLogic and Swiss Re.

[26] Only approximately 5 percent of homes in Texas have a basement.

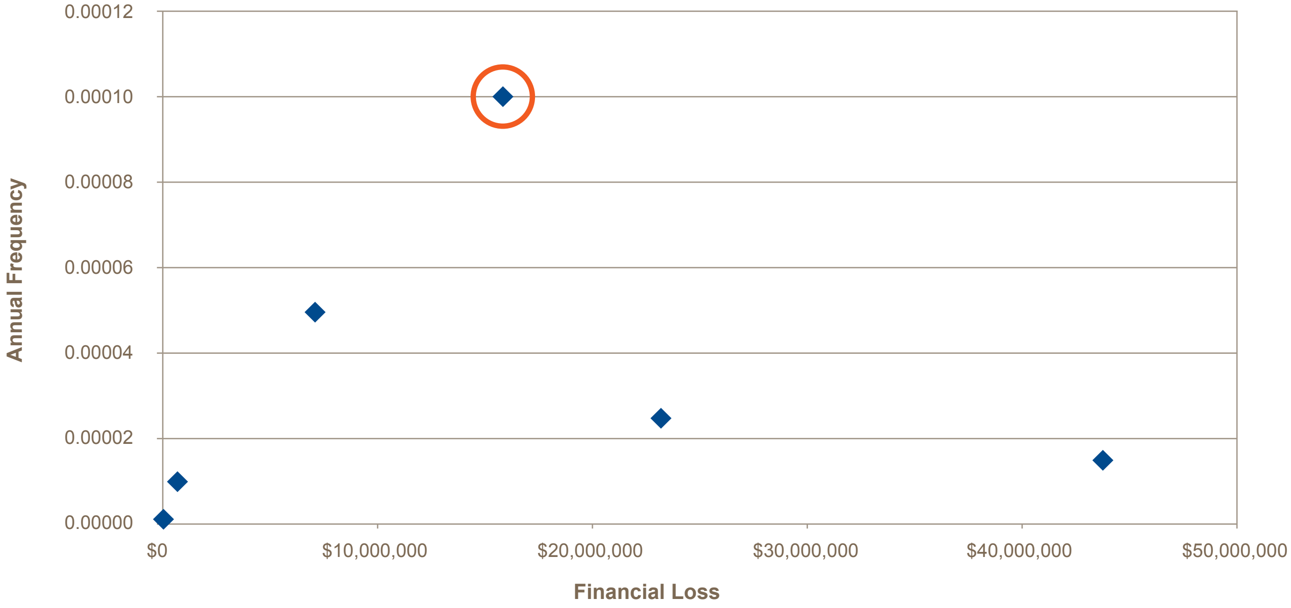

Figure 3.8 Illustrative Example of Weighted Average of Event Loss Accounting for Uncertainty

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Chapter 4

Quantification of Probabilistic Flood Risk in Texas

Chapter 4 Summary

Larger damages ensuing from extreme natural disasters have seemingly become the new norm. Quantifying the impacts of these extreme events is therefore critical for properly managing the associated risk. Focusing on Travis and Galveston Counties, this chapter provides a series of in-depth analyses of flood risk at both an aggregate county and individual single-family residence level based on the output from the CoreLogic and Swiss Re flood catastrophe models. For ease of exposition, the analysis provided for each county focuses on the following main components:

Overview of Single-Family Residence Exposure ▶ **Construction and Discussion of Aggregate EP Curves by County and FEMA Flood Zones** ▶ **Summary of Average Annual Loss Results Including Distributions and Geography**

Key Outcomes:

1) **Worst-case scenarios**

In ***Travis County***, the worst-case scenario (a 10,000-year flood event) results in **$890 million** in losses to residential properties from river flooding, which is 7.4 percent of the total county's $12 billion in single-family residence property values that have some level of flood risk associated with them. There is no storm surge flood risk in Travis County. (See Table 4.2 for this quantification and other key catastrophic flood events such as a 100-year, or a 1,000-year flood)

Galveston County is impacted by both storm surge and riverine flooding, with storm surge losses dominating river flooding losses for all catastrophic flood events. The worst-case scenario (a 10,000-year storm surge flood event) is **$2.3 billion** in losses to residential properties, which is 17 percent of the total county's $14 billion in single-family residence property values at risk. For riverine flood, the worst-case scenario (a 10,000-year riverine flood event) is **$825 million** in residential loss, which is 6 percent of this same total county exposure. (See Table 4.6 for this quantification and results for other flood events such as a 100-year, or a 1,000-year flood).

2) **Quantification of the "pure premium" (unloaded risk-based rate)**

We define the pure premium as the expected average annual loss over a 10,000 year period of time across thousands of possible scenarios generated by the CoreLogic and Swiss Re flood catastrophe models. We also classified our results so they correlate with the existing FEMA-defined flood zones (see appendix of Chapter 2 for definitions).

At the county level, expected average annual losses per $1,000 of exposure in Galveston County are significantly higher than those in Travis County, and true risk-based rates need to reflect this coastal and inland county risk variation.

Travis: (See Table 4.4)
Average annual loss (AAL) = $16.5 million
Mean AAL cost per $1,000 of exposure = $0.27

Galveston: (See Table 4.8)
Average annual loss (AAL) = $47.9 million
Mean AAL cost per $1,000 of exposure = $3.43

Further, substantial variation in pure premiums exists between coastal and inland locations within zones of similar NFIP risk classification. For instance, homes in the designated moderate risk X500/B zones in Galveston are exposed to a flood risk 2.5 times greater on average than residences in X500/B zones in Travis. There is also substantial variation of flood risk within a given coastal or inland county, as exemplified by the range of average values between high and low risk being much wider in Travis County than in Galveston County.

Travis mean AAL cost per $1,000 of residential exposure by flood zone: (see Table 4.4)
A zone (high risk) = $5.51
X500 / B (moderate risk) = $1.69
X / C (minimal risk) = $0.07

Galveston mean AAL cost per $1,000 of residential exposure by flood zone: (see Table 4.8)
V zone (coastal high risk) = $6.60
A zone (high risk) = $6.31
X500 / B (moderate risk) = $4.21
X / C (minimal risk) = $1.64

Our results indicate that undertaking a microanalysis of the true exposure of residents to riverine and storm surge risks is important to calculate in order for flood insurance groups to charge the true risk-based premiums. One cannot simply aggregate risks per flood zones because there is a lot of heterogeneity in a given flood zone.

3) Other enhanced views of flood risk from our analysis

i. Flood zones designated as minimal risk by FEMA do not necessarily equate to minimal losses for catastrophic flood events. In both counties, X zone (low risk) flood losses are larger than all other FEMA flood zones for extreme flood events such as 500- to 10,000-year floods, and even in some instances for less extreme 5- and 10-year flood events in Travis County, compared to moderate risk zone losses (X500/B). (See Table 4.3 for Travis and Table 4.7 for Galveston.)

ii. While on average in each county the average annual loss cost per $1,000 of exposure is higher in the designated higher risk flood zones, the range of AAL per $1,000 is essentially equivalent across all flood zones. For example, maximum values of approximately $14.00 in Travis County exist for high, moderate, and low risk zones (see Table 4.4 and Figure 4.5). This range indicates that large individual flood risks are not limited to existing designated high risk flood zones. (See Table 4.8 and Figure 4.13 for similar results in Galveston.)

iii. Following from the FEMA flood zone classifications, V and coastal A zones are the only flood zones subject to some level of storm surge flood risk. However, the probabilistic model results identify a significant amount of storm surge exposure and risk outside of the V and coastal A zones in Galveston County. For example, in the Galveston X500 and X flood zones there is $3.1 billion of storm surge only property exposure with an associated total storm surge AAL of $9.7 million, or 22 percent of the total storm surge AAL of the county. Further, storm surge is the main driver of the average annual loss costs in Galveston, comprising at least 89 percent of the average annual loss costs per $1,000 values across all flood zones—even for the non-V and non-coastal A zones. (See Table 4.8.)

4.1 Analysis for Travis County

A Measure of Single-Family Residence Exposure

Data on 226,407 single-family residences were collected and inputted into the CoreLogic and Swiss Re flood catastrophe models for Travis County. Table 4.1 provides the total number of residences per FEMA flood zone as well as the mean exposure values (building value plus an additional 40 percent to reflect content value) inputted into the model in each zone. Across all FEMA flood zones there is a total of over $54 billion in exposure in Travis County, with 95 percent of this exposure located in the designated X/C FEMA flood zone which is outside of the 100- and 500-year floodplains. In other words, nearly all of the single-family property exposure is in areas that are classified as having minimal levels of flood risk by existing FEMA flood maps. The X/C FEMA flood zone also accounts for 95 percent of the total single-family residences in the county and has the highest average exposure per home as well as the largest maximum single-home exposure value reaching nearly $20 million dollars. While in aggregate only 5 percent of residences are in the 100- and 500-year floodplains (A and X500/B zones respectively), there is still over a billion dollars of flood exposure located in each of these FEMA-designated higher-risk zones with average exposure values comparable to the X/C zone.

TABLE 4.1 TRAVIS COUNTY EXPOSURE VALUE SUMMARY BY FEMA FLOOD ZONE

FEMA Flood Zone	# of Single-Family Residences	% of Total Residences	Total Exposure Value*	% of Total Exposure Value	Average Exposure Value
A	6,790	3%	$ 1,536,512,177	3%	$ 226,290
X500 / B	5,010	2%	$ 1,125,747,322	2%	$ 224,700
X / C	214,607	95%	$ 51,806,029,170	95%	$ 241,400
Total County	**226,407**	**100%**	**$ 54,468,288,669**	**100%**	**$ 240,577**

*Exposure Value = Building Value + 40% Content

Figure 4.1 illustrates the distribution across all flood zones in Travis County of building values only; the mean single-family building value is $171,841 and the median is $133,686. Of the 226,407 homes in the county, there are over 37,000 homes (approximately 16 percent of the total number of homes) with a market building value greater than $250,000, which is the NFIP maximum building coverage limit. Figure 4.2 further illustrates the geographic location of 1,601 homes with building values greater than or equal to $250,000 in the FEMA A and X500 flood zones.

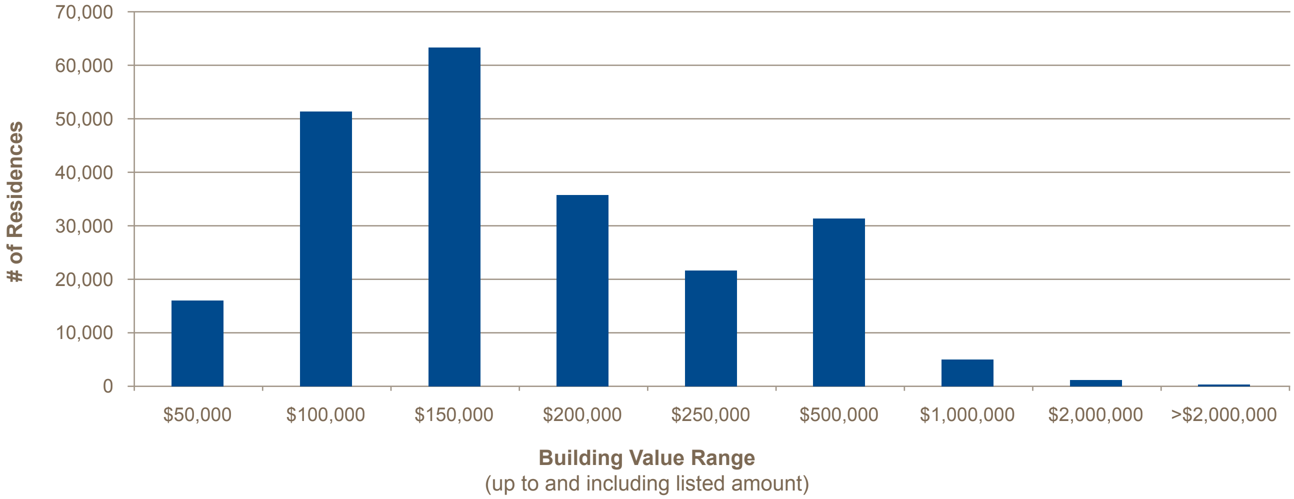

Figure 4.1 Travis County Building Value Distribution

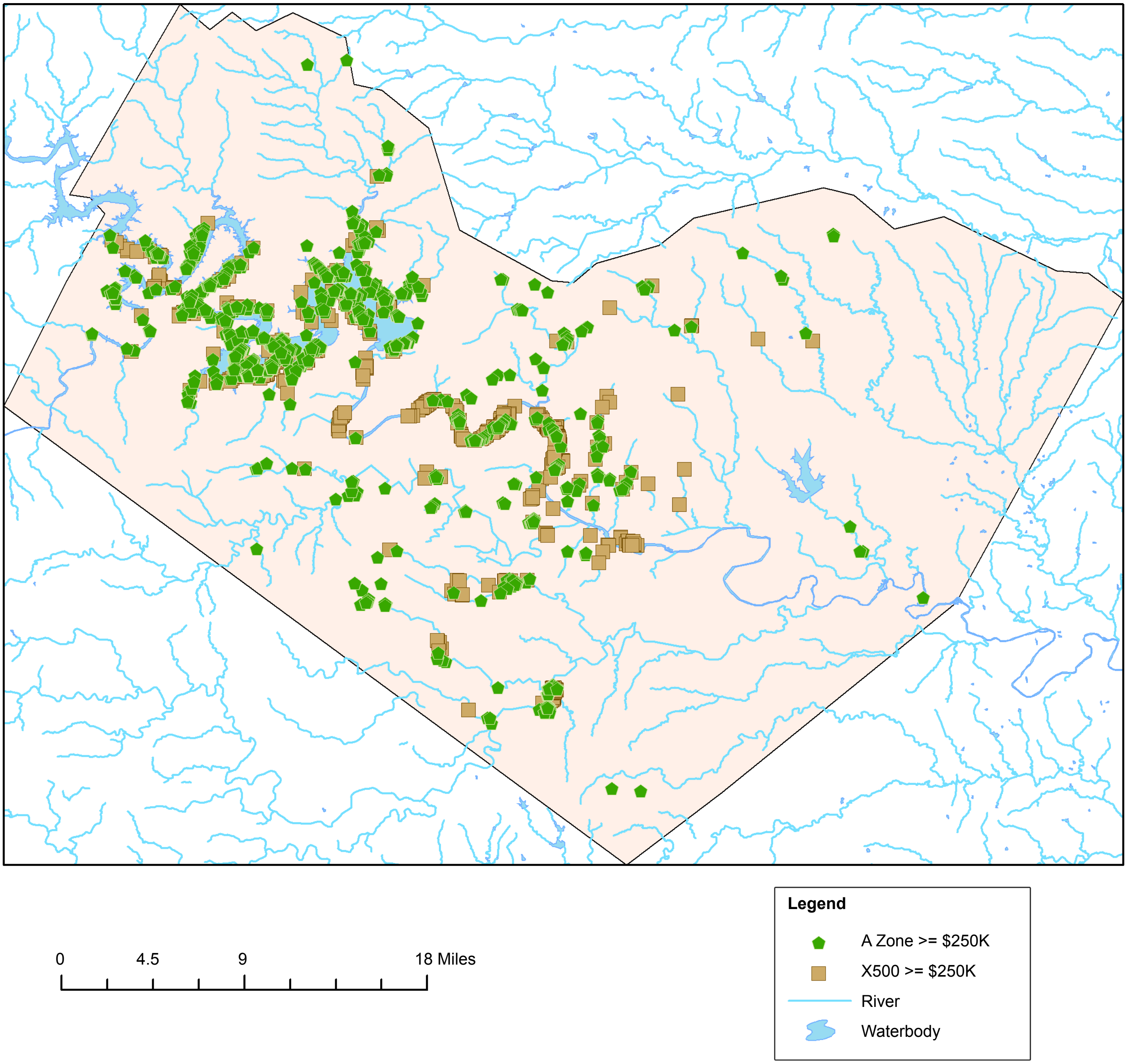

Figure 4.2 Travis County Homes with Building Values >= $250,000 in FEMA A and X500 Flood Zones

Construction of the EP Curves

Based on the outputs of the catastrophe model, as detailed in section 3.2, one can construct the exceedance probability (EP) curve for a given portfolio of properties in a given area. Figure 4.3 illustrates the EP curve for our portfolio of 226,407 structures at risk in Travis County. Focusing on the right-hand tail of the curve in Figure 4.3, the 10,000-year loss of nearly $890 million is approximately 1.6 percent of the total county's $54 billion in exposure. However, as we will show, 77 percent of the total 226,407 residences have no flood peril associated with them. When these homes are excluded, the 10,000-year loss of nearly $890 million is approximately 7.4 percent of the $12 billion in exposure for only those homes at risk for riverene flooding.

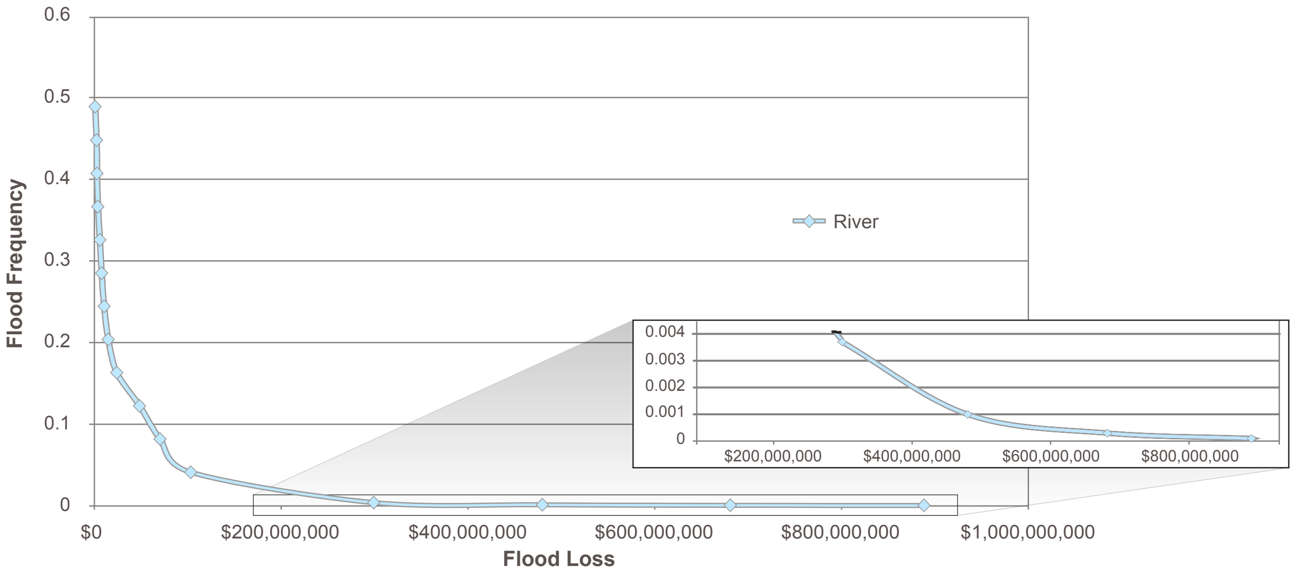

Figure 4.3 EP Curve for Portfolio of 226,407 Single-Family Residences in Travis County

Table 4.2 provides the other key return period losses for the county such as $14.7 million for the 5-year flood event and nearly $200 million for the 100-year flood event.

TABLE 4.2 TRAVIS COUNTY SUMMARY OF RIVER FLOOD LOSSES BY RETURN PERIOD (IN YEARS) FOR OUR PORTFOLIO OF 226,407 SINGLE-FAMILY RESIDENCES

Return Period	Flood Loss
10,000	$ 890,380,852
5,000	$ 863,771,000
1,000	$ 480,444,800
500	$ 420,172,535
250	$ 292,062,263
100	$ 192,226,890
50	$ 137,931,507
25	$ 104,274,094
10	$ 59,776,293
5	$ 14,724,782

EP curves by designated FEMA flood zones were also constructed, as illustrated in Figure 4.4. Again, focusing on the right-hand tail of the EP curve in Figure 4.4 the 10,000-year loss is largest in the FEMA X zone, reaching over $600 million. This large loss in a flood zone designated as minimal flood risk by FEMA is most likely due to the sheer number of total homes in this zone—a significant portion of which would be impacted by such an extreme flood event.

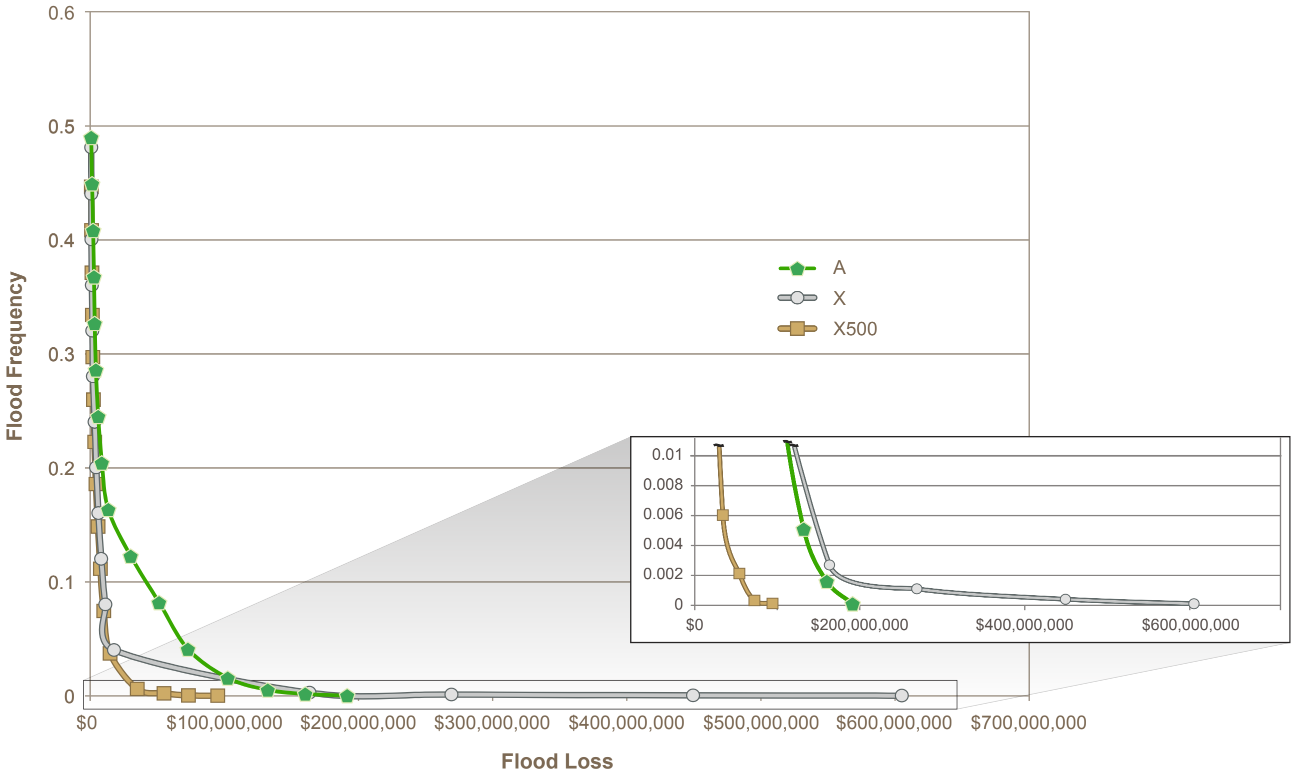

Figure 4.4 Travis County EP Curves for Our Portfolio of Single-Family Residences as Categorized by FEMA Flood Zones

Table 4.3 further provides the key return period losses across the various FEMA flood zones. From this table we see that for the 250-year return period (and all lower return periods), the A zone now has the largest loss at $134.8 million. However, the X500 zone losses are lower than the X zone across all return periods, even for the lower scale flood events such as the 10- and 5-year return periods.

TABLE 4.3 TRAVIS COUNTY SUMMARY OF LOSSES BY FEMA FLOOD ZONES AND RETURN PERIOD

Return Period	A Zone	X500 / B	X / C
10,000	$ 191,057,064	$ 94,382,984	$ 604,929,949
5,000	$ 189,863,439	$ 85,518,950	$ 602,690,321
1,000	$ 173,909,077	$ 64,193,555	$ 361,090,202
500	$ 155,842,805	$ 54,584,871	$ 208,791,602
250	$ 134,861,182	$ 41,440,145	$ 114,207,453
100	$ 115,816,580	$ 26,097,300	$ 61,477,846
50	$ 95,054,442	$ 18,251,944	$ 31,054,899
25	$ 72,803,526	$ 13,580,396	$ 17,132,647
10	$ 43,772,752	$ 7,571,444	$ 8,831,337
5	$ 8,306,459	$ 3,059,779	$ 3,693,197

Calculation of the Average Annual Loss (AAL)

As detailed in section 3.2, average annual loss (AAL) is the overall expected loss for the entire set of events, or the area under the EP curve. AAL can be determined as an outcome of our catastrophe model at the aggregate county and FEMA flood zone levels based upon the expected loss and return period data behind Figures 4.3 and 4.4, but also per each individual single-family residence.[27] The AAL for an individual residence as an outcome of our model is the basis for a risk-based premium that is probabilistic in nature. However, as would be expected, everything else being equal, the higher amount of exposure, the higher the AAL. Therefore, in order to account for the impact of the exposure value on the derived AAL the *ratio of AAL over quantity of exposure per $1,000* is also determined. AAL results are presented in Table 4.4.

TABLE 4.4 TRAVIS COUNTY AAL FOR SINGLE-FAMILY RESIDENCES BY FEMA FLOOD ZONE

FEMA Flood Zone	Peril	# of Single-Family Residences	Total Exposure Value (Building + 40% Content)	Total AAL = River AAL	Mean Total AAL per Home	Mean AAL Cost per $1000	Minimum AAL Cost per $1000	Maximum AAL Cost per $1000	Stnd Dev AAL Cost per $1000
A	River Only	6,790	$ 1,536,512,177	$10,241,077	$1,508	$ 5.51	$ 0.06	$ 14.19	$ 4.63
	None	-	$ -	$ -	$ -				
	Total	**6,790**	**$ 1,536,512,177**	**$10,241,077**	**$1,508**	**$ 5.51**	**$ 0.06**	**$ 14.19**	**$ 4.63**
X500 / B	River Only	5,010	$ 1,125,747,322	$ 2,309,197	$ 461	$ 1.69	$ 0.06	$ 14.07	$ 3.17
	None	-	$ -	$ -	$ -				
	Total	**5,010**	**$ 1,125,747,322**	**$ 2,309,197**	**$ 461**	**$ 1.69**	**$ 0.06**	**$ 14.07**	**$ 3.17**
X / C	River Only	49,069	$ 9,346,189,517	$ 3,955,547	$ 81	$ 0.31	$ 0.01	$ 14.28	$ 1.09
	None	165,538	$42,459,839,653	$ -	$ -				
	Total	**214,607**	**$51,806,029,170**	**$ 3,955,547**	**$ 18**	**$ 0.07**	**$ -**	**$ 14.28**	**$ 0.54**
County	**Total**	**226,407**	**$54,468,288,669**	**$16,505,821**	**$ 73**	**$ 0.27**	**$ -**	**$ 14.28**	**$ 1.43**

From the peril column in Table 4.4, one can see that all the homes in the A and X500 zones have some level of flood risk loss associated with them as an outcome of our catastrophe model, as the number of single-family residences with peril indicated as “none” totals zero. Total AAL in the A and X500 zones is $10.2 and $2.3 million respectively.[28] However, this is not the same case in the X zone as 77 percent of the homes in this zone have no riverine flood risk associated with them. Still, the other 23 percent of homes in the Travis County X zone with some flood risk loss determined as an outcome of our catastrophe model have a total AAL equal to $3.9 million from their associated total $9.3 billion in exposure.

On average, total AAL per home is over 3 times higher in the A zone ($1,508) as compared to the X500 zone ($461), and over 18 times higher than the 49,069 at-risk homes in the X zone ($81). Similarly, when accounting for the exposure value differences across zones, the $5.51 mean AAL cost per $1,000 in the A zone is still approximately 3 and 18 times higher than the $1.69 and $0.31 mean AAL cost per $1,000 for the X500 and X zones respectively.[29] Despite this decline in risk on average moving from A to X500 to X zones as represented by the lower average total AAL and mean AAL costs per $1,000, the range of AAL costs per $1,000 across all three flood zones is essentially the same, from a minimum of $0.06 per $1,000 of exposure to a maximum of $14 per $1,000 of exposure. In fact, the highest AAL cost per $1,000 of exposure is $14.28 located in the Travis County X zone, ostensibly a minimal risk flood zone. Indeed, the variance of risk across properties is nearly equal amongst designated high to low risk zones.

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[27] The model in fact calculates exceedance probability (EP) curves at each individual residence location and then aggregates these into the county and FEMA flood zone level EP curves shown.

[28] In Travis County, total AAL is comprised of only riverine flood loss, as Travis County is an inland county not subject to storm surge losses.

[29] Note that these values are the average across each *individual* home’s AAL exposure per $1,000 determined result. Consequently, taking the ratio of Total AAL/Total Exposure multiplied by 1,000 at the county or flood zone levels shown in the table will not provide the same result.

Figure 4.5 provides a further detailed view of the distribution of AAL cost per $1,000 of exposure across all three flood zones for those homes with river peril greater than $0. From this flood zone distribution we see that the A zone has the largest number of residences for higher values of AAL cost per $1,000 while the X zone has the largest number of residences for AAL cost per $1,000 up to $1.00.[30] However, for some AAL cost per $1,000 ranges, such as from $4.01 to $5.00, the difference in the number of residences within this AAL cost per $1,000 range across all flood zones is relatively minimal. Further, for a number of higher value AAL cost per $1,000 ranges, such as from $5.01 to $7.50, the X zone has a larger number of residences than the X500 zone within this AAL cost per $1,000 range.[31]

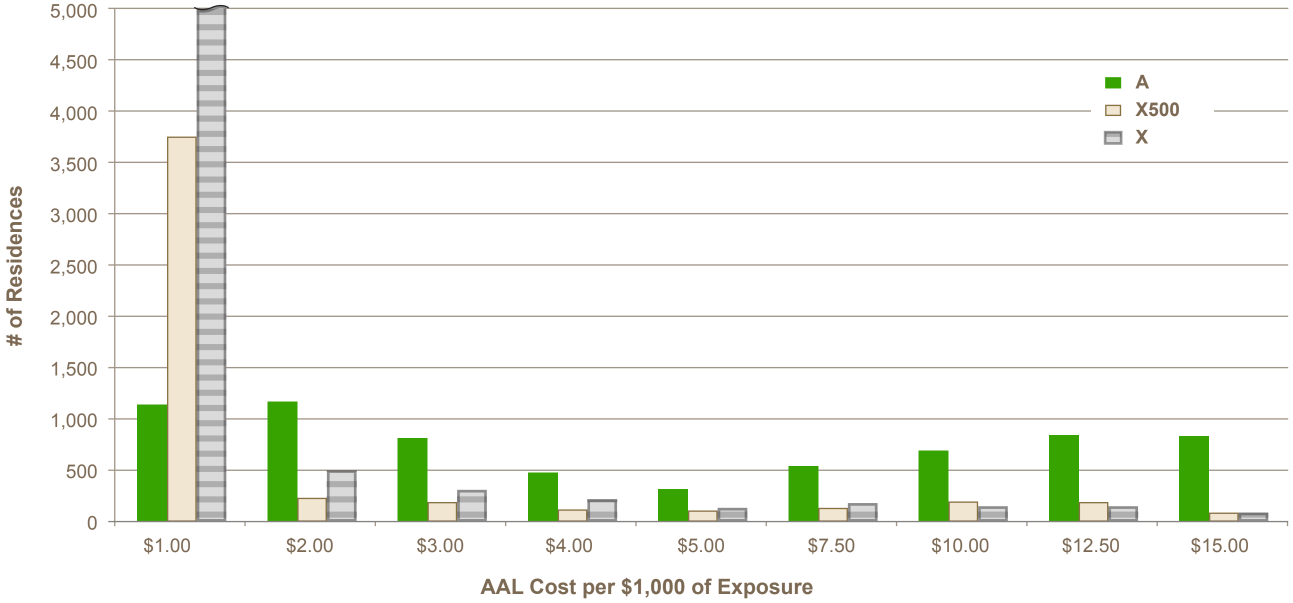

Figure 4.5 Distribution of Travis AAL Cost per $1,000 of Exposure by FEMA Flood Zone

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[30] For chart scaling purposes, the number of residences in the X zone in the $1.00 AAL cost per $1,000 value range was truncated at 5,000. There are actually 47,323 residences in this range for the X zone or nearly 97% of the total 49,069 residences.

[31] This result may simply be due to the total number of residences in the X zone being nearly ten times larger than the number in the X500 zone (49,069 vs. 5,010 respectively).

Finally, in order to have a geographic sense of where the largest AAL cost per $1,000 of exposure values are occurring, Figure 4.6 highlights the location of the 996 homes with an AAL cost per $1,000 between $12.51 and $15.00 (the last column in Figure 4.5). For comparative purposes the 1,601 A and X500 residences with building values greater than or equal to $250,000 from Figure 4.2 are also included (now all dark shapes). The circled areas denote homes with large AAL cost per $1,000 of exposure occur that do not coincide with high value homes in the 100- and 500-year floodplains.

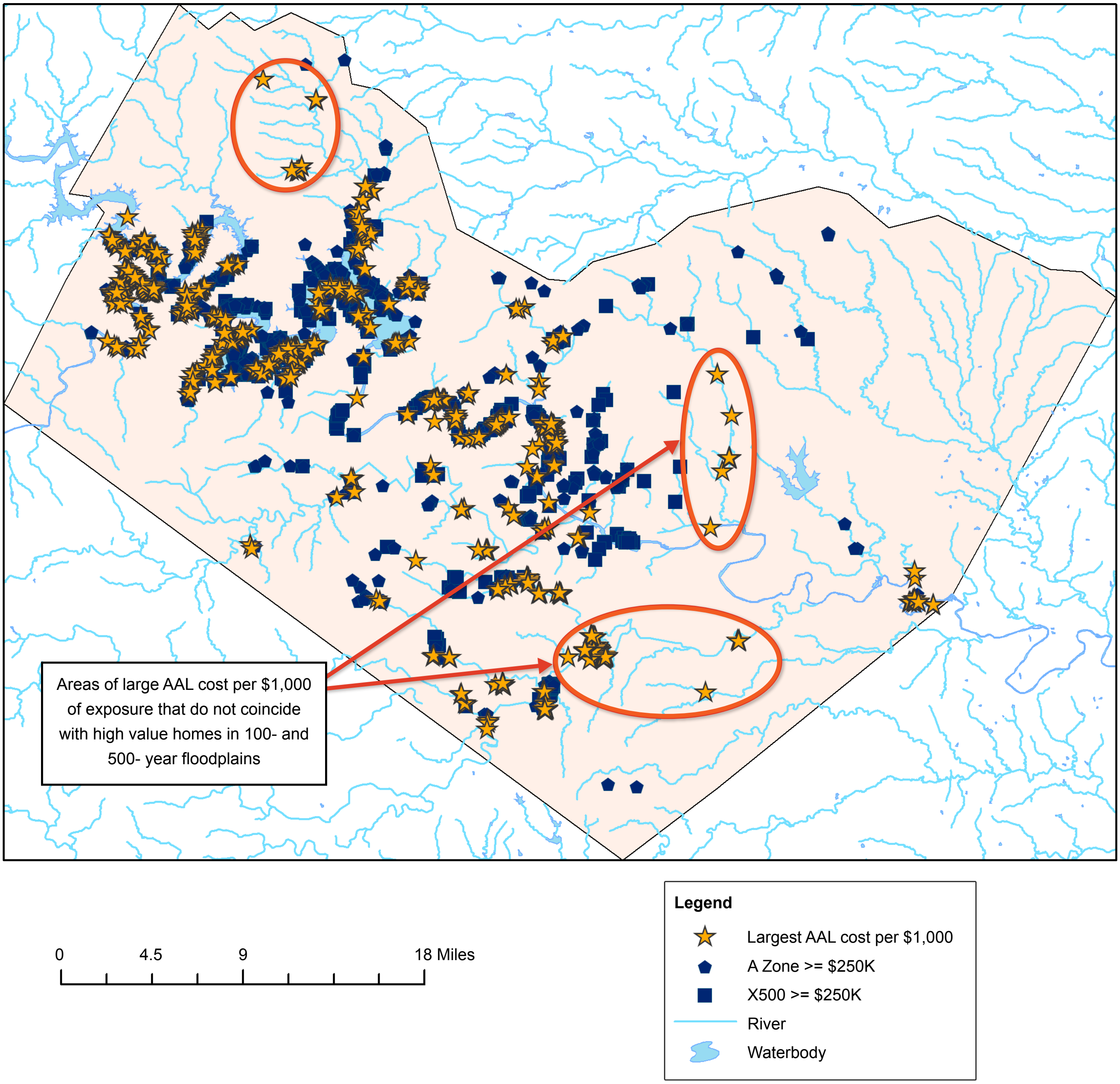

Figure 4.6 Geographic Distribution of Homes with Largest AAL Cost per $1,000 of Exposure in Travis County

4.2 Analysis for Galveston County

A Measure of Single-Family Residence Exposure

Data on 89,046 single-family residences were collected and inputted into the CoreLogic and Swiss Re flood catastrophe models for Galveston County. Table 4.5 provides the total number of residences per FEMA flood zone as well as the mean exposure values (building value + 40 percent content) inputted into the model in each zone. Across all FEMA flood zones there is a total of over $14 billion dollars in exposure in Galveston County. Fifty-five percent of this exposure is located in the designated X/C FEMA flood zone which is outside of the 100- (coastal and non-coastal) and 500-year floodplains. In other words, more than half of the single-family property exposure is in areas that are classified as having minimal levels of flood risk by existing FEMA flood maps. The X/C FEMA flood zone also accounts for 53 percent of the total single-family residences in the county and has the second-highest average exposure per home at $167,793. While in aggregate there is less exposure in the coastal 100-, non-coastal 100-, and 500-year floodplains (V, A, and X500/B zones respectively) as compared to the X zone, there is still over a billion dollars of flood exposure located in each of these FEMA designated higher risk zones. The V zone has the highest average exposure value at $266,645 as well as the largest maximum single home exposure value (nearly $4 million) as might be expected for coastal property.

TABLE 4.5 GALVESTON COUNTY EXPOSURE VALUE SUMMARY BY FEMA FLOOD ZONE

FEMA Flood Zone	# of Single-Family Residences	% of Total Residences	Total Exposure Value*	% of Total Exposure Value	Average Exposure Value
V	5,355	6%	$ 1,427,884,401	10%	$ 266,645
A	17,940	20%	$ 2,701,793,277	19%	$ 150,602
X500 / B	18,922	21%	$ 2,346,051,193	16%	$ 123,985
X / C	46,829	53%	$ 7,857,561,222	55%	$ 167,793
Total County	**89,046**	**100%**	**$ 14,333,290,093**	**100%**	**$ 160,965**

*Exposure Value = Building Value + 40% Content

Figure 4.7 further geographically illustrates all single-family residences in Galveston County. Although the majority of minimal (X zone) to moderate (X500) flood risk homes are located inland as illustrated, there are certainly pockets of these homes located very close to coastal waters subject to potentially significant amounts of storm surge as are circled in the figure.

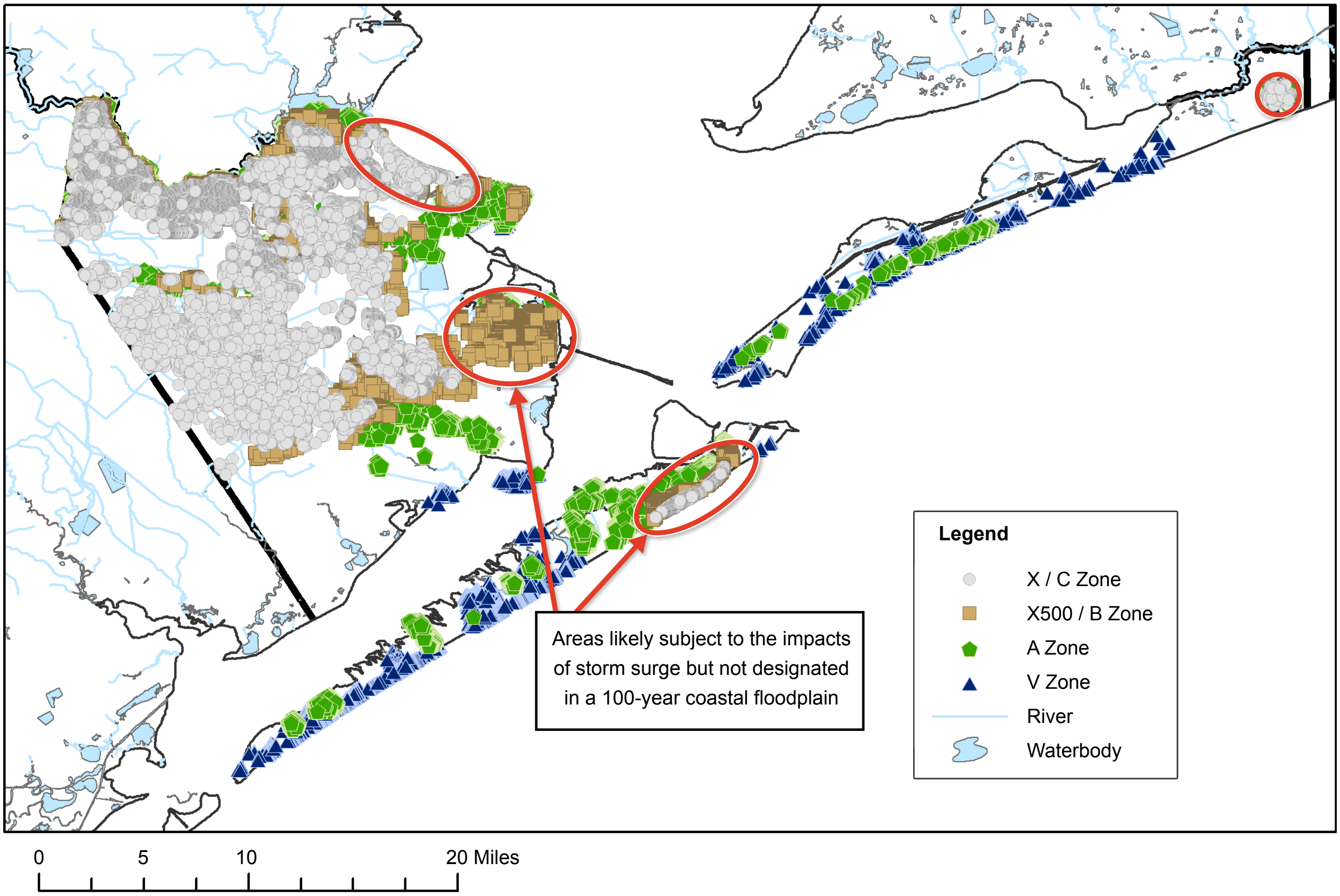

Figure 4.7 Geographic Distribution of Galveston County FEMA Flood Zone Single-Family Residences

Figure 4.8 illustrates the distribution of building values across all flood zones in Galveston County; the mean single-family building value is $114,975 and the median is $97,550. There are 5,380 homes in the county (6 percent of the total number of homes) with a market value greater than $250,000, the NFIP coverage limit.

Figure 4.9 further illustrates the location of 3,005 homes with building values greater than or equal to $250,000 in the FEMA V, A, and X500 flood zones.

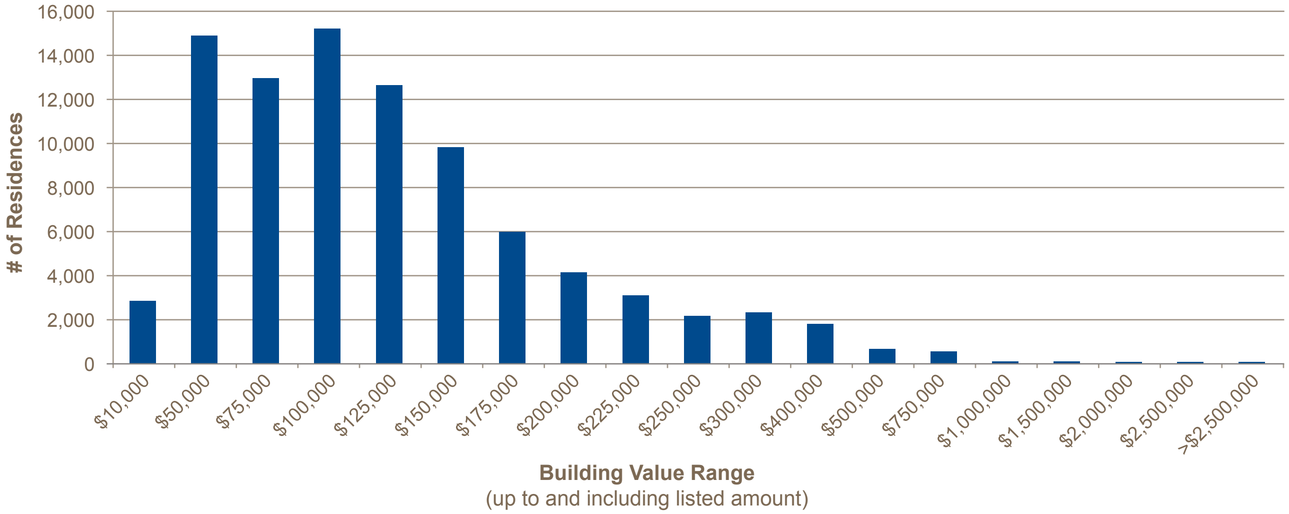

Figure 4.8 Galveston County Building Value Distribution

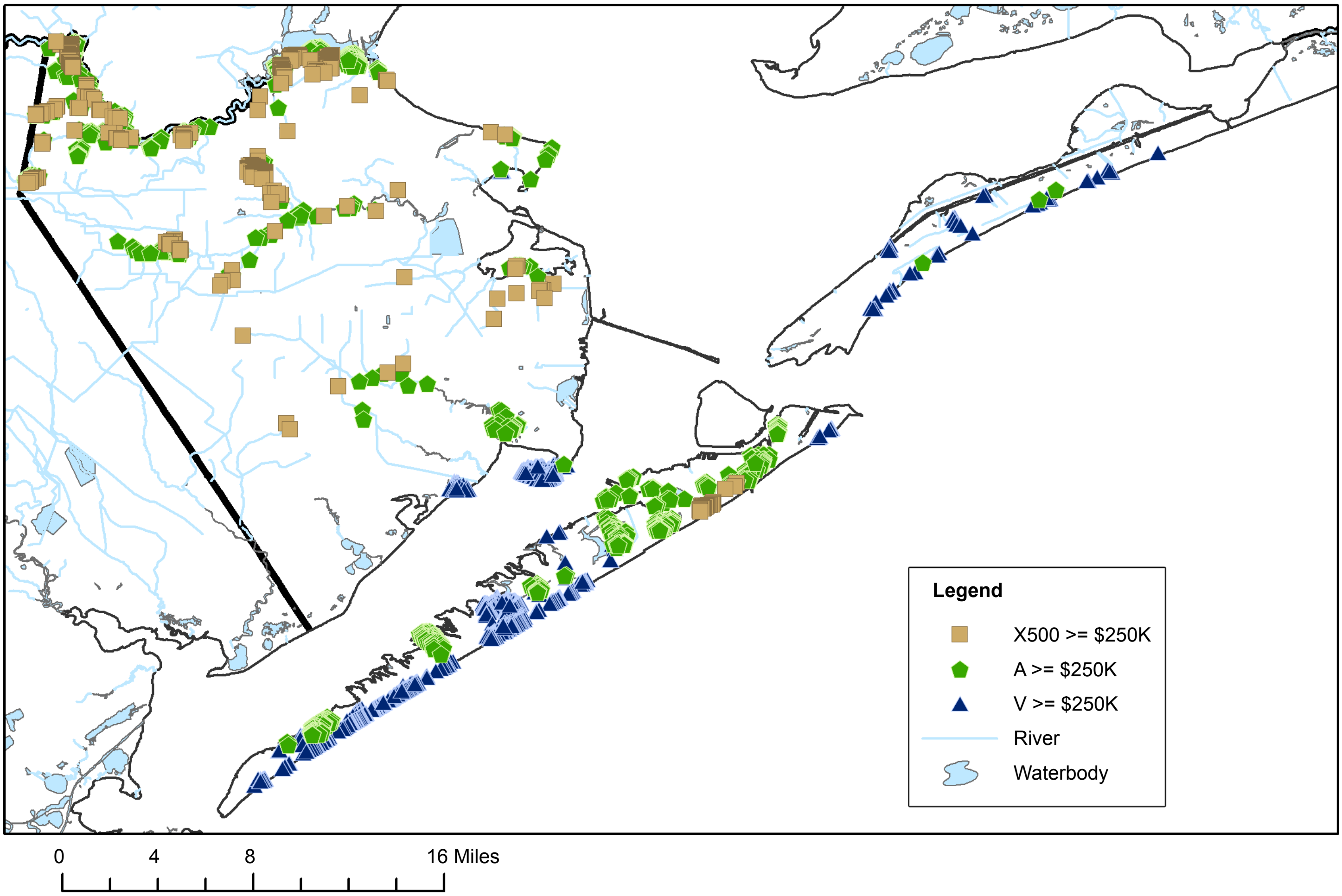

Figure 4.9 Galveston County Homes with Building Values >= $250,000 in FEMA V, A, and X500 Flood Zones

Construction of the EP Curves

As detailed in section 3.2, based on the outputs of the catastrophe model, the insurer can construct an exceedance probability (EP) curve. For our given portfolio of 89,046 structures at risk in Galveston County, Figure 4.10 illustrates the EP curve for the entire county split by flood peril—one for river flooding and one for storm surge flooding. Focusing on the right-hand tail of the curves in Figure 4.10 the 10,000-year storm surge loss of $2.3 billion is approximately 17 percent of the total county's $14 billion in exposure, while the 10,000-year river loss of $825 million is approximately 6 percent of the total county $14 billion in exposure.

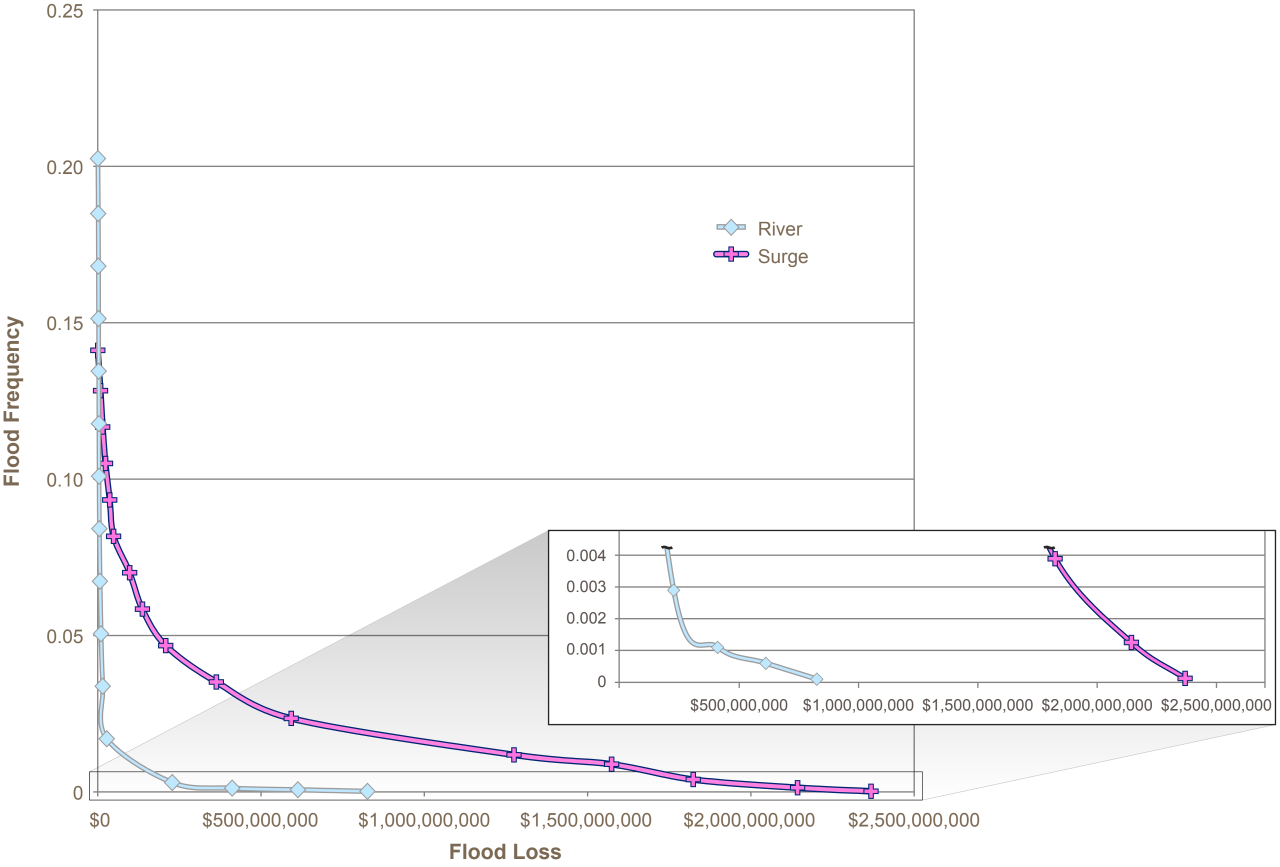

Figure 4.10 River and Storm Surge EP Curves for Our Portfolio of 89,046 Single-Family Residences in Galveston County

Table 4.6 provides the key return period losses for the county, which range from $351,000 for the 5-year river flood event to nearly $58 million for the 100-year river flood event, and $27 million for the 10-year storm surge flood event to nearly $1.3 billion for the 100-year storm surge flood event.[32] From the 10-year to the 10,000-year return period, storm surge flooding losses dominate river flooding losses in Galveston County, ranging from three to 30 times higher.

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[32] Comparatively, NFIP claims paid from Hurricane Ike in 2008 were $1.3 billion in Galveston County alone (http://www.fema.gov/hazard/hurricane/2008/ike/special/snapshot_galveston.shtm), suggesting a 100-year event from our model storm surge loss results. While Ike was a lower return period storm (somewhere in the 20 or 30 year range) it did produce storm surge above its landfall intensity.

TABLE 4.6 GALVESTON COUNTY SUMMARY OF RIVER AND SURGE FLOOD LOSSES BY RETURN PERIOD (IN YEARS) FOR OUR PORTFOLIO OF 89,046 SINGLE-FAMILY RESIDENCES

Return Period	River Loss	Surge Loss
10,000	$ 825,996,632	$ 2,368,562,513
5,000	$ 774,760,585	$ 2,362,406,396
1,000	$ 529,900,292	$ 2,145,119,442
500	$ 285,186,789	$ 1,980,610,575
250	$ 189,732,327	$ 1,813,840,744
100	$ 58,528,365	$ 1,351,793,132
50	$ 24,540,917	$ 718,009,519
25	$ 12,286,541	$ 296,457,828
10	$ 4,045,875	$ 27,473,479
5	$ 351,456	$ -

We also constructed EP curves by FEMA flood zone as illustrated in Figure 4.11. Again, focusing on the right-hand tail of the EP curve in Figure 4.11 the combined 10,000-year loss is largest in the FEMA X zone at more than $1 billion. That is, the Galveston County flood zone designated as minimal flood risk by FEMA has a 10,000-year loss that is approximately 7.5 percent of the total county exposure. This large loss at the tail of the X zone is most likely due to the sheer number of total homes in this zone, some significant portion of which would be impacted by such an extreme flood event. Further, this extreme $1 billion loss is a storm surge-related flood loss. From Figure 4.7, we learned that there are a significant number of X zone homes located directly on coastal waters in Galveston County.

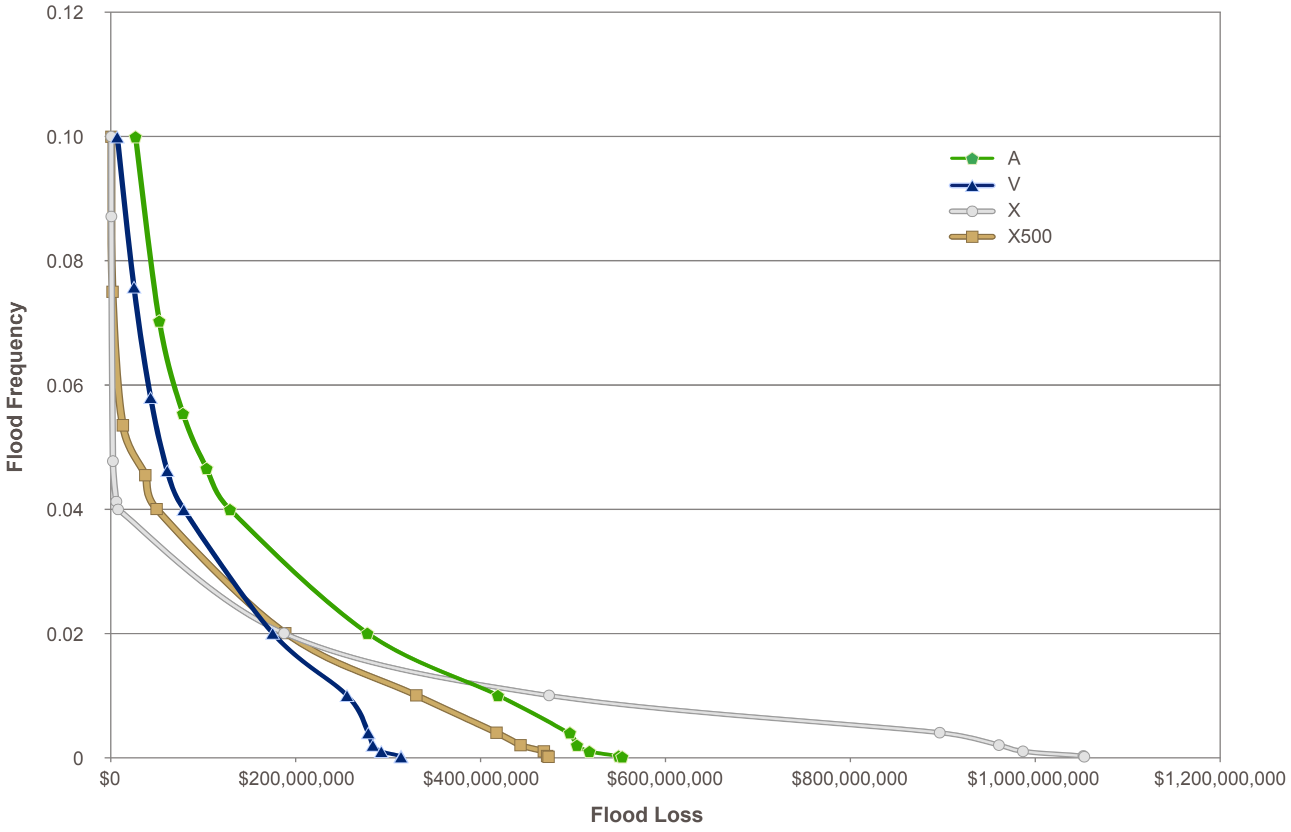

Figure 4.11 Galveston County EP Combined River and Surge Curves for Our Portfolio of Single-Family Residences as Categorized by FEMA Flood Zones

Table 4.7 provides the key return period losses across the various FEMA flood zones. From this table, one can see that near to the 100-year return period (and all lower return periods), the A zone now has the largest loss at $420 million. Across all four zones, there is a significant reduction of losses moving from the 50-year to 25-year events.

TABLE 4.7 GALVESTON COUNTY SUMMARY OF LOSSES BY FEMA FLOOD ZONES AND RETURN PERIOD

Return Period	V	A	X500 / B	X / C
10,000	$ 314,296,171	$ 553,827,787	$ 473,897,811	$1,053,939,121
5,000	$ 314,286,714	$ 549,974,423	$ 472,358,482	$1,052,938,427
1,000	$ 292,964,064	$ 518,174,008	$ 468,836,218	$ 987,498,777
500	$ 283,760,737	$ 504,772,507	$ 443,622,776	$ 961,481,827
250	$ 278,886,315	$ 494,455,753	$ 417,721,382	$ 897,560,712
100	$ 255,740,343	$ 419,124,020	$ 330,762,359	$ 474,527,937
50	$ 175,332,016	$ 277,921,341	$ 188,950,286	$ 187,736,713
25	$ 79,129,966	$ 129,223,683	$ 49,702,482	$ 8,095,455
10	$ 7,155,793	$ 27,003,850	$ 840,803	$ 561,773

Calculation of the Average Annual Loss (AAL)

As detailed in section 3.2, average annual loss (AAL) is the overall expected loss for the entire set of events, or the area under the EP curve. AAL can be determined as an outcome of our catastrophe model at the county and FEMA flood zone levels based upon the expected loss and return period data behind Figures 4.10 and 4.11, but also per each individual single-family residence.[33] The AAL for an individual residence as an outcome of our model is the basis for a risk-based premium that is probabilistic in nature. However, as would be expected everything else being equal, the higher amount of exposure, the higher the AAL. Therefore, in order to account for the impact of the exposure value on the derived AAL the *ratio of AAL over quantity of exposure per $1,000* is also determined. AAL results are presented in Table 4.8.

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[33] The model in fact calculates exceedance probability (EP) curves at each individual residence location (as long as latitude and longitude exist) and then aggregates these into the county and FEMA flood zone level EP curves shown.

TABLE 4.8 GALVESTON COUNTY AAL BY FEMA FLOOD ZONE

Flood Zone	Peril	# of Single-Family Residences	Total Exposure Value	Total AAL River	Total AAL Surge	Total AAL = River + Surge	Mean Total AAL per Home	Mean AAL Cost per $1000	Minimum AAL Cost per $1000	Maximum AAL Cost per $1000	Stnd Dev AAL Cost per $1000
V	River Only	-	$ -								
	Surge Only	5,164	$ 1,364,032,235	$ -	$ 9,469,790	$ 9,469,790	$ 1,834	$ 6.78	$ 2.42	$ 15.05	$ 2.45
	River & Surge	37	$ 5,346,810	$ 3,252	$ 37,083	$ 40,335	$ 1,090	$ 7.76	$ 5.84	$ 12.43	$ 1.76
	None	154	$ 58,505,356	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Total	**5,355**	**$ 1,427,884,401**	**$ 3,252**	**$ 9,506,872**	**$ 9,510,124**	**$ 1,776**	**$ 6.60**	**$ -**	**$ 15.05**	**$ 2.67**
A	River Only	354	$ 138,337,444	$ 236,666	$ -	$ 236,666	$ 669	$ 1.77	$ 0.16	$ 10.11	$ 1.87
	Surge Only	13,574	$ 1,968,068,542	$ -	$ 13,644,713	$ 13,644,713	$ 1,005	$ 6.52	$ 1.76	$ 13.26	$ 2.28
	River & Surge	3,897	$ 565,693,334	$ 1,431,961	$ 2,074,469	$ 3,506,429	$ 900	$ 6.19	$ 0.60	$ 21.92	$ 3.37
	None	115	$ 29,693,958	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Total	**17,940**	**$ 2,701,793,277**	**$1,668,627**	**$ 15,719,182**	**$17,387,809**	**$ 969**	**$ 6.31**	**$ -**	**$ 21.92**	**$ 2.68**
X500 / B	River Only	295	$ 94,706,934	$ 44,164	$ -	$ 44,164	$ 150	$ 0.45	$ 0.17	$ 4.26	$ 0.44
	Surge Only	12,258	$ 1,244,440,375	$ -	$ 5,943,206	$ 5,943,206	$ 485	$ 4.76	$ 1.68	$ 10.78	$ 1.38
	River & Surge	6,369	$ 1,006,903,884	$ 396,174	$ 2,797,555	$ 3,193,729	$ 501	$ 3.32	$ 0.44	$ 13.46	$ 1.08
	None	-	$ -								
	Total	**18,922**	**$ 2,346,051,193**	**$ 440,337**	**$ 8,740,761**	**$ 9,181,099**	**$ 485**	**$ 4.21**	**$ 0.17**	**$ 13.46**	**$ 1.52**
X / C	River Only	6,526	$ 1,450,772,274	$ 311,832	$ -	$ 311,832	$ 48	$ 0.20	$ 0.06	$ 2.02	$ 0.13
	Surge Only	13,070	$ 1,915,649,074	$ -	$ 3,775,634	$ 3,775,634	$ 289	$ 1.98	$ 0.24	$ 14.61	$ 1.05
	River & Surge	26,397	$ 4,403,229,485	$ 1,183,185	$ 6,500,918	$ 7,684,103	$ 291	$ 1.88	$ 0.33	$ 7.42	$ 1.01
	None	836	$ 87,910,389	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Total	**46,829**	**$ 7,857,561,222**	**$ 1,495,016**	**$ 10,276,552**	**$ 11,771,568**	**$ 251**	**$ 1.64**	**$ -**	**$ 14.61**	**$ 1.14**
County	**Total**	**89,046**	**$14,333,290,093**	**$ 3,607,232**	**$ 44,243,368**	**$47,850,600**	**$ 537**	**$ 3.43**	**$ -**	**$ 21.92**	**$ 2.67**

Mean River AAL Cost per $1,000	$ 0.22
Mean Surge AAL Cost per $1,000	$ 3.20

	V	A	X500 / B	X / C
Mean River AAL Cost per $1,000	$ 0.01	$ 0.49	$ 0.14	$ 0.18
Mean Surge AAL Cost per $1,000	$ 6.59	$ 5.82	$ 4.07	$ 1.46
	$ 6.60	**$ 6.31**	**$ 4.21**	**$ 1.64**

Given that Galveston County is subject to both riverine and storm surge flooding, residences here can incur river loss only, storm surge loss only, both river and storm surge losses, or no losses. From the peril column in Table 4.8 we see that essentially all homes in Galveston County (98.8 percent) have some level of AAL associated with them due to river flooding, storm surge flooding, or both as an outcome of our catastrophe model; in other words, all of Galveston County is exposed to flood risk. In the X zone, 98.2 percent of the homes have some flood risk loss determined as an outcome of our catastrophe model with total AAL equal to $11.7 million from their associated total $7.7 billion in exposure. Furthermore, we see a significant amount of storm surge risk outside of the V and coastal A zones which are the areas subject to storm surge flood risk according to FEMA flood zone classifications.[34] Focusing only on the "surge only" peril identified in Table 4.8, in zones X500 and X there is $3.1 billion of storm surge exposure with total storm surge AAL of $9.7 million, or 22 percent of the total storm surge AAL of the county. Figure 4.12 provides a geographical depiction of the location of the 12,258 homes in X500 zones that are subject to storm surge only (out of the 18,922 total homes in Galveston County's X500 zones). Of these storm surge only homes, 17.5 percent are located directly on the Gulf of Mexico, as circled in the figure.

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[34] Technically, in coastal areas, the entire A zone can potentially be divided into two separate zones—the coastal A zone and the A zone—with the distinction being that the coastal A zone's principal source of flooding is storm surge related, although not as severe as the V zone storm surge flooding (FEMA, 2009a). Further, while coastal A zone areas exist, they are not explicitly shown on the flood insurance rate maps (FEMA, 2009a) and we do not have access to their boundaries in the counties under analysis here. Thus, some unknown portion of the $2 billion of storm surge only exposure risk in the entire Galveston County A zone would be an additional storm surge flood risk identified by the model outside of the FEMA coastal A zone.

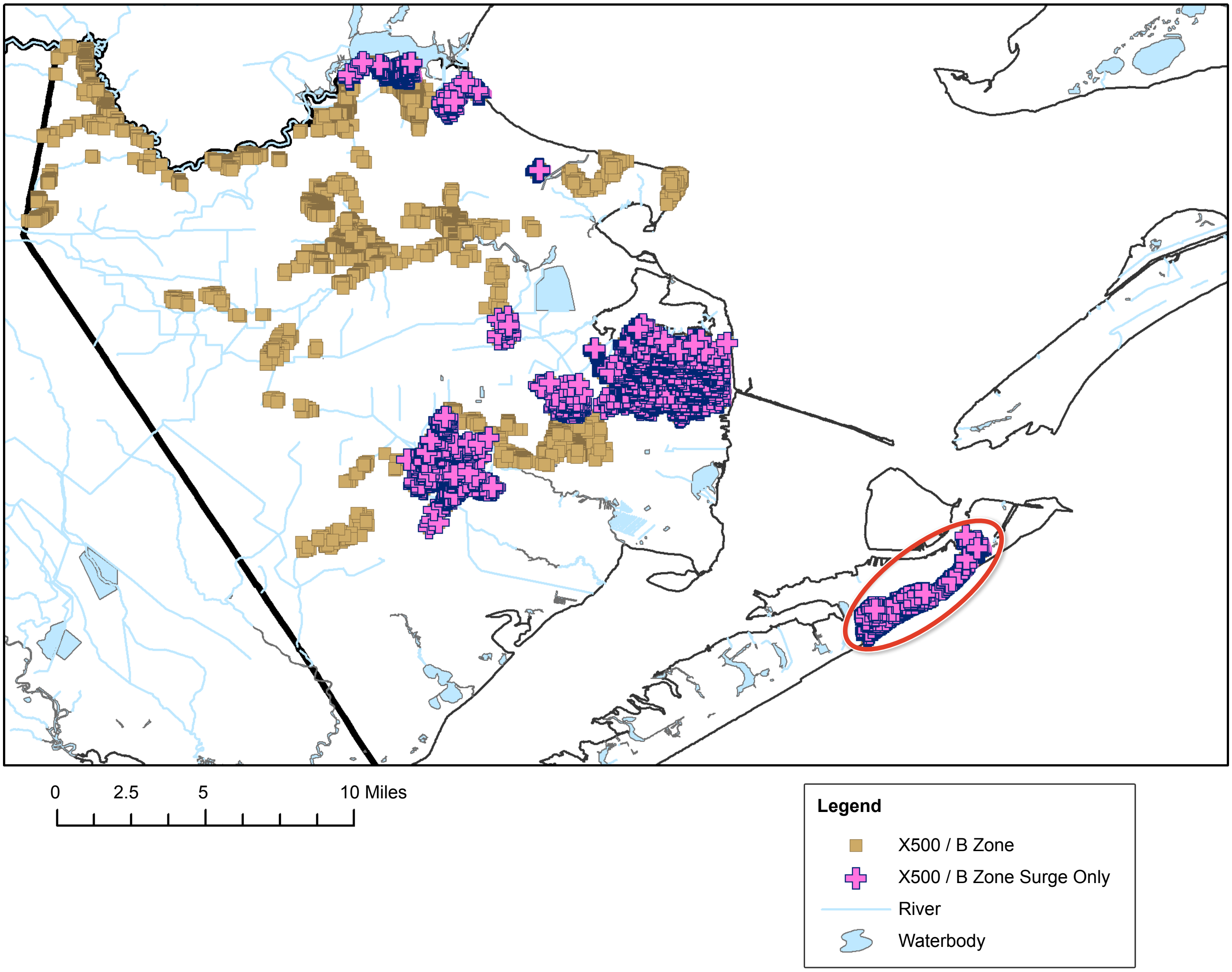

Figure 4.12 Galveston County X500 Residences Subject to Only Storm Surge Risk

In order to calculate the total AAL per home, we additively combine the derived river AAL and storm surge AAL. From a mean total AAL per home basis, V zone flood risk ($1,776) is 1.8 times higher as compared to the A zone ($969), 3.6 times higher as compared to the X500 zone ($485), and more than 7 times higher than the X zone ($251). However, when accounting for the exposure value differences across zones via the mean AAL cost per $1,000 of exposure, the V zone ($6.60) risk is approximately the same as the A zone ($6.31) and 1.5 and 4 times higher than the $4.21 and $1.64 AAL cost per $1000 for the X500 and X zones respectively.[35] Table 4.8 presents a breakdown of these mean AAL costs per $1,000 values by river and storm surge losses. Storm surge is the main driver of the AAL costs in Galveston County, comprising at least 89 percent of the mean AAL costs per $1,000 values across all flood zones— even for the non-V and non-coastal A zones which are not the areas subject to storm surge flood risk according to FEMA flood zone classifications. Focusing on the range of AAL costs per $1,000 across all four flood zones, we generally see similar values across all zones. While the highest AAL cost per $1,000 of exposure is $21.92, located in the Galveston County A zone, maximum AAL cost per $1,000 of exposure values in the X500 ($13.46) and X ($14.61) zones are comparable to the V zone maximum value of $15.05. Especially for those homes with surge only risk, there is little difference in the maximum AAL cost per $1,000 of exposure values across flood zones ($15.05, $13.26, $10.78, and $14.61 for V, A, X500, and X zones respectively).

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[35] Note that these values are the average across each individual home's AAL exposure per $1,000 determined result. Consequently, taking the ratio of Total AAL/Total Exposure multiplied by 1,000 at the county or flood zone levels shown in the table will not provide the same result.

Figure 4.13 provides a detailed view of the AAL cost per $1,000 of exposure distribution across all four flood zones. The A and V zones have the largest number of residences for higher values of AAL cost per $1,000 while the X zone has the largest number of residences for AAL cost per $1,000 up to $3.00.[36] However, for some AAL cost per $1,000 ranges, such as the two ranges from $5.01 to $10.00, the X500 zone has a larger number of residences than the V zone and is comparable to the A zone within these loss cost ranges.[37]

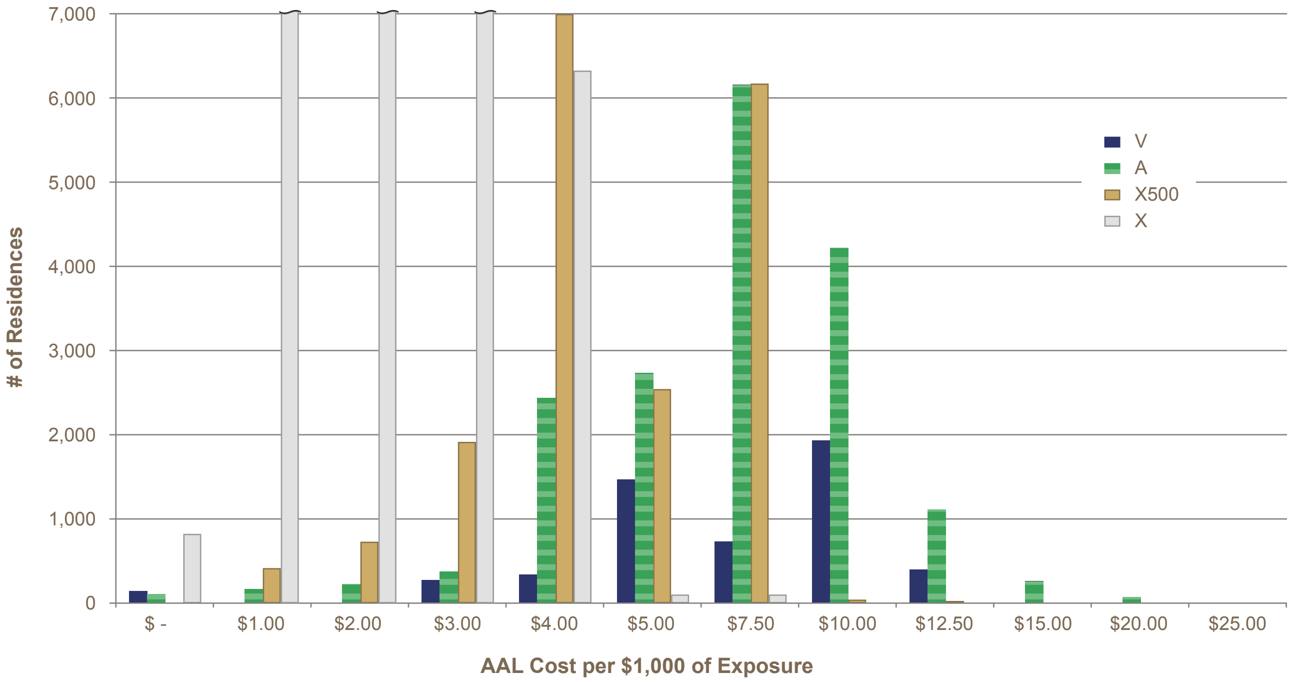

Figure 4.13 Distribution of Galveston AAL Cost per $1,000 of Exposure by FEMA Flood Zone

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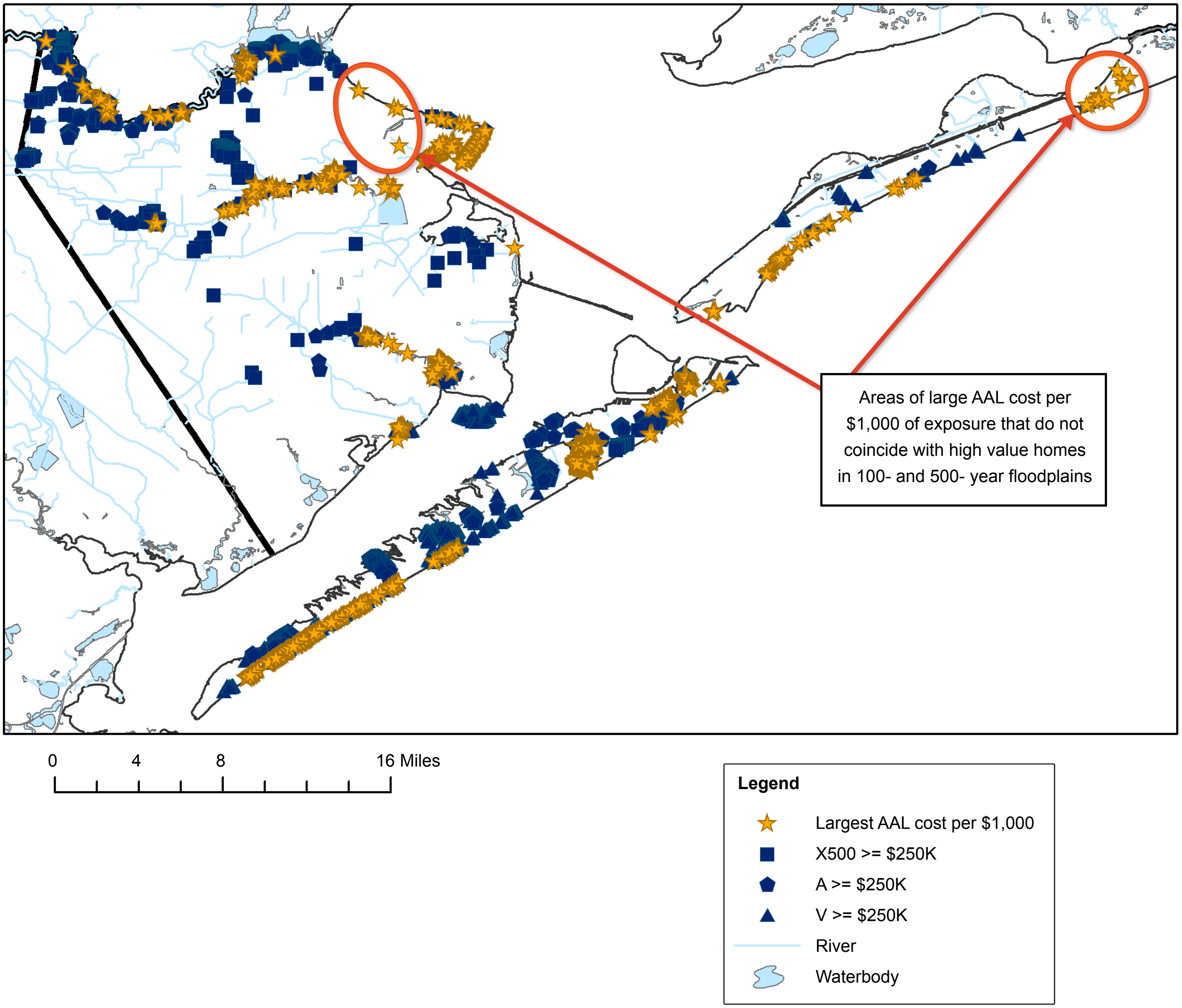
[36] For chart scaling purposes the number of residences was truncated at 7,000. There are 16,304, 12,157, and 10,918 X zone residences in each of the $1.00, $2.00 and $3.00 AAL cost per $1,000 of exposure ranges.

[37] This result may simply be due to the total number of residences in the X500 zone being nearly four times larger than the number in the V zone (18,922 vs. 5,355 respectively).

Finally, in order to give a geographical sense of where the largest AAL cost per $1,000 of exposure values are occurring, Figure 4.14 highlights the location of the 1,940 homes with an AAL cost per $1,000 greater than or equal to $10.01 (the last four AAL cost per $1,000 of exposure ranges from Figure 4.13). For comparative purposes, the 3,005 homes with building values greater than or equal to $250,000 in the FEMA V, A, and X500 flood zones from Figure 4.9 are also included (now all dark shapes). The circled areas denote homes with large AAL cost per $1,000 of exposure occur do not coincide with the high value homes in the 100- and 500-year floodplains.



Areas of large AAL cost per $1,000 of exposure that do not coincide with high value homes in 100- and 500- year floodplains

Figure 4.14 Geographic Distribution of Largest AAL Cost per $1,000 of Exposure

Accounting for the Galveston Seawall

As discussed in section 3.2.3, the model can be explicitly modified to account for locations at which a specific level of flood protection is already in place such as the Galveston seawall located on Galveston Island in Galveston County. Flood protection is currently available in the model to be set as either protection against 100-year or 50-year floods for riverine flooding, or similarly for Category 2 or Category 1 hurricanes for storm surge flooding. A total of 11,895 residences on Galveston Island (13.4 percent of the total Galveston County residences) were identified as being near enough to the seawall location to be assumed protected to some level by the Galveston seawall. For the identified X and X500 flood zone residences on Galveston Island protected by the seawall (733 and 2,147 residences respectively), flood protection is set to 100-year/Category 2 protection, while for the identified A and V zone residences on Galveston island protected by the seawall (7,231 and 1,784 residences respectively), flood protection is set to 50-year/Category 1 protection.[38] Figure 4.15 illustrates the 11,895 homes on Galveston Island modified from the original model loss estimation.

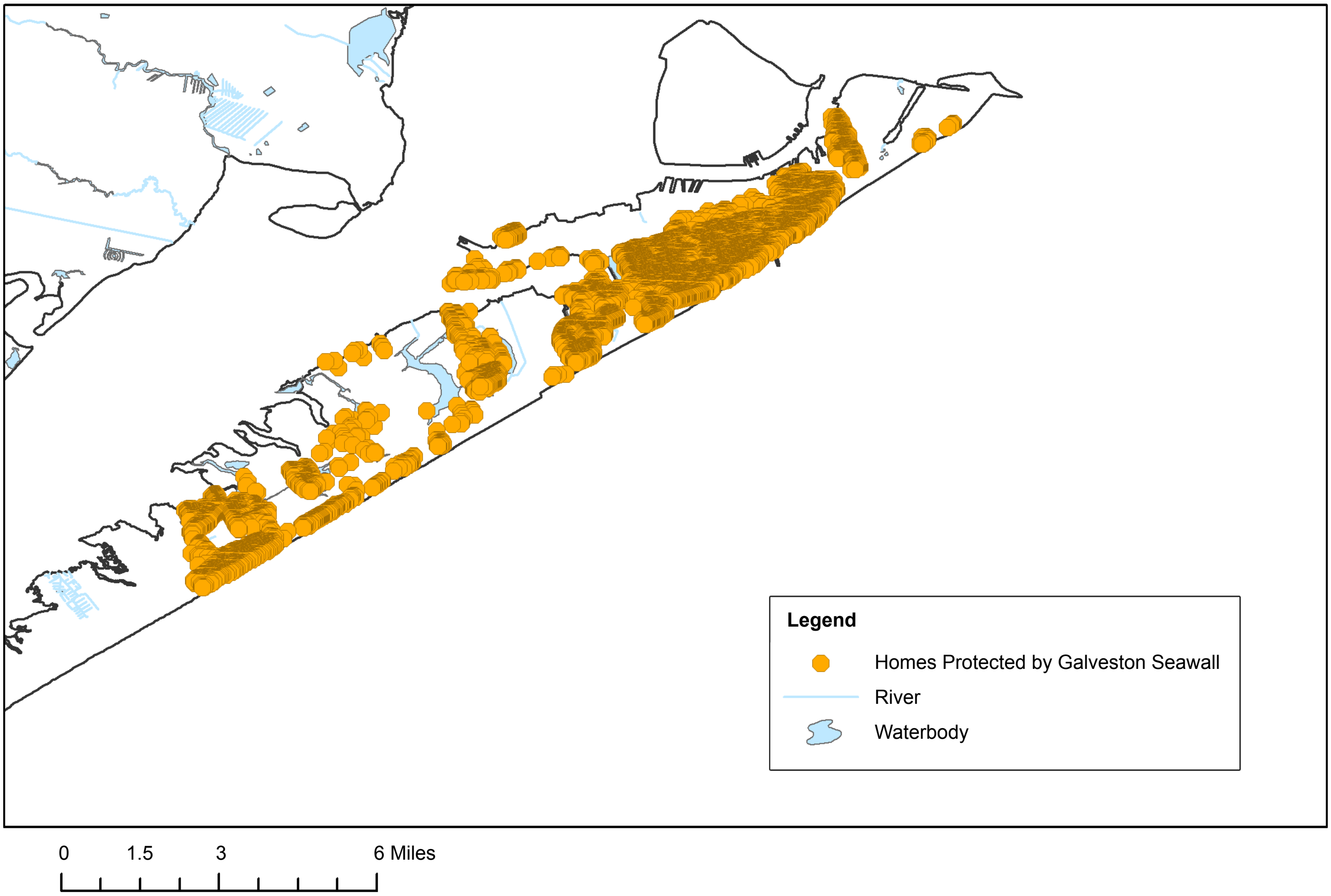


Figure 4.15 Homes on Galveston Island Assumed Protected by the Galveston Seawall

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[38] It is important to point out that a more detailed engineering and flood inundation study is necessary to properly determine the exact number of residences protected by the seawall and at what level the seawall actually provides flood protection for these residences. Our analysis here is meant to give a rough estimate of this protection in order to begin to account for the seawall protection in our loss estimates.

Table 4.9 presents a summary of the changes to the loss values not explicitly accounting for the Galveston seawall that were provided in Table 4.8. Overall, there is a 4.4 percent decrease in the total county AAL, with the largest decrease in total AAL occurring in the A zone, changing from $17.3 million to $15.5 million (an 11.1 percent decrease). All of the loss differences are due to storm surge losses only. In terms of mean AAL cost per $1,000, the A zone again has the largest decrease, going from $6.31 to $5.66. Our analysis here is meant to give a rough estimate of the impact of the seawall protection on the loss estimates provided above. Given the relatively small amount of impact on the loss results, as well as the level of uncertainty in properly accounting for the protection, we feel comfortable moving forward with the loss values from Table 4.8 for the remaining analyses of this report. However, we do note that a more in-depth accounting of this protection (as well as other protective measures in place in either county) is necessary in the loss estimation.

TABLE 4.9 SUMMARY OF LOSSES ACCOUNTING FOR GALVESTON SEAWALL

FEMA Flood Zone	# of Single-Family Residences	# of Impacted Residences (with Seawall)	% of Residences	Total AAL (Seawall N/A)	Total AAL (with Seawall)	% Decrease	Mean AAL Cost per $1000 (Seawall N/A)	Mean AAL Cost per $1000 (with Seawall)	% Decrease
V	5,355	1,784	33%	$ 9,510,124	$ 9,510,124	0.0%	$ 6.60	$ 6.60	0.0%
A	17,940	7,231	40%	$17,387,809	$15,464,157	-11.1%	$ 6.31	$ 5.66	-10.4%
X500 / B	18,922	2,147	11%	$ 9,181,099	$ 9,034,088	-1.6%	$ 4.21	$ 4.15	-1.6%
X / C	46,829	733	2%	$11,771,568	$11,733,426	-0.3%	$ 1.64	$ 1.63	-0.5%
Galveston County Total	**89,046**	**11,895**	**13%**	**$47,850,600**	**$45,741,796**	**-4.4%**	**$ 3.43**	**$ 3.28**	**-4.4%**

The next chapter compares these probabilistic results for Travis and Galveston Counties to related NFIP premiums.

Chapter 5

How Do the Pure Premiums Based on Our Probabilistic Flood Risk Assessment Compare with NFIP Premiums?

Chapter 5 Summary

Benefitting from unique access to the NFIP portfolio, this chapter provides a comparison of pure insurance premiums generated by our probabilistic flood model with NFIP premiums for Travis and Galveston Counties. Two levels of analysis were undertaken.

- **Unloaded premium comparison.** As discussed in Chapter 2, NFIP rates are essentially set for each flood zone for the nation as a whole, prompting concerns that some of these rates may not accurately reflect the flood risk a specific building faces as detailed probabilistically defined rates would. To shed some light on this question, we determine ***unloaded*** **NFIP premiums** by subtracting the administrative costs and fees the program pays to participating insurers and agents (which together represent a 50 percent loading) from the full NFIP premiums. We then compare those premiums to the results obtained with the catastrophe model.

  We find that the unloaded premiums currently charged by the NFIP are “too high” in some areas and “too low” in others relative to the probabilistic flood model results. For example, in Travis County (see Table 5.3), the NFIP on average seems to underprice the risk in A zones (high risk), but overprices the risk in the X500 and X zones (moderate and low risk) compared to the probabilistic model results in these zones. Consequently, the NFIP may not be adequately covering itself in the Travis County high risk zone and could be negatively impacting take-up rates in the moderate and minimal risk zones, potentially fostering adverse selection and fiscal insolvency. Furthermore, even in the Travis County A zones where the NFIP on average underprices the risk compared to the probabilistic results, this does not hold in absolute terms, where 50 percent of the A zone unloaded premiums from our study fall below average NFIP A zone premium amount. In Galveston County (see Table 5.4), our findings show that the NFIP on average may be underpricing the flood risk in the A, X500 and X zones, not adequately covering itself against the risk of storm surge in these areas compared to the probabilistic model results in these zones. On the other hand, NFIP premiums are higher on average than what the model predicts in V zones. Here, it may be negatively impacting take-up rates in specific high-risk coastal areas.

  This is likely to have important implications for the financial balance of the NFIP in Texas; for instance, while Galveston County has only about 3,000 policies in V zones, there were 20,000 claims for Hurricane Ike’s related storm surge flooding in 2008 in that county, potentially 85 percent of which were underpriced because they were out of the V zone.

- **Loaded premium comparison.** Even if probabilistic models are able to more accurately assess risk in a specific location, there is concern that the premium private insurers would charge would have to be much higher than what the NFIP currently charges in order to account for specific expenses private insurers face that the NFIP does not. Those additional costs include taxes, cost of capital, reinsurance and dividends to their shareholders, among others. Surprisingly, no systematic analysis has been undertaken yet to support or invalidate this concern.

We undertake a series of comparative analyses between the **full cost** charged by the NFIP and what would be charged by private insurers if they applied a loading cost of 50 percent, 100 percent, 200 percent, and 300 percent (to reflect different market conditions and expenses they face) on top of the pure premium we have calculated in previous chapters.

In flood zones where the NFIP is underpricing the risk on average relative to the probabilistic model results, such as the Travis and Galveston County A zones, this price discrepancy with what insurers would charge will only be further magnified with high loading factors (see Tables 5.5 and 5.6).

However, for those areas where the NFIP is overpricing the risk on average relative to the probabilistic model results, such as the Travis County X500 and X zones and the Galveston County V zones, we find that, in general, a private insurer's loading factor of 200 percent (that is, a tripling of the unloaded pure premium) must be applied for private insurers to charge more than what the NFIP is currently charging in these areas (see Tables 5.5 and 5.6).

Our analysis thus reveals that there might be important opportunities for the private insurance sector to become much more active in selling flood insurance. This could be done in complement to the NFIP if insurers are capable of determining in a granular fashion where residents are overcharged by the NFIP compared to what the insurers could offer. This could increase take-up rates and ensure more individuals are effectively covered against floods.

Chapter 2 discussed how NFIP premiums are set (before the application of some subsidies for those residences built before flood maps were established). According to FEMA, those premiums are "actuarially-based." The determination of this actuarial rate is used to calculate rates for A and V zones that vary by elevation difference of the structure from the 1 percent flood elevation. Although the model calculates rates for a variety of floodplains within the A and V zones, the final elevation based rates are set for each flood zone for the nation as a whole; rates for comparable structures with the same elevation difference in similar flood zones are the same everywhere in the country.

In the previous chapter, we have shown how a microanalysis of flood exposure revealed important discrepancies in how those different flood maps reflect the risks for a given set of houses. Consequently, rates are not always truly actuarially risk-based at the local level (probabilistically defined), but rather are averaged across flood zones. As a result, flood insurance costs are likely to be "too high" in some areas and "too low" in others when compared to the results based on probabilistic risk assessments. Without a detailed analysis of expected losses in various locations, however, it is impossible to say if, and by how much, the costs charged for NFIP policies may deviate from true risk-based rates (i.e. pure premiums). The purpose of this chapter is to make such a comparison.

5.1 NFIP Premiums[39]

We first present the Travis and Galveston NFIP premium values based upon 2009 NFIP policy data for those NFIP policies indicated as currently active and of single-family occupancy type. As the 2009 NFIP dataset to which we have access does not identify the county location per policy, we use the ZIP codes per county from our Galveston and Travis County model exposure modules to extract matched single-family policy data. A total of 60 ZIP codes from our catastrophe model exposure module are used to extract associated NFIP single-family policy data for Travis County and a total of 17 ZIP codes from our catastrophe model exposure module are used to extract associated NFIP single-family policy for Galveston County. However, there are certain ZIP codes within each county that are not restricted to that county for the NFIP data extracted.[40] Further, we have not accounted for the subsidies inherent to the NFIP data. Finally, in order to simplify the analysis, these 2009 NFIP rates have not been adjusted for inflation.[41] NFIP premium data for Travis County are presented in Table 5.1 and NFIP premium data for Galveston County are presented in Table 5.2.

TABLE 5.1 TRAVIS COUNTY 2009 NFIP PREMIUM DATA[42]

Flood Zone*	# of Single-Family Residences	Total Insured Value**	Total Premium	Average NFIP Premium	Average Premium per $1,000 Insured Value	Minimum Premium per $1,000 Insured Value	Maximum Premium per $1,000 Insured Value
A	3,726	$ 687,402,200	$ 2,847,520	$ 764	$ 5.18	$ 0.87	$ 222.00
X500 / B	48	$ 8,375,000	$ 33,118	$ 690	$ 4.76	$ 0.99	$ 10.98
X / C	3,949	$1,033,052,900	$ 1,406,645	$ 356	$ 1.68	$ 0.79	$ 13.29
Travis County Total	**7,723**	**$1,728,830,100**	**$ 4,287,283**	**$ 555**	**$ 3.39**	**$ 0.79**	**$ 222.00**

* The NFIP rate structure does not distinguish between X500/B and X/C flood hazard areas, and charges the same premium to structures in both of those areas.
** NFIP Insured Value = Total Building + 40% Total Content insured values. Deductibles are not subtracted.

From Table 5.1, we see that approximately 48 percent of the active single-family policies in Travis County are located in the A zone representing nearly 40 percent of the total county insured value, and that the X zone has 51 percent of the number of policies representing nearly 60 percent of the county total insured value. This compares to 95 percent of residences and total exposure values in the X zone from Travis County for the catastrophe model exposure data provided in Table 4.1. Comparing NFIP average premiums per $1,000 insured value across zones we find that premiums in the A zone ($5.18) are 1.1 times larger than in the X500 zone ($4.76) and 3.1 times larger than the X zone ($1.68). In comparison, from the probabilistic model, we found that AAL in the A zone were 3 times higher than in the X500 zone and 18 times higher than in the X zones for Travis County (Table 4.4). Finally, looking across the distribution of NFIP premium per $1,000 of coverage values we see the largest value is in the A zone ($222); this value is significantly higher than the largest values in the X500 and X zones ($10.98 and $13.29) (Table 5.1). This stands in contrast to the AAL results from our probabilistic model that had the largest maximum value in the X zone and the range of values similar across zones (see Table 4.4).

Table 5.2 shows that approximately 28 percent of the active single-family NFIP policies in Galveston County are located in the 100-year V and A zones representing nearly 24 percent of the total county insured value, and that the X zone has 63 percent of the number of policies representing nearly 68 percent of the county's total insured value. Excluding the X500 zone, these percentages compare relatively well to the total residences and total exposure percentage values from Galveston County for the catastrophe model exposure module data provided in Table 4.5. Comparing average NFIP premiums per $1,000 insured value across zones, we find that the V zone ($14.17) is 2.8 times larger than the A zone ($5.18), 7.4 times larger than the X500 zone ($1.92) and 9.9 times larger than the X zone ($1.44). This

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[39] Michel-Kerjan thanks FEMA for providing this data for research purpose.

[40] In other words, while our model results are limited to Galveston and Travis, the NFIP data extracted may contain ZIP code policy data that is shared by a neighboring county other than Galveston or Travis. However, we did conduct a series of robustness checks on this matched ZIP code data including previous year data matched by named county as well as accounting for those ZIP codes that had the shared data. The results produced from these analyses are very similar to those presented.

[41] Inflation since 2009 has been relatively low, 1.6% from 2009 to 2010 (U.S. inflation calculator - http://www.usinflationcalculator.com), and more significantly for our study the most critical component of a general measure of inflation, housing price values, have actually been falling since 2009 in most major metropolitan markets. Further, we compared changes to year over year 2008 and 2009 NFIP premiums for matched policies in our analysis dataset that also had no changes to their policy in terms of content and deductible coverage. For these homes, 60% of the policies in Travis and 80% of the policies in Galveston had no change to their premium between 2008 and 2009.

[42] Note that the average premium per $1,000 insured value from this table will not match to the similar Travis County value provided earlier in Table 3.1 for a number of reasons most notably the difference in time (2009 vs. 2008) and exposure values along with the aforementioned matched ZIP codes this table is based upon. Nonetheless, the county values are relatively similar—$3.39 above vs. $2.51 from Table 3.1.

compares to the V zone being approximately the same as the A zone and 1.5 and 4 times higher than the X500 and X zones respectively from the catastrophe model AAL cost per $1,000 results for Galveston County from Table 4.8. Finally, looking across the distribution of NFIP premiums per $1,000 of coverage values, we see the largest value in the A zone and that the V zone maximum value is significantly higher than the values in the X500 and X zones. This stands in contrast to the AAL cost per $1,000 results from our probabilistic model which had the largest maximum value in the A zone, but the other range of values are similar across zones, especially between V and X500/X zones.

TABLE 5.2 GALVESTON COUNTY 2009 NFIP PREMIUM DATA[43]

Flood Zone*	# of Single-Family Residences	Total Insured Value**	Total Premium	Average NFIP Premium	Average Premium per $1,000 Insured Value	Minimum Premium per $1,000 Insured Value	Maximum Premium per $1,000 Insured Value
V	2,938	$ 704,947,600	$ 9,751,336	$ 3,319	$ 14.17	$ 2.62	$ 73.47
A	16,286	$ 3,297,771,000	$ 12,968,810	$ 796	$ 5.12	$ 0.21	$ 118.00
X500 / B	5,988	$ 1,237,473,000	$ 1,923,657	$ 321	$ 1.92	$ 0.93	$ 17.10
X / C	43,432	$11,335,174,200	$ 14,048,862	$ 323	$ 1.44	$ 0.86	$ 15.47
Galveston County Total	**68,644**	**$16,575,365,800**	**$ 38,692,665**	**$ 564**	**$ 2.90**	**$ 0.21**	**$ 118.00**

* The NFIP rate structure does not distinguish between X500/B and X/C flood hazard areas, and charges the same premium to structures in both of those areas.
** NFIP Insured Value = Total Building + 40% Total Content insured values. Deductibles are not subtracted.

Given the way FEMA sets its rates across flood zones as discussed earlier, it is not surprising to see average rates in the various counties being nearly equal. For example, the average NFIP premium per $1,000 of insured value in the high-risk A zone is $5.18 in Travis County and $5.12 in Galveston County. The same is true for low risk X/C zones, where the average NFIP premium per $1,000 of insured value is $1.68 in Travis County and $1.44 in Galveston County.

5.2 Comparing "Apples with Apples"

As discussed in Chapter 2, in order to set premiums and support local governments, the NFIP maps participating communities, designating flood risks through different flood zones. These maps are called Flood Insurance Rate Maps (FIRMs). Prices for insurance, which are set nationally by the NFIP, vary by contract (deductible and limit), flood zone and elevation, characteristics of the house and whether that house has been built before the map was established (pre-FIRM; in which case it receives a subsidy, see below). They do not otherwise vary by state or locality.

Without a detailed analysis of expected losses in various locations, however, it is impossible to say if, and by how much, the costs charged for NFIP policies may deviate from true risk-based rates (i.e., pure premiums). The purpose of this chapter is to make such a comparison. However, this comparison is not a perfect one and here we discuss some of the limitations of this exercise. As detailed in section 3.2, our analysis does not assume any deductible per each single-family residence analyzed,[44] nor does the model explicitly account for the structural characteristics of the house. We also do not have detailed information on whether the homes in our analysis were built pre or post-FIRM, nor again, have we accounted for the subsidies inherent to the NFIP data. Further, the building and content market values used in this analysis have not been capped at the $250,000 and $100,000 NFIP coverage limits[45] as we are interested in understanding the pure premium requirement from the private insurer perspective, even though we are comparing that rate against sub-limited coverage.

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[43] Note that the average premium per $1,000 insured value from this table will not match to the similar Galveston County value provided earlier in Table 3.1 for a number of reasons most notably the difference in time (2009 vs. 2008) and exposure values along with the aforementioned matched ZIP codes this table is based upon. Nonetheless, the county values are relatively similar—$2.90 (Table 5.2) vs. $2.80 (Table 3.1).

[44] NFIP premiums we use here are thus likely to be slightly lower than they would be without deductible; that said, previous analyses have revealed that a large majority of NFIP policyholders select the lowest possible deductible, $500, so the "deductible effect" is likely to be minimal.

[45] The statutory caps on NFIP coverage pose a challenge to the NFIP rate structure. We find that 35% and 36% of NFIP single-family policyholders in Galveston and Travis Counties, respectively, purchase the maximum quantity of insurance available to them (i.e., $250,000 for building coverage); as a result many of those are potentially significantly under-insured compared to full replacement cost of the building, resulting in an underinsurance loading in the NFIP rates.

Therefore, the comparison must account for this exposure difference given that everything else being equal, the higher the exposure/quantity insured, the higher will be the AAL/premium. In this regard, the ratio of AAL over quantity of exposure per $1,000 from our model results is compared to the ratio of premium over quantity of insurance from the NFIP data including limits. Again, given the inherent exposure differences between the two datasets this is a better comparison than the AAL or the premium per policy, although this data is also presented. Finally as discussed in section 5.1, due to a lack of county geographical identification in our NFIP data, and while our model results will be limited to Galveston and Travis Counties, the NFIP data extracted may contain ZIP code policy data that is shared by a neighboring county other than Galveston or Travis.

5.3 Unloaded Premium Comparison and Discussion

Our Chapter 4 results are the calculation of the unloaded "***pure premium***," that is, the average annual loss accounting for the potential of a catastrophe but without any subsidy or administrative cost being loaded into the cost of insurance. In order to compare this *unloaded* premium to a similar unloaded NFIP premium, administrative expenses from the NFIP premium rates must be taken out. A detailed financial analysis of the program between 1968 and 2008 reveals that the NFIP charged on average a 50 percent loading on top of what is considered to be the actuarially based rate (that is, the expected loss as calculated by FEMA based on the average annual loss). This loading is charged to the policyholders to pay for different expenses the program faces (fees to participating insurers and agents which sell flood insurance policies on behalf of the NFIP and assess claims but do not bear any risk, operating costs of the program, flood risk maps, etc.) (Michel-Kerjan, 2010). To determine the unloaded premiums for NFIP policies, we thus reduce the full premiums by a third.

Table 5.3 presents the results of our unloaded premium comparison for Travis County using the NFIP data from Table 5.1 adjusted for administrative expenses.[46] AAL data are based on our analysis in the previous chapter using the CoreLogic and Swiss Re probabilistic flood risk assessment models. Note that the comparison is based on 7,723 residences in the comparable NFIP dataset for the 60 matched Travis County ZIP codes. This difference is greatest in the X500 (X) zone with the 48 (3,949) NFIP policies collected representing less than 1 percent (2 percent) of the single-family residences in Travis County within the X500 (X) zone from our model.

TABLE 5.3 TRAVIS COUNTY UNLOADED PREMIUM COMPARISON: UNLOADED PROBABILISTIC FLOOD MODEL AND UNLOADED NFIP

	Travis County Study AAL Data			**2009 NFIP Unloaded Premium Data***		
FEMA Flood Zone	**# of Single-Family Residences**	**Mean Total AAL per home**	**Mean AAL Cost per $1,000**	**# of Single-Family Residences**	**Adjusted (67%) Average NFIP Premium**	**Adjusted Average Loss Cost per $1,000**
A	6,790	$ 1,508	$ 5.51	3,726	$ 512	$ 3.47
X500 / B	5,010	$ 461	$ 1.69	48	$ 462	$ 3.19
X / C	214,607	$ 18	$ 0.07	3,949	$ 239	$ 1.13
Travis County Total	**226,407**	**$ 73**	**$ 0.27**	**7,723**	**$ 372**	**$ 2.30**

*NFIP data is for matched ZIP codes which are not necessarily restricted to Travis County.

A key result from this comparison is that the average probabilistically-based pure premium (as an outcome of our catastrophe model) is sometimes higher and sometimes lower than the comparable average premium being charged by the NFIP. For example, and as circled in Table 5.3, the average NFIP premium for the X500 zone is $3.19 per $1,000 of coverage vs. the average $1.69 per $1,000 of exposure from our probabilistic model. A similar lower average probabilistic pure premium model result holds for the X zone as well ($1.13 vs. $0.07). However, in the Travis County A zone we see that the average probabilistic pure premium per $1,000 of exposure ($5.51) is roughly 1.5 times larger than the comparable average NFIP premium ($3.47).

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[46] We also conducted a similar analysis for the 188,496 homes in Travis County with building value less than or equal to the NFIP building value coverage limit of $250,000 (83% of total homes analyzed). Average annual loss cost results per $1,000 were very similar.

But even in the case of the A zone's higher average unloaded premium, the probabilistic result is not larger in absolute terms. Figure 5.1 below shows the distribution of unloaded model and NFIP premiums for the 6,790 homes analyzed by the model and the 3,726 homes with an NFIP policy in the Travis County A zone. For example, in focusing on the percentage of total policies where the average premium per $1,000 of coverage is less than or equal to a dollar, we see that 17 percent of the 6,790 homes from our study fall into this category compared to 14 percent of the 3,726 NFIP policies. Clearly, a significant number of the 6,790 A zone unloaded premiums from our study fall below the average NFIP A zone premium amount of $3.47, 50.1 percent, to be exact. Similarly, 84.1 percent of the 5,010 X500 policies from the model have an unloaded premium less than the average X500 NFIP premium of $3.19, and 99.2 percent of the 214,607 X zone policies from the model have an unloaded premium less than the average X zone NFIP premium of $1.13.

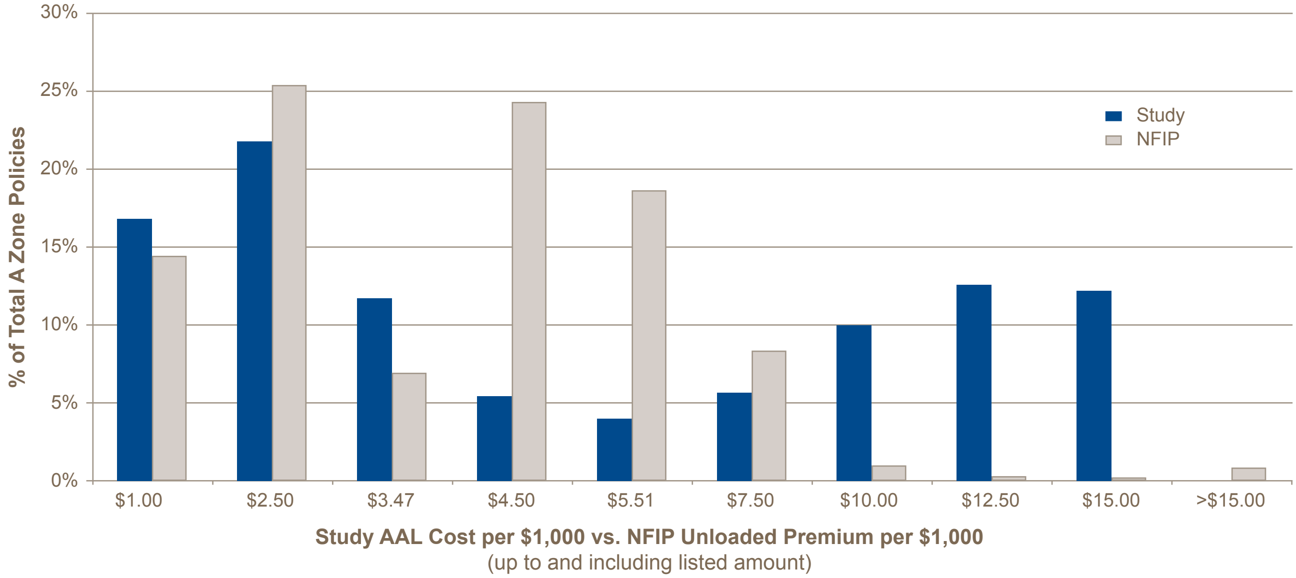

Figure 5.1 Travis County A Zone Distribution of Unloaded Model and NFIP Premiums

* Note: this figure is not a direct comparison between the same homes as we do not have access to the NFIP data at this level; rather, it is a summary of the premium distribution for the 6,790 homes in the study and the 3,726 NFIP policies in the Travis County A zone.

Our analysis thus reveals that, in general, the NFIP in Travis County is on average underpricing the risk in the A zone, but overpricing the risk in the X500 and X zones compared to the probabilistic premium generated from our model.47 This is an important result. Indeed, the NFIP is often criticized for not being able to deter adverse selection, i.e., only those most at-risk participate in the program.

Table 5.4 presents the results of our unloaded premium comparison for Galveston County using the NFIP data from Table 5.2 adjusted for administrative expenses.[48] For Galveston County, the model results are based upon 89,046 residences while there are 68,644 residences in the comparable NFIP dataset for the 17 matched Galveston County ZIP codes. This difference is greatest in the X500 zone with the 5,988 NFIP policies collected representing 31.6 percent of the single-family residences in Galveston County within the X500 zone from our model. Based upon our data for the two counties, it appears the NFIP market penetration rates are significantly higher in Galveston. The large number of NFIP X zone policies in Galveston (93 percent of the 46,829 model policies) seems to support the notion that there is significant risk in this X zone despite its classification of minimal risk.

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[47] Of course, these conclusions must be taken with caution given the differences in the datasets as detailed in section 5.2. Additionally, an exact single-family residence comparison is not able to be completed given the access limitations of the NFIP dataset. For example, we cannot match the unloaded premiums from the 3,726 NFIP A zone policies to the exact same parcels from our model because we do not know the exact location of these 3,726 NFIP policies. If we had access to this geospatial data, we could do this comparison.

[48] We also conducted a similar analysis for the 83,666 homes in Galveston County with building value less than or equal to the NFIP building value coverage limit of $250,000 (94% of total homes analyzed). Average annual loss cost results per $1,000 were very similar.

TABLE 5.4 GALVESTON COUNTY UNLOADED PREMIUM COMPARISON: UNLOADED PROBABILISTIC FLOOD MODEL AND UNLOADED NFIP

	Galveston County Study AAL Data			2009 NFIP Unloaded Premium Data*		
FEMA Flood Zone	**# of Single-Family Residences**	**Mean Total AAL per home**	**Mean AAL Cost per $1,000**	**# of Single-Family Residences**	**Adjusted (67%) Average NFIP Premium**	**Adjusted Average Loss Cost per $1,000**
V	5,355	$ 1,776	$ 6.60	2,938	$ 2,224	$ 9.49
A	17,940	$ 969	$ 6.31	16,286	$ 534	$ 3.43
X500 / B	18,922	$ 485	$ 4.21	5,988	$ 215	$ 1.29
X / C	46,829	$ 251	$ 1.64	43,432	$ 217	$ 0.96
Galveston County Total	**89,046**	**$ 537**	**$ 3.43**	**68,644**	**$ 378**	**$ 1.94**

* Matched NFIP ZIP codes are not restricted to Galveston County.

In comparing the unloaded premiums across flood zones (note that the mean AAL cost per $1,000 of exposure values from our study are the same as those presented in Table 4.8 from Chapter 4), we see that the average probabilistically-based pure premium as an outcome of our model is not always higher than the comparable average premium being charged by the NFIP, here in the V zone only.[49] The average NFIP premium for the Galveston County V zone is $9.49 per $1,000 of coverage versus $6.60 per $1,000 of exposure from our model. However, in all other zones we see that the average probabilistic pure premium per $1,000 of exposure ($6.31, $4.21, and $1.64 in the A, X500 and X zones respectively) is roughly 1.7 to 3.2 times larger than the comparable average NFIP premiums ($3.43, $1.29, and $0.96). This seems to indicate that the NFIP is on average underpricing the risk of storm surge in these zones which is the main driver behind the probabilistic model unloaded premium results. On the other hand, it appears to be on average overpricing the risk of storm surge in the V zone, one of the two areas where the impact of storm surge flooding is limited by the FEMA flood zone designations. In fact, 90.1 percent of the 5,355 V zone unloaded premiums from our study fall below the average NFIP premium amount of $9.49. However, only 12.1 percent of the 17,940 A zone policies from the model have an unloaded premium less than the average NFIP A zone premium of $3.43. Furthermore, 2.6 percent of the 18,922 X500 zone policies and 34.5 percent of the 46,829 X zone policies are below the respective $1.29 and $0.96 NFIP X500 and X zone average unloaded premiums.

5.4 Loaded Premium Comparison and Discussion

The NFIP's goals with regard to setting prices differ from those of a private insurance company because the NFIP does not seek a profit, nor must its prices reflect the cost of capital private insurers need to set aside to meet solvency requirements from regulators and rating agencies. In this section, we are interested in comparing the full premiums charged by the NFIP to what private insurers would have to charge given their own constraints should they want to offer the same coverage.

Results provided in Chapter 4 presented the unloaded "pure premium," that is, the average annual loss accounting for the potential of a catastrophe but without any subsidy or administrative cost being loaded into the cost of insurance. In order to compare this unloaded premium to a loaded NFIP premium, an appropriate private sector's loading factor must be added to the model pure premium values. Table 5.5 presents the results of our loaded premium comparison for Travis County using as-is loaded values of the NFIP from Table 5.1 compared to loaded values of the average loss cost per $1,000 model results from Table 4.4 with loading factors of $\lambda = 0.5$, 1, 2, and 3 (50 percent, 100 percent, 200 percent, 300 percent). Here it is important to note that there is no such thing as a unique loading factor for all insurers. This loading will depend on the characteristics of each firm, its portfolio diversification across geographies and types of risks (e.g., an insurer covering hurricane risks in coastal states might diversify its portfolio by selling flood risk insurance in Minnesota), correlation of risks regions, and hazards it covers (for example, riverine flooding versus storm surge), whether or not it purchases some reinsurance and if so at what price, taxes it has to pay, administrative costs, etc. What is often misunderstood though, is that this loading factor can be particularly high when the insurer covers catastrophic risks (since the capital it needs to set aside will be very costly) (see sidebar 5A which provides a simplified view of the mechanism).

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[49] This result also holds when using the AAL values accounting for the Galveston seawall presented at the end of Chapter 4 ($6.60, $5.56, $4.15, and $1.63 for the V, A, X500, and X zones respectively).

Sidebar 5A: Importance of the Cost of Capital

The importance of capital as a requisite to secure an adequate rate of return is often not sufficiently understood. In particular, the prices charged for catastrophe insurance must be sufficiently high to cover the expected claims costs and other expenses, but also must cover the costs of allocating risk capital to underwrite this risk (to pay losses that cannot be funded from cash flow [premium income]). Moreover, because large amounts of risk capital are needed to underwrite catastrophe risk relative to the expected liability, the resulting premium is high relative to its loss expenses, simply to earn a fair rate of return on equity and thereby maintain the insurer's credit rating.

There is indeed a temptation for parties to imbue the notion of a fair premium to serve their own interests. For example, the term "actuarially fair premiums" has a precise definition: the premium is equal to the expected loss. Much of the public debate surrounding a fair price of catastrophe insurance implicitly uses the concept of actuarially fair premium because it is simple and results in a low cost to the policyholder. However, while "actuarially fair" is a useful statistical concept, the implied premiums are not economically sustainable; insurers must cover their fixed costs and marketing expenses in addition to their expected claims in order to survive and attract capital.

An expanded understanding of fair premiums derives from the notion of a fair rate of return on capital. A fair return is one that offers the investor a competitive return on capital so that the investor will want to place its funds with the insurer rather than elsewhere. A fair premium would then be one that just offered the investor a fair rate of return. To offer a fair return, the premium would have to cover all costs (expected claims, expenses of various sorts and taxes), and then produce an expected return to the investor which was equal to the cost of capital or fair return. The premium would yield some profit, but only the normal level of profit necessary to attract and maintain the insurer's capital base.

While a sustainable premium must offer a return consistent with the cost of capital, we need also to pay attention to how much capital the insurer will want to have so that it can promise to pay claims with an acceptably low probability of default. The amount of capital necessary to do so will depend on the risk characteristics of its liability portfolio, its asset portfolio and the effectiveness of its risk management strategy. What is an acceptably low risk will be interpreted differently by prospective policyholders, by regulators and by rating agencies who impose standards ostensibly on behalf of such policyholders. For current purposes, we can think of the economic capital as that required to maintain the insurer's credit rating or the capital needed to satisfy regulatory requirements if this is higher than the rating agency's requirements.

Each policy the insurer sells imposes its own capital burden. If an additional policy were sold without adding to the insurer's overall capital, there would normally be a small increase in the likelihood that the insurer would default. Just how much of a change would depend on the riskiness of the policy and its covariance with other policies and assets held by the insurer. The appropriate allocation of capital to a policy would be that amount required to maintain the insurer's credit status; i.e., the addition of the policy and the accompanying capital would leave the insurer with the same credit status as before.

We thus define a fair price for insurance as a premium that provides a fair rate of return on invested equity. To illustrate, we construct a somewhat conservative hypothetical example that ignores taxes and regulatory constraints. Consider a portfolio that has $1,000 in expected losses, E(L). Let k be the ratio of capital to expected losses for the insurer to maintain its credit rating. For this example k=1, a value utilized by many property liability insurers for their combined book of business.

In addition to paying claims, the insurer is assumed to set aside capital for covering additional expenses (X) in the form of commissions to agents and brokers, and underwriting and claims assessment expenses. For this example, X = $200. Given the risk characteristics of the portfolio, investors require a return on equity (ROE) of 15 percent to compensate for risk. The insurer invests its funds in lower-risk vehicles that yield an expected return, r, of 5 percent. What premium π would the insurer have to charge its policyholders to cover them against natural disasters and to secure a return of 15 percent for its investors?

The formula is given by:

$$\pi = \frac{E(L) + X(1+r)}{(1+r) - k(ROE - r)}$$

which yields a value of π = $1,274 for this hypothetical example. We can think of this premium now as the expected loss of $1,000 plus a proportionate loading, λ, of 0.274. Thus, the premium is

$$(1+\lambda)E(L) = (1 + 0.274)\$1,000 = \$1,274$$

This calculation is very sensitive to the ratio of capital to expected liability, k, needed to preserve credit. In the above example, the ratio was one dollar of capital for one dollar of expected liability. This ratio is in the ballpark for the combined books of business of many property liability insurers. However, for catastrophic risk, with its very large tail risk (which severely affects the insurer's credit risk), the capital to liability ratio needs to be higher. Indeed, the capital to liability ratio depends on volatility of the catastrophe liability and its correlation with the insurer's remaining portfolio. For the catastrophe risk premium for individual homeowners, this may translate into a loading, λ, perhaps approximating 0.5. Thus the premium would be 150 percent of the expected loss. This does not reflect undue profitability, but simply that insurers need considerable capital to supply this insurance and the cost of that capital is included in the premium.

When it comes to reinsurance of catastrophic risk, the relative capital cost is much higher. For higher layers of catastrophe reinsurance, the expected loss is often quite low and the volatility very high. At these layers, the required capital/liability ratio can be considerably greater than the one-to-one used in the above example. An increase in the capital/liability ratio will increase the premium required to generate a fair return on equity.

A second issue with respect to catastrophic risk is that it can be expensive to underwrite since it requires extensive modeling. Many companies buy commercial models and/or use their own in-house modeling capability. We recalculate the premium formula with X = $600 and k = 5. The required premium is now $2,965, more than twice the value of π computed above and now nearly three times the expected loss. Notice this translates into a loading, λ, of 1.965, so the premium is

$$(1+\lambda)E(L) = (1 + 1.965)\$1,000 = \$2,965$$

Sources: Kunreuther and Michel-Kerjan (2011), Chapter 6.

From our unloaded premium comparison in the previous section, we know that average NFIP premium per $1,000 was higher than the average pure premium per $1,000 from our model in the X500 and X zones in Travis County. We see from Table 5.5 that in order for loaded market values in the X500 zone to be greater than the loaded NFIP values on average, a loading factor of 2 must be applied, or a tripling of the unloaded pure premium. In the X zone, even applying a loading factor of up to 2 we see that the loaded pure premium values are still significantly lower than the NFIP premiums on average. This result still holds if using the $0.31 mean AAL cost per $1,000 value for only those homes in the Travis County X zone with some level of flood peril loss.

TABLE 5.5 TRAVIS COUNTY LOADED PREMIUM COMPARISON: PROBABILISTIC FLOOD MODEL WITH VARIOUS LOADING FACTORS AND LOADED NFIP

	NFIP	**Study AAL**				
FEMA Flood Zone	**Average Premium Loss Cost per $1,000**	**Unloaded Mean AAL Cost per $1,000**	**λ = 0.5**	**λ = 1**	**λ = 2**	**λ = 3**
A	$ 5.18	$ 5.51	$ 8.26	$ 11.02	$ 16.53	$ 22.03
X500 / B	$ 4.76	$ 1.69	$ 2.54	$ 3.38	$ 5.07	$ 6.76
X / C	$ 1.68	$ 0.07	$ 0.11	$ 0.14	$ 0.21	$ 0.28
Travis County Total	**$ 3.39**	**$ 0.27**	**$ 0.40**	**$ 0.54**	**$ 0.81**	**$ 1.08**

Table 5.6 presents the results of our loaded premium comparison for Galveston County using as-is loaded values of the NFIP from Table 5.2 compared to loaded values of the mean AAL cost per $1,000 model results from Table 4.8 with loading factors of λ = 0.5, 1, 2, and 3 (50 percent, 100 percent, 200 percent, 300 percent). From our unloaded premium comparison, average NFIP premium per $1,000 was higher than the average pure premium per $1,000 from our model in the V zone only in Galveston County. We see from Table 5.6 that in order for loaded market values in the V zone to be greater than the loaded NFIP values on average, a loading factor of 2 must be applied, or a tripling of the unloaded pure premium.

TABLE 5.6 GALVESTON COUNTY LOADED PREMIUM COMPARISON: PROBABILISTIC FLOOD MODEL WITH VARIOUS LOADING FACTORS AND LOADED NFIP

	NFIP	**Study AAL**				
FEMA Flood Zone	**Average Premium Loss Cost per $1,000**	**Unloaded Mean AAL Cost per $1,000**	**λ = 0.5**	**λ = 1**	**λ = 2**	**λ = 3**
V	$ 14.17	$ 6.60	$ 9.89	$ 13.19	$ 19.79	$ 26.38
A	$ 5.12	$ 6.31	$ 9.47	$ 12.63	$ 18.94	$ 25.26
X500 / B	$ 1.92	$ 4.21	$ 6.32	$ 8.42	$ 12.64	$ 16.85
X / C	$ 1.44	$ 1.64	$ 2.46	$ 3.28	$ 4.92	$ 6.56
Galveston County Total	**$ 2.90**	**$ 3.43**	**$ 5.14**	**$ 6.85**	**$ 10.28**	**$ 13.71**

5.5 Some Concluding Comments

It is commonly believed that insurance premiums charged by the NFIP are lower than the private insurance sector could offer. But our analysis demonstrates that some regions are currently charged more by the NFIP that what a representative insurer, behaving as we described here, would charge.

Taken together, these results offer several important insights in the debate about reforming flood insurance.

- First, undertaking a microanalysis of the true exposure of residents to riverine and storm surge risks is important if one wants to charge the true risk-based premiums. One cannot simply aggregate risks per flood zones because there is a lot of heterogeneity in a given flood zone.
- Second, it would be important to compare more systematically the risk assessment approach developed by the NFIP, which is based on the determination of the average annual loss year, with probabilistic models such as the one used here, to see where the two approaches diverge and where they converge, and why.
- Third, the definition of what one means by “risk-based premium” matters greatly. Here, it is important to first determine the *pure premium* associated with a given property in a given area, which represents the true risk associated with flood (including the risk for truly catastrophic losses even though they are very unlikely). Then, one needs to itemize all the other costs a federal disaster insurance program like the NFIP or a private insurer will incur when selling flood insurance. All of these costs will then have to be levied against the policyholders. Unfortunately, the overall premiums charged can be very misleading because these two elements, pure premium and loading, are combined. A policyholder does not know whether the premium that s/he paid is high because the risk is high or because of other costs.
- Our analysis thus reveals that there might be important opportunities for the private insurance sector to become much more active in selling flood insurance. This could be done in complement to the NFIP if insurers are capable of determining in a granular fashion where residents are overcharged by the NFIP compared to what the insurers could offer. This could increase take-up rates and ensure that more individuals are effectively covered against floods.

5.6 Comparison with Flood Insurance Markets in Other Countries

In the spirit of our concluding remarks concerning the opportunity for the private insurance sector to sell more flood insurance in Texas, it is instructive to look at how other countries have responded to the problem of flood insurance. In the United Kingdom, flood insurance is provided exclusively by private insurers and is usually included in homeowners' insurance policy (Clark, 1998). Mortgage lenders require that a property to have full insurance coverage, and in this way, many homeowners are in effect covered against flood. In France, insurance coverage against flooding and other natural hazards is mandatorily included in homeowners' policies sold by private insurers as well. Homeowner's insurance itself is mandatory and well-enforced. Flood insurance penetration is thus virtually 100 percent. In return for providing this coverage, French insurers benefit from reinsurance capacity at a very competitive price via the government-run reinsurer, which benefits from an unlimited guarantee from the French Treasury. In Germany, flood insurance is provided exclusively by private insurers but on a voluntary basis and as a supplement to homeowners' insurance coverage. Although homeowners' insurance penetration is high in the country (nearly 90 percent), flood insurance penetration was only about 10 percent for single homes in 2006; while this figure has increased in the last few years as a results of awareness campaigns by German insurers, the market penetration remains quite low (Thieken et al., 2006; von Ungern-Sternberg, 2004). In the Netherlands, a country that is highly exposed to flood risk, the population relies entirely on government relief after the disaster. There is no flood insurance available, although a private insurance option is currently being discussed (Botzen and van den Bergh, 2008). These examples suggest that private insurance might well take more of the risk of flood insurance in a well-designed system; something to consider in the U.S. as well (Michel-Kerjan, 2010).

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Chapter 6

Evaluating the Impact of Flood Mitigation Measures

Chapter 6 Summary

One of the most important aspects of making the NFIP (or any sort of private market option for that matter) more effective in the long-run is encouraging individuals to invest in risk mitigation measures. In this chapter we are interested in better quantifying the benefits and costs of individual risk reduction measures homeowners could invest in to reduce their exposure to the flood hazard. We determine the benefits of mitigation for both **elevation** and **generic flood protection** (e.g., an individual flood wall) as an outcome of the catastrophe model we use. We also conduct an economic cost-benefit analysis of elevating all existing structures based upon FEMA cost of elevation data.

Benefits of Mitigation (Reducing Future Losses)

Mitigation can have an enormous impact. For a 100-year event, we find that elevating all houses by 2 feet or 8 feet would reduce the total losses from riverine flood in Travis County by 40 percent or 89 percent, respectively. For a 100-year storm surge event, we find that elevating all houses by 2 feet or 8 feet would reduce the total losses in Galveston County by 16 percent or 64 percent, respectively. Thus, elevation is generally more effective at reducing the losses from riverine flood than it is for storm surge (see Tables 6.2 and 6.3). Elevation is further found to be generally more effective than flood protection for which expected loss reductions for the 100-year event are a maximum of 30 percent (see Tables 6.10 and 6.11). We also find that the average annual reduction in expected flood losses with all homes elevated by 8 feet is 92 percent in Travis and 82 percent in Galveston (Table 6.4). Implementing a 100-year flood protection (e.g., individual home flood wall) for all homes would reduce flood losses by 62 percent in Travis and 28 percent in Galveston (Table 6.12).

Benefit-Cost Analysis

Undertaking such mitigation measures can be expensive, though (see Table 6.7). Our benefit-cost analysis of elevation (which includes different discount rates) reveals that on average, dollar savings associated with these significant percentage AAL reductions are not enough to balance the costs of such measures for *existing construction* (see Tables 6.8 and 6.9). We do find some specific instances where elevation is economically worthwhile (see Table 6.6 and Figure 6.9), suggesting that elevating *existing homes* could be cost effective if done selectively. Note that we have calculated only the direct economic benefits stemming from elevation and did not consider other direct benefits (e.g., reduced fatalities and injuries), nor have we looked at the indirect economic benefits such as the savings in the costs of permanently relocating residents. Elevation costs for new construction would be significantly lower than for existing construction, which could make mitigation of new homes much more appealing. This suggests the need for a holistic approach to mitigation: implementing land-use restrictions, community based-mitigation efforts and individual measures.

6.1 Mitigation Options and Assumptions

Based on the data inputs available from the CoreLogic and Swiss Re models, mitigation options in this study include two main possibilities: elevation and flood protection level.

Elevation

As detailed in section 3.2.3, vulnerability for flood hazards in the CoreLogic and Swiss Re models represents the relationship of water depth and mean damage ratio on standardized categories of residential properties. However, for mitigation assessment purposes, the model has the ability to assess flood risk for elevated properties by reducing inundation levels due to higher elevation of structures based on user inputted elevated height. Figure 6.1 presents a conceptual rendering of reducing the 1000-year inundation level due to increased home elevation. We inputted elevation levels of 2, 4, and 8 feet across our model run of impacted homes in order to assess the reduced loss due to elevating properties by these various levels. These specific levels of elevation were chosen based upon cost of elevation data obtained from FEMA associated with elevating homes 2, 4, and 8 feet.

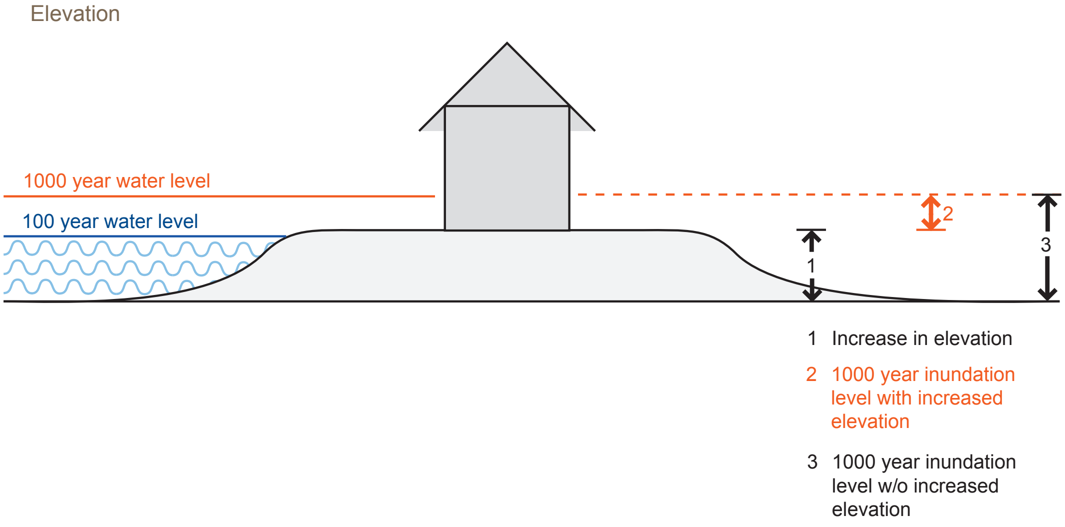

Figure 6.1 Illustrative Flood Model Elevation Mitigation Option

Flood Protection Level (FPL)

As detailed in section 3.2.1, the depth of river flooding is an outcome of the empirical relationship between the probability of flood occurrence at a location combined with the flood intensities (event return period). Also, storm surge flood depth is an outcome of the storm surge heights associated with hurricanes of different intensities at different landfall locations combined with the stochastic hurricane event set defining storm surge location, frequency and intensity. Vulnerability for riverine or storm surge flood hazards in the CoreLogic and Swiss Re models then represents the relationship of water depth and mean damage ratio on standardized categories of residential properties. Consequently there is a direct relationship between riverine and storm surge intensity on the level of water depth that ultimately impacts the level of damage.

The model has the capability to account for flood protection measures for existing residences where no flood protection measures currently exist.[50] Flood protection can be set as either protection against 50-year or 100-year floods for riverine flooding, or similarly for Category 1 or Category 2 hurricanes for storm surge flooding. Figure 6.2 presents a conceptual rendering of reducing the 1,000-year inundation level by providing 100-year flood protection. For 50-year/Category 1 or 100-year/Category 2 flood protection, the model removes flood events

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[50] The earlier discussion on flood protection was in terms of modifying losses to account for existing flood protection structures such as the Galveston seawall. For purposes of this analysis individual residences are modified to account for flood protection moving forward where none currently exists. While each exercise is done to serve a different purpose, the actual modification to the model inputs is essentially the same.

with intensities less than these return periods/intensity levels for both riverine and storm surge flooding respectively. By setting the flood protection level to either 50-year/Category 1 or 100-year/Category 2, losses are reduced by truncating the exceedance probability curve at the associated return period/ intensity level as illustrated in Figure 6.3.[51]

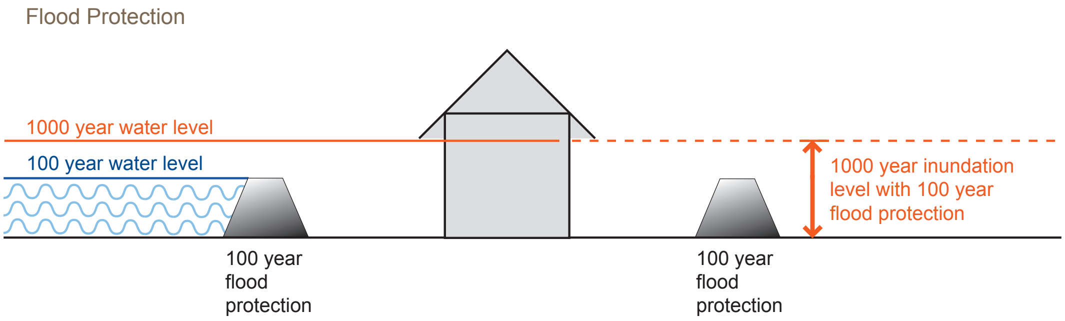
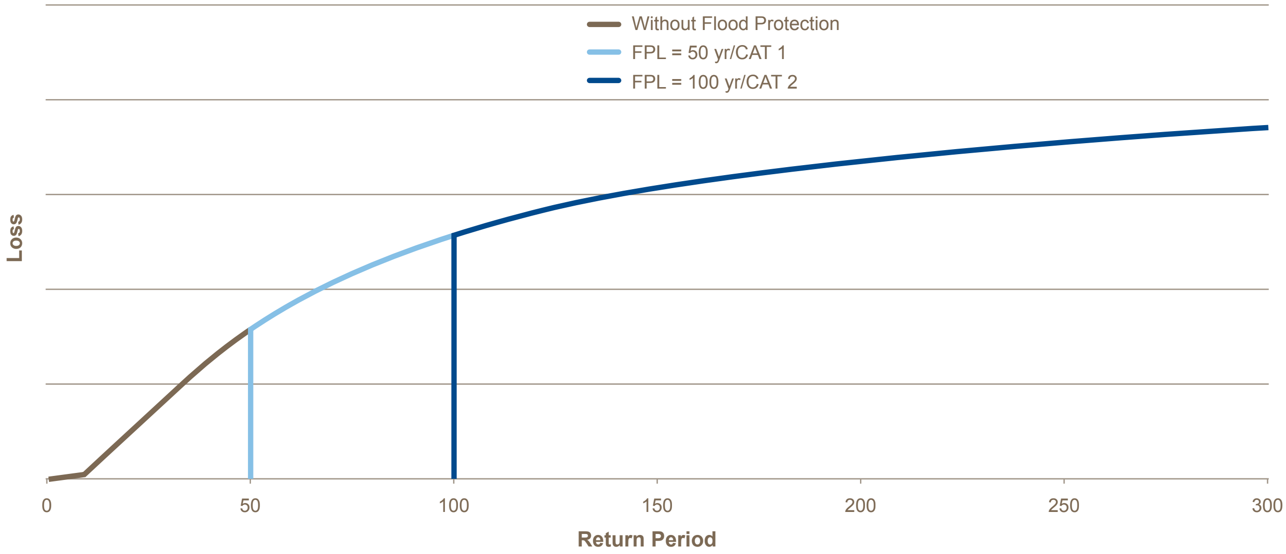


Figure 6.2 Illustrative Flood Model Flood Protection Level Mitigation Option



(Source: Swiss Re Internal Documentation)

Figure 6.3 FPL Impact on EP Loss Curves[52]

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[51] Note, that this is only correct for a single location or a portfolio of locations with perfect correlation (i.e., all risks are exposed to the same hazard intensity in terms of return period at the same time). With a portfolio of locations that do not correlate perfectly, we may also see losses with return periods lower than the truncation level.

[52] This EP curve depicts losses on the y-axis, while our generated EP curves have losses onthe x-axis.

6.2 Benefits of Mitigation: The Case for Elevation

Benefits due to elevation are ultimately shown through reductions in the determined unloaded AAL values. As AAL reductions will be larger for higher valued buildings, everything else being equal, we create equally valued representative homes of low, average, and high building values ($75,000, $175,000 and $500,000 respectively) for the elevation mitigation analysis.[53] Furthermore, as benefit reductions are simply scaled up by the same ratio of the building values used (e.g., reductions for $175,000 homes are approximately 2.33 times higher than those for $75,000 value homes, or the ratio between the $175,000 and $75,000 building values) for simplification purposes we present only the results from the representative $175,000 home value analysis. For each county, the mitigation analysis was undertaken on all of the residences in the entire county.

As we have undertaken this analysis on each entire county with representative home values, it is worthwhile understanding how applicable the results would be to the counties in general. Table 6.1 provides a breakdown of the number of residences in each county by FEMA flood zone and summarizes the number of homes in each location that have building value less than or equal to $175,000 as well as having some base flood loss AAL associated with them (and hence the potential for benefits due to implementing mitigation). From this data we see that in especially the 100- and 500-year floodplains there are significant percentages of homes that fit these criteria, such as the 85 percent of homes in the Galveston A zone, and consequently our results can be thought of as representing a best-case feasible reduction in AAL due to mitigation in the county.

TABLE 6.1 APPLICABILITY OF MITIGATION ANALYSIS ON $175,000 BUILDING VALUES IN GALVESTON AND TRAVIS COUNTIES

	Total County		V Zone		A Zone		X500 Zone		X Zone	
	Galveston	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
Total # of Single-Family Residences (SFR) in FEMA Flood Zone	89,046	226,407	5,355	N/A	17,940	6,790	18,922	5,010	46,829	214,607
% of SFR in County with Building Value <= $175,000 and AAL > $0	82%	21%	55%	N/A	85%	75%	92%	78%	81%	18%

Table 6.2 presents the key return period loss values for Travis County assuming no elevation mitigation as well as elevation of 2, 4, and 8 feet. The associated county baseline EP curve and the shifted downward curves due to 2, 4 and 8 feet of elevation are illustrated in Figure 6.4. Of the 226,407 residences in Travis County, 60,869 had some level of loss reduction associated with the elevation implementation. Based on the data in Table 6.2, the total losses associated with the 10,000-year event without mitigation are reduced by 13 percent, 24 percent and 57 percent for levels of 2, 4, and 8 feet of elevation. Loss reductions for the other key return periods due to elevation range from 30-90 percent of the unmitigated losses.

TABLE 6.2 TRAVIS COUNTY KEY RETURN PERIOD LOSSES WITH AND WITHOUT ELEVATION[54]

Return Period	No Mitigation	2 Feet	4 Feet	8 Feet
10,000	$ 1,012,836,772	$ 880,428,366	$ 768,023,069	$ 437,453,474
1,000	$ 585,633,951	$ 409,284,929	$ 249,609,742	$ 95,733,654
500	$ 424,267,558	$ 276,504,642	$ 187,933,290	$ 65,444,889
250	$ 296,221,335	$ 185,902,081	$ 119,265,425	$ 33,576,788
100	$ 191,655,065	$ 115,194,851	$ 66,488,639	$ 21,380,664
50	$ 124,496,724	$ 76,482,603	$ 41,642,040	$ 10,329,674

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[53] These values were determined from an analysis of the existing county building distributions.

[54] Note that the unmitigated losses here will not match to return period values presented in Chapter 4 due to the exposure value differences.

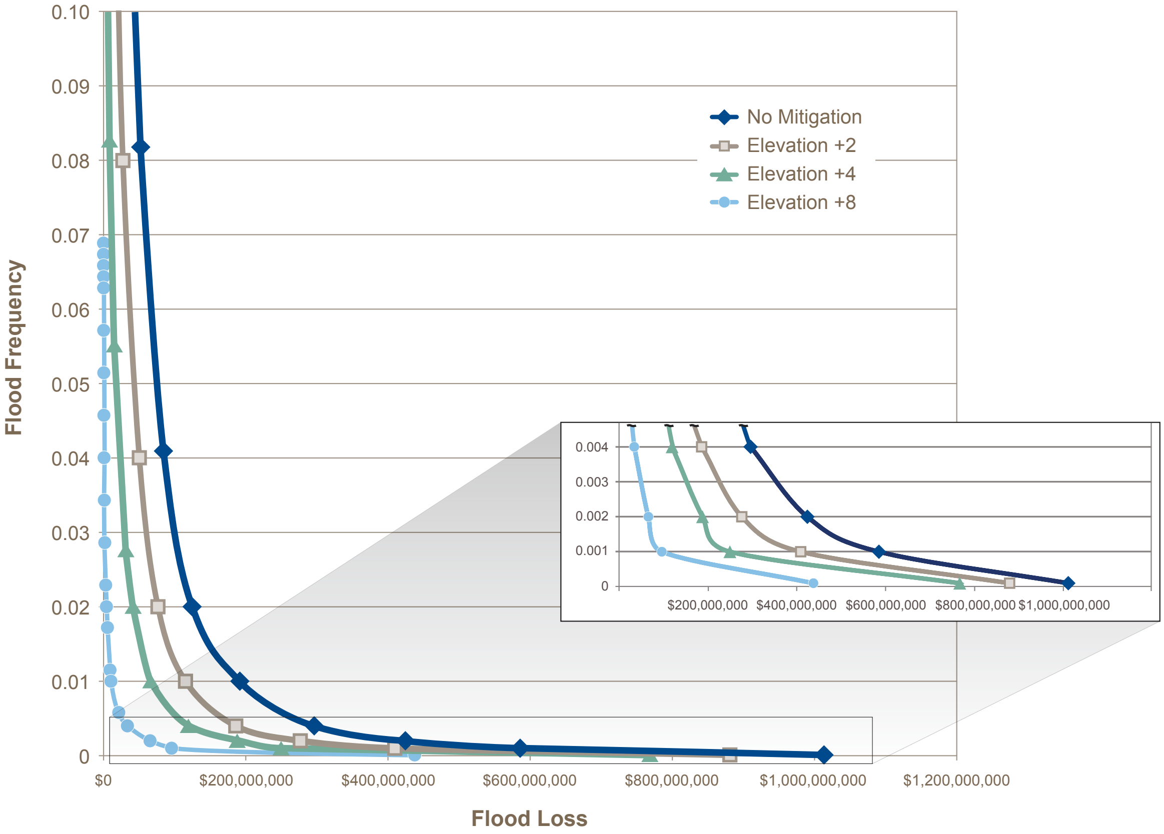

Figure 6.4 Travis County EP Curves With and Without Elevation

Tables 6.3a and 6.3b present Galveston County key return period loss values for riverine and storm surge flooding separately assuming no mitigation as well as with elevation of 2, 4, and 8 feet. The associated county riverine and storm surge flooding baseline EP curves and the shifted downward curves due to 2, 4 and 8 feet of elevation are illustrated in Figure 6.5a and 6.5b respectively. Of the 89,046 residences in Galveston County, 87,941 had some level of loss reduction associated with the elevation implementation. Based on the data in Table 6.3a the total losses associated with the 10,000-year riverine flood event without mitigation are reduced by 28 percent, 61 percent and 99 percent for levels of 2, 4, and 8 feet of elevation. Riverine loss reductions for the other key return periods due to elevation range from 47 percent to 100 percent of the unmitigated losses. Based on the data in Table 6.3b, the total losses associated with the 10,000-year storm surge flood event without mitigation are reduced by 11 percent, 23 percent, and 49 percent for levels of 2, 4, and 8 feet of elevation. Storm surge loss reductions for the other key return periods due to elevation range from 13 percent to 77 percent of the unmitigated losses.

TABLE 6.3A GALVESTON COUNTY KEY RETURN PERIOD LOSS REDUCTIONS WITH AND WITHOUT ELEVATION FOR RIVERINE FLOODING[55]

Return Period	No Mitigation	2 Feet	4 Feet	8 Feet
10,000	$1,205,829,119	$ 862,982,709	$ 476,025,037	$ 11,735,969
1,000	$ 608,900,447	$ 323,301,522	$ 41,045,382	$ 335,573
500	$ 436,780,768	$ 196,089,776	$ 16,613,942	$ 223,467
250	$ 322,872,450	$ 47,095,391	$ 6,197,742	$ 42,651
100	$ 83,861,294	$ 14,788,878	$ 983,716	
50	$ 33,426,408	$ 5,456,492	$ 200,578	

TABLE 6.3B GALVESTON COUNTY KEY RETURN PERIOD LOSS REDUCTIONS WITH AND WITHOUT ELEVATION FOR STORM SURGE FLOODING

Return Period	No Mitigation	2 Feet	4 Feet	8 Feet
10,000	$ 3,764,396,012	$ 3,349,335,878	$ 2,879,890,951	$ 1,910,419,424
1,000	$ 3,366,773,839	$ 2,931,647,894	$ 2,582,489,161	$ 1,817,694,065
500	$ 3,283,865,847	$ 2,843,744,878	$ 2,452,555,976	$ 1,593,228,149
250	$ 2,942,582,688	$ 2,522,343,478	$ 2,133,456,664	$ 1,423,470,037
100	$ 2,302,173,875	$ 1,929,911,198	$ 1,515,971,664	$ 840,027,937
50	$ 1,154,264,539	$ 846,923,380	$ 621,839,349	$ 261,883,924

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[55] Note here too, that the unmitigated losses in Tables 6.3a and 6.3b will not equate with return period values presented in Chapter 4 due to the exposure value differences.

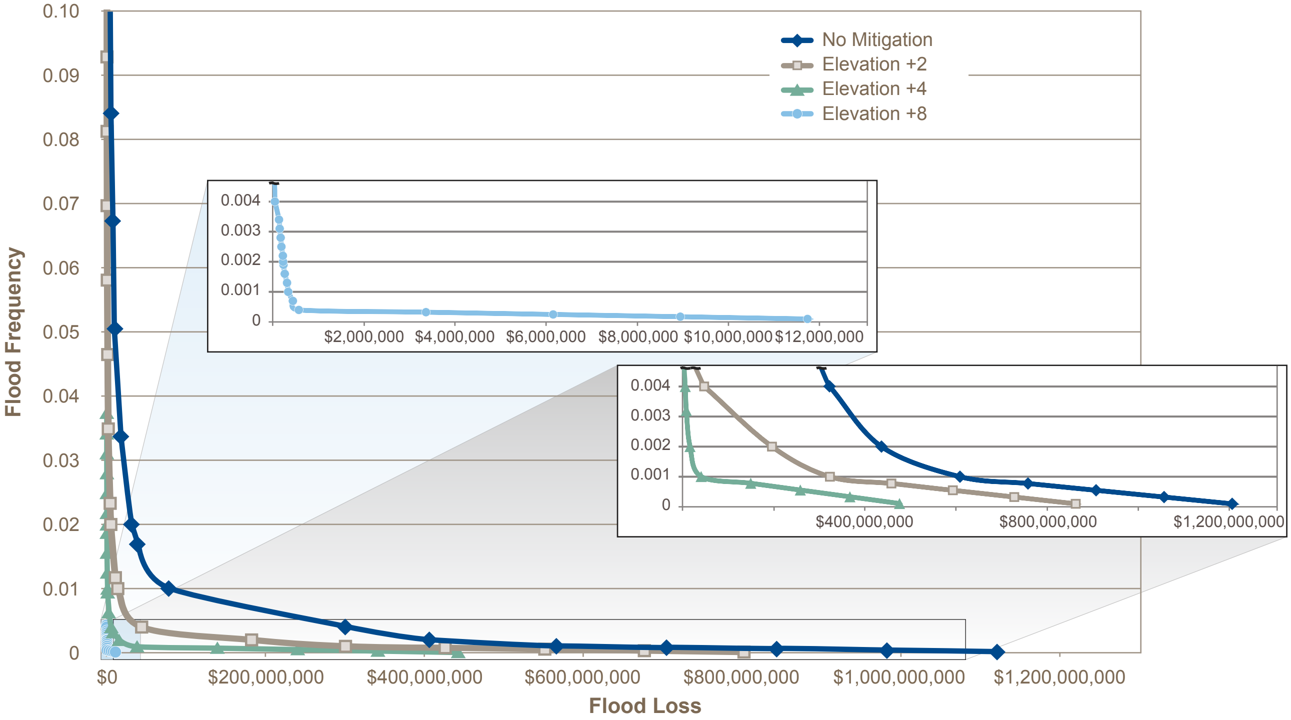

Figure 6.5a Galveston County EP Curves With and Without Elevation for Riverine Flooding

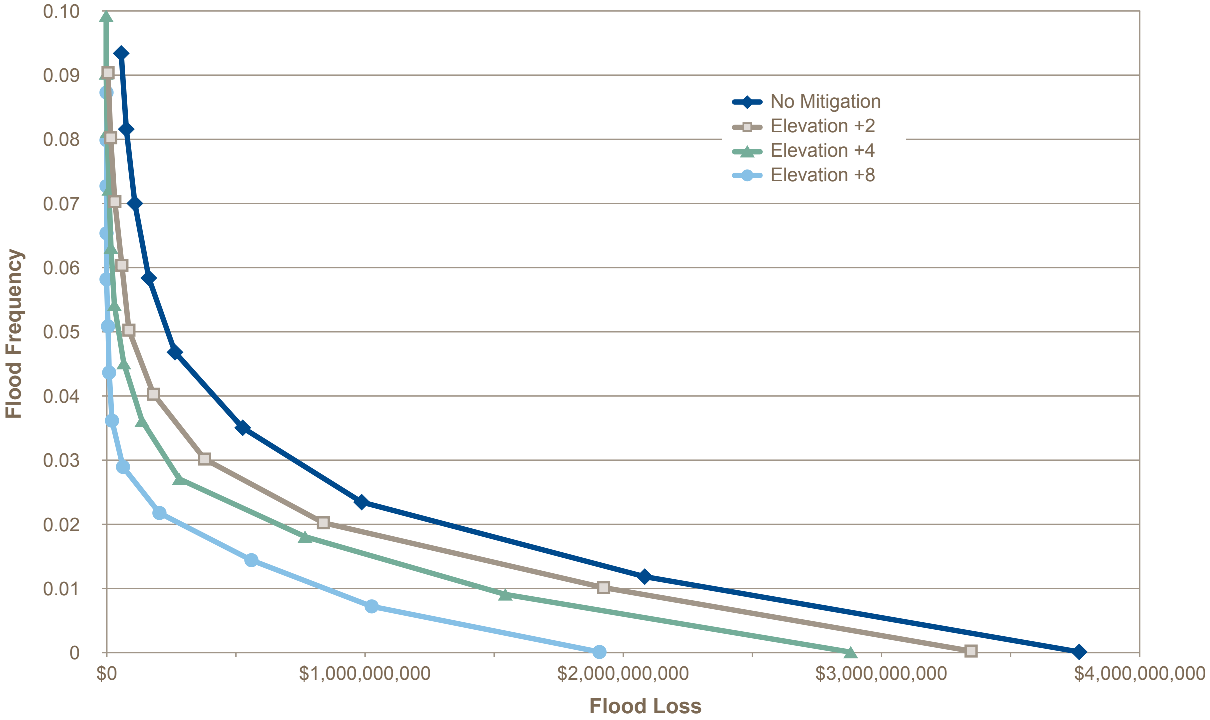

Figure 6.5b Galveston County EP Curves With and Without Elevation for Storm Surge Flooding

Based upon the results from the constructed EP curves in Figures 6.4, 6.5a, and 6.5b, Table 6.4 further provides the mean AAL reduction due to 2, 4, and 8 feet of elevation for each county as well as across the applicable FEMA flood zones in each county. From this data we see that the AAL reduction due to elevation is generally significant ranging from 27 percent to 55 percent for 2 feet of elevation, 44 percent to 80 percent for 4 feet of elevation, and from 69 percent to 97 percent for 8 feet of elevation. The elevation reductions are larger in Travis as compared to Galveston. Further, in Travis the percentage reductions are generally larger in the 100- and 500-year floodplains, while in Galveston, the X zone (outside the 500-year floodplain) has the largest percentage reductions across all levels of elevation. Finally, Figures 6.6 and 6.7 graphically illustrate these percentage reductions showing diminishing returns to elevation reduction benefits moving from 4 to 8 feet in Travis County while Galveston County illustrates increasing returns to elevation reduction benefits from 4 to 8 feet for all flood zones but the X zone.

TABLE 6.4 MEAN AAL PERCENTAGE REDUCTION TO ELEVATION BY COUNTY AND FEMA FLOOD ZONE

	Total County		**V Zone**		**A Zone**		**X500 Zone**		**X Zone**	
Elevation	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
2 ft	-40%	-53%	-30%	N/A	-33%	-51%	-27%	-55%	-49%	-53%
4 ft	-60%	-76%	-46%	N/A	-50%	-79%	-44%	-80%	-73%	-75%
8 ft	-82%	-92%	-72%	N/A	-71%	-97%	-69%	-95%	-92%	-92%

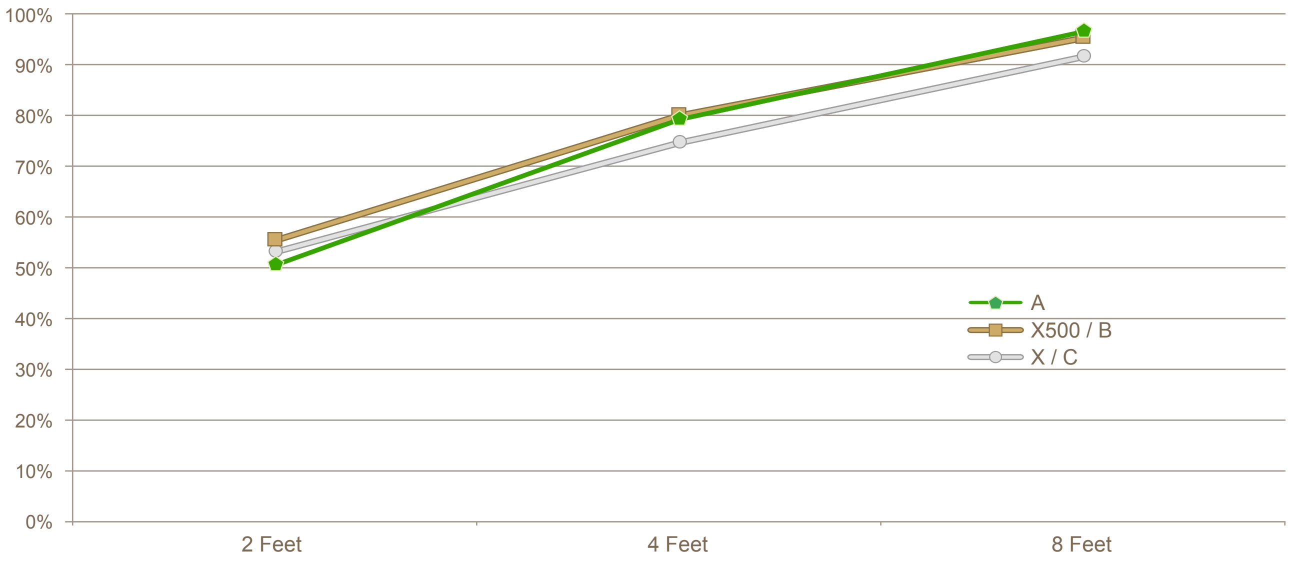

Figure 6.6 Travis County Mean AAL Percentage Reduction per Feet of Elevation

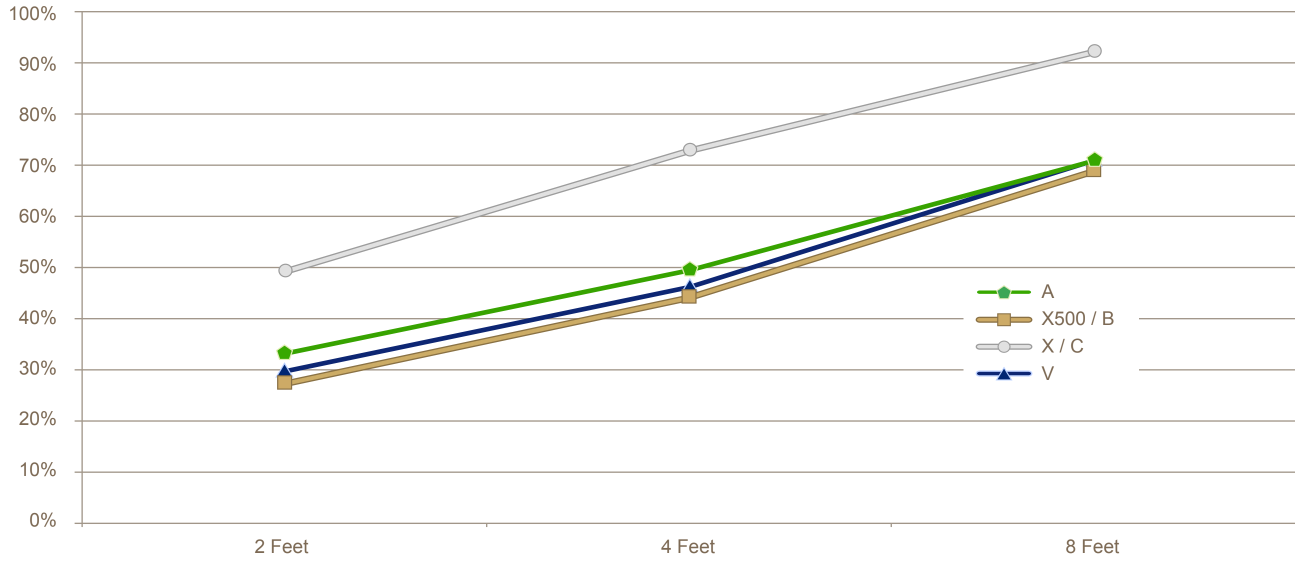

Figure 6.7 Galveston County Mean AAL Percentage Reduction per Feet of Elevation

While the above percentage reduction results indicate significant reductions to AAL in percentage terms, it is necessary to understand the magnitude of these benefits in economic terms which will be used in a benefit-cost analysis. Table 6.5 provides the average benefits to elevation taken over a 25-year time period with no discounting. From this table we see that from an economic perspective, while the percentage reductions in AAL are significant, this does not necessarily translate into relatively significant dollar values. For example, the mean 95 percent AAL reduction due to 8 feet of elevation in the Travis County X500 zone is worth $10,025 over 25 years, or roughly a $401 annual benefit. Mean benefits to elevation over 25 years range from $973 to $14,227 for 2 feet of elevation, $1,472 to $25,455 for 4 feet of elevation, and from $1,799 to $32,603 for 8 feet of elevation. These values are greater in Galveston than in Travis, and more significant in the 100-year floodplains in each county as compared to outside of them (i.e., in the X zone).

TABLE 6.5 MEAN ANNUAL REDUCTION TO ELEVATION OVER 25 YEARS, NO DISCOUNTING

	Total County		V Zone		A Zone		X500 Zone		X Zone	
Elevation	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
2 ft	$ 6,800	$ 2,793	$ 11,754	N/A	$ 12,885	$ 14,227	$ 6,496	$ 5,127	$ 4,007	$ 973
4 ft	$10,519	$ 4,703	$ 18,496	N/A	$ 19,123	$ 25,455	$ 10,636	$ 8,219	$ 6,234	$1,472
8 ft	$15,462	$ 5,912	$ 28,494	N/A	$ 27,260	$ 32,603	$ 16,833	$ 10,025	$ 8,852	$1,799

Of course, these are just average numbers meaning there are values that are higher and lower accordingly. Table 6.6 presents the maximum values for each zone again taken over 25 years and with no discounting. From this table we clearly see instances of significant benefits to elevation with maximum values being $55,938 for 2 feet, $78,597 for 4 feet, and $106,460 for 8 feet, or a $2,237, $3,143, and $4,258 annual benefit per level of elevation respectively.

TABLE 6.6 MAXIMUM ANNUAL REDUCTION TO ELEVATION OVER 25 YEARS, NO DISCOUNTING

	Total County		V Zone		A Zone		X500 Zone		X Zone	
Elevation	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
2 ft	$ 55,938	$ 38,676	$ 22,755	N/A	$ 55,938	$ 38,676	$ 42,885	$ 37,749	$ 19,293	$ 37,652
4 ft	$ 78,597	$ 59,082	$ 30,736	N/A	$ 78,597	$ 59,082	$ 55,423	$ 58,404	$ 31,277	$ 58,105
8 ft	$ 106,460	$ 80,338	$ 43,657	N/A	$ 106,460	$ 79,373	$ 63,646	$ 80,338	$ 58,357	$ 79,183

* AAL reductions derived from an assumed normal/average quality house. Reductions would be less for a good quality house, and more for a poor quality house.

6.3 Elevation Benefit-Cost Analysis

Costs of Elevation

In order to undertake a benefit-cost analysis of elevation, we need to determine the costs of elevating existing structures. For existing residences, FEMA provides the cost of elevation per square foot by construction and foundation types in their guide to retrofitting existing structures for providing flood protection (FEMA, 2009b). This information is replicated in Figure 6.8 below. On a cost per square foot basis, this cost ranges anywhere from $29 to $96 per square foot; they are significantly different for slab-on-grade foundations as compared to basement or crawlspace foundations. For our benefit-cost analysis we use the values from the two cost extremes: 1) frame construction having a basement or crawlspace foundation with cost per square foot of $29, $32, and $37 for 2, 4, and 8 feet of elevation; and 2) masonry construction with a slab-on-grade foundation with cost per square foot of $88, $91, and $96 for 2, 4, and 8 feet of elevation.

Construction Type	Existing Foundation	Retrofit	Cost (per square foot of house footprint)
Frame (for frame house with brick veneer on walls, add 10 percent)	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$ 29
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation	$ 32
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation	$ 37
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation*	$ 80
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation*	$ 83
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation*	$ 88
Masonry	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$ 60
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation	$ 63
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation	$ 68
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation*	$ 88
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation*	$ 91
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation*	$ 96

*Price shown is for raising the house with the slab attached.

(Source: FEMA, 2009b)

Figure 6.8 FEMA Costs of Elevation

For our $175,000 homes we assume 2,000 square foot of house footprint for our analysis.[56] The total elevation costs used in this analysis based on this assumption are presented in Table 6.7. We see that elevating any existing structure, even wood frame homes with a crawlspace, is relatively expensive. For example, to elevate a 2,000 square foot wood frame home with a crawlspace 4 feet costs $64,000. Elevating slab-on-grade masonry homes is approaching nearly $200,000 in expenses whether for 2, 4, or 8 feet of elevation. This cost of elevation information was verified with data from a number of other studies summarized in a MMI Engineering flood mitigation cost-benefit analysis research review (MMI Engineering, 2011) and was found to be within typical ranges presented in this review.

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[56] Values determined based upon our county building value and square footage analysis.

TABLE 6.7 TOTAL COST OF ELEVATION BY HOUSING TYPE

Construction	Foundation	Cost per Square Foot of Elevation	Total Elevation Cost for 2,000 Sq Ft Home
Wood Frame	Crawlspace	2 ft = $29	$ 58,000
		4 ft = $32	$ 64,000
		8 ft = $37	$ 74,000
Masonry	Slab-on-grade	2 ft = $88	$ 176,000
		4 ft = $91	$ 182,000
		8 ft = $96	$ 192,000

Benefit-Cost Analysis

From an economic perspective, undertaking an action such as flood mitigation via elevation is considered worthwhile when the benefits are greater than the costs, or similarly, when the ratio of benefits over costs is greater than one. Further, these benefits and costs can be accrued over different future time periods, where benefits and costs occurring in future periods need to be discounted to compute the present value. Using our derived benefits from elevation detailed in section 6.2 (which occur on an annual basis over the length of the house such as 25 years), combined with our upfront costs of elevation summarized above, we undertake a benefit-cost analysis of elevation across different time horizons and discount rates. The average benefit-cost ratios by flood zone for Travis County for our two construction/foundation housing types are provided in Table 6.8. These particular average ratios are determined assuming 25 years of benefits at a 0 percent discount rate.

TABLE 6.8 TRAVIS COUNTY AVERAGE BENEFIT-COST RATIOS PER LEVEL OF ELEVATION BY FLOOD ZONE AND HOUSING TYPE OVER 25 YEARS AND A 0 PERCENT DISCOUNT RATE

House Type	FEMA Flood Zone	Average B/C Ratio 2 Feet Elevation	Average B/C Ratio 4 Feet Elevation	Average B/C Ratio 8 Feet Elevation
Wood Frame / Crawlspace	A	0.25	0.40	0.44
	X500	0.09	0.13	0.14
	X	0.02	0.02	0.02
Masonry / Slab-on-grade	A	0.08	0.14	0.17
	X500	0.03	0.05	0.05
	X	0.01	0.01	0.01

Given the discrepancy between the benefit values due to elevation and the relative large costs of elevation for existing structures, it is not surprising to find these values on average are all less than one. However, we do see certain housing types within specific flood zones doing better than others such as A zone homes that are wood frame with a crawlspace. We further illustrate in Figure 6.9 a Travis County best-case scenario for an X500 wood frame/crawlspace home elevated 8 feet using various time horizons of 25, 10, 5, and 1 year as well as various interest rates of 0 percent, 5 percent, 10 percent, and 15 percent. While the 25-year time horizon at 0 percent discount rate is greater than one so that it is deemed economically worthwhile, as soon as these benefits are discounted by an interest rate of 5 percent the ratio drops below one to 0.61. Similar drop-offs in benefit-cost ratios occur for the 10- and 5-year time horizon scenarios that are at 0.43 and 0.21 even with 0 percent discounting.

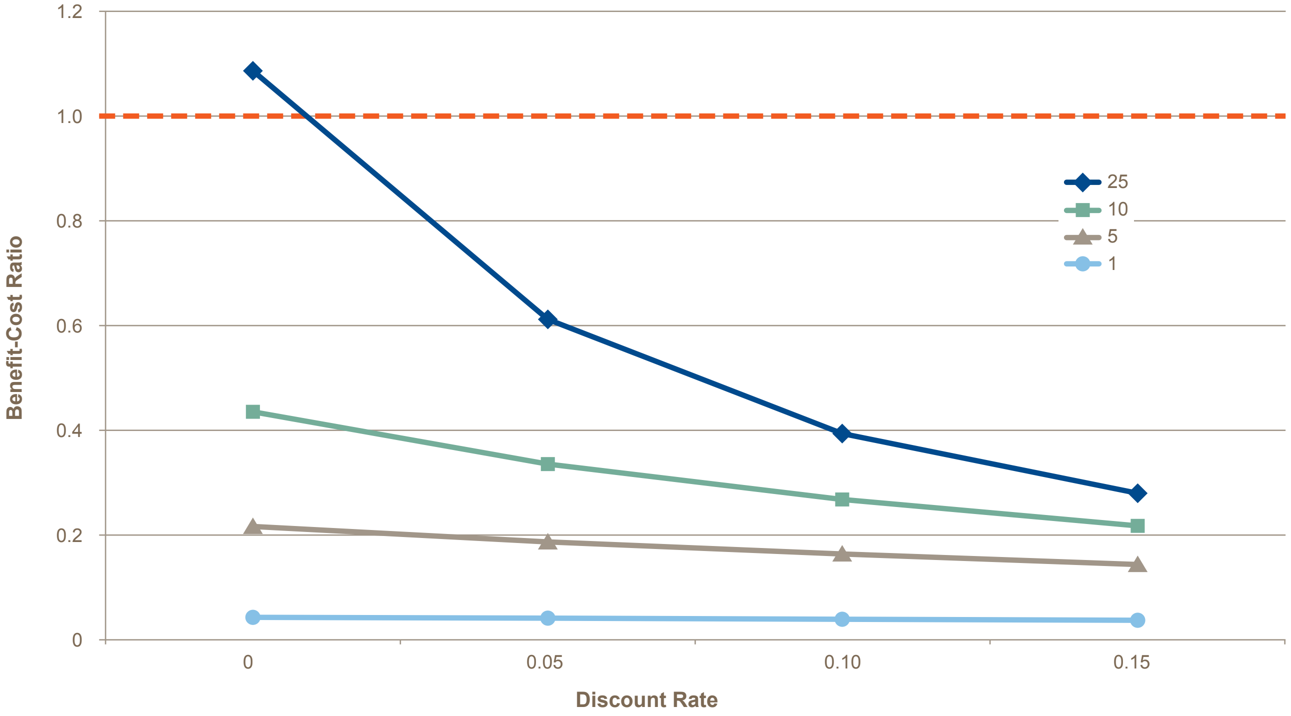

Figure 6.9 Travis County Benefit-Cost Ratio Best-Case Scenario for an X500 Zone Wood Frame/Crawlspace Home Elevated 8 Feet

The average benefit-cost ratios by flood zone for Galveston County for our two construction/foundation housing types are provided in Table 6.9. Again, these particular average ratios are determined assuming 25 years of benefits at a 0 percent discount rate. Given the discrepancy between the nominal benefit values due to elevation and the relatively large costs of elevation for existing structures, it is again not surprising to find these values on average to be all less than one. However, we do see certain housing types within specific flood zones doing better than others such as V and A zone homes that are wood frame with a crawlspace.

Benefit-cost results from both counties suggest that if elevation to existing homes is to be undertaken as a flood mitigation effort, it must be done very selectively from an economic perspective due to the relatively significant costs of elevation to existing structures. Note that we have calculated only the direct economic benefits stemming from elevation and not considered other direct benefits, such as reduced fatalities and injuries, or reduced damage to infrastructure and the environment. Nor have we looked at the indirect economic benefits such as the savings in the government costs of permanently relocating residents. Elevation costs for new construction may be significantly lower than for existing construction, which could make mitigation of new homes much more appealing.

TABLE 6.9 GALVESTON COUNTY AVERAGE BENEFIT-COST RATIOS PER LEVEL OF ELEVATION BY FLOOD ZONE AND HOUSING TYPE OVER 25 YEARS AND A 0 PERCENT DISCOUNT RATE

House Type	FEMA Flood Zone	Average B/C Ratio 2 Feet Elevation	Average B/C Ratio 4 Feet Elevation	Average B/C Ratio 8 Feet Elevation
Wood Frame / Crawlspace	V	0.20	0.29	0.39
	A	0.22	0.30	0.37
	X500	0.11	0.17	0.23
	X	0.07	0.10	0.12
Masonry / Slab-on-grade	V	0.07	0.10	0.15
	A	0.07	0.11	0.14
	X500	0.04	0.06	0.09
	X	0.02	0.03	0.05

6.4 Benefits of Mitigation: The Case for Flood Protection

Benefits due to mitigation via flood protection are ultimately shown through reductions in the determined unloaded AAL values. We make the same assumptions to home values as we did in the elevation mitigation analysis discussed in section 6.2. Table 6.10 presents the key return period loss values for Travis County assuming no flood protection mitigation as well as for 50- and 100-year flood protection from riverine flooding.[57] The associated county baseline EP curve without mitigation and the return period EP curves due to 50- and 100-year protection are illustrated in Figure 6.10. Of the 226,407 residences in Travis County, 7,253 residences had some level of loss reduction associated with 50-year flood protection, and 9,620 residences had some level of loss reduction associated with 100-year flood protection. Based on the data in Table 6.10, the total losses associated with the 10,000-year event without mitigation are reduced by only 2 percent and 4 percent for 50-year and 100-year flood protection respectively. Because flood protection is associated with less intense events (i.e., 100 years or less) this low amount of loss reduction is reasonable. Loss reductions for the 100-year event are 17 percent and 30 percent for 50-year and 100-year flood protection respectively, while loss reductions for the 50-year event are 27 percent and 45 percent for 50-year and 100-year flood protection respectively.

TABLE 6.10 TRAVIS COUNTY KEY RETURN PERIOD LOSS REDUCTIONS WITH AND WITHOUT FLOOD PROTECTION

Return Period	No Mitigation	FPL = 50 Yr	FPL = 100 Yr
10,000	$ 1,012,836,772	$ 992,211,192	$ 968,993,072
1,000	$ 585,633,951	$ 542,196,356	$ 502,611,165
500	$ 424,267,558	$ 402,387,237	$ 373,548,266
250	$ 296,221,335	$ 277,776,491	$ 241,517,767
100	$ 191,655,065	$ 158,569,420	$ 134,337,364
50	$ 124,496,724	$ 90,849,941	$ 67,897,047

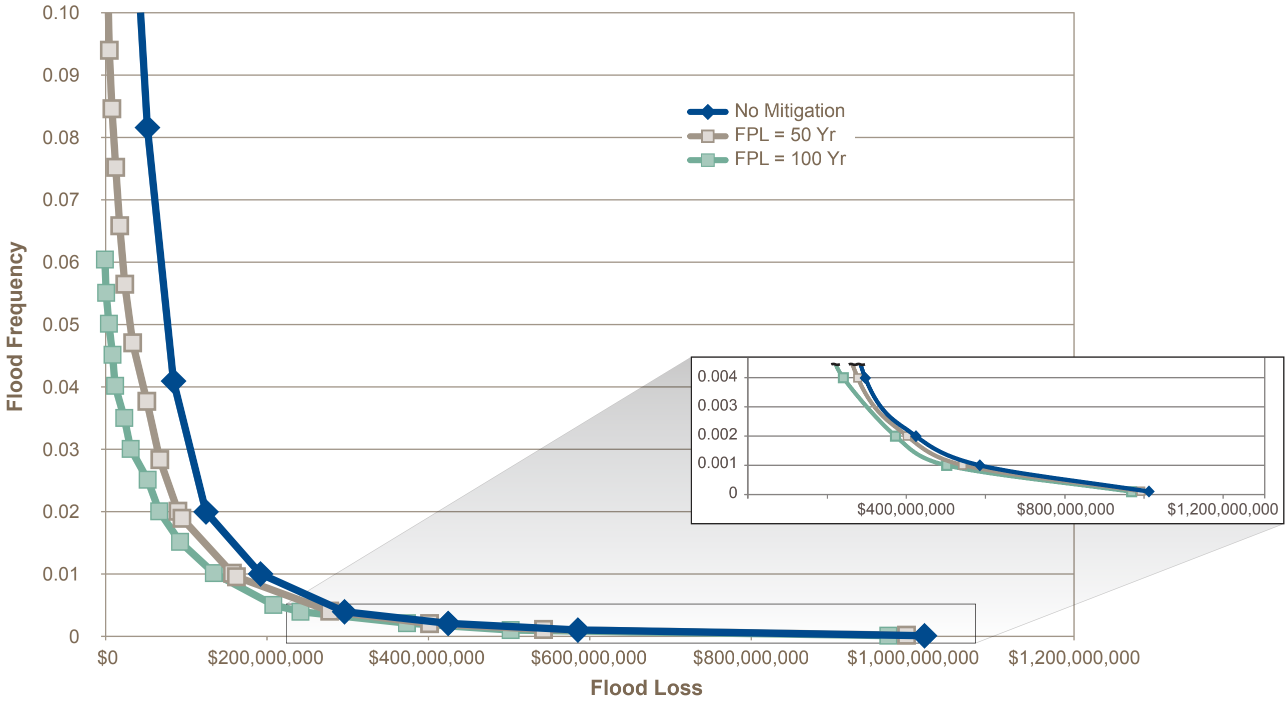

Figure 6.10 Travis County EP Curves With and Without Flood Protection

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[57] Note that this was modeled on the assumption that each individual risk was protected to a 50/100-year event level rather than the community being protected to these levels as a whole. Community protection would likely provide greater economic benefit to the entire group of residents within a given community.

Tables 6.11a and 6.11b present Galveston County key return period loss values for riverine and storm surge flooding separately assuming no flood protection mitigation as well as for 50- and 100-year flood protection levels for riverine flooding and Category 1 and Category 2 protection for storm surge flooding. The associated county riverine and storm surge flooding baseline EP curves and the return period EP curves due to 50- and 100-year/Category 1 and Category 2 protection are illustrated in Figures 6.11a and 6.11b respectively. Of the 89,046 residences in Galveston County, 26,093 residences had some level of loss reduction associated with 50-year/Category 1 flood protection, and 52,637 residences had some level of loss reduction associated with 100 year/Category 2 flood protection.

From Table 6.11a we see that the losses associated with the 10,000-year riverine flooding event are not reduced for 50-and 100-year flood protection respectively. Loss reductions for the 100-year event are 0 percent and 1 percent for 50- and 100-year flood protection respectively, while loss reductions for the 50-year event are 9 percent and 99 percent for 50- and 100-year flood protection respectively.

From Table 6.11b we see that the losses associated with the 10,000-year storm surge flooding event are essentially not reduced for Category 1 and Category 2 flood protection respectively. Loss reductions for the 100-year surge event are 1 percent and 7 percent for Category 1 and Category 2 flood protection respectively, while loss reductions for the 50-year surge event are 2 percent and 19 percent for Category 1 and Category 2 flood protection respectively.

TABLE 6.11A GALVESTON COUNTY KEY RETURN PERIOD LOSS REDUCTIONS WITH AND WITHOUT FLOOD PROTECTION FOR RIVERINE FLOODING

Return Period	No Mitigation	FPL = 50 Yr	FPL = 100 Yr
10,000	$ 1,205,829,119	$ 1,205,829,119	$ 1,205,829,119
1,000	$ 608,900,447	$ 608,900,447	$ 569,467,514
500	$ 436,780,768	$ 434,037,121	$ 424,891,632
250	$ 322,872,450	$ 322,872,450	$ 322,872,450
100	$ 83,861,294	$ 83,861,294	$ 83,406,879
50	$ 33,426,408	$ 30,286,844	$ 493,298

TABLE 6.11B GALVESTON COUNTY KEY RETURN PERIOD LOSS REDUCTIONS WITH AND WITHOUT FLOOD PROTECTION FOR STORM SURGE FLOODING

Return Period	No Mitigation	FPL = CAT 1	FPL = CAT 2
10,000	$ 3,764,396,012	$ 3,746,489,031	$ 3,744,563,174
1,000	$ 3,366,773,839	$ 3,366,773,839	$ 3,308,106,369
500	$ 3,283,865,847	$ 3,249,673,203	$ 3,177,309,995
250	$ 2,942,582,688	$ 2,926,428,651	$ 2,917,358,367
100	$ 2,302,173,875	$ 2,271,126,197	$ 2,131,120,724
50	$ 1,154,264,539	$ 1,132,362,322	$ 932,148,994

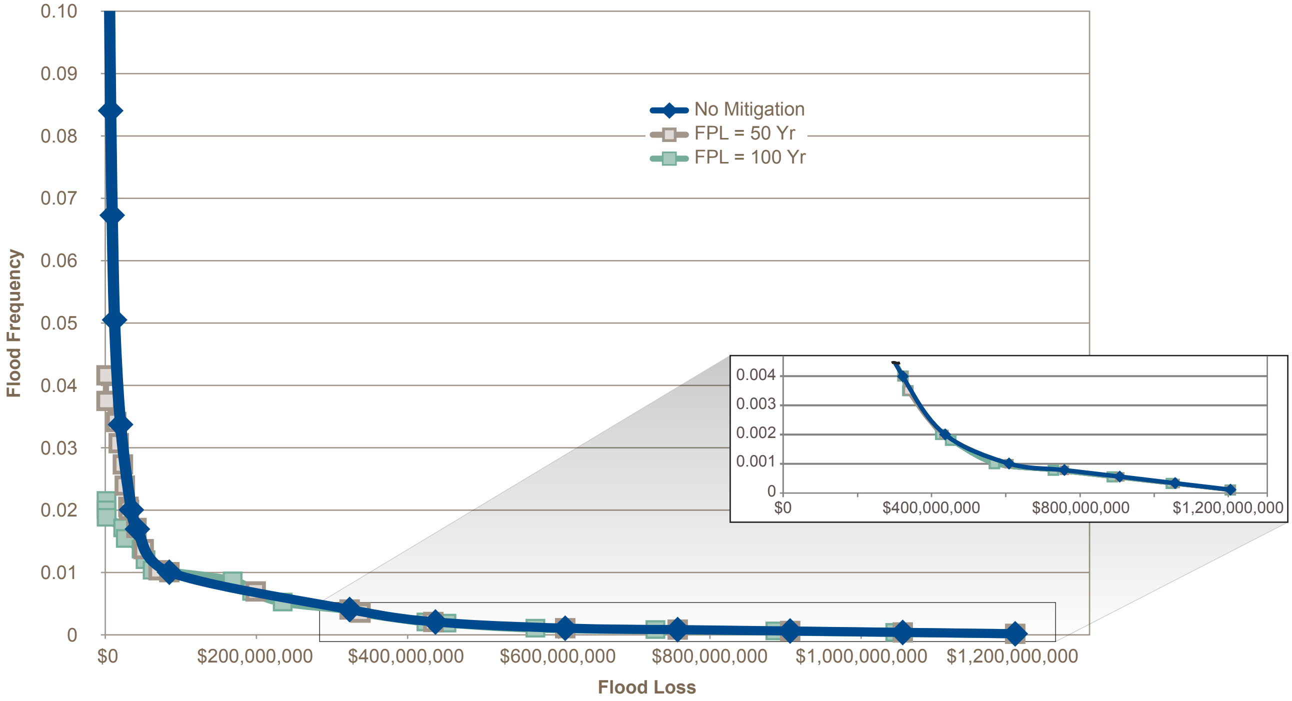

Figure 6.11a Galveston County EP Curves With and Without Flood Protection for Riverine Flooding

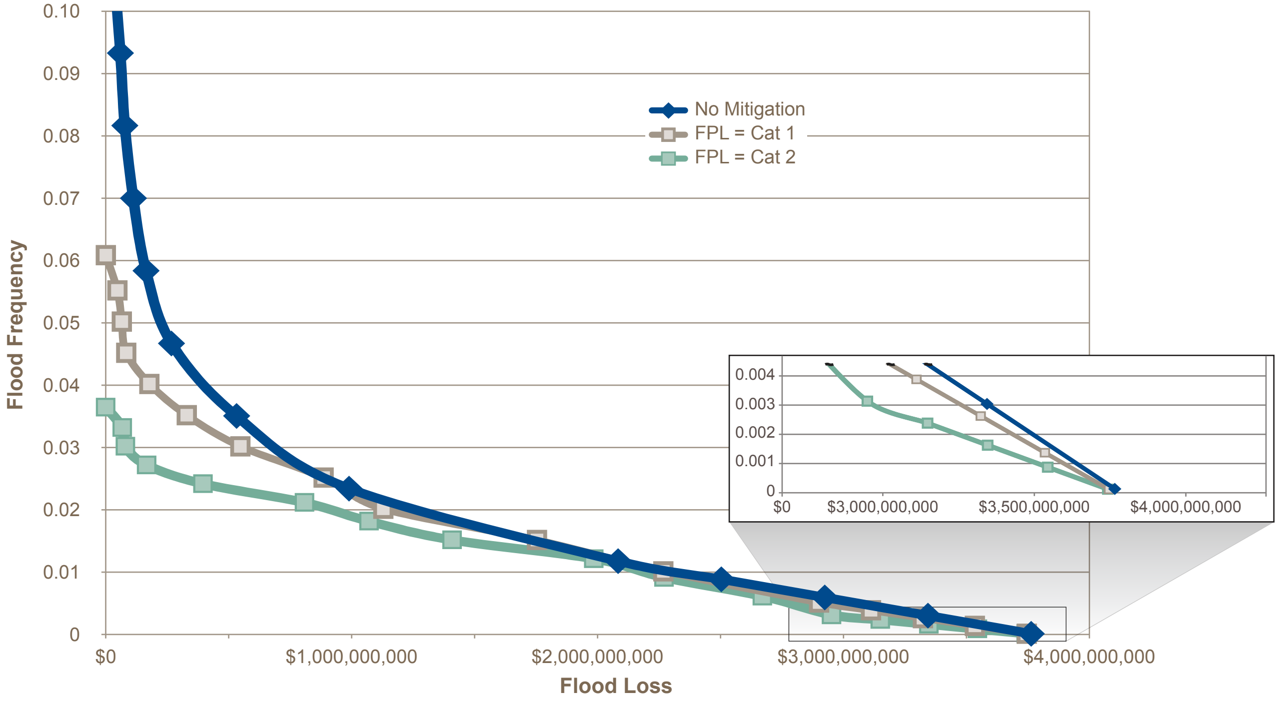

Figure 6.11b Galveston County EP Curves With and Without Flood Protection for Storm Surge Flooding

Based upon the results from the constructed EP curves above, Table 6.12 further provides the mean AAL reduction due to flood protection set to 50-year/Category 1 and 100-year/Category 2 for each county as well as across the applicable FEMA flood zones in each county. From this data we see that the AAL reduction due to flood protection is generally significant ranging from 11 percent to 57 percent for 50-year/Category 1 protection and 9 percent to 69 percent for 100-year/Category 2 flood protection. The flood protection percentage reductions are larger in Travis as compared to Galveston. Further, in Travis the percentage reductions are generally larger in the 100- and 500-year floodplains, and similarly in Galveston in the V and A zones. Finally, Figures 6.12 and 6.13 graphically illustrate these percentage reductions by flood protection level.

TABLE 6.12 MEAN AAL PERCENTAGE REDUCTION TO FLOOD PROTECTION BY COUNTY AND FEMA FLOOD ZONE

	Total County		**V Zone**		**A Zone**		**X500 Zone**		**X Zone**	
FPL	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
50 yr/CAT 1	-22%	-54%	-31%	N/A	-24%	-57%	-11%	-54%	-19%	-44%
100 yr/CAT 2	-28%	-62%	-52%	N/A	-41%	-61%	-21%	-69%	-9%	-59%

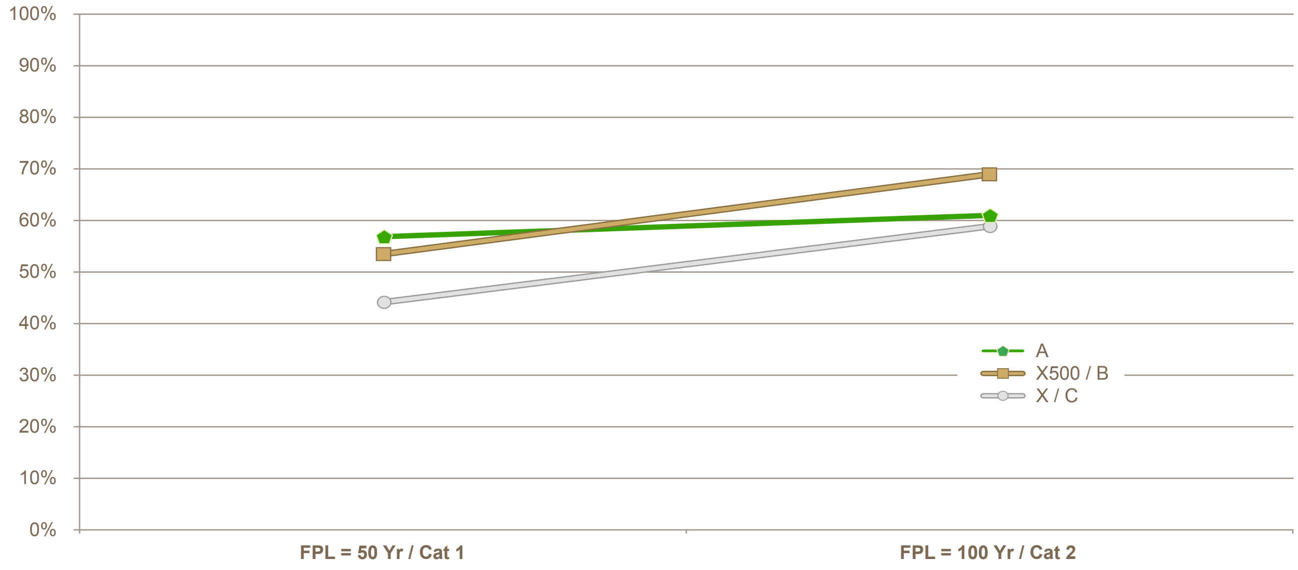

Figure 6.12 Travis County Mean AAL Percentage Reduction per Flood Protection Level

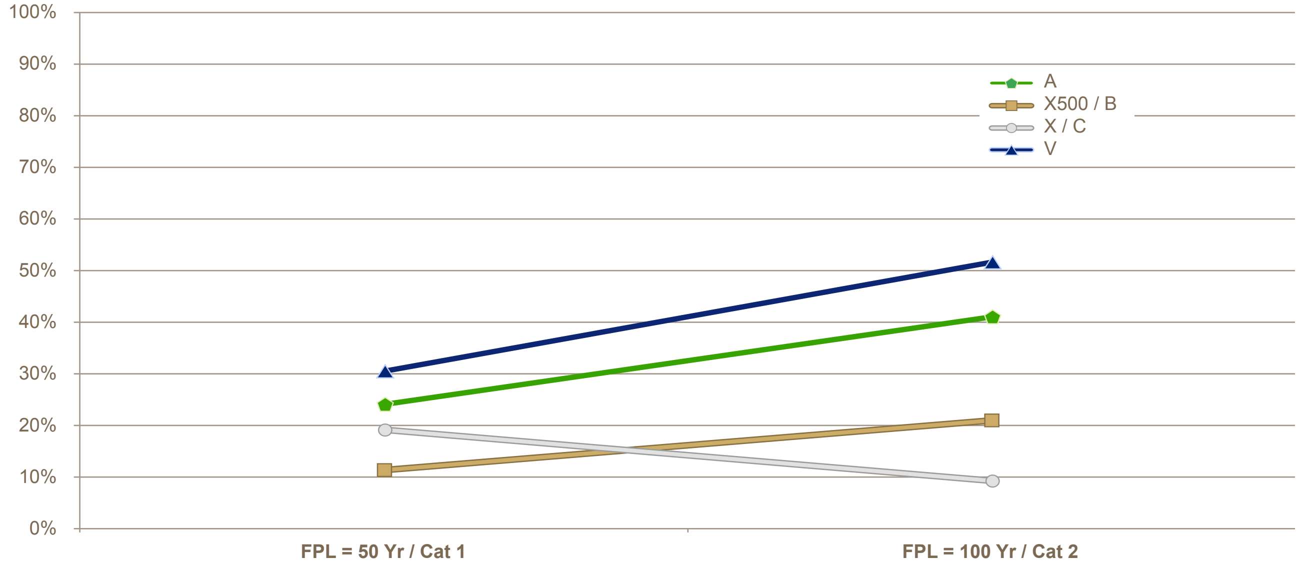

Figure 6.13 Galveston County Mean AAL Percentage Reduction per Flood Protection Level

While the above percentage reduction results indicate significant reductions to AAL in percentage terms, it is necessary to understand the magnitude of these benefits in economic terms. Table 6.13 provides the average benefits to flood protection taken over a 25 year time period with no discounting taking place. From this table we see that from an economic perspective (while the percentage reductions in AAL are significant) this does not necessarily translate into relatively significant dollar values. For example, the average 69 percent AAL reduction due to 100-year flood protection in the Travis County X500 zone is worth $29,083 over 25 years, or roughly a $1,163 annual benefit. Average benefit reductions over 25 years range from $4,311 to $31,702 for 50-year/Category 1 flood protection and from $1,904 to $29,083 for 100-year/Category 2 flood protection. These values are greater in Travis than in Galveston, and more significant in the 100-year floodplains in Galveston while relatively equally significant across all floodplains.

TABLE 6.13 AVERAGE ANNUAL REDUCTION TO FLOOD PROTECTION OVER 25 YEARS, NO DISCOUNTING

	Total County		V Zone		A Zone		X500 Zone		X Zone	
FPL	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
50 yr/CAT 1	$ 10,814	$ 28,605	$ 15,130	N/A	$ 12,361	$ 31,702	$ 4,311	$ 26,811	$ 9,480	$ 19,678
100 yr/CAT 2	$ 11,268	$ 27,028	$ 23,616	N/A	$ 18,647	$ 28,489	$ 6,799	$ 29,083	$ 1,904	$ 20,446

Of course, these are just average numbers. There are values that are higher and lower accordingly. Table 6.14 presents the maximum values for each zone again taken over 25 years and with no discounting. From this table, we clearly see instances of significant benefits to elevation with maximum values being $78,795 for 50-year/Category 1 flood protection and $98,791 for 100-year/Category 2 flood protection, or a $3,152 and $3,952 annual benefit per level of flood protection respectively.

TABLE 6.14 MAXIMUM ANNUAL REDUCTION TO FLOOD PROTECTION OVER 25 YEARS, NO DISCOUNTING

	Total County		V Zone		A Zone		X500 Zone		X Zone	
FPL	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**	**Galveston**	**Travis**
50 yr/CAT 1	$ 78,795	$ 68,930	$ 45,917	N/A	$ 78,795	$ 67,929	$ 35,359	$ 68,930	$ 44,509	$ 66,913
100 yr/CAT 2	$ 98,791	$ 77,819	$ 65,389	N/A	$ 98,791	$ 76,542	$ 51,053	$ 77,819	$ 63,755	$ 76,271

* AAL reductions derived from an assumed normal/average quality home. Reductions would be less for a good quality home, and more for a poor quality home.

Note:

Ideally, we would like to use these above benefit estimates in a flood protection benefit-cost analysis similar to that conducted for elevation in section 6.3. This could be done from an individual flood protection perspective or from a community perspective such as the proposed "Ike Dike" in Galveston County. However, we currently lack sufficient cost information for relevant flood protection measures such as placing sandbags, as well as lacking sufficient engineering knowledge of exactly how effective different protection measures would be in terms of the model's flood protection inputs such as an individual home levee, or a community levee.

Chapter 7

Conclusion and Future Research Directions

The National Flood Insurance Program has provided coverage to millions of residents and enhanced communities' flood protection across the country for more than four decades. In the aftermath of the 2005 and 2008 hurricane seasons, which triggered unprecedented amounts of flood insurance claims, the program had to borrow nearly $19 billion from the U.S. Treasury to cover its financial obligations to its policyholders. As a result, there have been calls for reforming the program from experts, insurers and reinsurers, and local, state and federal government bodies, including Congress. A major difficulty in judging the validity of the proposed reforms is that they typically provide a conceptual vision without any quantitative analysis of their pros and cons, how they will impact different stakeholders and their comparison with the status quo.

Congress and the President have renewed the NFIP twelve times between 2008 and 2011 (sometimes for less than one month), without ordering in-depth analyses. Building on recent research undertaken by the Wharton Risk Center, this study takes a step to fill this gap by estimating the flood-risk at the single-family residence level, focusing on two counties in Texas. Importantly, it provides the first systematic analysis of the potential for private flood insurance to complement the current NFIP operation so as to increase insurance protection for homeowners in hazard-prone areas, and thus reduce the need for post-disaster federal relief.

Technology has greatly improved since the 1960s, making flood risk much easier to quantify today. Four decades of claims from the NFIP provides the research team with important historical data to estimate future flood losses. Our findings show that current NFIP pricing does not always reflect local flood conditions; some properties are being undercharged while others are paying premiums that are greater than their actuarial risk as determined from the probabilistic model results. These findings also indicate that private insurers could provide coverage for some of these risks at premiums below those currently charged by the NFIP, even after applying a loading charge. Risk reduction measures also have a critical role to play in lowering exposure to future flooding and thus reducing the cost of flood insurance if premiums reflect risk. Our analysis on the cost and benefit of elevating existing houses in Galveston and Travis Counties reveals, however, that such a risk reduction measure would typically be expensive and not cost-effective except in certain circumstances. These findings suggest the need for a holistic approach to mitigation, such as implementing land-use restrictions and community based-mitigation efforts. The report provides insights that should be of interest to Congress and the Office of Management and Budget (OMB) at the White House as they examine ways to reform the flood insurance program. It should also enable the insurance industry and other stakeholders to consider the role that the private sector can play in reducing America's exposure to future floods.

More generally, for flood insurance to be entirely privatized—one of the policy options FEMA is exploring—a number of other issues must be addressed. These include but are not limited to: the ability of insurers to charge rates reflecting risk predicated on probabilistic modeling in a highly regulated market, special treatment for those who cannot afford risk-based premiums, a strategy for transitioning existing NFIP policies into the private market, the management of high-risk repetitive loss locations, data sharing, accurate mapping and the possible correlation or diversification of flood risk with wind exposure from hurricanes or other risks in an insurer's portfolio. Until at least these and possibly other issues are addressed, primary insurers are unlikely to be in a position to offer adequate amounts of flood insurance to homeowners.

Addressing these issues forms the basis for future research on how private insurers could be more active in providing flood coverage as a complement to the NFIP. For example, a survey analysis could be undertaken to better understand the desire and ability of primary insurers to participate in a private flood insurance market and what they believe are the major impediments in this regard. One could also conduct an analysis of the demand for flood insurance, assessing household perceptions of flood risk under situations where premiums reflect risk, and incorporating measures to deal with affordability issues. Other important questions along these lines to be researched include:

- Can FEMA provide insurance vouchers to homeowners whose premiums increase due to the implementation of premiums reflecting risk?
- Should flood insurance be required for everyone residing in a flood-prone area?
- Should flood insurance be tied to the property rather than the individual?
- How does one revise premiums that reflect risk, as risk of flooding changes in the near term (for example, due to the occurrence of a major event) or long term (for example, due to climate change)?
- What lessons can be learned from private flood insurance markets outside of the U.S.?

This study has modeled riverine and storm surge flood risk at the household level in two counties in Texas. It would be useful to expand this analysis to more counties in the state facing potential flood damage as well as other areas of the country with significant riverine and storm surge flood exposure. It would also be useful to incorporate features of the NFIP insurance policy such as deductibles and structural attributes of homes into the catastrophe model. Comparison between the NFIP rates and model risk-based rates for private insurance would also be enhanced by accounting for the existing subsidies in the NFIP to homes built prior to the construction of the Flood Insurance Rate Maps (pre-FIRM homes).

Our mitigation results highlight the need for further analysis on the impact of other direct benefits of flood mitigation, such as reduced fatalities and injuries. Future studies could also include analysis of indirect economic benefits, such as the savings in the costs of relocating residents if a mitigation measure were in place that enabled families to remain in their homes after a flood. It would also be useful to do a more detailed analysis of the cost-effectiveness of elevating new homes, where the mitigation cost may be considerably less than on existing homes. It would also be important to better quantify the cost-benefit of collective mitigation measures and the effectiveness of the community rating system (CRS) in providing incentives for more communities to be active in flood risk communication, mitigation and preparedness.

While it goes beyond the scope of this report, it would also be useful to learn more about how residents’ expectations of federal disaster relief impact their demand for flood insurance. Many residents might believe they will receive much more in funding than is actually the case. It would be interesting to undertake a survey of residents in exposed areas to better understand their beliefs about disaster relief, versus the benefits of being fully insured by flood insurance. Some of these questions are the focus of complementary work currently being undertaken by our team and research partners.

We look forward to continuing this research effort across many of these fronts in order to provide further value to both Congress and the Office of Management and Budget at the White House as they decide upon reforming flood insurance, and to the insurance industry and other stakeholders to reconsider the insurability of flood risk and how to reduce America’s exposure to future floods.

Please contact the authors for more information.

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The Center now includes 70 faculty, research fellows, and visiting scholars from all over the world to undertake large-scale initiatives. Providing expertise and a neutral environment for discussion, the Center team is also concerned with training decision makers and promoting a dialogue among industry, governments, interest groups and academics through its research and policy publications and through sponsored seminars, roundtables and forums.

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