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Community Insurance as a Flood Management Element in California

By

KATHLEEN KAY SCHAEFER
DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Civil and Environmental Engineering

in the

OFFICE OF GRADUATE STUDIES

of the

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DAVIS

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Committee in Charge

2024

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This has truly been an *It Takes a Village* effort. This is the culmination of a decade long quest to find alternatives to the National Flood Insurance Program. It started with a conversation about the potential role of Geologic Hazard Abatement Districts (GHAD) with Joe Tootle and a paper exploring the concept of community based insurance by Carolyn Kousky and Leonard Shabman. Both Carolyn and Leonard would become trusted advisors, providing an invaluable sounding board. The concept grew with the support of Uri Eliahu, Mark Niebuhr, Jeff Adams. For almost a decade, we have been meeting every Friday morning to explore the obstacles and advance the ideas. We have been joined most recently David Daniels, Patrick Ghallagher , Dennise Calixto-Michel, Raghuveer Vinukollu and Kim Floyd.

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Abstract

This dissertation addresses critical inadequacies in current flood risk management strategies by proposing an innovative community-based insurance (CBI) model. The research introduces a paradigm shift in flood insurance, reimagining it as 'Life Insurance for Levees' - a vital tool for community resilience in the face of escalating climate risks.

The study presents a novel three-tier, insurance-facilitated program for flood-risk management, integrating multidisciplinary approaches from economics, finance, insurance, engineering, and social sciences. This comprehensive alternative to the National Flood Insurance Program (NFIP) employs modern Enterprise Risk Management (ERM) concepts to actively manage flood risk's financial impacts.

Through a mixed-methods approach, including policy analysis, case studies, and stakeholder interviews, the research examines the potential of Geologic Hazard Abatement Districts (GHADs) as a governance mechanism for CBI programs. A case study of Isleton in the Sacramento-San Joaquin Delta illustrates the challenges and opportunities of implementing community-wide flood insurance. It also highlights the importance of GHADs in this new risk management strategy.

The findings suggest that while a community-based disaster resiliency and recovery program could provide a more equitable and cost-effective alternative to the NFIP, its widespread implementation necessitates targeted support from federal, state, and local entities. Key elements for success include strong public-private partnerships, innovative insurance strategies, upfront no-regrets seed funding, action-based academic research, and long-term commitment from local officials.

This research contributes significantly to the evolving field of climate risk management, offering a practical, community-centered approach that could transform disaster preparedness and recovery outcomes. By positioning flood insurance as a form of community life insurance, and as one component of a community ERM portfolio, this study aims to revolutionize the discourse surrounding flood risk management and community resilience.

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Chapter 1 Introduction and Methods

Introduction

The National Flood Insurance Program (NFIP) is the primary provider of non-federally-sourced flood disaster recovery payments (Fugate, 2015). It is the world's largest flood insurance provider (Maurstad, 2021). It is also deeply in debt. As of April 2023, the NFIP owed $20.5 billion to the U.S. Treasury (Government Accountability Office [GAO], 2023, p. 47). A 2023 GAO report estimated that an annual payment of $1.9 billion for the next 30 years would be needed to pay off the debt (GAO, 2023, p. 47). This study projected that over the next decade, the NFIP will incur an additional $5.8 billion in interest and related expenses, culminating in $10.6 billion in interest expenditures by the end of Fiscal Year 2029 (Federal Emergency Management Agency [FEMA], 2020 as cited in Congressional Research Service [CRS], 2021). If interest rates rise, FEMA's annual interest payments rise; thus, even in years with minimal loss, FEMA may be unable to discharge all its debt (GAO, 2017). In a 2021 testimony before Congress, NFIP Director Maurstad stated, "The NFIP is simply not fiscally sustainable in its current configuration" (Maurstad, 2021, p. 8).

The NFIP has been on the Department of Treasury's High-Risk List since 2006 (GAO, 2023; Wriggins, 2014) primarily because it is an insurance program that accrues more than $1 million a day in interest (GAO, 2023). Some point to its pricing structure, but the program's challenges are not confined to fiscal management. Scholarly and government inspector reports find deficiencies within the program's governance, administrative protocols, fee structures, and claims processing mechanisms collectively contribute to its fiscal unsustainability (Brown, 2010; Congressional Budget Office [CBO], 2017; GAO, 2020a; GAO, 2023: Strother, 2018). Others suggest that mismanagement of existing flood risks (Rosenthal, 2020), more severe weather

events, and rising housing costs are to blame (Kousky, 2022; Warner et al., 2009). Still, others view it as a "failed land use program and a misapplied environmental policy" (Elliott, 2021, p. 33). A Government Accountability Office (2023) report finds that financial conditions are unlikely to change even with Risk Rating 2.0, the program's new premium pricing structure.

Not all insurance programs are as fiscally challenged. Berkshire Hathaway Inc. (BHI) has been a broad and successful conglomerate for over fifty years (Berkshire Hathaway Inc., 2023). Although it has diverse interests in the rail, energy, manufacturing, and retail industries, insurance is vital to BHI's overall business strategy (Berkshire Hathaway Inc., 2023). Property and casualty insurance form the foundation of Berkshire's prosperity (Buffett, 2023). The success of BHI compared to the NFIP's challenges prompts questions. Why is BHI's portfolio of insurance companies successful when NFIP has struggled fiscally? What can be learned from comparing the NFIP to successful insurance companies? How did the NFIP become so fiscally challenged? What conditions are needed for a risk such as flooding to be considered insurable? Can a community-level program manage flood risk more effectively than the NFIP? If so, what might such a program look like, and how might it be implemented? At the NFIP's 50-year mark, is there a case for dismantling it and devising innovative programs that build on advances over the past decades? Although the inadequacies of the NFIP are well documented (GAO, 2017; GAO, 2020a; GAO, 2023; Knowles & Kunreuther, 2014), there is a gap examining these shortcomings in terms of what it takes to be a successful, fiscally sustainable insurance company. This dissertation explores these questions and makes some suggestions.

Given the vital role of insurance in society and the importance of the NFIP in the nation's disaster risk management program, it is relevant to examine why NFIP is not thriving like some other property and casualty insurance enterprises. Insurance provides financial protection against

potential losses or damages from unexpected events, such as accidents, natural disasters, or theft (Liedtke, 2007; Weingärtner et al., 2017). Insurance fosters economic stability by distributing the costs of losses across a larger pool of policyholders (Eckles et al., 2021; Weingärtner et al., 2017). It facilitates economic growth through its functions, ranging from risk allocation to governance and public relief (Skipper & Klein, 2000; Zhou et al., 2023). Prompt insurance payouts mitigate uncertainty, boost aggregate demand and investment in reconstruction, expedite economic recovery, and minimize periods of diminished economic productivity (Liedtke, 2007; Weingärtner et al., 2017; Zhou et al., 2023). Insurance is a safety net, providing financial stability, security, and peace of mind (Liedtke, 2007; Weingärtner et al., 2017; Shou, 2023). It allows individuals and businesses to focus on their daily lives without constant fear of catastrophic losses (Weingärtner et al., 2017). It buffers the sudden surge of financial liquidity after a disaster (Liedtke, 2007; Zhou et al., 2023).

Lacking insurance, federal assistance is sometimes available to help with recovery, although it is uncertain, fragmented, and inadequate (GAO, 2022). A 2022 GAO report found that federal disaster aid is spread across over 30 agencies after decades of incremental reforms (GAO, 2022). The primary providers of disaster aid are the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (USACE), and, increasingly, the Department of Housing and Urban Development (HUD) (GAO, 2022). Recovery payments from these agencies often take months, delaying the community's recovery. In response to calls for change, in January 2024, the Biden administration enacted changes in FEMA’s Individual Assistance (IA) program designed to speed up payments to individuals (FEMA, 2024, January 19). The effectiveness of these measures will be tested as communities try to recover from Hurricane Helene and Hurricane Milton.

Examining what distinguishes a successful insurance company from a failing one is relevant to the civil engineering profession. Both engineering and insurance must navigate the complexities of risk and uncertainty. Effective management of societal risk and uncertainty aligns with the expanded role of civil engineers as proposed by the American Society of Civil Engineers (ASCE) nearly two decades ago (American Society of Civil Engineers [ASCE], 2006). Examining NFIP's challenges provides an opportunity to formulate new programs that overcome existing shortcomings.

Methods

This research incorporates both quantitative and qualitative methods. Porter (2014) argued that community-level changes are complex. He helped community members with business development decisions using mixed-method research with a case study. This dissertation follows a similar approach. This mixed-method approach is also called for in recommendations from the 2018 Delta Social Science Task Force (Bidenweg et al., 2020). A quantitative analysis of NFIP policy and claims data provided information and insight into the program's current state. The concepts of grounded theory and appreciative inquiry (Barrett & Fry, 2005; Dick, 2007) influenced the qualitative methods used in this dissertation. We deployed them in a case-study approach.

The appreciative inquiry complements traditional theory-driven methods. "Evidence-based practice" can underestimate or overlook the complexity of low-probability, high-consequence decision-making (Dick, 2007, p. 13). In contrast, appreciative inquiry supports broader Community-Based Disaster Risk and Recovery Management (CBDRRM) initiatives, helping communities understand and manage disaster risk (Wolff, 2021). This approach grants communities ownership of their flood risk and empowers citizens, shifting them from victims to empowered community members (Wolff, 2021).

I applied concepts from appreciative inquiry and insights from qualitative analysis to a case study of Isleton, California. Yin (2009) asserts that case studies offer valuable insights into complex problems. The Isleton case study revealed many challenges facing small rural communities, emphasizing the value of building community resilience through education, collaboration, and capacity building. The study also highlighted the need for solutions tailored to a community's unique challenges.

A team of industry experts aided this research. Experts included representatives from EPIC Brokers, the 15th largest insurance broker in the US, and ENGEO, an engineering and geology firm managing most of California's Geologic Hazard Abatement Districts (GHADs). The team has met every Friday morning for over eight years. Representatives from MiniCo Insurance Agency, an insurance innovation firm, and Munich RE, a global reinsurer, joined the calls two years ago. Munich RE is one of the world's leading reinsurers and an innovator in working with nature-based solutions. Representatives from other companies periodically joined the conversation, providing guidance and suggestions.

We evaluated our assumptions with a case study in the California Delta community of Isleton. Isleton is located within a polder (island) in the Sacramento-San Joaquin Delta. Many small communities in California share its small size and larger financial challenges. Isleton is protected on all sides by levees that provide less than a 100-year level of protection. The entire community is in a FEMA Special Flood Hazard Area (SFHA), which is unlikely to change. The research examines the community's flood risk within Isleton's governance and physical location, considering its unique history, cultural background, and socioeconomic challenges. Chapter 5 presents case study details.

Thesis Structure

This dissertation has six chapters. This introductory chapter presents an overview of research questions. Chapter 2 provides a short history of the insurance industry and the NFIP. Chapter 3 explores what makes a flood event insurable. It also discusses various risk financing options. This provides the background and framework for a new flood insurance arrangement proposed in Chapter 4. Chapter 5 explores opportunities for implementation through the case study. It examines the existing governance gap, proposing options for its closure. Finally, Chapter 6 summarizes the findings and proposes future research topics.

Chapter 2 NFIP Background and History

This dissertation aims to design a new flood insurance scheme for California residents. The NIFP is an underperforming insurance program, particularly for California, where less than 1% of flood-prone properties are insured (First Street Foundation, 2020). Studies of why the NFIP is underperforming generally focus on the program's inability to charge actuarially fair rates (FEMA, 2018; GAO, 2017; Tambala Strategy, LLC, 2022). This dissertation argues that a broader examination of contributing factors provides insights for designing alternative arrangements.

The genesis of the NFIP began in 1966 when a Senate Committee on Banking and Currency recommended that the nation's flood insurance needs could be met with "a program of flood insurance of an essentially private character, but with continued large-scale participation of the federal government" (Senate Committee on Banking and Currency, 1966, p. IX). Although aspects of this report were incorporated into the legislation creating the NFIP, they were quickly abandoned. This dissertation argues that these original recommendations should be revisited when designing a new flood insurance program.

Not all insurance entities are underperforming; some provide liquidity that drives more extensive, successful investment portfolios (Zhou et al., 2023). Valuable insights can be gained by comparing an underperforming insurance program to a successful private insurance enterprise. A successful insurance program requires a robust organizational structure that effectively supports product sales and distribution, meeting consumer demand while maintaining fiscal solvency (American Academy of Actuaries, 2017; Skipper & Kwon, 2008). To provide context, this chapter begins by comparing the administration, management, and fiscal policy of the NFIP with those of successful property and casualty insurance companies.

This chapter then explores the insurance industry's history and the NFIP's transformation. The insurance industry's evolutionary changes are presented as the backdrop to the abrupt changes experienced of the NFIP. Although the NFIP may have initially had a fiscally sustainable framework, it rapidly became unsustainable. Subsequent abrupt and incremental changes have failed to address fiscal unsustainability and exacerbated the problem. This discussion is organized by decades as changes in the insurance industry have been continual. In contrast, changes in the NFIP have occurred only after significant disasters. The choice of period length is driven by the desire to tell the story of change from both perspectives.

It is often said that the NFIP was created because private insurers left the market. This chapter shows that this is only partially true. Insurers left the flood insurance business after the Great Midwestern Floods of 1926. However, by 1968, they were willing to re-enter the market. The NFIP began with a robust public-private partnership. Examining why the NFIP abandoned its private partnership supports the idea that Californians' flood recovery needs could be better served with an insurance arrangement that returns to the original thinking, essentially private in character but with continued large-scale state and federal government participation.

A Comparison of NFIP Management to Private Insurance Management

FEMA's organizational structure and primary mission influence its administration fo the NFIP, creating unique challenges and priorities. FEMA, the agency tasked with administering the NFIP, is within the Department of Homeland Security (DHS) (GAO, 2014). FEMA’s integration into DHS means it must comply with DHS priorities, policies, and procedures. Although FEMA administers the NFIP, flood insurance is not its primary mission (FEMA, 2022a). FEMA’s primary focus is emergency management, including civil defense emergency management and natural hazards emergency management (FEMA, 2022a). FEMA’s current goals include instilling equity

as a foundation of emergency management, leading entire communities in climate resilience, and promoting and maintaining a prepared FEMA and a prepared nation (FEMA, 2022a). The FEMA Director has dual responsibilities: leading the US emergency management system while simultaneously managing the world's largest flood insurance program.

FEMA's priorities change with each presidential administration. The NFIP was initially within the Department of Housing and Urban Development (HUD). During the Johnson administration, HUD prioritized "Great Society" reforms (Elliott, 2021; Knowles & Kunreuther, 2014). Placing the NFIP in HUD reinforced its land-use priorities. During the Nixon administration, the nation's focus changed from providing services to people in poverty to preparing for nuclear war. In 1979, to streamline disaster relief activities, the Carter administration created FEMA and moved the NFIP management from HUD to FEMA. Under the Reagan administration, FEMA's mission focused on supporting the nation's Cold War civil defense efforts. Clinton appointed James Lee Witt as FEMA administrator, who reverted to a focus on emergency management. Witt created Project Impact, a program that funded communities to do local disaster planning. Under the Bush administration, Project Impact was abandoned, and the September 11, 2001, attack shifted the focus to counterterrorism (Knowles & Kunreuther, 2014). Some scholars and policymakers have argued that DHS's prior emphasis on counterterrorism may have led to a neglect of other aspects of FEMA's mandate (Bea, 2007; Knowles & Kunreuther, 2014; Parker et al., 2009). The Obama administration attempted to return the focus to disaster preparedness, only to have the Trump administration repeal Obama's executive orders (Hanna, 2017). Being a successful insurance enterprise may prove challenging if insurance is not the primary focus, leadership lacks insurance expertise, and priorities shift every four years for non-business reasons.

In contrast, successful insurance companies keep a single focus—managing an insurance company. They strongly emphasize customer service, ensuring that products and services are tailored to meet the specific needs of their clientele (EY, 2023). This involves understanding customer preferences and developing solutions that address these needs (EY, 2023). Exceptional customer service emphasizes efficient claims processing and transparent communication to support high customer satisfaction and loyalty (EY, 2014). They leverage technology and innovation to create user-friendly digital platforms that facilitate policy management, claims processing, and support services to enhance the customer experience (EY, 2023).

Successful insurance companies emphasize prudent risk management (Buffett, 2023; Liedtke, 2007; Vaughan & Vaughan, 2007). Accurate risk assessment through robust underwriting practices allows for proper risk pricing, while diversification across insurance products and geographic regions minimizes exposure to significant losses (Buffett, 2023; Liedtke, 2007; Vaughan & Vaughan, 2007). When they acquire a concentration of risk, they often transfer some risk to reinsurers who protect against large claims and catastrophic events, ensuring financial resilience (Liedtke, 2007; Vaughan & Vaughan, 2007).

Successful insurance companies have a knowledgeable and experienced insurance professional as the Chief Executive Officer (CEO) (Vaughan & Vaughan, 2007). For example, the head of GenRE, one of BHI's insurance companies, has over 20 years of experience as an actuary (GenRE, 2024.). In contrast, current FEMA Director Deanne Criswell's 30 years of professional experience is in emergency response, starting as a Deputy Fire Chief for the Colorado Air National Guard (Criswell, n.d.).

Financial stability is essential for an insurance company's long-term success (Buffet, 2023; Liedtke, 2007; Vaughan & Vaughan, 2007). This involves maintaining adequate capital reserves

to meet policyholder obligations and implementing a prudent investment strategy to generate returns while managing risk (Vaughan & Vaughan, 2007). Cost control is also essential to improve profitability without compromising service quality (Vaughan & Vaughan, 2007). Adhering to regulatory compliance and maintaining transparency in financial reporting and governance practices builds trust with regulators, investors, and customers (Cummins & Weiss, 2016).

To enhance financial stability, insurers are increasingly blurring the line between financial markets and traditional insurance (Csiszar, 2007). Insurance-linked securities (ILS) move insurance risks to the financial markets (Csiszar, 2007). ILS will be discussed in more detail in Chapter 3. Csiszar (2007) argues that Hurricane Katrina spurred the insurance industry's interest in moving risk to broader financial markets. A brief history of the evolution of insurance and the NFIP is provided to understand the opportunities this transition brings.

History Of Insurance Development and the NFIP

Over the past century, the insurance sector has evolved from primarily serving the merchant class and shipping industry to becoming a global financial powerhouse, facilitating the movement of billions of dollars across international markets. In 2007, the value of the world's stock markets was about $41 trillion (Csiszar 2007, p. 321). In contrast, in 2006, the notional value of swaps and derivatives (financial instruments that include insurance) was $327 trillion. In 2024, the gross premium of the US property insurance market was expected to be $240.4bn (Statisica, 2024). As financial markets seek investment opportunities, insurance markets seek ways to further diversify their risks, bringing insurance and financial markets closer together.

The insurance industry has undergone continuous change, accelerating in the last two decades. In contrast, the NFIP's development has followed a pattern of "punctuated equilibrium" (Knowles & Kunreuther, 2014; Ruseva et al., 2019. p. S68). Punctuated equilibrium is a policy

model with periods of relative stability punctuated by abrupt changes (Baumgartner et al., 2018). For the NFIP, changes typically are triggered by significant regional flood catastrophes that prompt legislative reforms. These reforms remain static until the next major flood catalyzes further change (Knowles & Kunreuther, 2014). The following section contrasts the NFIP episodic transformation against the backdrop of the insurance industry's more constant yet increasingly rapid evolution. Understanding this background helps to make the business case for the insurance-supported community resiliency framework. We examine changes in five periods: pre-World War II, 1950s to 1980s, 1980s to 2020s, 2020s to present, and the future.

The following section examines the evolution of the NFIP in the broader context of the insurance industry's transformation. In addition to the financial changes, the role of insurance in land development is discussed. After World War II, the insurance industry influenced urban development, pushing many people of color into flood-prone areas (Horan, 2021). Many of these areas, occupied by non-white residents, remain flood-prone, and as the NFIP strives to establish a sound financial footing, it exacerbates long-standing inequalities (Mileti, 1999; Elliott, 2021).

Insurance Before World War II

In the nineteenth century, when commercial insurance was only available through the merchant class, familial networks, fraternal societies, and mutual aid organizations supported the working class and minority populations (Beito, 2000, as cited in Horan, 2021). Fraternal organizations pool the resources of their members to provide for the less fortunate (Horan, 2021). Participants were drawn to these mutual aid organizations for a sense of community and solidarity (Horan, 2021). They embraced risk spreading to maintain solidarity and a shared commitment to the community (Horan, 2021).

The 1920s and 1930s brought significant expansion of employer-based benefit plans, typically including pensions, annuities, and health insurance (Horan, 2021). These comprehensive packages offered workers and their families financial security (Horan, 2021). However, as Klein (2003, as cited in Horan, 2021) argues, these benefits were a form of employer paternalism strategically implemented to curb the influence of labor unions. This era saw large employers purchasing extensive insurance plans, consolidating capital and political influence within the insurance industry (Horan, 2021). This shift reshaped employee benefits and altered the balance of power between employers, employees, and insurers, setting the stage for the complex interplay of public and private interests in the American welfare system for decades (Herrick & Stuart, 2005). This is pertinent to flood insurance, as the capital accumulated in the life insurance business line fueled land development after the war (Horan, 2021).

The 1920s and 1930s brought changes to flood control. The Mississippi flood of 1927 breached federal levees, causing widespread destruction and advancing the case for a federal role in building hazard reduction projects (Berry, 1997). The Flood Control Act of 1936 set up federal responsibility (Shabman, 2014). The justification for the federal role was that flood mitigation was best done on a watershed scale (Shabman, 2014).

The 1940s, dominated by World War II, saw modest changes in the insurance industry. A pivotal development in this period was the passage of the McCarran-Ferguson Act of 1945 (Horan, 2021). This legislation established a unique regulatory framework for the insurance industry, allowing federal oversight of antitrust issues while delegating all other insurance regulations to individual states (Horan, 2021). This arrangement enabled insurance companies to leverage competition among states for more favorable regulatory conditions, leading to the concentration

of insurers in business-friendly states like Delaware and contributing to interstate variations in policy costs (Horan, 2021).

The state-versus-federal dynamic in insurance regulation is a challenge for flood insurance. In private insurance, disputes frequently stem from unclear policy terms (Horan, 2021; Mathewson et al., 2011). Disputes over coverage in private insurance are typically adjudicated in state court (Mathewson et al., 2011). Under a common legal doctrine that interprets contracts against their drafters, courts often resolve these ambiguities in favor of the policyholder. In contrast, the NFIP operates at the federal level, meaning disputes over claims payments are adjudicated in federal courts. Federal laws and regulations mandate the language of NFIP flood policy contracts. Insured individuals may not claim ignorance of the policy terms in coverage disputes. This dichotomy creates a complex legal landscape with potential implications for policy interpretation, claims processing, and consumer protection.

Insurance From 1950s to the 1980s

The 1950s and 1960s were a period of growth for the insurance industry, driven by advances in actuarial science and financial management (Zuckerman, 2019). By 1964, Prudential Insurance had become the third largest private company in the world, with $2.4 billion in annual revenue (Sheehan, 1964, p. 99), as cited in Horan (2021). During this era, insurance companies emerged as some of the largest providers of private capital in the US housing market (Sheehan, 1964, p. 99), as quoted in Horan (2021). Prohibited by law from investing in stocks, insurers found investing in mortgages attractive. Between 1950 and 1975, life insurance companies were the most prominent backers of home loans (Horan, 2021). This diversification into real estate financing bolstered the insurance industry's financial power and intertwined it into local land development decisions (Horan, 2021; Rothstein, 2017).

Spurred by post-World War II demand for housing, insurers invested in mortgages and land development (Horan, 2021; Rothstein, 2017). City and state governments, desperate for funds to build the much-needed housing and life insurance companies flush with cash, seeking to diversify, formed partnerships. During this time, life insurance helped finance, build, and manage some of the first large-scale construction projects. Insurers controlled every step of the development, from the selection of construction materials (pushing fire-resistant materials) to the selection of tenets (segregated by race and class) (Horan, 2021; Rothstein, 2017). Insurers found these developments attractive because of the greater control over operations than if they had merely held the mortgage (Elliot, 2022; Horan, 2021).

This arrangement did not work out as envisioned (Horan, 2022). Investment returns from housing construction that did not meet expectations and cost overruns for construction contributed to the insurance industry pulling away from the market (Horan, 2022). To protect their investments, they insisted on a policy of racial segregation that would eventually affect their reputation (Horan, 2021; Rothstein, 2017). During this period, restrictions prohibited Black homebuyers from buying homes in fast-growing suburbs like those in San Jose (Rothstein, 2017). Black workers in the growing aerospace industry would have to commute daily from low-lying, flood-prone areas in Richmond to take advantage of the high-paying jobs in San Mateo County (Horan, 2021; Rothstein, 2017).

In 1954 and 1956, hurricanes disrupted the economies of Connecticut, Rhode Island, and North Carolina (Grossman, 1958). These events began a pattern of punctuated equilibrium in the development of the NFIP. Private citizens, industrialists, merchants, labor groups, and local governments demanded some form of flood insurance program (Grossman, 1958). Despite opposition from private insurance firms, a Senate Banking and Currency subcommittee conducted

hearings to assess if flood insurance was a proper subject for federal legislation (Knowles & Kunreuther, 2014).

The committee's deliberations led to several conclusions (Grossman, 1958). The committee agreed that an insurance program was needed, and if it were to succeed, it would need the federal government's broad jurisdiction and financial strength (Grossman, 1958). There was also consensus that the program would need (1) a sizeable financial reserve for a flood insurance program; (2) subsidies to make premiums affordable, at least until broad coverage was achieved; (3) widespread participation; and (4) flood-risk reduction programs (Grossman, 1958). From these hearings, Sen. Prescott Bush of Connecticut proposed a public/private program flood insurance program with federal authority to set rates (Grossman, 1958).

In 1956, Congress passed the Flood Insurance Act of 1956 (Flood Insurance Act, 1956), with only minor technical amendments to Senator Bush's legislation (Grossman, 1958). This act established public-private partnerships for flood insurance provision (Grossman, 1958). Private insurers were to offer policies, while the federal government agreed to subsidize the overhead costs from sales and administration, as well as 40% of the remaining cost of the insurance (Grossman, 1958, p. 154). The 40% subsidy was to be split between the federal government and the state (Grossman, 1958, p. 154). However, due to lack of funding, the program lasted only one year (Grossman, 1958). It is unclear why Congress declined to fund the program, except that the record reflects that the legislation was passed over the opposition of private insurance companies (Grossman, 1958). This concept of shared financial subsidy between state and federal governments will be reintroduced later when alternatives to the NFIP are explored.

In 1965, a hurricane known as "Billion Dollar Betsy" destroyed New Orleans and the Gulf Coast, including President Johnson's home state of Texas (Hurricanes: Science and Society,

2018).) Hurricane Betsy prompted Congress to direct HUD's Comptroller General to study the feasibility of flood insurance (Comptroller General of the U.S., 1976). The HUD study, *A Unified National Program for Managing Flood Losses* (House Document 465), affirmed it would be feasible to provide subsidized flood insurance to homeowners who purchased homes in flood-prone areas without fully understanding the risks (Comptroller General of the U.S., 1976). However, the study included two caveats: premium rates for new construction would need to be actuarily based, and communities would need to implement floodplain management regulations to reduce future losses (Comptroller General of the U.S., 1983). These recommendations laid the groundwork for more comprehensive flood risk management, balancing the need for affordable insurance with the overarching goals of risk reduction and responsible development.

Shortly after the 1966 task force report, the Senate Committee on Banking and Currency released its report. The report presented four insurance alternatives ranging from a wholly private program to an all-federal program (National Research Council, 2015; Senate Committee on Banking and Currency, 1966). The report envisioned "a program of flood insurance of an essentially private character, but with continued large-scale participation of the federal government" (Senate Committee on Banking and Currency, 1966, p. IX). These two studies led to the National Flood Protection Act of 1968 (42 U.S.C. et. seq.; Knowles & Kunreuther, 2014).

HD 465 asserted that federal policies regarding development in the floodplain could encourage development as long as the benefits of locating people and structures outweighed the costs (Shabman & Scodari, 2014). In this view, costs included all possible damages incurred by floodplain occupants, any financial risks transferred to others, and any lost recreational and wildlife conservation values (Shabman & Scodari, 2014). Costs also encompassed protection measures to reduce the extent and frequency of flood damage, damages inflicted on others due to

encroachment, and public costs for disaster relief and rehabilitation (Shabman & Scodari, 2014). This document was interpreted to mean that the federal policy's recommended purpose was not solely to reduce damages and promote economic development but also to support economically efficient floodplain uses (Shabman & Scodari, 2014). Over the next 50 years, federal policy shifted away from economic efficiency goals toward a focus on continuously reducing the likelihood and magnitude of adverse consequences, measured by property damage values, human fatalities, and environmental damages.

When the National Flood Protection Act of 1968 was passed, private insurance was expected to be an active partner in implementing the program. The Act authorized a public-private partnership between the Federal Government and the private insurance industry (42 U.S.C. §4001(b),(d)). Implementation was to start only after consultation with insurance industry representatives (42 U.S.C. §4041). The Act gave the Secretary of HUD two ways to operate the program. It could be an industry program with Federal financial assistance (Part A). Part A encouraged insurance companies to form a pool to provide flood insurance coverage authorized by law (Ascik, 1977). Only if the Secretary of HUD determined that the program could not be carried out under Part A, or if the Secretary determined that the Federal Government would materially assist the operation, could it convert the program to Part B (Ascik, 1977). Part B of the Act provided for a wholly government-run program if the government-industry program proved unworkable (Ascik, 1977). If it converted to a wholly government-run program, Congress directed the Secretary to actively use the services of private insurance firms (42 U.S.C §4041; American Institutes for Research et al., 2002).

In January 1969, the Federal Insurance Administration began operation, entering into agreements with the National Flood Insurers Association (NFIA) (Ascik, 1977). NFIA, a

consortium of 132 insurance companies, dealt with flood disasters (Ascik, 1977). NFIA created an insurance pool with over $44 million in risk capital, sharing the aggregated profits or losses (Ascik, 1977). The pool covered part of the losses and operating costs. The federal government was to subsidize the program with equalization payments that represented the Federal Government's share of the cost of providing affordable insurance to existing property owners (U.S. Congress, Banking, and Currency Committee, 1967). NFIA handled purchasing excess loss reinsurance to assist with catastrophic losses. NFIA was also responsible for many administrative and accounting functions related to the program and the sale of insurance policies (Eschwege, 1978). In June, the first insurance policies were sold.

The National Flood Insurance Act made insurance available in states interested in providing insurance and willing to adopt land-use regulations (Knowles & Kunreuther, 2014). However, the maximum limit of flood insurance was only available if a detailed flood insurance study for the community had been completed (Knowles & Kunreuther, 2014). Because detailed studies were costly and took a long time to complete, the Act was amended in 1969, establishing an emergency program that allowed a minimum amount of insurance to be sold if the community adopted a flood hazard boundary map (Comptroller General of the U.S., 1976; Knowles & Kunreuther, 2014). These Flood Hazard Boundary Maps (FHBMs) were temporary maps delineating flood hazard areas using major roads as boundaries (Comptroller General of the U.S., 1976; Knowles & Kunreuther, 2014). The 1968 Act also mandated that detailed Flood Insurance Rate Maps (FIRMs) be provided to every flood-prone community by June 30, 1974 (American Institutes for Research et al., 2002).

Insurance sales were initially slow (Ascik, 1977; Knowles & Kunreuther, 2014). As of December 1969, only 16 policies had been sold (Knowles & Kunreuther, 2014). Two years later,

the number increased to 87,000. In 1972, rates were lowered to encourage participation (Knowles & Kunreuther, 2014). NFIA had 40,000 insurance agents participating in the program (Ascik, 1977). However, when Hurricane Agnes struck the East Coast in June 1972, less than 1% of damages were covered (FEMA, 2002, p. 3). Of more than $400 million in structural damages, only $5 million was covered by flood insurance, with 95,000 policies nationwide, representing $1.4 billion in coverage (FEMA, 2002, p. 3).

After Hurricane Agnes, Congress enacted significant changes in the NFIP (Mathewson et al., 2011). The Flood Disaster Protection Act of 1973 required property owners with federally-backed mortgages to buy NFIP flood insurance (American Institutes for Research et al., 2002; Kunreuther, 2015). Five years later, active policies increased to 1.2 million (Mathewson et al., 2011). Besides enacting new requirements for homeowners, it added the requirement that communities adopt FEMA's FIRMs as a condition for receiving federal disaster assistance (Mathewson et al., 2011). As the program changed from voluntary to mandatory, these changes increased the need for maps with boundaries that followed topography instead of major roads (Comptroller General of the U.S., 1976).

In addition to changes for homeowners and communities, the Flood Disaster Prevention Act of 1973 (Flood Disaster Prevention Act, 1973) changed private insurer's compensation rules. Private insurers were restricted to a maximum of 5% of the NFIP premium income, with any surplus premium revenues allocated to a reserve for future losses (Flood Disaster Prevention Act, 1973). While making private insurers responsible for the first loss layer, the enabling legislation provided reinsurance through the federal treasury for catastrophic losses (Flood Disaster Prevention Act, 1973). This meant private insurers could exclude reinsurance costs in their premiums, reducing the cost of insurance (Ascik, 1977). In extremely high-risk areas, the federal

treasury was to make an annual equalization payment of the difference between an NFIP risk-based rate and a set affordable premium (Ascik, 1977; Flood Disaster Prevention Act, 1973).

From 1969 to 1977, the Department of Housing and Urban Development (HUD) and NFIA disagreed on cost, performance, and federal payments (Ascik, 1977). During this period, the NFIP paid $220 million in claims, of which $138 were paid in a single year (Ascik, 1977, p. 2). NFIA's 132 companies shared an annual profit of only $1.5 million (Ascik, 1977, p. 2). After negotiating for over 18 months without success, NFIA notified HUD that it did not intend to renew the Part A agreement, which was to expire on December 31, 1977 (Ascik, 1977, p.2; Eschwege, 1978).

NFIA's notification to end the agreement prompted HUD to issue a request for proposals to operate the program under either Part A or Part B, the latter being a fully government-run program (Ascik, 1977). HUD received two Part B proposals: one from Electronic Data Systems (EDS), one of the first "big data" companies, and another from NFIA (Eschwege, 1978). HUD asserted that a government-run program, with actuarial accounting managed by EDS, would save the government $15 million per year (Ascik, 1977, p. 3; Eschwege, 1978). The House and Senate financial committees challenged this decision and asked for more time to assess the claim (Ascik, 1977, p.3; Eschwege, 1978). The private firms argued that shifting NFIA's data on over a million flood policies to EDS computers would be costly and time-consuming, and homeowners would lose insurance experts and access to NFIA's partnership of 132 insurance companies (Ascik, 1977, p.3; Eschwege, 1978).

HUD compared the two proposals and determined that EDS's proposal was $15 million less than NFIA's (Eschwege, 1978). At the request of Congress, the Congressional Budget Office (CBO) also reviewed the proposals (Eschwege, 1978). Because they were dissimilar, CBO found it challenging to make a recommendation (Eschwege, 1978). Ultimately, due mainly to the $15

million cost disparity, the EDS proposal was approved, resulting in the transfer of the flood insurance program and the whole Federal Insurance Administration to the newly established FEMA (Eschwege, 1978; 42 U.S.C. § 4001(d)(1); Id. § 4041; Id. §§ 4051-4056; Id. § 4071; Id. § 4071(a); Id. § 4071(a)(1)). From 1969 to 1975, cumulative administrative, surveys, and study costs totaled about $204 million (Comptroller General of the U.S., 1976, p. 4). A Comptroller General (1983) report found that between 1970 and 1980, despite the relatively small scale of the program (1,897,271 policies in 1980), the NFIP borrowed $854 million from the US Treasury. (Comptroller General of the U.S. 1983, p. 34).

Thus, the largely private program run under NFIA went from having a $43 million surplus to a government-run program with a $854 million deficit. Equally significant, it went from a program where financial risks from catastrophic losses are identified and actively managed through the purchase of reinsurance to one where the financial risks from catastrophic losses are shelved and passively assumed to be borne by the federal government. Less than ten years after enactment, the original arrangement, in which the private sector had the primary responsibility to manage the insurance risk pool, was replaced by a government-led partnership, where the federal government underwrites the insurance risk pool (National Research Council, 2015).

In less than a decade, a program intended to have strong private-sector involvement was replaced by a program with little private-sector involvement. Thus, the federal government became the sole underwriter of flood insurance risk (Ascik, 1977; National Research Council, 2015). The program transitioned from one with strong private-sector involvement to one with no private-sector participation, shifting the entirety of the insurance risk to the federal government. Furthermore, the program evolved from a wholly voluntary system to mandatory requirements for communities and homeowners in high-risk flood zones (Knowles & Kunreuther, 2014). This

fundamental transformation in the program's structure and risk profile significantly departed from its initial design and set the stage for the ongoing challenges and debates surrounding the NFIP.

In the 1980s, when FEMA issued the first Flood Insurance Rate Maps for the Bay Area, low-lying areas historically relegated to people of color were subject to the NFIP mandatory purchase requirements. Wealthier white communities upstream were protected by flood control channels constructed decades earlier by USACE (Wong, 2014). The flood control channels were certified as meeting FEMA's 100-year design criteria, and thus, the surrounding area was removed from the requirement to buy flood insurance (Wong, 2014). The low-income residents residing in low-lying areas near the bay would subsidize the insurance for wealthier homeowners along the Gulf Coast for the next fifty years (Michel-Kerjan & Taglioni, 2017).

From 1978 to 1983, EDS (a big data company) marketed and administered NFIP flood insurance policies (GAO, 2009). EDS handled record keeping for policyholders, accepting premiums, settling claims, and providing the Federal Insurance Administration (FIA) with statistical and financial data on insurance operations. As of July 1982, the program had $104 billion in insurance policies in force (Comptroller General of the U.S., 1983). Hewlett Packard would buy EDS out and eventually sell off the company. This author believes that vestiges of the EDS team and their proteges continue to provide program management services, but the records are unclear. Government contracts expire every few years. As a result, the names of the companies often change, but the personnel leading the contracts often remain the same.

Because of concerns about the magnitude of the federal subsidies to the insurance program, Congress asked the Comptroller General to examine alternatives to eliminating the federal subsidy and to examine the opportunity of direct appropriations to the program (Comptroller General of the U.S., 1983). The 1983 Comptroller General Report discovered methodological and data flaws

in EDS's rate-setting strategy, resulting in inadequate revenue to meet the expenses of providing insurance or establishing a reserve (Comptroller General of the U.S., 1983). Between 1970 and 1980, the NFIP borrowed $850 million (Comptroller General of the U.S., 1983, p. i). The Comptroller General concluded that lack of a regular requirement to request funding to repay borrowings limited Congress's capacity to manage the program and determine if it was operating in deficit (Comptroller General of the U.S., 1983). The 1983 report found that NFIP premiums were inadequate to cover payouts and other operating costs. The rate-setting process needed to change to increase premium income (Comptroller General of the U.S., 1983).

Attempts were made to attract the private industry back into the flood insurance scheme around this time, but industry executives were unwilling to return on a risk-sharing basis (Ascik, 1977). The reasons included a belief the program was too heavily subsidized to be operated as an insurance business, the program was not operated in a businesslike manner, and they resented how they had previously been treated (Comptroller General of the U.S., 1983).

During this period, the definition of disaster changed (Alexander, 1997). Natural disasters started to be viewed as social conditions and less as "acts of God" (Alexander, 1997). Academics struggled to agree on the definition of disaster (Alexander, 1997). Academics studying disasters internationally began to question the U.S. non-structural model incorporated into the NFIP, suggesting that it ignores the cultural aspect of community life (Alexander, 1997). Other challenges academics observed included misinformation in the mass media, overspecialization, and the lack of cross-disciplinary training in the academic community (Alexander, 1997). "Failure to appreciate developments in fields other than one's own means that attitudes remain outdated and innovations in theory are not easily propagated" (Alexander, 1997, p. 298).

Insurance From the 1980s to 2020s

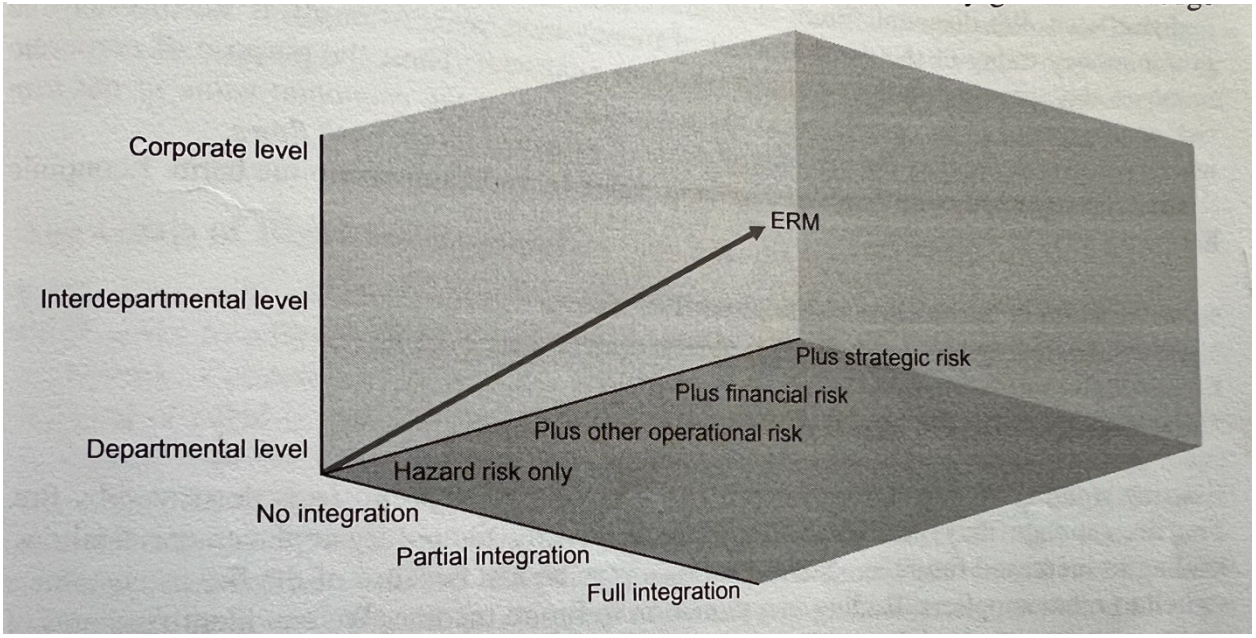
The period from the 1980s to the 2020s marked a period of profound changes in risk management. The view of risk management in the corporate sector broadened from a narrow focus on managing financial risk to a broader focus on operational and human resources risks (Skipper & Kwon, 2009). While traditional financial risk management primarily dealt with market, credit, and liquidity risks, there was a growing awareness that risks cannot be easily isolated (and therefore managed separately) (Skipper & Kwon, 2009). This realization led to the rise of enterprise risk management (ERM) by multinational corporations (Skipper & Kwon, 2007).

Unlike financial risk management, which concentrates on protecting the company's financial position, ERM takes a holistic approach, considering all types of risks that could affect an organization's objectives. ERM was used to collectively manage financial, operational, and strategic risks (Skipper & Kwon, 2009). This more comprehensive approach allows for better coordination and integration of risk management activities across the entire organization, providing a more complete picture of the company's risk landscape.

As ERM gained prominence, risks became increasingly viewed not as cost centers but profit centers (Skipper & Kwon, 2009). This shift in perspective was a significant departure from the traditional financial risk management view, which often focused on risk mitigation and cost reduction. Instead, ERM encouraged a more balanced approach, recognizing that some risks could present opportunities for value creation. Corporate risks have an overall risk profile that could help maximize firm profits (Skipper & Kwon, 2009), emphasizing the potential for strategic risk-taking to drive business growth and competitive advantage.

Figure 1, from Skipper and Kwon (2009), illustrates the evolution of ERM. Initially, corporations viewed risks as hazards and managed them at the departmental level, as shown by the ERM arrow starting in the lower left corner. Hazards were usually safety related. Over time,

Figure 1 Evolution of Enterprise Risk Management.



This figure shows the evolution of ERM from a hazard-only program to a financial and strategic risk program. It shows that as the risk management activities broadened, ERM rose in importance from a department-level program to a corporate-level strategy. Source: Skipper & Kwon, 2007, p. 289

corporations began to consider other types of operational risks. In doing this, they often integrated these considerations into managing multiple departments. For example, a vintner might consider integrating new stainless-steel tanks to reduce the risk of wine being tainted by a faulty oak barrel. This change also reduces the safety hazards from moving barrels. Moving the ERM line up and to the right. Eventually, risk management included financial risk management. For instance, a vintner might mitigate the financial risk of a poor vintage by buying insurance that would pay if the wine were tainted. The expense of insurance might then be shared across all departments. In this arrangement, the insurer typically inspects all aspects of production before offering an insurance policy. They might require the vintner to make some changes in their production or in their facilities as a condition of insurance. Moving the ERM line further up and to the right. Thus, while some corporations continue to focus on managing hazards, others include the management of

operational, corporate financial, and even some strategic risks under the umbrella of enterprise risk management. In contrast, only the most sophisticated city and county governments have moved beyond hazard management. A few include operational risk management, which takes the form of HR management, but financial and strategic risks are rarely considered.

Academics began to argue that insurance, with its goal of classifying risks, preserved existing inequities (Simon, 1988). They would argue that "insurance institutions not only maintain status, they also assign it" (Baker, 2001, p48). In their view, insurance's emphasis on individual protection led to the idea that individuals no longer needed to be responsible for each other, reinforcing atomized individualism (Horan, 2021). They would argue that assigning risk in an "actuarially fair" way separated individuals from each other in ways that broke long-standing communal ties (Horan, 2021)

This period also marks the start of the "embrace of risk," thinking where risk-taking, particularly among elites, is embraced (Simon, 1988; Baker, 2001, as cited in Horan, 2021). This risk-taking contributed to the 2008 financial crisis, which had disastrous consequences for middle-class families (Horan, 2021). The "embrace the risk" mentality forced low- and middle-class households to take on the economic and financial security burden on their own (Horan, 2021).

In 1981, the Reagan administration mandated that the NFIP cover its costs on an average loss year (i.e., losses averaged over the program's life) (Abbott, 2008; Elliott, 2021). To meet this goal, premiums rose substantially. When these increases brought congressional resistance, to save costs, FEMA reduced the scope of the coverage (Elliott, 2021). It limited coverage for basements and detached garages (Abbott, 2008; Elliott, 2021). In addition, the NFIP would only pay replacement cost coverage under limited circumstances. Consumers were unaware that, unlike their homeowner's policy, which generally provides actual cash value payments, the NFIP policy

would only cover replacement cost value. This means that a homeowner with a 10-year-old furnace would receive a claim payment to replace a 10-year-old furnace, not a new one. This was changed in 2022 with the implementation of Risk Rating 2.0. The financial impact of this change on the program, while helping consumers, is a concern expressed by GAO (2023).

In 1983, the NFIP administration sought to enhance service to NFIP policyholders by integrating industry expertise within the existing management framework (Department of Homeland Security [DHS], Office of Inspector General [OIG], 2020). FEMA initiated the Write-Your-Own (WYO) program to expand the NFIP policy base and geographic reach (DHS-OIG, 2020; FEMA, 2002). It was called Write-Your-Own because it allowed participating private insurers to write NFIP policies under their brands (FEMA, 2002). From the insurer's viewpoint, it incentivized policyholders to buy all their insurance through a single broker. In return, WYO businesses administer, resolve, compensate, and contest claims from these policies (FEMA, 2002). They offer insurance, collect premiums, deduct commissions and operational expenses from these premiums, and remit the residual monies to NFIP (FEMA, 2002). When flood damages occur, policyholders inform their agents, who then alert the WYO insurers. These insurers assess and process approved claims (GAO, 2009).

At the time, the vast majority of NFIP policies were sold by the 51 companies participating in the WYO program (Horn, 2017). Most NFIP policyholders dealt solely with a WYO company rather than a FEMA representative, so they were generally unaware that FEMA underwrote their insurance (Horn, 2017). This program continues today, and the GAO has expressed concerns that FEMA is not providing adequate oversight to WYO companies and that WYO firms receive excessive compensation for their services (GAO, 2023). This issue will be discussed further.

In 2005, Hurricane Katrina damaged more than a million housing units in the Gulf Coast (Plyer, 2013) and changed the nation's view of flood risk. After Hurricanes Katrina, Rita, and Wilma, the NFIP received a $19 billion bailout, partially covering the losses. The financial consequences of these events would prompt concerns decades later (Maurstad, 2021; GAO, 2010; GAO, 2017). Largely ignored in the literature is the role USACE played in contributing to the tragic loss (Rosenthal, 2020; Seed et al., 2006). To prevent a catastrophic levee failure from happening again, academics would recommend that the USACE adopt a High-Reliability Organization (HRO) management philosophy to prevent future disasters (Bea et al., 2009). They would make the same recommendation following the Oroville Dam failure (Bea & Johnson, 2017). An HRO is an organization that is capable of operating without error in complex, high-risk environments such as nuclear power plants, aircraft carriers, and operating rooms. HROs cultivate a culture of mindfulness, continuous learning, and proactive risk management to prevent errors and adapt to unexpected challenges (Klein et al., 1995).

The losses from Hurricane Katrina prompted private insurance firms to diversify with insurance-linked securities (ILS), greatly expanding the ILS market (Csiszar, 2007). ILS links insurance to the financial markets (Hofmann & Pooser, 2017). These financial instruments, such as catastrophe bonds or weather derivatives, are sold to institutional investors (Hofmann &Pooser, 2017). Because there are fixed costs in setting up ILS instruments, they are used only to finance larger losses (Hofmann & Pooser, 2017).

A 2010 report by the Government Accountability Office (GAO) highlighted several management deficiencies that hindered FEMA's ability to effectively address the budgetary challenges of the NFIP (GAO, 2010). For example, whereas disbursements to Write-Your-Own (WYO) insurers are one-third to two-thirds of total premiums received, FEMA did not consistently

integrate precise flood insurance expense data in its payment calculations (GAO, 2010, p. 1). Additionally, the GAO found that FEMA did not follow established protocols for monitoring non-WYO contractors and lacked proper coordination in its contract oversight responsibilities (GAO, 2010, p. 1).

Moreover, FEMA has been and remains deficient in establishing an effective system for managing flood insurance policies and claims data. (GAO, 2010; GAO, 2019). In the 2000s, FEMA invested seven years and $40 million to develop a new electronic data management system but abandoned the effort (GAO, 2009). Even today, FEMA data management is described “as piecemeal and disparate in organizational silos” (FEMA, 2023a, p.2). Management and technological deficiencies further undermine FEMA's ability to ensure the NFIP's long-term financial sustainability.

For many years, FEMA allowed some policyholders to pay grandfathered rates (GAO, 2029). The intention was that homeowners should not be penalized for building unwisely because of a lack of flood hazard information by having them pay actuarial premiums (GAO, 2019). This kept rates for many households below the actuarily fair rates. FEMA's installation of Risk Rating 2.0 abolished grandfathered rates (GAO, 2023). For many properties, particularly those along the Gulf coast, rates will increase significantly. However, FEMA is restricted in how much it can raise premiums each year, resulting in a prolonged period until grandfathered policyholders incur full actuarial rates, an action that ultimately contributes to the NFIP deficit (GAO, 2023).

Since 1983, Congress has known that the NFIP premium income was inadequate to cover the program's payouts and operating costs (Comptroller General of the U.S., 1983). The NFIP's fee structure faces three broad challenges. First, it does not charge rates commensurate with the losses incurred. Second, it does not consider what economists call "expected utility." Expected

utility theory posits that individuals make decisions under uncertainty by evaluating the desirability of possible outcomes weighted by their probabilities. In the context of flood insurance, this means that people's willingness to pay for insurance should be influenced not just by the probability of a flood, but also by the subjective value they place on avoiding potential losses. The NFIP's failure to incorporate this concept results in premiums that do not align with individuals' true risk preferences. Third, it does not consider behavioral biases for low-probability, high-consequence events, like floods. Each of these challenges will be discussed in more detail throughout this dissertation.

The NFIP faces significant debt because it has been unable to adequately price premiums to reflect the flood risk. Between 1968 and 2010, the NFIP accumulated a deficit of $1.5 billion (American Academy of Actuaries, 2017; Michel-Kerjan, 2010). Beyond the program's financial solvency challenges, the NFIP lacks regulatory authority and political support to address these pricing concerns (CBO, 2017). Although Congress mandated FEMA to provide subsidized premium rates for some policyholders, it failed to commit sufficient funds to offset the subsidies, causing FEMA to borrow from the General Fund (GAO, 2017). Despite this requirement to provide subsidies that result in insufficient premium revenue, current law still obligates FEMA to repay its borrowing from the U.S. Treasury.

In 2012, in response to increasing solvency concerns, Congress passed the BW-12 (Biggert-Waters Flood Insurance Reform Act [BW-12], 2012; Brusentsevet & Vroman., 2016). BW-12 eliminated subsidies for some policyholders and moved premiums toward more risk-based pricing (American Academy of Actuaries, 2017). BW-12 phased out the pre-FIRM subsidy up to 18% per year for primary residences and 5% per year for non-primary residences (BW-12, 2012). After expressing outrage over the rapid increase in insurance premiums, Congress re-evaluated the

rate increases and subsequently passed the Homeowner Flood Insurance Affordability Act of 2014 (HFIAA) (Homeowner Flood Insurance Affordability Act of 2014 [HFIAA], 2014; Knowles & Kunreuther, 2014). While the new law slowed rate increases, capping them at 15% for primary residences for homeowners receiving subsidized rates, it did not eliminate the premium increases (HFIAA, 2014).

Three months after BW-12 was passed, Superstorm Sandy struck the East Coast, resulting in $9 billion in losses to the NFIP (American Academy of Actuaries, 2017; Knowles & Kunreuther, 2014). FEMA had to request Congress for additional funding to remain solvent. This prompted a heated debate on disaster relief funding, making a change in attitudes regarding the federal role in disaster relief (Knowles & Kunreuther, 2014).

Insurance in the 2020s

Private property and casualty insurance demand has surged in response to natural disasters and climate change-related risks. This growth has spilled over to flood insurance. In 2020, private flood insurance providers wrote $721m in flood insurance premiums (Rabb, 2024). By 2023, the amount had doubled to $1,414.7m (Rabb, 2024).

Since September 2017, the NFIP has been operating under a succession of short-term reauthorizations that persist today (GAO, 2023). The NFIP will expire again in December 2024 when it is expected to be extended to March 2025 (GAO, 2023). Although there are calls for legislative change, it is unlikely that reforms will benefit California, as the states receiving the highest subsidies hold the most policies (GAO, 2018).

In October 2022, FEMA began implementing a new method for calculating flood insurance premiums, Risk Rating 2.0 (GAO, 2023). This is the first change to the NFIP's premium pricing method since its inception (GAO, 2023). Risk Rating 2.0 addresses previous inequities in premium

pricing but has encountered significant political opposition from those benefiting from subsidies (Tambala Strategy, LLC, 2022). A 2023 GAO report found that the median annual NFIP premium in 2022 was $689, while the median premium required to achieve full risk-based rates was $1,288 (GAO, 2023, p. 1). Annual premium increases for most policyholders are limited to 18 % (HFIAA, 2014). These statutory caps perpetuate the unfunded premium shortfall (GAO, 2023).

Insurance in the Future

In the past twenty years, advances in science, finance, and the expansion of global financial markets have allowed insurers to spread financial risk around the globe (Keating et al., 2014; Zhou et al., 2023). However, as the financial impacts of geopolitical, economic, technological, and environmental risks grow, insurers' ability to distribute losses internationally is strained, increasing the gap between what stakeholders want and what the industry can do (Schanz, 2023; Zhou et al., 2023). The gap threatens the conventional risk transfer business model at the insurance industry's core for decades (Schanz, 2023). To stay relevant, insurers are looking for sustainable ways to provide financial protection for natural disaster risks (Schanz, 2023).

Industry experts propose that while risk transfer will remain a core business, insurers must provide other services, such as risk assessment, prevention, and sharing with the public sector, to remain viable (Schanz, 2023). Insurers need to provide these services for natural disasters like floods. This creates opportunities for new collaborations between the public and private sectors that can lead to comprehensive flood risk assessments, proactive risk mitigation, and innovative risk-sharing alternatives (Bruno et al., 2011; Schanz, 2023).

As state and local governments recognize the growing need for risk assessment, prevention, and risk-sharing services, they can leverage insurers' expertise to enhance disaster resilience (Bruno et al., 2011). The private sector's knowledge and capacity are underutilized (California

Department of Insurance [CDI] Climate Change Working Group, 2021). The insurance industry's deep understanding of risk places it at the intersection of private stakeholders and the public sector (Bruno et al., 2011). By providing affordable insurance to homes and businesses, insurers contribute to more robust, resilient communities (Zhou et al., 2023). When most households and businesses are insured, the community becomes more resilient (Surminski et al., 2016; Tanner et al., 2016; Weingärtner et al., 2017).

A 2021 report by the California Department of Insurance (CDI) Climate Change Working Group (2021) asserts that insurance bolsters community resilience. The 2021 CDI study examined how insurance can enhance the resilience of vulnerable communities facing escalating climate impacts. The report recommended a comprehensive strategy for California to address these challenges, combining top-down leadership with bottom-up initiatives focused on local risk reduction and affordable insurance coverage (CDI Climate Change Working Group, 2021). The report advocated community-based insurance pilot programs as a practical step toward these goals (CDI Climate Change Working Group, 2021). This approach could strengthen California's ability to withstand and recover from climate-related disasters while ensuring equitable access to insurance protection (CDI Climate Change Working Group, 2021).

Insurance is crucial in more comprehensive disaster risk management programs, which have gained global attention and urgency in recent years (White, 2020; World Bank Group, 2017; Mahul et al., 2014; White, 2020). International organizations, such as the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR, 2015), along with crucial policy frameworks like the Sendai Framework for Disaster Risk Reduction (Gall et al., 2014) and the Sustainable Development Goals (SDG) (CDI, 2022), all emphasize the need for ex-ante Disaster Risk Management (DRM) efforts.

DRM investments offer significant benefits beyond avoiding losses. Tanner et al. (2016) identified three key dividends: losses avoided, unlocked economic potential, and development co-benefits. The first dividend, losses avoided, encompasses saved lives and reduced damage to infrastructure and assets. The second dividend promotes forward-looking planning and investment, unlocking economic potential. The third dividend generates co-benefits, such as dual-purpose structures like shelters that serve as community centers or levees doubling as roads.

Weingärtner et al. (2017) argue that insurance offers three benefits identified by Tanner et al. (2016). Firstly, insurance provides direct benefits to policyholders by 1) compensating for economic losses, 2) promoting community-wide investments, and 3) facilitating conversations about the community's future that include informed, risk-sensitive investment decisions.

Although the NFIP's historical development explains its original intentions, structural inefficiencies prevent it from becoming fiscally sustainable for over two decades (GAO, 2010; GAO, 2023). Three areas of concern are cross-subsidization, inadequate claims settlements, and excessive operational overhead.

Actuarily fair rates. The Casualty Actuarial Society advocates for sound actuarial practices regarding property and casualty insurance rate making (American Academy of Actuaries, 2017; GAO, 2023; Mathewson et al., 2011). They advocate that actuarially sound ratemaking should be calculated using an estimate of the projected value of future costs (American Academy of Actuaries, 2017; Committee on Levees and the National Flood Insurance Program et al., 2013; GAO, 2023). Risk transfer expenses should be included in the price, and the rate should cover these expenses (American Academy of Actuaries, 2017). Further, the rate should be reasonable, neither excessive, insufficient, or unfairly discriminating (American Academy of Actuaries, 2017; Mathewson et al., 2011).

The NFIP deviates from these principles through several congressionally mandated charges that are not risk-based (GAO, 2023). These include a reserve fund assessment, a HFIAA surcharge (Homeowner Flood Insurance Affordability Act of 2014 [HFIAA], 2014), and a cross-subsidy through the Community Rating System (CRS) program (GAO, 2023). Consequently, some homeowners continue to underpay while others overpay, violating actuarial principles (American Academy of Actuaries, 2017; Elliott, 2021).

The CRS is a voluntary program implemented in 1990 to encourage communities to exceed minimum requirements by offering premium discount incentives (GAO, 2023). For example, Sacramento County is a CRS Class 2 community, one of a few nationwide (Sacramento County Department of Water Resources, 2020). Residents in Sacramento County get a 40% discount on premiums. Consequently, policyholders in the Sacramento County Legacy Communities of Hood, Walnut Grove, and Ryde pay 40% less than the policyholders in the equally at-risk community of Isleton because Isleton lacks the resources to participate in the CRS program (C. Bergson, personal communication, June 22, 2022). Even if it took part in the program, the geographic boundaries of the community prevent it from getting more than a 20% discount. Because of county support of the CRS, Isleton policyholders financially support more affluent policyholders in Sacramento County. The unintended outcome of the CRS structure leads to a financial burden shift from more affluent towns to those with limited resources.

Extra Fees. Policyholders pay additional fees and surcharges (GAO, 2023) to a reserve fund assessment mandated by Congress that is not based on individual property risk (GAO, 2023). Owners of second homes pay a policy surcharge of $250, compared to $25 per primary residence (GAO, 2023). A 2023 GAO report (2023) suggested eliminating these extra fees would allow private insurance to compete more effectively for flood insurance policies (GAO, 2023).

FEMA levies fees on policyholders sufficient to account for their present flood loss risks and a surcharge for debt repayment of the program (GAO, 2017; Horn, 2023). A 2017 GAO (2017) investigation advised that imposing charges on current policyholders to cover debts from previous years contravenes actuarial standards. Per actuarial principles, the premium rate is determined by the risk of future losses and excludes historical expenditures (American Academy of Actuaries, 2017; Mathewson et al., 2011). These expenses from previous years exacerbate the burden, rendering flood insurance unappealing to all except the most risk-averse households (Schlesinger, 2013).

A GAO report (2017) highlighted negative impacts of these additional charges. The report noted that non-risk-based fees could make premiums less affordable for some policyholders in high-risk flood areas. The report expressed concerns that the system may not be sustainable in the long term, as it relies on subsidies and cross-subsidies to keep premiums artificially low for some policyholders. Risk Rating 2.0 attempts to overcome some ratemaking challenges, but concerns remain (GAO, 2023).

Excessive overhead (load). The NFIP does not consider fundamentals of insurance demand in pricing, notably the impact of overhead rates (commonly called 'load'). Mossin (1968) showed that it is never optimal to purchase full insurance when the premium contains a load (transaction cost). The expected utility model says that although it is not optimal, risk-averse individuals will purchase insurance when premiums exceed their expected loss (Mossin, 1968). How much a person is willing to pay depends on how risk-averse the person is and the particulars of the risk (Kunreuther et al., 2013). The expected utility model says that even a risk-averse person is likely to decline coverage if the premium is high compared to an actuarially fair premium (Mossin, 1968). Research suggests that a willingness to pay for additional fees (load) caps at around 40% (Louaas

& Picard, 2021; Michel-Kerjan & Kousky, 2010). Thus, the NFIP load of over 60% (GAO, 2023) is at odds with buyers' perceptions of value and financial rationality.

After the payment of claims, the primary source of spending is the payment by NFIP to the insurer and agents participating in the WYO program (GAO, 2009; GAO, 2016; GAO, 2023). Over one-third of NFIP premiums nationwide have gone to the WYO participating companies and their insurance agents (GAO, 2009; GAO, 2016; GAO, 2023; Michel-Kerjan, 2010). Correcting for inflation between 1984 (the first year WYO insurers collected fees) and 2008, they collected $9.7 billion (Michel-Kerjan, 2010, p. 175). From 1984 to 2008, the NFIP disbursed one-third of its collected premiums to financial intermediaries that assume no risk (Michel-Kerjan, 2010, p. 175).

Claims payments costs. FEMA compensates insurers from the NFIP fund for claim amounts plus the costs of claim adjustment and processing based on rates set by FEMA. FEMA does not evaluate actual flood insurance costs when deciding compensation for WYO's sales, service, and claim adjustments (GAO, 2009). The GAO and the Department of Homeland Security, Office of the Inspector General (DHS-OIG) have investigated how much WYO companies were compensated for their services to the NFP (DHS-OIG, 2016; GAO, 2009; Horn, 2023). FEMA's payments to WYO exceeded actual expenses by $327.1 million, or 16.5% of total payments, as noted in a 2009 GAO report (GAO, 2009). The GAO found FEMA establishes payment rates to WYO without knowing how much of these payments are for expenses versus profit (GAO, 2009). GAO suggested that when FEMA sets these rates, it should consider flood insurance cost data from the National Association of Insurance Commissioners and propose ways to check the quality of the flood insurance data that WYO sends to the insurance commissioners every year (GAO, 2009). In 2009, GAO advised FEMA to factor in actual flood-related expenses and profits of WYO when setting payment rates and to take

additional steps to verify the accuracy of its financial data (GAO, 2009). BW-12 directed that FEMA create a method to determine correct reimbursement amounts for property and casualty insurance companies in the WYO program (BW-12, 2012). The 2009 GAO report noted, "FEMA does not have the information it needs to determine whether its payments to WYO are reasonable" (p. 32). The payments to WYO companies add to the "load' that makes up the NFIP premium cost. In contrast, a 20% to 30% load for operational expenses is standard for private lines of insurance (Czajkowski et al., 2012; Michel-Kerjan & Kousky, 2010), and in these cases, the companies pay for rate-making products and product development.

Behavioral economics considerations. Insurance behavior for low-probability risks differs from that for higher-probability risks. Individuals either disregard low-probability risks or are so concerned that they will pay more than expected (Kousky & Shabman, 2015; McClelland et al., 1993). Individuals and government officials often perceive the likelihood of disaster damage as sufficiently low as to not to justify investments in insurance or mitigation, relying on underlying general response capacities of the public and private sectors from general revenues and credit and general emergency authorities and capabilities (Kunreuther & Pauly; 2004, Kunreuther et al., 2013). The economic effects of low-probability events are further discounted when the economic discount rate is too high (Rothschild & Stiglitz, 1978).

Homeowners typically desire a return on their premium payments for low probability/high consequence occurrences, aiming to maximize their policy benefits in the case of a loss while avoiding overpayment for coverage they may never fully utilize (Kousky & Michel-Kerjan, 2017). Insurance buyers rarely want full coverage of losses for rare events (Arrow, 1963; Louaas & Picard, 2021). Research shows that for a $200,000 loss with a 1% chance of occurring, the optimal coverage for most individuals is between $84,000 and $140,000, provided the insurer's load is less

than 39% (Louaas & Picard, 2021). This aligns with the industry standard load of less than 40%, substantially lower than the NFIP load (Czajkowski et al., 2012; Michel-Kerjan, 2010; GAO, 2023). The current NFIP model, however, presents a mismatch between insurance coverage for low probability/high consequence events and consumer preferences. Homeowners often prefer to absorb part of the potential loss, as evidenced by their willingness to purchase $100,000 coverage for a possible $250,000 loss when the risk is low (Kousky et al., 2017; Louaas & Picard, 2021). At the same time, buyers prefer a low-deductible when the loss probability is rare. This suggests that promoting a $100,000 policy more heavily could increase policy uptake, especially if offered along with a $10,000 first layer of coverage policy. For underinsured households, FEMA offers low-cost Small Business Administration loans, or a means-tested voucher system could be implemented. Augmenting this with a program that covers the first layer of loss is likely attractive.

Claims payments. One of the most important considerations for an insurance entity is trust that claims payments will cover the loss and that claims payments will be prompt and fair (EY, 2014). Trust is essential in purchasing decisions (Petrolia et al., 2013). People buy insurance from insurance providers that sell contingent promises to pay, often at a distant and unspecified future time (Petrolia et al., 2013). NFIP policyholders are often unaware of the many exclusions in the NFIP Standard Flood Insurance Policy (SFIP), eroding trust (Kousky & French, 2022). For instance, the NFIP SFIP does not cover alternative living expenses, business interruption expenses, damage caused by earth movement, septic system damage, or access road damage (Horn & Webel, 2023). These exclusions can lead to financial insolvency for homeowners, as it often takes several months for the necessary infrastructure to be restored, enabling households to start the recovery process (Kousky & French, 2022).

Another form of inadequate claims payments involves the purchase of increased cost of compliance (ICC) coverage (Horn & Webel, 2023). The NFIP requires most SFIP policyholders to purchase ICC coverage, a separate policy to offset the expense of complying with more rigorous building codes in post-flood reconstruction (Horn & Webel, 2023a). However, ICC coverage (with a separate rate structure) only provides a maximum of $30,000 for specific eligible expenses (Horn & Webel, 2023a). California has adopted the international building code, which mandates items such as sprinklers and additional insulation when repairing or remodeling a home (CA Building Standards Commission, n.d.), whose costs often exceed $30,000. This is likely for communities like Isleton, where a home might need to be elevated to comply with current requirements. The current cost to elevate a home in Sacramento County exceeds $100,000 (G. Booth, personal communication, July 17, 2023). For low-income households without access to post-disaster liquidity, the $70,000 out-of-pocket expense can be an insurmountable hurdle. Thus, FEMA encourages increased building code requirements but does not pay the full cost for NFIP mandated upgrades.

The NFIP SFIP includes several restrictions to keep flood insurance affordable. It sets the maximum insurable limit at $250,000 and provides no coverage for loss of access or use. Until Risk Rating 2.0, it paid actual cash value minus depreciation instead of replacement cost (Horn & Webel, 2023). This means that if you have a 20-year-old refrigerator, FEMA will only pay to replace it with a 20-year-old model. While maintaining low payments, this condition prevents many low-income homeowners from fully recovering. The limitations of the SFIP demonstrate the need for more comprehensive and accessible coverage for those affected by natural disasters (Horn & Webel, 2023)

In summary, the NFIP was initially envisioned as a public-private program, with private insurance firms managing it and a federal financial backstop. However, over time, it evolved into a program where private insurance firms sell most policies but bear no loss responsibility (Grigg. 2019). With the loss of the private firms, the program lost a strong advocate for fiscal responsibility. The first meaningful fiscal reforms were not enacted until the passage of BW-12 (Horn, 2018). When the financial consequences to constituents were brought to light, elected officials rolled back many of the BW-12 reforms (Horn, 2018).

Many well-known issues contribute to the insolvency of the NFIP (GAO, 2017). If the NFIP had been managed under Part A, private firms would have overseen the program. Private firms typically limit their exposure to risk by not insuring repetitive loss properties, which helps prevent significant financial losses. Concentrated risks like the levee-protected areas of New Orleans would have been actively managed with HRO management practices, and the risk would have been spread across multiple firms to mitigate potential impacts. Additionally, private firms would have implemented best management practices to enhance risk assessment and underwriting processes. They would have also incorporated the latest statistical, actuarial, and financial advances to manage the financial aspects of the risk portfolio. In return, the federal government could have provided a financial backstop to help maintain affordable premiums.

Instead, the NFIP is managed as a government program without a public, meaning there were no strong advocates for the program by the general public. Thus implementation policies are made by technocrats and policy entrepreneurs (Strother, 2018). Strother (2018) proffered that after BW-12, the NFIP became a program with the public, meaning that as prices increased, the public became interested in how premiums were priced. Before, it had been a "politic without a public." Although reforms are still elusive, there is convergence on several reforms. Risk Rating 2.0 is the

first change in the actuarial rating method since the program began in 1968. Before Risk Rating 2.0, the FEMA rating system considered two sources of flood risk: the 1%-annual-chance fluvial (river) flood and the 1%-annual-chance coastal flood (FEMA, 2021a). Risk Rating 2.0 incorporates a broader range of flood frequencies and sources, as well as geographical variables such as the distance to water, the type, and size of the nearest bodies of water, flood frequency, and the elevation of the property relative to the flooding source (FEMA, 2021a).

Although the NFIP is the world's largest flood insurance provider, it has not been conducted as a proper insurance enterprise. This research highlights three key findings stemming from this core problem:

1. Governance Gap. There is a significant lack of insurance expertise at the local level for managing flood-related financial risks. No government entity is thoroughly assessing the community's overall financial impacts from flooding. As a result, no government entity has the mission or expertise to utilize insurance-linked securities to manage the community's financial risk. Natural disaster risk management is primarily limited to the hazard assessments mandated by the Disaster Mitigation Act of 2000. The potential financial impacts of natural disasters are not evaluated, pre-disaster planning is rarely done, and modern ERM methods are not employed.

2. Misalignment of Risk Perception. Flood insurance is often viewed as akin to automobile insurance—a high-probability, low-consequence event. However, floods are often low-probability events that can impact entire communities. This characteristic suggests that flood insurance decisions should be approached more like life insurance purchases—with careful consideration and family discussions about long-term implications—rather than routine automobile insurance acquisitions. Because there is a governance gap, these discussions are never held.

3. Non-Ergodicity in Small Communities. Small communities and their residents have non-ergodic properties, meaning individual experiences may not reflect the average outcome over time. The long-term impacts of small but recurring losses are not considered. The insurance industry typically aims to make non-ergodic events ergodic through risk pooling and actuarial science. Insurance provides much-needed liquidity that reduces the impact of losses.

This dissertation addresses the first two findings, while the complex topic of ergodicity in flood insurance is reserved for future research.

Chapter 3 Flood Insurance Challenges

The last chapter identified characteristics of a successful insurance enterprise. It traced the history of selected events in the evolution of the insurance industry and the NFIP and concluded with a description of critical issues contributing to the NFIP's underperformance. These issues included cross-subsidies, extra fees, and claims payments.

This chapter examines the industry's challenges and what makes a risk insurable. Insurance can provide resilience services, but to do so, it must balance insurance availability with demand to make insurance both affordable and accessible (Kunreuther, 2021; Schanz, 2018). Balancing these challenges for floods has always been challenging (Schanz, 2018). Flood risks, rebuilding costs, homeownership costs, and the cost of liquid assets to pay claims are increasing premiums, which decrease insurance policy purchases. As fewer people buy flood insurance, the financial protection gap increases (the share of uninsured losses to total economic losses) (Schanz, 2018).

This chapter shows that flood risk can be insurable under some conditions. The information in this chapter will support the design of the insurance scheme proposed in the next chapter. This chapter discusses industry challenges, including increasing flood risks, rebuilding costs, and homeownership costs, contributing to the insurance gap. It then discusses what is needed to make a risk insurable, considering actuarial, societal, and market criteria.

Flood risks are increasing. Climate change is increasing the variability, frequency, and magnitude of extreme precipitation in California, leading to more frequent and severe droughts and floods, with intense atmospheric river (AR) driven storms (Das et al., 2013; Dettinger, 2007; Polade et al., 2017; Swain et al., 2018). Historically, flood losses have correlated with high-intensity ARs (Corringham et al., 2019). As AR intensity increases, so do likely flood losses (Corringham et al., 2019).

Rebuilding costs are increasing. The Department of General Services (DGS) Construction Cost Index (CCCI) reported that in 2021, costs to rebuild increased 13.4% (CA Department of General Services, 2023). In 2022, costs increased 9.3%. From October 2022 to October 2023, California saw some of the country's highest increases in residential construction costs (Verisk, 2023). The increasing costs of rebuilding, supplies, materials, and labor shortages, among other things, affect insurance markets. Cost increases can cause policyholders to have inadequate insurance to recover (Kousky & French, 2022). When these costs are passed down to consumers through increased premiums, insurance is less affordable (FEMA, 2018; Kousky & French, 2022).

Homeownership costs are increasing, leaving less room for insurance. According to the Census Bureau's American Community Survey, homeownership for 2020 for all Californians was 56%, 64% for whites, 61% for Asians, 46% for Hispanics/Latinos, and 37% for Blacks (Shoag et al., 2023, p. 1). Homeownership is becoming particularly unaffordable for Black and Latino households. In 2021, the share of California adults who owned their own home was just 43.5%, over 15 percentage points lower than the rest of the U.S. (Shoag et al., 2023, p. 1). The share of Californians aged 60-75 who owned their home outright is 26.4% (Shoag et al., 2023, p. 1). Another study found homeowners over 65 who continue to have mortgage payments appear nearly as financially constrained as renters (Mayer, 2017). Rising insurance premiums, in addition to mortgage payments, challenge older households on fixed incomes. These financial pressures highlight the need for policy interventions to address housing affordability and insurance accessibility for vulnerable groups.

The insurance protection gap is increasing. The insurance protection gap is smaller than the overall financial protection gap because it refers to the amount of economically beneficial insurance, considering some self-insurance or alternative risk transfer and the

amount of insurance purchased (Schanz, 2018). Rising flood insurance costs are causing fiscally constrained households to drop flood insurance policies, leading them to self-insure when they lack the savings to do so, which widens the uninsured protection gap (Kousky & French, 2022; Schanz, 2018). The non-profit First Street Foundation estimates that more than 1,128,290 California properties have more than a 25% chance of flooding in the next 30 years (First Street Foundation, 2023). Nevertheless, California has less than 185,000 NFIP policies in place (2023), significantly less than the 280,000 policies in force in 2015 (FEMA, 2022b).

Underinsurance occurs when policyholders have insurance coverage substantially less than actual or potential losses (Schanz, 2018). There are several reasons for underinsurance. The rising cost of rebuilding increases the underinsurance gap. According to the analytics firm CoreLogic (2021), whose software is widely used by the insurance industry, three of every five homes in America are underinsured by an average of 20% less than full value. Behavioral economics suggests that underinsurance will always be a problem for flood losses. For low-probability events, like floods, households prefer less than full coverage, particularly if transaction costs are high (Louaas & Picard, 2021). A widening insurance protection gap might also affect housing prices and future creditworthiness (Roth Tran & Sheldon, 2017; Seifert-Dähnn, 2018; Zhou et al., 2023).

What Makes a Risk Insurable?

If insurance is to be used to manage climate change and natural disaster risk, the risk must be insurable. Evaluating insurability comprises actuarial, societal, and market criteria (Berliner, 1982; Charpentier & Le Maux, 2014; Kousky, 2019; Schanz, 2023). If community leaders understand what makes a risk insurable, they can partner with insurance providers to make flood insurance policies more accessible and affordable, encourage more people to purchase insurance,

and reduce or close the insurance gap. The following examines actuarial, social, and market conditions that make risk insurable.

Table 1

Conditions That Make Risk Insurable

Risk must be actuarially feasible	
	Loss occurrence is random. Losses are independent of the insured actions – limited moral hazard. The risk is quantifiable. The maximum possible loss is manageable. Average loss per event is predictable and manageable. Many independent exposure units spread the risk. Risk information is open and transparent – limited adverse selection.
Insurance must be administratively feasible.	
	Institutional Obstacles and Shortcomings. Long-term financing. Administrative costs must be funded and not excessive.
Risk must marketable.	
	Awareness of risk. Affordable insurance premiums. Clear coverage limits.

Risk Must Be Actuarially Feasible

Actuarial feasibility entails risk assessment and pricing, considering historical data to estimate the probability and severity of losses, average loss, and the number of exposure units (Skipper & Kwon, 2008). (An exposure unit is the basic unit of risk used to calculate premiums and assesses potential claims. For property insurance, it is often the value of the home per square foot.) These assessments consider information asymmetries that may affect risk evaluation. Actuaries must be able to set premiums that cover expected losses and expenses while remaining

fair and affordable for policyholders (American Academy of Actuaries, 2017; Skipper & Kwon, 2008). The following examines factors that influence actuarial feasibility (Table 2).

Table 2.

Factors that Influence Actuarial Feasibility

Factor	**Summary**
Occurrence of loss is random	Losses must be mostly uncorrelated and independent of the insured's actions
Loss is independent of the insured actions	Moral hazard (the probability of a person has greater risk because someone else bears the cost) occurs when individuals or communities change their behavior after getting insurance coverage because they are protected from the full financial consequences of their actions
Risk is quantifiable	The frequency and severity of claimable events must be quantified with reasonable confidence
Maximum possible loss is manageable	Managing the maximum loss is challenging for natural disaster risks because the disaster can affect many properties simultaneously.
Average loss per event is predictable and manageable	The insurer must estimate the risk's expected cost. Tail risk must be manageable.
Many independent exposure units	Risk should be spread across many policyholders.
Risk information is open and transparent	Transparent risk information reduces adverse selection where people with more likelihood of a loss are more likely to purchase insurance.

The occurrence of loss is random. For losses to be insurable, they must be mostly uncorrelated and independent of the insured's actions (Academy of Actuaries, 2017; Antwi-Boasiako, 2014; Schanz, 2023). This criterion is difficult for flood insurance because flood losses are often highly correlated by location or event. In California, flood losses are highly correlated

with large, rare Category 4 and 5 atmospheric rivers (AR) storms (Corringham et al., 2019). However, at the continental or global scale and across several years, losses are much less correlated.

When losses are correlated with smaller, more frequent events, such as king tides, the premiums required to cover these known risks can become prohibitively expensive, posing an unacceptable reputational risk to insurers; insurers would be unwilling to sell policies even if people are willing to buy (Antwi-Boasiako, 2014; Zboron, 2006). This situation prevails for flood risks with a more than 1-in-50-year annual probability (McAneney et al., 2016).

As the science of atmospheric rivers advances, ARs may be viewed less as random events and more as a global cycle of precipitation that occurs on a decadal scale (Dettinger et al., 2018). As the predictability of Category 4 and 5 Atmospheric Rivers (ARs) improves, insurance companies are likely to raise premiums in years when severe events are more likely.

Several things can be done to meet the randomness criterion. Currently, insurance is issued annually. To make losses random, potential losses may need to be viewed on a multi-year to decadal scale to coincide with the significant fluctuations in precipitation. Jaffee et al. (2010) suggest multiyear insurance policies attached to the property, not to the homeowner, could be attractive compared to existing annual contracts. A multi-year policy contract would also frame the purchase as a long-term investment, like life insurance (Jaffee et al., 2010; Michel-Kerjan, 2010). A multiyear contract could be coordinated with mitigation loans, incentivizing mitigation. From the insurer's perspective, a multiyear contract spreads losses over drought years, making wet years more attractive to insure (Jaffee et al., 2010).

Another option is to manage as much risk as possible with mitigation measures (CDI Climate Change Working Group, 2021). In California, smaller, more frequent atmospheric rivers

largely benefit water supply and the environment (Corringham et al., 2019). More "nature-based" and other solutions, such as flood-resilient building construction, could significantly reduce flood losses from these events.

The loss is independent of the insured actions. Moral hazard (the probability of a person has greater risk because someone else bears the cost) occurs when individuals or communities change their behavior after getting insurance coverage because they are protected from the full financial consequences of their actions (Antwi-Boasiako, 2014; Elliott, 2021; Schanz, 2018). rs.

Moral hazards take collective and individual forms in implementing the NFIP. A collective moral hazard occurs when structural flood protection and disaster relief protect people and communities from loss, encouraging them to make riskier choices. This was heavily debated when the NFIP was first proposed (Elliott, 2021). This led to the idea that floodplain maps would help homeowners know their risks and make more rational choices (Elliott, 2021). Individual moral hazard occurs when insurance leads policyholders to be less careful in reducing post-flood damages. If immediate actions are taken to mitigate mold, the policyholder's recovery is expedited, and costs and damages are reduced. If policyholders delay, mold damage becomes much more extensive and costly, increasing costs to insure.

Non-insurance professionals examining the challenges of the NFIP overlook moral hazards in insurance arrangements. Insurers reduce moral hazard with risk-sharing agreements such as higher deductibles. For low-probability risks, such as floods, this presents a challenge. Behavioral economics studies find consumers prefer lower not higher, deductibles for rare events (Kunreuther et al., 2013). Further, studies of NFIP buying habits find that the hazard must rise to a level of concern (Knowles & Kunreuther, 2014). A high deductible, while reducing moral hazard,

increases the level of concern needed to make flood insurance attractive (Knowles & Kunreuther, 2014).

One way to reduce the moral hazard shortcoming is to offer parametric (index-based) insurance (Sengupta & Kousky, 2020). Because parametric insurance pays for an event exceedance regardless of the loss amount, it gives policyholders financial resources for immediate disaster recovery. It reduces losses from the insured lack of action (Sengupta & Kousky, 2020).

The risk is quantifiable. For a risk to be insurable, the frequency and severity of claimable events must be quantified with reasonable confidence (Schanz, 2023). Accurately calculating the frequency and severity of flooding is challenging, particularly for California's Central Valley, where levees can underperform for numerous reasons (GEI Consultants, 2022). In much of California, the flood control system is also part of the water supply system; large dams also have water storage and flood control functions (CA DWR, 2022). This dual role adds complexity that industry catastrophe models cannot capture.

Much of the Central Valley is protected by the State Plan of Flood Control Levees. In the Sacramento Valley, these levees are maintained to a water surface elevation standard referred to as 'the '57 profile', similar to the FEMA 100-year water surface. To provide information for designing levee improvements for a FEMA 100-year design standard, hydraulic models, led mainly by DWR, focus on estimating flood flows that maintain the water surface matching 'the '57 profile.'

Modeling to support infrastructure design differs from catastrophe modeling used for actuarial estimates. Because the modeling processes differ, information from design models is not easily incorporated into catastrophe models used by actuaries.

Other challenges to quantifying the risk occur in parts of California, where a year's supply of rainfall can occur in one or two days (Dettinger et al., 2018). Traditional runoff gages poorly capture flash flood runoff from these events. Without gage data to calibrate and test catastrophe models, insurers find it difficult to price

the risk accurately (Grossi & Kunreuther, 2005). These and other modeling obstacles force insurers to add substantial uncertainty to premium loads,[1] which increases insurance costs (Michel-Kerjan, 2010).

Public-private partnerships that improve catastrophe models can greatly improve quantification of flood risks (Bruno et al., 2011; Grossi & Kunreuther, 2005; Kunreuther, 2015). Through the ARkStorm 2.0 project, DWR is working on an agreement with the USACE to create a statewide flood runoff model that uses supercomputer-driven hydraulic models. Insurance providers could use this model to improve their catastrophe models. Such a partnership could reduce modeled loss uncertainty, which is a significant cost driver.

The maximum possible loss is manageable. Managing the maximum loss is challenging for natural disaster risks because the disaster can affect many properties simultaneously (Froot, 2001; Grossi & Kunreuther, 2005). For example, an insurer with many policies protected by the levee must pay all claims immediately if the levee underperforms and floods the community. Insurers often manage the maximum loss by spreading the risk across space or by dividing the risk into layers and ceding some layers of risk to other insurers or reinsurers (Hochrainer-Stigler & Reiter, 2021).

Insurers often rely on reinsurers to help them manage large losses (Hochrainer-Stigler & Reiter, 2021). Insurers often establish a Value at Risk (VaR) cap (Hochrainer-Stigler & Reiter, 2021). VaR quantifies the extent of possible financial losses over a specific time frame.[2] Risk managers use VaR to measure and control their risk of financial ruin (Hochrainer-Stigler & Reiter, 2021). Insurers often use reinsurance to reduce VaR (Hochrainer-Stigler & Reiter, 2021). A public

[1] *Load is the insurance industry term for overhead costs. The price of an insurance policy consists of the expected loss, or pure premium, plus the load (Michel-Kerjan, 2010). Uncertainty is one component of the load.*
[2] https://www.investopedia.com/terms/v/var.asp

private partnership that results in a reduction in VaR through a variety of mitigation measures, will ultimately reduce insurance costs.

The average loss per event is predictable and manageable. The insurer must estimate the risk's expected cost (Schanz, 2023). This is challenging for rare events or losses, such as levee failures. For areas protected by levees, it may be generations before the levees fail, or they may fail for unknown and unpredictable reasons, making estimates of an average loss less reliable. This produces *tail risk* (the risk of rare events with a very low probability that can cause significant financial loss) (Skipper & Kwon, 2008). Tail risk is a significant source of uncertainty, resulting in increased costs.

Technological advances are helping insurers reduce tail risk (Focardi & Fabozzi, 2003). Insurers increasingly use catastrophe models to assess risks. By perturbing possible inputs and running the models thousands of times, insurers can overcome some statistical challenges and better estimate the average loss per occurrence (Grossi & Kunreuther, 2005). Although catastrophe models have shortcomings, the insurance industry's growing confidence in them makes private flood insurance options more accessible (National Association of Insurance Commissioners, 2011).

Many independent exposure units. Risk should be spread across many policyholders (Schanz, 2023). Bundling many independent risks into one risk pool allows the law of large numbers to create more stable and predictable losses. A program that spreads the aggregated risk of a community across multiple communities can address the aggregation of risk from community-wide flood events. For example, The Central Valley has over 30 small communities. If the aggregated risk of each community is spread across all 30 small communities, premium costs can be reduced.

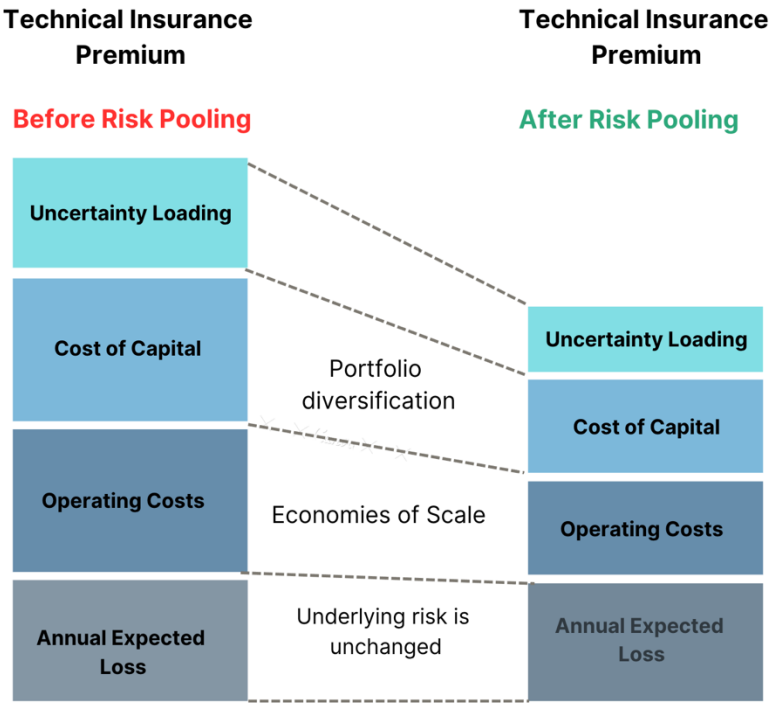
One way to spread risk is to aggregate smaller risks into more extensive, diversified financial portfolios. Disaster risk pooled at the national, state, or regional level can reduce the cost of accessing global financial markets (Mahul et al., 2014). Pooling risks diversifies benefits that can reduce insurance premiums (see Figure 2 which illustrates a total premium and its components before and after risk pooling) (Mahul et al., 2014).

Figure 2 Benefits of Risk Diversification.

[Adapted from World Bank Disaster Risk Financing and Insurance Program (2016)] Note: Box size for illustration only

Risk information is open and transparent (Schanz, 2018). Adverse selection happens when people with more likelihood of a loss are more likely to purchase insurance (Antwi-Boasiako,

2014; Cohen & Siegelman, 2010). Adverse selection causes an unequal distribution of risk among



policyholders. This increases claim costs, raises premiums, and financially strains the insurer (Skipper & Kwon, 2008). Adverse selection is less of a concern for flood risk than other risks, as the insurance provider often knows more about the flood risk than the consumer (Schanz, 2018). Insurers, however, can use the inverse to preferentially market to lower-risk consumers.

To combat adverse selection, insurers use risk-based pricing and underwriting practices, often making insurance unaffordable for those needing it most (Kousky & French, 2022). A partnership between the public and private sectors to improve flood risk information can address this imbalance and encourage better pre-disaster preparation and planning (Sanders et al., 2020). Making risk information open and transparent is a goal of the First Street Foundation (2020). Conversely, the lack of open and transparent data for pricing risk under FEMA's Risk Rating 2.0 program is viewed as a shortcoming of the new pricing method (Tambala Strategy, LLC,2023).

Insurance Must Be Administratively Feasible

Administrative feasibility addresses practical aspects of the insurance product. It includes the ability to underwrite, issue, and manage policies and handle claims efficiently (Powell et al, 2023; Skipper & Kwon, 2008). An insurer needs the people, infrastructure, technology, and processes to manage the insurance product in a cost-effective and customer-friendly way (Skipper & Kwon, 2008). A community-based flood recovery benefit program can make flood insurance more feasible (CDI-Climate Change Working Group, 2021). Still, it must overcome institutional and administrative obstacles.

Table 3

Factors that Influence Administrative Feasibility

Factor	**Summary**
Institutional Obstacles and Shortcomings	Insurers require an entity with "an insurable interest" to purchase the insurance
Long-term financing	Any financial risk transfer arrangement requires reliable, long-term financing

Institutional Obstacles and Shortcomings. A challenge for community-based flood recovery benefit programs is that insurers require an entity with "an insurable interest" to purchase the insurance (Prashanth, 2008). An insurable interest means the insurance buyer would experience a loss if the insured is damaged or destroyed. For example, a community non-profit cannot purchase flood insurance for low-income households because they lack "an insurable interest" (Kousky, 2023). Insurable interest is a fundamental principle in insurance law. If there is no insurable interest, the financial instrument is classified as a derivative and regulated under financial regulations. The absence of a government entity with the authority, knowledge, and willingness to

negotiate insurance contracts is a significant obstacle to implementing a community-based flood recovery benefit program.

Institutional obstacles extend beyond insurability, highlighting a broader governance gap in natural disaster resilience and recovery. As conversations around community climate resilience intensify, there is a recognition that discussions must extend beyond being "resilient to" disasters and also to "recovering from" disasters (Warner et al., 2009). In 2013, The Rockefeller Foundation launched the 100 Resilient Cities program, introducing the Chief Resilience Officer (CRO) role in city governments (The Rockefeller Foundation, n.d.). The CRO's mission was to strengthen community resilience to physical, social, and economic challenges (The Rockefeller Foundation, n.d.). Over the past decade, the value of the CRO has become widely acknowledged, with these officers being pivotal in integrating resilience actions into city governance, promoting cross-sector collaboration, and ensuring cities are better prepared to recover from climate-related disasters and economic disruptions (The Rockefeller Foundation, n.d.). However, not every community has a CRO.

There is increasing awareness of financial resilience and recovery gaps from natural disasters (Kousky & French, 2022). Not all disaster risks can be mitigated. While financial preparation can reduce disasters' long-term economic impacts, risk transfer options are poorly understood (Kousky, 2022). CROs generally lack knowledge of how insurance works and the growing availability of insurance options, insurance-linked securities, and financial instruments such as resiliency bonds (Kousky, 2022).

The governance gap might be overcome in rural areas by establishing an assessment district, such as a GHAD (Geologic Hazard Abatement Districts [GHAD], n.d.). GHADs are often professionally managed by engineering firms with physical and financial risk management

(GHAD, n.d.). They often have formal agreements with insurance brokers who can educate stakeholders and develop risk transfer arrangements that close the financial resiliency gap (personal communication, Mark Niebuhr, September 3, 2024). When a GHAD has a Plan of Control with actions triggered in the event of a flood, this provides an "insurable interest" needed to support the purchase of a parametric insurance policy.

Long-term financing. A second institutional hurdle involves long-term financing. Any financial risk transfer arrangement requires reliable, long-term financing. Financing a once-in-a-generation flood recovery payment program with public funds is challenging (Taylor, 2017). If elected officials view flood recovery payments as a social benefit program, it will likely be eliminated during an economic downturn. If the recovery payment comes from insurance proceeds, there must be a reliable, long-term source to pay for insurance premiums.

Flood risk financing poses financial challenges (Taylor, 2017). The low probability of a flood event offers an opportunity to accumulate reserves that collect interest, reducing the cost of future parametric insurance payments (Taylor, 2017). However, the low probability of an event is a challenge for supporting sizable and sustained financial investments in a recovery payment program, where the proceeds may be unneeded for many years (Taylor, 2017). California's tax structure and general government accounting rules make providing long-term reliable funding challenging for rare but inevitable natural disasters, such as floods (Taylor, 2017). City and county general fund budgets restrict rainy day funding. Future events must compete with mounting immediate needs (Taylor, 2017).

One solution might be to require local governments to allocate 5% of their general fund revenue to a Local Disaster Risk Reduction Management Fund, a portion of which could help to pay insurance premiums. For example, the Philippines' national government provides local

governments with funding through the Philippine Internal Revenue Allotment (PIRA) (Capuno et al., 2024). The PIRA is an unconditional, formula-based grant that provides about 65% of the local government revenue (Capuno et al., 2024). To receive the grant, local governments must allocate 5% of the funding to the Local Disaster Risk Reduction Management Fund (Capuno et al., 2024)

Risk Must be Marketable

The market dimension assesses if demand exists for the insurance product at a price that covers the insurer's costs and provides a reasonable profit (Schanz, 2018). It considers the willingness of potential policyholders to purchase insurance and the insurer's ability to sell and service the policy (Kousky, 2022). Market feasibility ensures that consumers find the product attractive and can be effectively marketed and distributed (Skipper & Kwon, 2008). In addition, people should be aware of their flood risk and the need to buy insurance (Kunreuther, 1984).

Table 4

Factors that Influence Marketability

Factor	**Summary**
Awareness of risk.	Numerous homeowners are unaware of flood risk and the availability of flood insurance.
Behavioral biases.	Biases include myopia, amnesia, optimism, inertia, simplification, and herding.
Affordable insurance premiums	Insurance premiums should be affordable and reflect the expected cost of the risk
Transaction costs.	Transaction costs for distribution and general administration typically consume 30 to 40 cents of each premium dollar in non-life insurance.
Clear coverage limits.	The insurance coverage limits should be clearly defined at a reasonable level of complexity.

Awareness of risk. Numerous homeowners are unaware of flood risk and the availability of flood insurance, particularly for residences outside FEMA-designated SFHAs or behind a FEMA-accredited levee (Antwi-Boasiako, 2014; Botzen et al., 2009; Ludy & Kondolf, 2012). A moving population exacerbates this situation. The 2018 1-year American Community Survey indicates that inhabitants outside coastal areas live in their houses an average of less than 12 years (National Association of Realtors, 2021). New homeowners in areas protected by levees or other flood control systems may be unaware that their residences depend on infrastructure that can fail (Ludy & Kondolf, 2012). Despite California's stringent disclosure regulations (Gourevitch et al., 2023), disclosure forms sometimes rely on obsolete NFIP Flood Insurance Rate Maps (FIRMs). Despite homeowners' awareness of potential flood risks, many remain uninformed that ordinary homeowners' policies do not include flood damage. A national poll showed that 56% of Americans lack awareness of this exclusion (Overman, 2024).

> *The most important variables in the analysis are whether the person considers the problem serious and whether he knows someone who has purchased insurance. - (Kunreuther, 1984, p. 130).*

Advances in Geographic Information Systems (GIS) and large-scale modeling make it easier for organizations like the First Street Foundation to provide flood risk awareness and information (First Street Foundation, 2023). Collaborative modeling with fine-resolution data enhances flood awareness, minimizes differences in flood perception, and produces more actionable flood maps (Sanders et al., 2020). Supporting initiatives such as California's Flood Awareness Week, held every October, can help promote awareness (CA DWR, n.d.). These efforts inform homeowners and encourage them to take preventive measures, such as obtaining flood insurance, fostering greater resilience across vulnerable communities (CA DWR, n.d.).

Behavioral biases. Individuals often fail to protect themselves against low-probability, high-consequence events due to behavioral biases (Kunreuther, 2021; Meyer & Kunreuther, 2017).

These biases include myopia, amnesia, optimism, inertia, simplification, and herding (Kunreuther, 2021; Meyer & Kunreuther, 2017). Myopia is the inclination to prioritize short-term future time frames for immediate expenses. Amnesia is the tendency to forget lessons from past disasters (Kunreuther, 2021; Meyer & Kunreuther, 2017). Optimism is the tendency to underestimate the likelihood of loss. Inertia is the tendency to maintain the status quo or adopt a default option. Simplification is the tendency to choose a narrow set of options when facing risk. Herding is the tendency to base decisions on the observed actions of others. Advances in behavioral economics provide insights into overcoming these decision-making biases, making insurance more attractive.

One way to overcome behavioral biases is a behavioral risk audit to characterize how individuals are likely to perceive risks (Kunreuther, 2021). Experts can propose strategies that align with people's decision biases by drawing on the principles of choice architecture proposed in the book Nudge (Thaler & Sunstein, 2021). These biases can be overcome with short-term economic incentives (Kunreuther, 2021). Changes might include providing low-interest loans coupled with a reduction in insurance premiums, offering multi-year insurance policies, expressing potential losses over a 30-year period offering flood insurance as a rider on existing properties as an opt-out provision (Kunreuther, 2021). An opt-out provision would place everyone in the insurance pool, but allow them to opt-out if they did not want the coverage. This would be similar to many 401k arrangements.

Affordable insurance premiums. Insurance premiums should be affordable and reflect the expected cost of the risk (Schanz, 2023). Although no one has agreed on how to measure affordability, various sources have proposed several measures. One measure of affordability is the ratio of mortgage principal and interest, payments, taxes, and insurance (including flood insurance), or principal, interest, taxes, and insurance (PITI) to household income (FEMA, 2018).

Households with a PITI ratio exceeding 0.43 are housing-burdened (FEMA, 2018; U.S. Housing and Urban Development, 2011). A 2018 FEMA study found that roughly 12% of homeowners in a SFHA with an NFIP flood insurance policy are housing challenged using a PITI ratio of 0.40 (FEMA, 2018, p. 17).

The median household income ratio to insurance premiums is another measure of affordability. A 2018 FEMA affordability study (2018) found 51% of households in areas of high flood risk (i.e., a designated Special Flood Hazard Area (SFHA) by FEMA) are defined by the HUD as low-income (p.6). This study found the median household income outside the SFHA in California is $10,998 more than inside the SFHA (FEMA, 2018, p. 59). The median income of those in an SFHA who purchased flood insurance was estimated to be $31,369 more than those who did not (FEMA, 2018, p. 62). The median household income of those not buying a flood insurance policy was $64,945 compared to $91,106 for policy purchasers (FEMA, 2018, p. 62).

The 2018 FEMA affordability study found that around 49% of SFHA policyholders spent less than 1% of their annual income on flood insurance, including premiums and fees (FEMA, 2018, p.6). However, of the remaining 51% of the homeowners within the SFHA, 24% spent 1 to 2% of their income on flood insurance, 11% spent 2 to 3%, 5% spent 3 to 4%, and 7% spent over 5% of their income on flood insurance (FEMA, 2018, p. 16). Outside of the SFHA, only 20% spent over 1% of their income on flood insurance (FEMA, 2018, p. 16). The May 2023 release of FEMA's Risk Rating 2.0 data finds that the median price of flood insurance in California, when Risk Rating 2.0 is fully implemented, will be $1,689 (FEMA. 2023). Given the median household income in California of $78,672 (2020 census), a flood insurance premium above $1,600 would be unaffordable.

The historical purchasing patterns for the NFIP in California suggest consumers are generally willing to pay up to $800 for their insurance policy (FEMA, 2022b). Around half of the NFIP policies sold in California are bought by consumers who willingly choose to buy the insurance rather than being required by their lender (FEMA, 2022b). Despite a higher average price of policies ranging from $400 to $800, the number of discretionary policies has remained constant over the years (FEMA, 2022b). However, there has been a large decrease in policies costing more than $800 (FEMA, 2022b). California households might have a limit of about $800/year in mind when buying flood insurance, treating it as a planned expense that should not exceed this amount, considering their other financial obligations and expenses (Kunreuther et al., 2013). Low- to moderate-income households would find insurance costs exceeding $800 even less affordable.

Transaction costs. Transaction costs for distribution and general administration typically consume 30 to 40 cents of each premium dollar in non-life insurance (Kunreuther et al., 2013; Schanz, 2018). These overhead costs reflect the complexity of insurance but reduce its economic appeal. In particular, the transaction costs of completing and filing application and claim forms, paying premiums, maintaining records, and possibly obtaining information make flood insurance less attractive to consumers (Kunreuther et al., 2013)

Reducing transaction costs is a key to making flood insurance affordable. The ability to reduce transaction costs distinguishes the NFIP and the potential community-based flood recovery benefit program. The transaction costs for NIFP premiums exceed 60% of every premium dollar (GAO, 2023). To reduce transaction costs, a community may purchase one master policy rather than each individual purchasing one. Parametric insurance policies often have lower transaction

costs because the need for adjusters is eliminated. Lastly, technological advances are making online transactions possible, removing the need for an insurance agent to write a policy.

Clear coverage limits. The insurance coverage limits should be clearly defined at a reasonable level of complexity (Schanz, 2023). By establishing clear parameters, policyholders can better understand their coverage and any potential out-of-pocket expenses (Schanz, 2023). This approach minimizes confusion and ensures all parties know the policy limits and protections offered (Schanz, 2023).

Summary. Kousky (2022) suggests that insurance is a bit of a Goldilocks product—it works best for risks that are not too small and not too big, but just right" (p. 33). If claims are too small, transaction costs exceed the claim value. If claims are too large, the cost of reserves to pay them becomes unaffordable. If claims are too frequent, premiums may become too expensive. If claims are too rare, premiums may be too meager, or buyers may view the risk below a level of concern that would justify insurance. If premiums are too high, consumers will not be interested; if premiums are too low, insurers will be unwilling to offer insurance. Claims that are too high or too frequent are uninsurable, and payments that are too low erode trust, which is crucial for the viability of insurance (Schanz, 2018). Any successful insurance program must balance these challenges.

Unsuitability of Current Insurance Schemes

Sudden Onset, Slow Onset Events, And Non-Economic Loss and Damage (NELD).

Some types of floods may be uninsurable (Nordlander et al., 2020). Traditional insurance schemes are ill-suited to assess sudden-onset events, slow-onset events, and events with high non-economic losses and damage (NELD) (Gewirtzman et al., 2018; Nordlander et al., 2020). A sudden-onset event is significant rainfall after a prolonged drought, such as the Oroville Dam

spillway failure. Sea level rise is an example of a slow-onset disaster. NELD losses occur in three areas: individuals, society, and nature (Nordlander et al., 2020; UNFCCC, 2013). Loss of life, health, territory, and cultural heritage are inherently uninsurable since they lack economic value (Nordlander et al., 2020). Climate change is increasing the frequency and severity of quick-onset events, slow-onset events, and NELD, challenging the function of insurance since meeting insurability standards may become infeasible (Kehinde, 2014; Roberts et al., 2016; Warner et al., 2009). Parametric insurance is one way to make uninsurable losses insurable (Nordlander et al., 2020). But several challenges must be overcome before it can be used for NELD events (Nordlander et al., 2020), such as determining the payout needed to compensate NELD adequately (Nordlander et al., 2020). NELD compensation programs have potential for some people to receive excess compensation and others inadequate compensation (Nordlander et al., 2020).

Risk Financing

Sometimes, flood risks are more effectively managed with risk control rather than risk financing. Insurance is a way to transfer risk. While this is the focus of this dissertation, there are sometimes better solutions for some flood risks. Risk control and risk financing are two fundamental methods to manage risks.

Risk control involves strategies aimed at decreasing the likelihood or impact of losses (Rejda & McNamara, 2014). The three common risk control measures include avoidance of hazard, loss prevention, and loss reduction (Rejda & McNamara, 2014). Risk managers frequently apply a mix of these techniques to address various exposures. Returning to the vintner example avoidance might involve deciding not to plant vineyards in frost-prone areas. Loss prevention might include installing bird netting over vineyards to reduce the probability of crop loss due to bird damage. Loss reduction measures might include a winery implementing a sophisticated

temperature control system in their cellars to minimize the risk of wine spoilage due to temperature fluctuations. Another example of loss reduction could be diversifying grape varieties to include some that are more resistant to specific pests or diseases, thereby reducing potential losses from these threats. Risk managers in wineries often combine these approaches; for example, a vintner might avoid planting in low-lying areas prone to standing water (avoidance), implement regular pest monitoring and management programs (loss prevention), and install wind machines to protect against frost damage (loss reduction) to create a comprehensive risk control strategy for their vineyard operations.

Risk financing is a method for covering losses (Rejda & McNamara, 2014). The three primary techniques for risk financing are retention, non-insurance transfers, and insurance (Rejda & McNamara, 2014). Companies can use these methods to plan for and manage their risks. Risk retention is frequently used when insurance options are lacking or when the risk cannot be shifted. Risk retention is used when no amount of money will save the business from disaster. This approach is also suitable if the potential loss is not significant or when the losses are somewhat foreseeable. For instance, a vintner might absorb the cost of broken equipment, and a community-focused risk financing initiative may choose to retain the risk from smaller storms, such as Category 1, 2, or 3 atmospheric rivers. Additionally, firms may retain risk passively (Rejda & McNamara, 2014). This passive retention occurs when a company neglects to recognize, is indifferent to, or fails to identify the risk (Rejda & McNamara, 2014). Passive risk might be the failure to acknowledge risks in their operations. If retention is used, the retention level is critical.

If retention is used, the retention level, or the dollar amount of losses the firm will absorb, should be estimated (Rejda & McNamara, 2014). A firm with more liquidity can have a higher retention level (Rejda & McNamara, 2014). In addition, the risk manager must be able to cover

these losses financially. These can include paying for losses with current net income, reserve funds, and a line of credit (Rejda & McNamara, 2014). Low-income households frequently lack the finances to actively retain flood risk. Because they cannot afford insurance, they passively retain the risk, putting them in a precarious position.

Proponents of the NFIP fail to acknowledge the passive retention passed along to policyholders. For example, the cost to elevate a home in the Sacramento area is $100,000. ICC coverage only provides a maximum of $30,000. In addition, the NFIP is a reimbursable policy, meaning the household must pay the contractor before being reimbursed. Unlike other homeowner policies, the NFIP does not pay for living expenses while the home is being rebuilt. NFIP policyholders are rarely aware they have over $100,000 retained risk.

Captive insurance represents an alternative risk management strategy for firms seeking greater control over their loss exposures. A captive insurer, wholly owned by a parent company, serves to underwrite the parent's specific risks (Rejda & McNamara, 2014). Organizations typically establish captives when faced with challenges in obtaining commercial insurance, aiming to reduce costs, leverage more favorable regulatory environments, or potentially generate profit from their risk management operations (Rejda & McNamara, 2014). The University of California system exemplifies this approach, financing a significant portion of its risk through multiple captive entities (University of California Office of the President, n.d.). While traditionally domiciled in offshore locations like Bermuda, captive insurance companies are increasingly finding homes within the United States, as numerous states have enacted supportive legislation. Utah, for instance, has recently implemented captive statutes that may prove particularly advantageous for community-based insurance programs (Utah Department of Insurance, n.d.).

This evolving landscape of captive insurance offers new possibilities for tailored risk management solutions across various organizational structures.

Another option may be to form a risk retention group (RRG) (Rejda & McNamara, 2014). Federal legislation allows trade groups and governmental units to form RRGs. (Rejda & McNamara, 2014). An RRG is a group captive that can provide many types of insurance. It is exempt from many state insurance laws that apply to other insurers (Rejda & McNamara, 2014).

Retaining part or all of a risk offers several benefits. A company may save money when actual losses are lower over time than the loss portion included in a private insurer's premium (Rejda & McNamara, 2014). By keeping some losses, a firm can minimize insurance overhead, promote loss prevention efforts, and boost cash flow since funds typically spent on insurance premiums can be allocated to other uses (Rejda & McNamara, 2014).

Retaining risk also has disadvantages (Rejda & McNamara, 2014). Companies may face higher-than-expected losses or experience significant volatility (Rejda & McNamara, 2014). Expenses can increase, resulting in potentially higher taxes (Rejda & McNamara, 2014).

Dpending on the situation, self-insurance or insurance-linked security, such as a catastrophe bond, may be cheaper for insuring risks that are not retained. Self-insurance is money put aside in a bank account to pay for specific losses just as an insurer would pay. It is different from risk retention because self-insurance involves deliberately setting aside funds to cover potential losses, whereas risk retention often occurs when an entity chooses to bear the financial consequences of a risk without specific preparation.

With self-insurance, there's a proactive approach to accumulating resources to address potential future losses. This method allows for greater control over funds and potentially lower costs compared to traditional insurance premiums. However, it also requires discipline in

maintaining the fund and may not provide sufficient coverage for catastrophic losses. Risk retention, on the other hand, might be a passive decision or result from an inability to transfer or avoid the risk. It doesn't necessarily involve dedicated funds and may leave the entity more vulnerable to financial strain in the event of a loss.

Additionally, self-insurance can be more flexible, allowing the entity to adjust the amount set aside based on changing risk assessments or financial capabilities. It also avoids the overhead costs associated with insurance companies. However, it lacks the risk-spreading mechanism of traditional insurance, which can be crucial for managing large or unexpected losses. As recovery benefit programs grow and mature, other risk transfer options may become more cost-effective, so they are briefly discussed.

Table 6

Risk Transfer Tools

Insurance	
	Indemnity Parametric
Insurance-linked Securities	
	Weather Derivatives Catastrophe Bonds

Insurance

Insurance operates on a fundamental principle: economic agents regularly contribute predetermined sums (premiums) into a shared fund. When a predefined event covered by the policy results in a loss, the insured receives compensation from the fund for the damages (Jarzabkowski et al., 2021). In this system, insurance providers use premium dollars to

transfer potential financial losses to the capital markets (Jarzabkowski et al., 2021). By accepting the premium payment, the insurer assumes the insured's risk, committing to pay claims for future financial losses as stipulated in the policy's terms and conditions (Jarzabkowski et al., 2019). Catastrophic natural disasters challenge this arrangement because insurers face the possibility of paying out numerous claims simultaneously (Jarzabkowski et al., 2019; Zhou et al., 2023). To mitigate this risk, insurers often transfer some of their risk to reinsurers, who have access to global capital markets (Jarzabkowski et al., 2019; Zhou et al., 2023). This complex risk transfer and financial protection network forms the insurance value chain, as illustrated in Figure 3.

Figure 3 Insurance Value Chain.

[Adapted from Jarzabkowski et al., 2019]

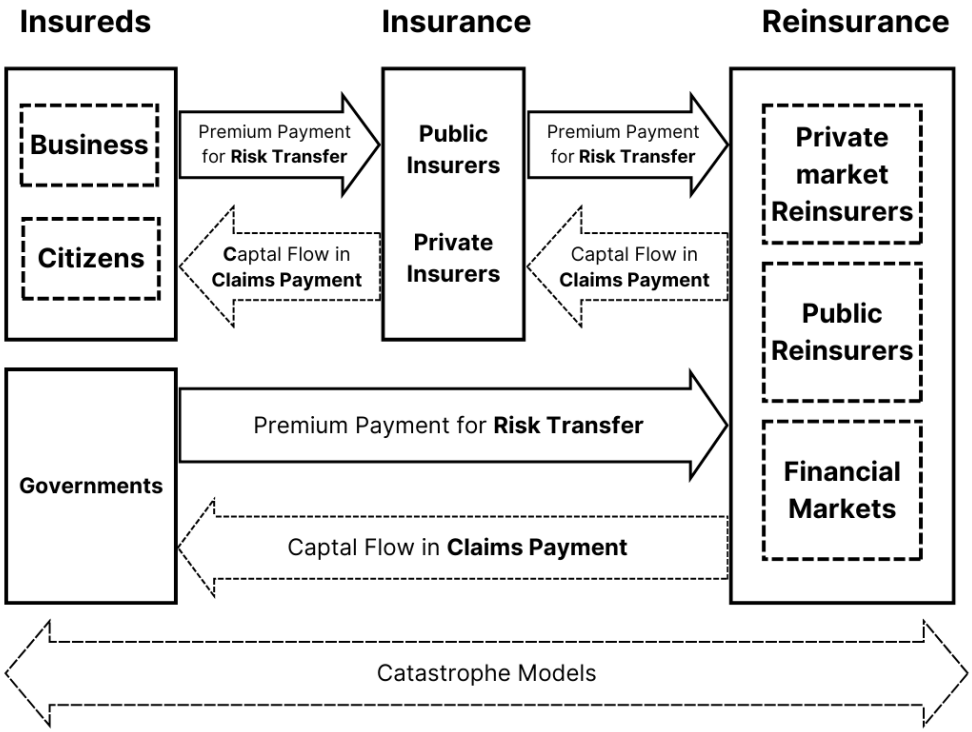


Figure from: Insurance for climate adaptation: opportunities and limitations, Jarzabkowski et al., 2019

Catastrophe models are vital to making the insurance value change work for natural disaster risks (Jarzabkowski et al., 2019; Powell et al., 2023). Catastrophe models have five modules (Grossi & Kunreuther, 2005).

1. *Stochastic Event Module:* A database of thousands of possible events, each defined by a strength or size, location or path, and probability.
2. *Hazard Module:* A module that computes the probabilities of loss occurrence and severity.
3. *Exposure Module:* Enter the inventory of elements for insurance coverage. The exposure assessment includes building attributes, including construction type, age, dimensions, and replacement cost.
4. *Vulnerability Module:* A module that assesses the various levels of damage to be expected.
5. Loss Module: The loss module generates the exceedance probability (EP) curve for losses. Insurers use the EP curve to appraise their portfolio of risks, paying attention to tail risks, which are unlikely but have potential for significant devastating consequences.

The EP curve is the main output of a probabilistic catastrophe model (Grossi & Kunreuther, 2005). The area under the EP curve is the average annual loss (AAL), which estimates the annual premium needed to cover losses from the modeled perils over time, assuming the exposure remains constant (American Academy of Actuaries, 2017; Grossi & Kunreuther, 2005). AAL is commonly called the pure premium because it does not include overhead and other expenses (Grossi & Kunreuther, 2005).

Indemnity Insurance

Most people are acquainted with an indemnity policy. It is based on compensation for the loss of a tangible asset. An asset possesses a defined value for which it can be compensated (Jarzabkowski et al., 2019). The insurance premium is determined by the indemnity value, with a payment contingent on the asset's actual loss (American Academy of Actuaries, 2017). Indemnity insurance is prevalent for low-severity, high-frequency incidents such as automobile damage and

losses that may affect the policyholder financially without societal repercussions. It can also accommodate risks of low-frequency, high-severity catastrophic occurrences (Jarzabkowski et al., 2019). The NFIP policies are indemnity contracts (American Academy of Actuaries, 2017). Indemnity plans are particularly appropriate for the costly reconstruction phase of post-disaster management. However, claims adjustment delays and costs make indemnity insurance ill-suited for the initial disaster response. Indemnity insurance compensates based on the insured value, which may exclude supplementary funds required to reconstruct to an elevated standard following a loss (American Academy of Actuaries, 2017; Elliott, 2021). The NFIP offers an option to encompass elevated construction standards, with coverage limited to $30,000 (Elliott, 2021).

Parametric or Index-Based Products

Parametric insurance departs from indemnity policies like automobile or homeowner policies, which reimburse the insured for damages. Parametric insurance pays a predetermined amount when an event exceeds a predetermined index (trigger) (Sengupta & Kousky, 2020). The index is an objective measure (e.g., rainfall, river gauge height, wind speed) highly correlated to the variable of interest (e.g., flood depth, flood loss) (Sengupta & Kousky, 2020). Triggers can also be based on total losses in an industry for a given event (Teh & Woolnough, 2019). An index must have the following properties (Teh & Woolnough, 2019):

- observable and easily measured
- objective
- independently verifiable
- transparent
- reported promptly
- consistent over time
- experienced over a wide area.

For example:

A triggering event in the Central Valley could be a levee failure, the elevation of the water surface of the Sacramento River exceeding a predetermined height, losses of a certain magnitude or an atmospheric river of a certain AR category.

Parametric insurance has many benefits. It can address catastrophic risks (Sengupta & Kousky, 2020). Because the triggers and payouts can be linked to low-probability, high-consequence events, they can support macro-insurance programs for catastrophic events (Zhou et al., 2023). Parametric insurance can address the needs of the most vulnerable by aggregating insurance in a way that would not be viable with an indemnity policy (Sengupta & Kousky, 2020).

The most significant and impactful benefit of parametric insurance is the speed of payment (Sengupta & Kousky, 2020). With parametric insurance, payments can be almost immediate, making it a disaster liquidity product. Quick financial liquidity from a parametric insurance policy can reduce indirect effects, such as human distress and loss of income, facilitate rapid recovery, instill confidence in recovery, and reduce long-term consequences of disasters (Kousky & French, 2022; Warner et al., 2009).

Parametric insurance can fill some coverage gaps in traditional policies, providing more comprehensive protection. For example, it can offer business interruption insurance even when the event does not directly impact the business (Kousky & French, 2022). Furthermore, the payments can be used as the insured sees fit, covering direct and indirect losses and any expenses from the event. These could include temporary housing, replacement of equipment, additional transportation expenses, and ensuring that any aspect of recovery is covered (Kousky & French,

2022). Parametric insurance can be used as a supplement or replacement for traditional indemnity policies.

Parametric Insurance Pricing

Implementing a community-based recovery benefit program starts with providing parcel information to the insurer, who then assesses an Average Annual Loss (AAL) for the full suite of properties.

Industry experts suggest that two to three times the AAL is a reasonable initial budget estimate. After the initial estimate is established, a public-private partnership can work to reduce the costs and to acquire long-term funding.

For Example:

If a community of 500 homes is protected by a levee with a 1 in 75-year chance of failing (annual probability of 0.013). If the community wishes to provide a $10,000 recovery payment to every household. The AAL is computed as 500 x $10,000 x 0.013 = $66,666. If the insurance policy cost is 3 times the AAL, the annual premium for a $5,000,000 policy is $66,666 x 3 = $200,000.

Other benefits of parametric insurance include ease of purchase and fair treatment of claims. Ease of purchase is vital in insurance purchase decisions (Baicker et al., 2012). Buyers want insurance to be easy to understand and clear when purchasing insurance (EY, 2023). If the purchase process is too cumbersome or time-consuming, it may never raise a level of concern high enough for consumers to take action (Kunreuther, 1984). Homeowners who believe they will be treated fairly are more likely to purchase insurance (Schanz, 2018). A survey of parametric flood insurance buyers found that certainty on the payment size was desirable for households of color (Stillwell, personal communication, July 20, 2024).

Ease of purchase is critical in individual insurance purchases. It is equally crucial when considering insurance for community-based flood recovery benefit programs. Conversations with community officials find that the purchase process can be a chicken-and-egg problem between the community and the insurer. Community officials are unwilling to commit resources to acquire an insurance policy for a community-based flood recovery benefit program until they know how

much it will cost and if their constituents are willing to pay. Insurers are unwilling to commit resources to estimating a premium price until they know which properties will be covered by the policy.

While parametric insurance has advantages, is also has disadvantages. The compensation may not fully offset the losses, or the index may remain unmet despite the occurrence of actual losses (Sengupta & Kousky, 2020). This phenomenon is called basis risk. With careful design, basis risk can be minimized but never eliminated. Two ways to reduce basis risk are to carefully design the payment trigger and ensure that it matches the potential source of loss. Another option is to pair the policy with an indemnity policy. For example, the parametric policy might cover a basic loss amount, with an indemnity policy covering higher loss limits (Sengupta & Kousky, 2020).

Micro-, meso- and macro-levels of insurance

Insurance products can operate at the micro-, meso-, and macro-levels (Jarzabkowski et al., 2019). Each is described briefly.

Micro-insurance is the direct insurance of individuals or small-business policyholders (Ghesquiere & Mahul, 2010; InsuResilience Global Partnership, n.d.; Jarzabkowski et al., 2019). It can parallel with micro-finance to insure the most vulnerable individuals for modest amounts. An insured might pair micro-insurance with a micro-loan. Micro-insurance is a $95 billion industry (Research & Markets, 2024). With developments in insurtech (new technologies to improve insurance efficiency and service delivery), partnerships with FinTech and telecommmunications companies (where financial technology companies and telecommunications companies work together to improve insurance accessibility and digital financial services), the use of parametric insurance, the rise of on-demand models, and perhaps use of blockchain for greater trust and

transparency, the number, and types of microinsurance policies are expected to increase (Zhou et al., 2023).

Meso-insurance is insurance acquired by a group of persons within an organized entity (Jarzabkowski et al., 2019; Kouskly, 2023). For example, the Association of Geologic Hazard Abatement Districts might buy an insurance product to provide a basic level of coverage for property owners within a GHAD. The meso-level organization purchases an insurance product intended to protect the collective individuals, who are indirect beneficiaries of the policy (InsuResilience Global Partnership, n.d.). Upon a claim, the individuals receive the claims payment (InsuResilience Global Partnership, n.d.). Recently, FEMA has stopped issuing Letters of Map Revision based on FILL (LOMR-F). As a result developers that have traditionally relied on filling in low-lying areas to remove the requirement to buy flood insurance can no longer file paperwork removing the requirement to buy flood insurance. They may still obtain a permit from the local government to bring in fill, but they are unable to change the Food insurance Rate Map removing the mandatory flood insurance requirement. The California Home Builders Association is currently exploring a meso-insurance arrangement that would provide low-cost flood insurance for a short period as a part of the new home purchase.

Macro-insurance is purchased by a government or quasi-governmental entity. It is often called “sovereign-level insurance” (Baur & Parker, 2015; Volz et al., 2020). In this arrangement, a government entity purchases a parametric insurance policy for property owners within the government’s jurisdiction. The government policy payout can serve several purposes. It can support government services or be linked to helping the most vulnerable through a disaster contingency plan.

Insurance-linked Securities

Insurance-linked securities (ILS) are another tool for diversifying climate-related risks on a global scale. ILS are financial products for various insurance risks (Hofmann & Pooser, 2017). Their principal function is securitization of risks from natural hazards (Kraehnert et al., 2021). Two types of ILS insure against severe weather events: catastrophe bonds (cat bonds) and weather derivatives (Kraehnert et al., 2021).

Weather Derivatives

Weather derivatives, including futures and options, are assets whose value is contingent on the price of another asset, referred to as the "underlying" asset (Pollard et al. 2008). Their value is linked to specific meteorological indices, such as wind speed, temperature, and rainfall, calculated from meteorological data, which closely coincide with actual weather conditions (Pollard et al., 2008). These financial tools diverge from insurance in three ways: they do not require the purchaser to "have an insurable interest"; there is no proof of loss requirement; and they pay for high-probability, low-consequence events instead of insurance designed for low-probability, high-consequence events.

For example:

A stream restoration contractor might purchase a weather derivative for a few months to cover the potential weather-related loss of seedlings or the cost of workers who may be unable to plant because of extreme heat.

Catastrophe or Resilience Bonds

A catastrophe bond, often called a "cat bond," is a financial instrument primarily used for reinsurance or potentially significant losses. In this arrangement, an insurer transfers a specific risk, such as the financial impact of a natural disaster, to a special purpose vehicle (SPV)—a separate legal entity created to isolate this risk from the insurer's balance sheet (Kraehnert et al.,

2021). The SPV issues cat bonds to investors, who receive periodic interest payments in exchange for a premium.

Resilience Bonds are a financial instrument that combines elements of Catastrophe Bonds with financing for risk reduction projects (Keenan 20189). They provide coverage against climate-related events while simultaneously funding adaptation and resilience initiatives. They work by offering rebates to sponsoring local governments, which invest in risk-reducing projects (Keenan, 2019). These investments reduce the exposure, which in turn lowers investment risk for bondholders and premiums for sponsors (Keenan, 2019,) Resilience Bonds face challenges, linking risk to risk reduction strategies with sufficient precision to justify rebate Keenan, 2019). Flooding is considered especially difficult to model in this context. Scale is another issue, as meaningful rebates require large-scale operations, suggesting that national sponsors or organizations with extensive asset portfolios might be better suited for this instrument (Keenan, 2019). Despite these challenges, improved climate change impact modeling and increases in market sophistication are expected to increase demand. (Keenan, 2019)

Opportunities To Make Flood Risk Insurable.

It can be challenging to make flood risk insurable. Increasing building and housing costs, along with rising floods, challenge the traditional insurance business model. However, advances in behavioral economics, parametric insurance, and new insurance-linked securities provide new opportunities to do so. Engineers and disaster risk managers can use this knowledge to create a new insurance arrangement that is more affordable and more attractive to consumers

The next chapter describes such a program. The proposed arrangement divides the insurable flood risk into three tiers. Each tier addresses a subset of the challenges described in this chapter. For example, Tier 1 provides the first layer of coverage that buyers want, but insurers find

challenging to provide. Tier 2 provides a high deductible, making a risk more insurable and thus more affordable. Tier 3 is designed to accommodate outside funding from state and federal sources, much as Congress envisioned when they passed the Flood Insurance Act of 1956 (Flood Insurance Act, 1956; Grossman, 1958).

Chapter 4 Community -Based Disaster Finance and Insurance Risk Management (CoDFiRM)

California's flood risk protection gap is immense: over 1 million homes are vulnerable, yet less than 200,000 have flood insurance (First Street, 2020, FEMA, 2023). This is a dramatic insurance protection gap—the difference between potential flood losses and the amount of economically feasible insurance (Jarzabkowski, et al., 2023). There is also a broader financial protection gap—the difference between potential flood losses and the financial resources to recover. While insurance is one way to close the financial protection gap, there are other ways, such as with reserves or with insurance-linked securities (Jarzabkowski et al., 2023; Rejda & McNamara, 2014; Schanz & Wang, 2014). This study introduces a framework to address both protection gaps with an emphasis on closing the insurance protection gap.

For the past 60 years, the US has had two ways of managing floods. Prior to 1968, the nation focused exclusively on flood control, with the Corps of Engineers tasked with building flood control structures to "keep floodwaters away from people." In 1968, the NFIP was added "to keep people away from floodwaters." This was accomplished by requiring communities to adopt FEMA FIRMs by local ordinance and to use them to regulate development. FIRMs show the estimated 100-year SFHA boundaries. Land development within the SFHA was managed as part of a suite of "flood management activities" (Lassiter, 2015. p. 168). Former San Joaquin County Office of Emergency Services Director Ron Baldwin often called the SFHA boundary the "Maginot Line." A clear boundary where development inside the boundary is actively managed and development outside the boundary is ignored. The Maginot Line creates an incentive to reduce the area bounded by the line while ignoring the flood risk consequences outside of the line. Although NFIP flood management occurs only inside the Maginot Line, NFIP flood insurance is

made available to everyone. Because flood insurance is available, people who experience a flood and do not have flood insurance are expected to suffer consequences, regardless of their location or knowledge of their risk.

The existing National Flood Insurance Program (NFIP) faces several notable challenges. It is often perceived as a burdensome regulatory land development program, rather than a functional insurance entity. When compared to well-run insurance companies, the NFIP exhibits significant shortcomings. Rising insurance premiums are rendering NFIP coverage increasingly unaffordable for many, while its growing debt threatens the program's long-term solvency. This dissertation proposes the establishment of a new governance framework to address these challenges and bridge the existing financial protection gap. The proposed entity would be versed in modern enterprise risk management practices and possess familiarity with the range of available risk transfer mechanisms. This innovative approach aims to reposition flood insurance as an effective risk management tool, rather than an onerous regulatory requirement.

But what should we call this entity? Jarzabkowski et al. (2023) refer to these entities as Protection Gap Entities (PGE), established when specific disasters are uninsurable. (In California, PGE commonly refers to Pacific Gas and Electric, potentially confusing the acronym.) Kousky and Shabman (2011) call these entities community-based insurance providers. While this entity would provide insurance, its role is intended to extend beyond mere insurance provision to include community financial risk management. The term "community" can be ambiguous, as it may describe either a collection of people or a defined political boundary. Many times the community flood risk boundary affects only a portion of the community's housing stock, preventing the flood-prone households from getting the attention and resources.

The entity could be termed Disaster Risk Management (DRM) agency. Depending on the activities involved, it might also be called a Disaster Risk and Reduction Management Agency (DRRMA). Another option might be Disaster Risk Reduction and Recovery Management Agency (DRRRMA). These DRM activities are closely aligned with Climate Change Adaptation (CCA), and some refer to the intersection of these activities as Climate Risk Management (CRM). After some thought and discussion with stakeholders, this dissertation will refer to the activities to manage the financial protection gap as Community-Based Disaster Financial and Insurance Risk Management (CoDFiRM).

CoDFiRM takes a different view of risk than the traditional disaster definition. It adopts the view economists, actuaries, finance, and insurance professionals adopted in the last two decades. In this framework, risk is neither good nor bad. Risk is the "randomness of a variable that can be reasonably described by an objective probability distribution" (Friberg, 2015, p. 7). In this definition, the measure of riskiness is taken to be the volatility of a variable (Friberg, 2015). Uncertainty is the variability that cannot be fully described by a single simple continuous probability distribution (Friberg, 2015).

This financial view of risk, which is neither inherently bad nor good but measures volatility, drove Enterprise Risk Management's (ERM) growth (Rejda & McNamara, 2014: Skipper & Kwon, 2007). In the 1970s, multinational corporations began practicing risk management. By the 1990s, risk management included collective financial, operational, and strategic risk management. The Chief Risk Officer (CRO) position was created and elevated to report directly to the company's Chief Executive Officer (Figure 1) (Rejda & McNamara, 2014: Skipper & Kwon, 2007). The CRO guides the corporate response to risk (Rejda & McNamara, 2014: Skipper & Kwon, 2007). This response can involve risk control activities such as avoidance,

loss prevention (frequency control), and loss reduction (severity control) (Rejda & McNamara, 2014: Skipper & Kwon, 2007). It also includes risk financing, with options like full retention, hybrid transfer, and full transfer (Rejda & McNamara, 2014: Skipper & Kwon, 2007).

The CoDFiRM framework separates flood risk into three layers: manageable risk, insurable risk, and uninsurable risk. Manageable risks are frequent, often low loss events, that are managed with reserves, mitigation or just-in-time events. Uninsurable risks are large catastrophes that are managed with financial instruments, such as catastrophe bonds. The insurable risk layer further divides the insurable risk into three insurance tiers designed to be attractive and affordable to consumers, reducing the insurance protection gap. The focus of this dissertation is on establishing the insurable risk layer and on the three tiers within the layer.

The following sections describe the three-tiered program. *Tier 1: It Takes a Village* recovery payment program provides a recovery payment to every household in the affected neighborhood and is foundational to the other two tiers. *Tier 2: Basic Property Tier*. Flood risks with a greater than 1 in 100-year chance of occurring are challenging to insure affordably. These two tiers are designed to meet most California households' financial flood recovery needs. Lastly, we discuss *Tier 3: Concierge Tier*. The concierge tier offers additional insurance options. This includes additional coverage to meet a lender's mandatory purchase requirements.

Insurance Tier 1: It Takes a Village

What Does It Provide?

Insurance Tier 1: It Takes a Village is a community or neighborhood-based disaster recovery program that provides a quick, post-flood financial recovery payment of up to $10,000 per property to all property owners within an assessment district boundary. This tier promotes equity in disaster recovery. Similar to “inclusive insurance,” it is a *system of policies, programs,*

and products that make appropriate and affordable insurance available to those unserved or underserved by the market (Kousky & French, 2022, p. 7). Regardless of income, all property owners covered under the Tier 1 program receive a payment for any recovery expense. *Tier 1* recognizes that, while natural disasters disproportionately affect low-income households (Elliott, 2021; Kousky & French, 2022), even high-income households may have insufficient liquidity to manage flood losses (Kimbro, 2021). As the name implies, it is a disaster benefit program everyone pays into and benefits from.

Tier 1 fills several existing disaster recovery funding gaps. Tier 1 augments the less reliable federal IA program with a guarantee of claims money. It funds immediate needs such as cleaning, structural repairs, and mold abatement. It also can pay for temporary living expenses. It allows homeowners to accept a higher deductible, reducing the cost of an indemnity policy, such as an NFIP policy. Lenders often require that borrowers maintain a $2,000 deductible. Tier 1 would provide a certificate allowing the deductible to increase from $2,000 to as much as $10,000, reducing the cost of a traditional indemnity policy by 30 to 40% (FEMA, 2021b).

Tier 1 reduces cash flow challenges of indemnity flood insurance policies, such as the NFIP (Kimbro, 2021). The NFIP is a cash-reimbursable insurance program, so households must pay for services and repairs before receiving reimbursement from the NFIP (Kimbro, 2021). The Tier 1 recovery payment can provide liquidity to cover contractor expenses while property owners await reimbursement from their NFIP policy.

Tier 1 establishes a robust governance structure centered on disaster risk reduction. The implementation of an assessment district facilitates the efficient receipt and management of federal, state, and philanthropic funding. This foundational layer of coverage serves a dual purpose in encouraging broader flood insurance adoption. Firstly, it provides a baseline level of protection,

potentially making additional coverage more financially accessible. Secondly, it creates a structural framework that simplifies the decision-making process for purchasing supplementary insurance. The subsequent Tiers 2 and 3 further enhance this system by addressing low-probability, high-consequence events. These tiers function as an annual risk communication mechanism, serving as a tangible reminder of the community's or neighborhood's flood vulnerability. This tiered approach not only improves financial protection but also fosters ongoing risk awareness among residents.

How Is Tier 1 It Implemented?

Tier 1 is implemented as a macro-insurance program where a government entity, such as an assessment district, purchases a parametric insurance policy (Master Policy) on behalf of the property owners in the district. The payment is made directly to the government entity, which then decides how the payments are to be dispersed. Alternatively, this insurance policy can be issued as a Master Policy where the property owners are listed as insured by subscription to the Master Policy. In this arrangement, each assessed property owner receives a Certificate of Insurance as evidence of coverage. If a triggering event (flood) occurs, the assessment district receives the payment and sends funds as specified by the Certificate of Insurance.

A key consideration in the implementation involves proof of loss. California regulations governing parametric insurance require a clearly defined payment trigger and a proof of loss (Halberstadt, 2024). If a GHAD implements the program, a flood would trigger abatement actions called for in the Plan of Control. The costs of the abatement actions meet the definition of a loss. Another government agency would have to have a similar governance document that directs actions to meet the definition of a loss. In the event of a master policy, homeowners would

demonstrate a proof of loss. This could be accomplished by submitting a photo via a phone application.

How Is Tier 1 Financed?

A critical hurdle in implementing community or neighborhood-based disaster recovery programs is establishing a sustainable, long-term funding mechanism to consistently pay premiums for low-frequency, high-consequnce events. These events may occur only once in a generation, yet require ongoing financial commitment. In California, the most viable and reliable long-term funding source for the proposed Tier 1 program is the Proposition 218 annual property-related assessment. Historical precedent suggests that when presented with a clear and compelling value proposition, voters have often been receptive to approving fees for flood control measures. This willingness to support such assessments indicates a potential for extending this approach to broader flood risk management strategies, including insurance-based solutions.

Proposition 218 (1996) allows for a property-related assessment as long as the community can show the explicit benefit to each property owner in direct proportion to how much they pay (Taylor, 2017). Proposition 218 fees are voted on and must receive a 50% plus one vote of property

owners (weighted by assessed property value) (Taylor, 2017).[3] Experience with Proposition 218 elections in the Central Valley for levee improvements suggests that property owners will vote for a reasonable fee with a clear and compelling value proposition. In 2023 over 56 percent (weighted average) of the property owners within the San Joaquin Area Flood Control Agency boundary voted to assess themselves to maintain the levees (San Joaquin Area Flood Control Agency, 2023).

For example:

Assume a community of 500 homes is protected by a levee with a 1 in 75-year chance of failure. The annual premium for a parametric insurance policy can be estimated to be $200,000 or $400 per household. If the community is low-income, the willingness-to-pay for an insurance policy may only be $150 per household per year, leaving a $250 per year financial gap.

Other flood control agencies with successful Proposition 218 votes include the Sutter Butte Flood Control Agency, Pajaro Regional Flood Control Agency and the Sacramento Area Flood Control Agency. A Proposition 218 assessment district fee that reduces flood insurance costs by more than the cost of the fee is likely to be voted on favorably. For this reason, a local government entity with authority to manage a Proposition 218 assessment is proposed to manage the program. The local entity might be a Joint Powers Authority (JPA), a Climate Resilience District (CRD), or another local governing entity with authority to administer Proposition 218 assessments (Taylor, 2017).

While assessment district revenues are anticipated to be the primary funding source for the Tier 1 Recovery Payment, supplementary funding is likely necessary. This need arises from the practical limitations of assessment fees in California. Based on historical voting patterns and economic considerations, the maximum annual fee likely to garner voter approval in many California regions is approximately $200 per residential property. Assuming a $50 annual

[3] Proposition 13 (1978) prohibits local governments from assessing a property tax. Proposition 218 (1996) allows for a property-related assessment as long as the community can demonstrate the explicit benefit to each property owner in direct proportion to how much they pay.

allocation for assessment district administration and mitigation efforts, the remaining $150 would be available for the parametric insurance policy premium. However, if the actual cost of the Tier 1 parametric insurance policy is $400 per household, there exists a funding gap of $250 annually. This deficit must be addressed to ensure the program's viability and effectiveness. Potential sources for this additional funding could include county or state general funds, or philanthropic contributions. The diversification of funding sources not only ensures the program's financial sustainability but also distributes the financial burden across multiple stakeholders, potentially increasing both its feasibility and public acceptance.

How Tier 1 Differs from FEMA's Individual Assistance Program?

The Tier 1 program is similar to FEMA's Individual Assistance (IA) program, but has several key differences (GAO, 2020a; Kousky et al., 2018). Both programs seek to provide a recovery payment to households affected by natural disasters. However, funding from the FEMA IA program depends on a federal disaster declaration and the state's request for disaster assistance (GAO, 2022). However, a federal disaster declaration can take months to obtain, and not every federal disaster declaration includes IA funding (GAO, 2022). Additionally, FEMA's IA program determines the amount of financial assistance on a case-by-case basis after the disaster; the maximum amount currently offered under the Individuals and Households Program (IHP) is $42,500 (FEMA, 2023b). Generally, the amount provided is less. And FEMA's IA program does not distribute funds to unauthorized households.

In contrast, the Tier 1 recovery payment program provides a predetermined payment when a flood of a predetermined magnitude occurs. Because the payment trigger is predefined, payments can be made quickly without waiting for a disaster declaration. Tier 1 payments assist regardless of immigration status.

Initially, the assessment district will provide each household with a payment that might be viewed as a grant. The decision to disperse payments based on a Certificate of Insurance or as grants will depend on the community's circumstances. Disbursing the payments as grants may provide more flexibility. For example, a community might purchase a $5,000,000 policy based on an estimate of the needs. They might disperse half of the proceeds immediately, reserving the rest to fill gaps left by other state and local disaster recovery programs. This flexibility may not be available if the insurance payment is tied to a Certificate of Insurance. However, a Certificate of Insurance is an enforceable contract. The amount and conditions for payment are clearly defined, providing some assurance that funds will be available when needed.

Because Tier 1 is to be funded with a Proposition 218 fee, whether the funds are disbursed as a grant or a Certificate of Insurance may be immaterial. Proposition 218 mandates that the benefit must be proportional to the assessment. Further, it mandates that the benefit cannot go for non-property-related activities. Thus, the proceeds from a parametric insurance policy purchased with Proposition 218 funds can only go to property owners for activities that specifically benefit the property owners. For example, the insurance proceeds could not be used to provide housing assistance to renters.

The decision to provide the recovery payment as either a Certificate of Insurance or a disaster recovery payment may be influenced by factors, including FEMA's disaster declaration process, its IA program, and potential tax implications. If the disaster leads to a federal disaster declaration, there may be tax implications for households (e.g., in some cases, the flood losses are a deductible expense. Proceeds from insurance must be declared when computing the deduction. Proceeds from a grant are not included in the deduction computation.) (Internal Revenue Service, 2023). Additionally, when the state obtains assistance from the IA program, each household

receiving IA assistance must provide a copy of the certificate of insurance when applying for aid (GAO, 2020). A cash grant program would remove this documentation requirement. The community could immediately disburse recovery payments and discuss the total disbursement through a Tier 1 program with FEMA during the disaster declaration process. One shortcoming of the IA program is its inconsistency—it is not always requested or approved (GAO, 2020). Tier 1 would overcome these shortcomings by providing pre-defined payments triggered by specific, pre-defined events. By establishing pre-defined payments triggered by specific, pre-determined events, Tier 1 would eliminate much of the ambiguity and variability associated with the current IA program.

How Tier 1 Fit in a Larger Context of Climate Change Financing?

Tier 1 addresses recognized flood insurance supply and demand challenges. By providing a recovery payment to property owners in high-risk flood zones, funded by an annual assessment, the recovery payment incentivizes property owners to buy additional flood insurance offered by Tiers 2 and 3, increasing demand. This will help spread the financial burden of flood damage more evenly among policyholders. In addition, recovery payment promotes proactive steps to manage risks, such as elevating properties or making them flood-resistant to reduce the impacts of future floods. The supply and demand challenges to overcome include:

Tier 1 supports and encourages proactive management of smaller flood events caused by smaller storms (e.g., AR Categories 1 to 3). The general funds augment Proposition 218 assessments and provide an incentive to collaborate with insurance providers implementing risk reduction measures. Risk reduction measures could include nature-based solutions that increase perviousness, create “sponge cities,” and implement more traditional mitigation strategies, such as elevating homes.

Over time, financing is expected to shift from a purely insurance-provided program to one financed from a combination of sources, including reserves, a locally formed captive insurer, or some other collective insurance program. The public-private partnership will help communities find the most appropriate financing options.

In summary, Tier 1 is a parametric insurance policy purchased by the assessment district, with maximum losses capped at $10,000 per property. It can be a multi-year parametric insurance policy. The assessment district has a Plan of Control that is triggered when the event occurs. The activation of the Plan of Control establishes the 'insurable interest,' which is key to ability to purchase an insurance policy and making community-wide purchase feasible. The process of acquiring the policy ensures that risk information remains open and transparent. The community spreads the financial burden by distributing the risk among all assessment district parcels. Because households are assessed a fee each year, the Tier 1 community recovery payment increases flood risk awareness among residents. Accepting the first layer of risk aligns with industry norms and helps mitigate moral hazard. This approach provides a structured and transparent method to manage initial disaster recovery finances.

Tier 2: Affordable Insurance

What Does It Provide?

The Tier 2 *Affordable Insurance Tier* makes two types of insurance policies available to households within the Tier 1 assessment district. It includes an indemnity insurance policy that offers $100,000 worth of building coverage with a $10,000 deductible, provided at an annual cost between $500 and $800. An indemnity flood insurance policy compensates the insured for losses up to a specified limit. The Tier 2 indemnity policy focuses on homeowners. In addition to indemnity insurance, this tier includes a $10,000 parametric insurance policy, available for less

than $200 and payable in monthly installments. Renters are the intended beneficiaries of parametric insurance, but it is available to all residents within the assessment district. Tier 2 insurance policies seek to complement Tier 1 coverage and provide insurance attractive to renters or homeowners who require additional liquidity following a flood and need money for repairs.

When affordability is an issue, consumers generally prefer to reduce the amount of coverage. For consumers who only want to purchase insurance for what they expect to be a loss, the $100,000 limit is attractive. During the past decade, the average payment per claim in the U.S. was around $48,000 (Kalman et al., 2022, p. 351). During the last decade, California's average payment for claims was around $21,500 (Kalman et al., 2022, p. 351). Thus, a policy that provides $100,000 of building coverage should cover most flood losses.

How Is Tier 2 Implemented?

Unlike Tier 1, where the community purchases a master flood insurance policy, individuals would purchase Tier 2 policies. The assessment district facilitates the arrangement by working with insurance providers to help residents obtain the most favorable rates. Facilitation activities could include providing more detailed information on flood risk, building stock to be insured, and mitigation efforts. It could also include outreach and communicating with the public about available flood insurance options. Residents would buy insurance directly from the provider. Any claims would be made directly to the insurance provider if there were a loss.

How Does Tier 2 Fit in a Larger Context of Climate Change Financing?

Tier 2: Basic property insurance balances demand and supply for low-probability, high-consequence events like natural disasters. It meets consumers' needs for affordable and easy-to-purchase insurance while addressing providers' need to control potential losses. Using data and

behavioral economics advances, Tier 2 aims for a 'Goldilocks arrangement' that sustainably addresses flood challenges.

Tier 3: Concierge Tier–Additional Property Damage Insurance

What Does Tier 3 Provide?

Tier 3: Concierge Tier is an indemnity policy covering losses above $100,000. This tier's indemnity policy is similar to the Tier 2 indemnity policy but provides additional coverage. It is designed to be combined with Tiers 1 and 2 to meet a lender's mandatory flood insurance purchase requirement. For example, suppose a lender requires a $250,000 flood insurance policy for a home. In that case, a household might choose a package of Tier 1 (provided by the assessment district) plus Tier 2 plus Tier 3 (funded by the property owner). Homeowners without a lender requirement might choose to self-insure and only buy Tier 3 coverage. Because the assessment district provides Tier 1, they would be self-insured for losses of $10,000 to $100,000.

The term 'concierge' is inspired by a trend in health insurance where people pay extra for enhanced access to personalized services. This adaptability allows households to customize their coverage to their specific requirements. This tier allows consumers to buy added protection for such things as high-end interior finishes, larger homes, or business interruption insurance. Because Tier 2 covers the first $100,000, the extra cost for the *Concierge Tier* is expected to be reduced.

Tier 3 addresses a subset of supply and demand challenges. Tier 3 would be attractive to insurers because the high deductible reduces the number of claims. This insurance layer is likely only attractive to consumers if paired with Tier 1 coverage. Behavioral economics studies find that households prefer a low deductible when faced with a low-risk probability. Therefore, Tier 1 provides a $10,000 initial recovery payment that can serve as the low deductible desired by

consumers. Besides helping keep prices low, Tier 1 is expected to make Tier 3 attractive to many consumers.

How Is Tier 3 Implemented?

Like Tier 2, the assessment district would facilitate the arrangement by collaborating with insurance providers to help residents obtain favorable rates. Residents would buy insurance directly from the provider; if there were a loss, claims would be made directly to the insurance provider.

How Does Tier 3 Fit in a Larger Context of Climate Change Financing?

Initially, Tier 3 insurance would be offered by private insurers without government funding, similar to Tier 2. However, over time, state or federal governments might consider financing Tier 3 through mechanisms such as a state-backed solidarity fund to assist economically vulnerable homeowners and renters with premium payments. This approach aligns with the 2021 California Department of Insurance's Climate Working Group recommendation.

Both Tiers 2 and 3 require substantial liquidity to ensure insurer solvency. As demand grows, it may become cost-effective for the state to provide financial support by issuing catastrophe bonds or using general fund reserves as a financial backstop. Catastrophe bonds, though typically used for substantial risks due to their upfront costs, could be a viable option for financing Tier 3.

To adress social justice concerns, the state could offer Tier 3 policies to low-income households or those in areas protected by unaccredited levees. While the state has invested heavily in flood protection to remove the NFIP's mandatory insurance requirements in protected areas, many low-income communities remain in SFHAs (FEMA 100-year flood zones) due to prohibitive

flood protection costs. Funding Tier 3 would provide more equitable flood risk reduction, encouraging the purchase of Tier 2 coverage.

Although private insurers already offer Tier 3 coverage, particularly for high-value properties requiring coverage beyond the NFIP's $250,000 limit, a Tier 3 community-based program would require Tier 1 to be established first. Tier 1 would define the properties covered, assess flood risk, and gauge community support for Tier 3.

CoDFiRM Overview

This chapter has presented an overview of the CoDFiRM framework. Drawing upon established principles of insurability, the framework divides flood risk into three manageable insurance tiers: *Tier 1 It Takes a Village, the Tier 2 Affordable Insurance Tier, and Tier 3 Concierge Tier.* Each tier is designed to address specific aspects of flood risk and community needs. The subsequent chapter will delve into the practical aspects of implementing such a program, focusing on the challenges and opportunities presented by a case study of the small community of Isleton. Despite the inherent complexities, Isleton has made significant progress, securing funding for a Tier 1 policy for a two-year period. Currently, negotiations are underway to finalize the purchase of this policy, marking a tangible step towards realizing the CoDFiRM framework in practice. This case study will provide valuable insights into the real-world application of the proposed framework and its potential to enhance community resilience against flood risks.

Chapter 5 Isleton Case Study Overview

This chapter presents the case study used to pilot and partially test the CoDFiRM framework. The town of Isleton is a small community of slightly more than 500 homes, representative of many small flood-prone communities in the Central Valley. It has a significant flood risk not well addressed with existing flood control and flood management options. Less than half the households currently have flood insurance.

Isleton shows the governance gap for small towns and rural areas in the current system. It is uneconomical to strengthen the levees to a 100-year standard. They will never be "out" of the SFHA. While parts of town are likely to flood to a depth of 8 feet, other parts of town may flood only inches. It is uneconomical to raise these homes to the NFIP 100-year base flood elevation. So these structures and properties continue to deteriorate. They are often bought as rental properties, with about half the properties rental properties. Less than half the properties have any form of flood insurance. The entire community will be financially affected if levees protecting the community underperform. No government entity is managing the community's flood risk

Chapter 2 discussed the history of the NFIP laying the groundwork for a proposal that suggests going back to the 1966 Senate Committee on Banking and Currency recommendation of "a program of flood insurance of an essentially private character, but with continued large-scale participation of the federal government" (Senate Committee on Banking and Currency, 1966, p. IX). Chapter 3 discussed what would be needed to implement this idea and make flood risk insurable. With this insight, the CBDFRM insurance framework was presented in Chapter 4.

This chapter presents an implementation of the CoDFiRM framework. It starts with an overview of the community of Isleton and its flood risk. Next, it presents an overview of the new governance structure, a GHAD. It discusses activities undertaken to put Tier 1 in place.

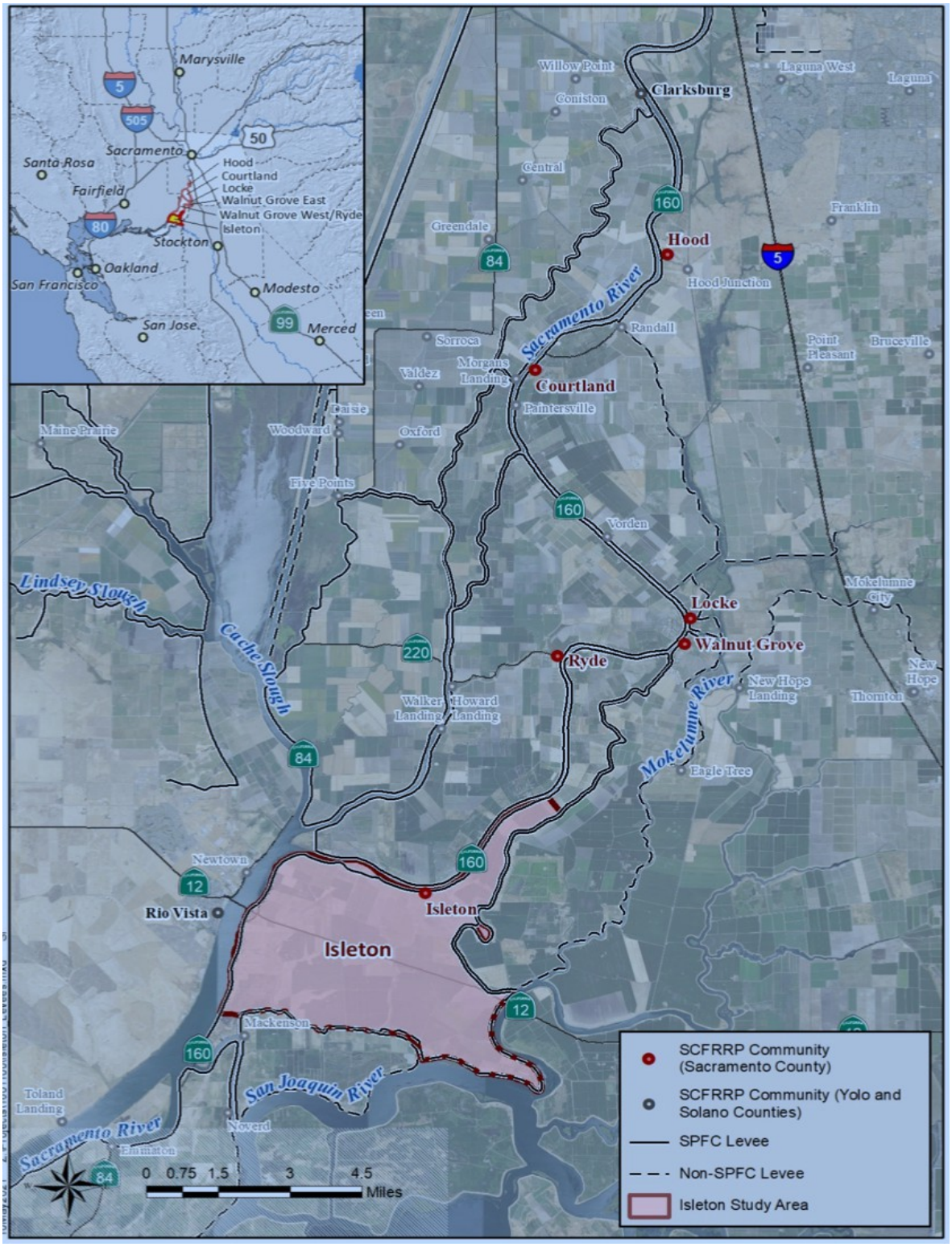
The GHAD was key to implementing the CoDFiRM program. Without the GHAD, the city leadership would have been overwhelmed with day-to-day activities, and the initiative would have failed. The other insight from the case study is the difference in thinking about low-probability/high-consequence events. Managing these events is akin to buying life insurance, as opposed to buying automobile insurance. The GHAD allowed community leaders to think about how much money the community would need to keep the social connections, who would get the money, and how a program would be financed.

There is growing awareness of the need to transition from flood control to flood risk management. This case study provides insights into what a new flood risk governance structure might look like. It demonstrates that the CoDFiRM framework presents a viable alternative to the underperforming NFIP and highlights the value of mixed-method appreciative inquiry research.

Isleton Characteristics

Isleton is a Sacramento-San Joaquin Delta legacy community on Brannan Andrus Island in the Sacramento-San Joaquin River delta ("the Delta") (Delta Protection Commission [DPC], 2015). Isleton is one of eleven small Delta legacy communities, including Locke, Bethel Island, Clarksburg, Courtland, Freeport, Hood, Knightsen, Rio Vista, Ryde, and Walnut Grove ( ) (DPC, 2015). They are called legacy communities because of their development in the late 1800s to serve water-borne commerce on the Sacramento River and Delta. Each is protected by a ring of levees weaker than the mandated state urban level of protection (i.e., 200 year-flood). The lack of flood protection hinders these homes and properties from receiving financing and permits that would further their development, keeping the communities suspended in time, reinforcing the name "legacy community" (DPC, 2015).

Figure 4 City of Isleton location map. Source: GEI Consultants, 2022



Isleton has a rich history. It was once known as the Asparagus Capital of the World (City of Isleton, 2017). A rail cart tunnel through the Sacramento River levee once moved crates of asparagus from the island to barges on the Sacramento River. It was the canning center for the Delta until 1972, when flooding closed the canning factory. In the early 20th century, it was home to a thriving Chinese and Japanese community, often barred from living elsewhere (City of Isleton, 2017). Isleton's Chinese and Japanese commercial districts are listed on the National Register of Historic Places (DPC, 2015).

Isleton is among the smallest, poorest, and most diverse Delta legacy communities. Its census population was 538 (Census Bureau, 2021) with a median household income less than $45,000. Half its residents are renters because rent is cheaper than in the surrounding urban areas. The community is 57% Hispanic, 38% White, and 4% Asian (Census Bureau, 2021). The Small Communities Flood Risk Reduction Plan (GEI Consultants, 2022) estimates Isleton has 459 structures with a total depreciated replacement value of $165 million (2022) within the city limits (GEI Consultants, 2022). Other studies estimate there are 530 structures (CA DWR, 2022).4 The median NFIP premium in Isleton in 2020 exceeds $1,100 (FEMA, 2022b). Less than a quarter of households have flood insurance (FEMA, 2022b). Isleton lacks city resources to participate in the Community Rating System (CRS) program (C. Bergson, personal communication, June 22, 2022).

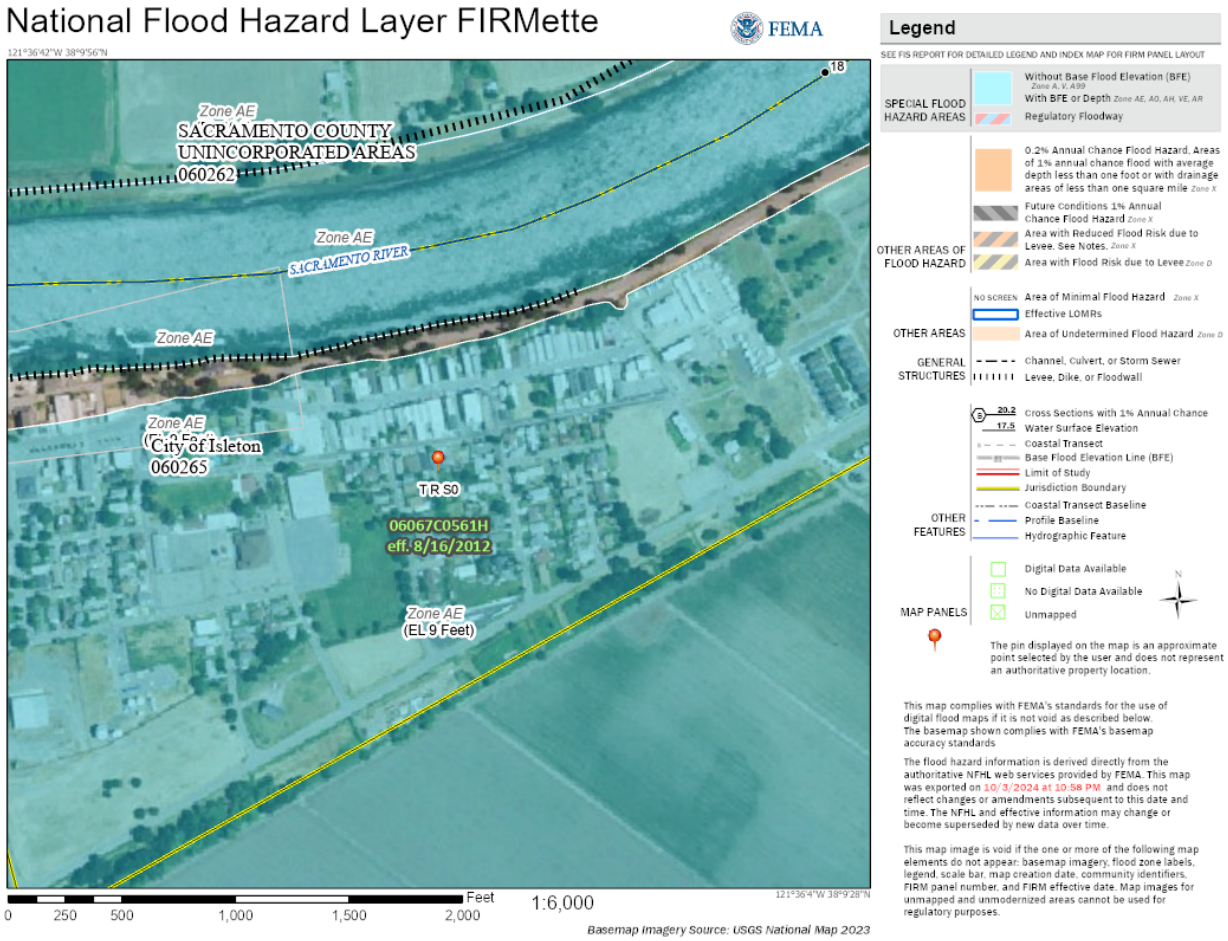
The City of Isleton's geographic location presents multiple flood risks. As a subsided island with an elevation of -6 to 6 feet NAVD 1988, it is vulnerable to flooding from several sources (GEI Consultants, 2022). These include underperforming levees, excessive interior

[4] The discrepancy is likely from the incorporation of a mobile home park on the outskirts of town. This dissertation uses the 530 structure estimate.

rainfall overwhelming the storm drain system, and groundwater infiltration into cracked sewer pipes, which causes a system surcharge (GEI Consultants, 2022).

The 41.8 km (26 miles) of levees protecting Isleton are of varying qualities (GEI Consultants, 2022). The levees were constructed initially between 1860 and 1880 using material dredged from the Sacramento River and nearby Georgiana Slough (GEI Consultants, 2022). Decades ago, the levees along the Sacramento River were integrated into the State Plan of Flood Control (SPFC) (CA DWR, 2021). They have been upgraded over time but do not meet the FEMA 100-year certification criteria. The levees along Georgian Slough are agricultural levees that provide less protection (GEI Consultants, 2022). Thus, the entire town is within a FEMA Special Flood Hazard Area (SFHA) (FEMA, n.d.a). Figure 5 shows the FEMA Flood Insurance Rate Map (FIRM) for Isleton. If any island levee were to fail, floodwater would inundate the city and its wastewater treatment ponds to depths up to eight feet (GEI Consultants, 2022).

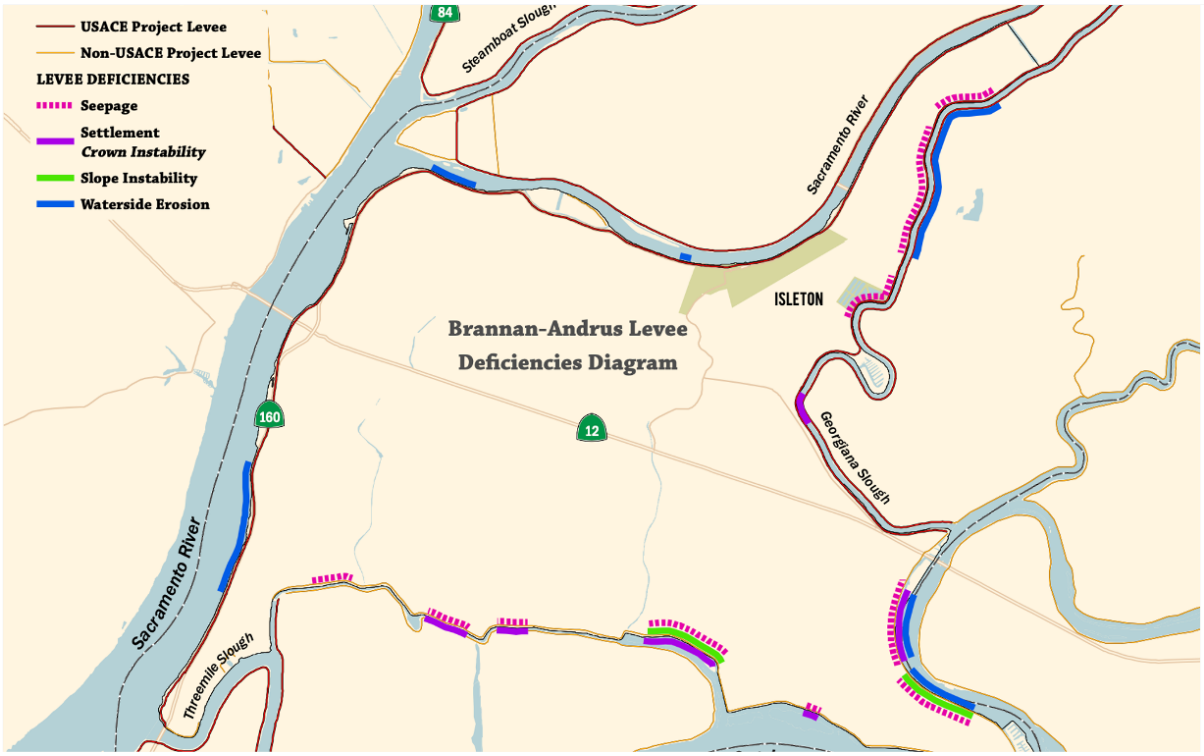
Figure 5 FEMA Flood Insurance Rate Map for Isleton. Source: FEMA, n.d.a



The levees are maintained by the Brannan-Andrus Island Levee Maintenance District (BALMD), a joint authority between Reclamation Districts (RD) 317 on Lower Andrus Island, RD 407 on Andrus Island, and RD 2067 on Brannan Island (Brannan-Andrus Levee Maintenance District [BALMD], n.d.). The three RDs that comprise BALMD are hydrologically connected (BALMD, n.d). BALMD receives limited funding for levee maintenance through the state subventions program (CA DWR, 2022; BALMD, n.d.). Assessments from landowners provide additional funding, but there is consensus that levee maintenance funding is grossly inadequate (E. Pappalardo, personal communication, September 17, 2024). The California Department of

Water Resources (DWR) rates Isleton as having a high flood hazard with a potential deep flood frequency that exceeds 1% per year (CA DWR, 2017). Investigations concluded that some levee segments protecting Isleton near Oxbow Marina and the Delta Loop Recreation Area suffer under-seepage, through-seepage, landslide instability, and geometric deficiencies (CA DWR, 2022; City of Isleton, 2017; GEI Consultants, 2022). The approximate locations of known levee problems appear in .

Figure 6 Locations of Known Levee Problems. Source: City of Isleton, 2017



Climate change and land subsidence exacerbate these flood risks (Mount & Twiss, 2005). The levees protecting Isleton are subject to tidal and riverine conditions, with sea level rise, increased flows in the river on the waterside, and ongoing subsidence on the land side all contributing to the escalating flood risk (CA DWR, 2022). An example of these vulnerabilities occurred in 2023 when intense rainfall and cracked sewer pipes caused the town's wastewater treatment ponds to overflow and fail, resulting in raw sewage spilling into the Mokelumne River.

In 2018, the US Army Corps of Engineers (USACE) completed a study of the feasibility of improving the levees (Semonite, 2018). Much of the 51.8 km2 (12,800 acres) Brannan-Andrus Island is agricultural. Because Isleton is only 0.769 km2 (190 acres) of the 51.8 km2 (12,800 acres) of Brannan-Andrus Island, USACE determined that the annual cost to upgrade the island's levees exceeded the reduction in flood benefits by $2,192,000. Thus, they determined that upgrading all 41.8 km (26 miles) of levees was not economical to protect the island from flooding (Semonite, 2018). The report mentioned an analysis of a flood fight berm (i.e., a berm that can support a temporary flood barrier), but it is unclear if USACE seriously studied the option. The study suggested that residents seek funding elsewhere to protect their community.

The second flood source for Isleton is inadequate storm drain capacity. The town's drainage system was not designed to carry runoff from strong atmospheric rivers. Heavy rains overwhelm the system, flooding low-lying areas at the south end of town.

The third source of floods is the leakage of stormwater and groundwater into the sewer system from the cracked laterals. Heavy rains can raise the groundwater table to near the surface, which causes groundwater to infiltrate into the sewer collection systems. The combined stormwater and wastewater are discharged from maintenance holes, flooding low-lying areas at the south end of town.

In 2017, Isleton received a grant from the DWR's Small Communities Flood Risk Reduction Program (SCFRRP) to study options to reduce the risk associated with underperforming levees (GEI Consultants, 2022). The SCFRRP study included outreach to local stakeholders, providing an opportunity to solicit volunteers for a Community-Based Climate Insurance Program (CBCI). With support from the Sacramento County Floodplain Coordinator and the SCFRRP study contractor, this author invited interested stakeholders to a meeting in the nearby town of Hood to

solicit volunteers for a community-based insurance pilot. Increasing premiums under the NFIP burden low-income residents of Isleton. When presented with the opportunity to reduce flood insurance rates through a CBCI pilot, the city manager volunteered the town to be a pilot.

Isleton makes a good pilot. The community is large enough to have a flood risk attractive to insurance carriers and small enough that the total insured amount is not a deterrent. The citywide source of flooding is a levee failure, a clearly defined event. Additionally, many community members were children when the levee failed in 1972. They view the potential for levee failure not as an abstract idea but as an event they remember vividly. Isleton is similar to other small communities in the Central Valley. Isleton is an incorporated city. The other legacy communities are census-designated places governed by the County Board of Supervisors. For small census-designated places, getting a CBCI program on the agenda of the Board of Supervisors would have been extremely difficult. Lastly, the problems of the Delta are ". . . complex, sometimes chaotic, and always contentious" (Luoma et al., 2015, p. 1). How to address the flood risk is one of many "wicked" problems for Delta.

The program aimed to design a community-based disaster recovery payment program to help residents affected by natural disasters recover by providing financial assistance to cover temporary housing, food, and other essential needs during recovery.

The initial stage in executing the program involved establishing the Delta Region Geologic Hazard Abatement District (DR-GHAD). Geologic Hazard Abatement Districts (GHADs) are established to manage the long-term mitigation and upkeep of real estate at risk from geological hazards (GHAD, n.d.). The California Legislature established them in 1979 with the passage of the Beverly Act in response to a significant landslide issue (GHAD, n.d). They are designed to enable local communities to establish a self-sustaining system to alleviate the detrimental impacts

of large-scale hazards, including landslides, earth movement, erosion, and other analogous threats (GHAD, n.d.). Their governance structure provides the flexibility needed to address the changing conditions that come with geologic hazards (GHAD, n.d.).

GHADs are independent state-level organizations with broad authority to address hazardous geologic conditions through prevention, quick response, and funding. Their key authorities include (GHAD, n.d):

- Assessing fees and issuing bonds
- Acquiring property and exercising eminent domain
- Implementing mitigation measures
- Coordinating with state and local agencies
- Suing and being sued (with certain legal immunities)

These districts can be established for areas of any size, including non-contiguous parcels, making them particularly suitable for Delta Legacy Communities (GHAD, n.d). GHADs can implement Proposition 218 assessments to raise funds for community-wide insurance policies and critical mitigation measures such as levee reinforcement and infrastructure improvements (GHAD, n.d).

The ability of a GHAD to acquire property and exercise eminent domain allows for swift and effective action in the face of potential disasters (GHAD, n.d). It can fill a critical governance gap by providing a legal entity that state and local agencies coordinate with and fund. It can sue and be sued, which provides the communities that formed them with certain immunities (GHAD, n. d). It can also ensure a unified and organized response to emergencies, helping to streamline the process and minimize confusion. GHADs are uniquely poised to implement the CBDFRM framework.

The Isleton City Council established the DR-GHAD on March 29, 2022. The engineering firm of ENGEO provided the Plan of Control that serves as "the constitution" for the GHAD (ENGEO, 2021). It is a comprehensive document that outlines the district's approach to managing

geologic hazards (ENGEO, 2021). It begins with a detailed description of the district, including its boundaries, geology, and history of hazards (ENGEO, 2021). The plan then identifies specific risks and proposes preventive and remedial measures to address them (ENGEO, 2021). Critical components include a maintenance and operations plan, a financial strategy for funding proposed measures, and an implementation timeline (ENGEO, 2021).

The DR-GHAD boundaries align with Isleton's city boundaries (ENGEO, 2021). The DR-GHAD board consists of five property owners (ENGEO, 2021). As of October 2024, only three board positions were filled, all by city council members, with ongoing efforts to recruit two additional members.

The formation of the DR-GHAD has been a key factor in the success of the community-based disaster recovery framework. The DR-GHAD board meets bimonthly, with this researcher and the technical advisory team providing presentations during hour-long sessions. These meetings provide a platform for the team to present implementation ideas and for the board to ask questions and offer feedback.

In contrast to the city's severe financial distress due to a 2022 wastewater evaporation pond failure, the DR-GHAD is managed by the engineering firm ENGEO, which successfully oversees many GHADs in California. As a separate entity from the city council, the DR-GHAD enables focused, long-term discussions and visioning processes that would otherwise be impossible, allowing continued progress on disaster preparedness and recovery planning.

All parties involved in this effort are currently donating their time and expertise. If a Proposition 218 assessment is passed, the engineering firm ENGEO will be reimbursed for its GHAD management services, which it currently provides without guaranteed payment. This interim arrangement demonstrates the feasibility of a long-term financing framework for a

community-based disaster recovery program, even if procuring upfront funding proves challenging.

This researcher obtained a $900,000 grant from the California Office of Emergency Services (CalOES). However, the city's financial and management difficulties initially delayed the grant's implementation. These challenges have been overcome, and the grant is progressing. The grant will be used to hire a consulting team to assist the community in recovering from the wastewater treatment plant failure and to help gather support for a Proposition 218 assessment. The consulting team will develop a comprehensive plan to address the issues and secure funding for necessary upgrades.

The Technical Advisory Team collaborated with the global insurance firm MunichRE to obtain a quote for a $5,000,000 parametric insurance policy to fund the Tier 1 "It Takes a Village" disaster recovery benefit program. The policy will pay based on the water surface height recorded by a sensor at the city's wastewater pumping station. The original quote for this policy was $150,000 per year or 3% of the insured value. The team shared this information with DWR staff, who used it to obtain $100,000 to purchase the parametric insurance policy. At the September DC-GHAD board meeting, the board approved accepting the grant and asked the team to negotiate the parametric insurance policy to finalize the agreement by the end of the year.

Findings

This case study provided several key insights. The purchase of an insurance policy that provides recovery payments offers benefits for community discourse akin to buying a life insurance policy, which covers a low-probability, high-consequence event, rather than a car insurance policy, which covers a high-probability, lower-consequence event. The GHAD provides a safe space for the thoughtful conversations necessary for long-term, high-consequence risk

management. Additionally, the project highlighted further benefits, as insurance benefits the insured households, the community, and supports other community-related development and visioning efforts.

Another insight relates to risk pricing. Program implementation was initially hampered by a "chicken and egg" phenomenon: Communities were reluctant to accept the invitation to implement a community-based program without knowing the cost, and insurers were hesitant to get involved without knowing if there would be community interest. The Tier 1 framework, with its known recovery benefit, allows the insurance entity to develop a price quickly, as 3% of the insured value becomes a straightforward amount that can be budgeted for.

The Brannan-Andrus Levee Maintenance District is unlikely to secure funds, estimated at $282 to $387 million, to upgrade all 37.4 miles of its levees (GEI Consultants, 2022). Thus, Isleton will continue to face significant flood risks. This inadequate protection puts workforce housing and a state historic district at risk. It depresses housing prices and hampers residents' ability to build wealth through home equity. Furthermore, it limits the potential for developing the region's agri-tourism industry.

The current NFIP-led flood control and flood management system ill-serves communities like Isleton. Flood control structures that meet NFIP standards are economically infeasible. NFIP insurance is unaffordable and inadequate to ensure disaster recovery. The NFIP building requirements, designed to minimize future flood losses, hinder homeowners seeking to remodel properties and build generational wealth. The residual risk goes beyond individual homeowners and becomes a city-wide concern. The absence of a clear, responsible party for the residual risk leads to a lack of governance and financial mechanisms to address the residual risk effectively. Many residents are reluctant to acknowledge the issue, hoping that "it will never happen." The NFIP, with its regulatory measures, contributes to the

problem, as there is a collective aversion to admitting there is a problem for fear it might "awaken the sleeping giant."

For almost two decades, experts have advocated for new flood management arrangements (Bruno et al., 2011; Kousky & Shabman, 2015). They have suggested that new insurance tools, such as parametric insurance, could make community-based insurance an attractive alternative to traditional insurance arrangements. A CDI study calls for community-based insurance pilot programs to address climate change (Climate Change Working Group, 2021). This dissertation provides a design framework for community-based flood insurance.

Chapter 6 Discussion, Conclusions, and Further Research

Overview

The challenges faced by the NFIP, the world's largest flood insurance provider, show a pressing need for systemic change in how flood risks are managed and insured. The NFIP is $20.5 billion in debt. In 2021, NFIP Director Maurstad testified, "The NFIP is simply not fiscally sustainable in its current configuration" (Maurstad, 2021, p. 8). This dissertation summarizes the NFIP's structural and operational deficiencies while exploring alternatives and innovative solutions to enhance the sustainability of flood insurance in the United States.

There have been numerous attempts to reform the NFIP. All have failed. Since the passage of BW-12 in 2012, Congress has passed over 20 short-term reauthorizations or extensions. They are unable to pass meaningful reforms that would put the program on sound financial footing. This contrasts with a profitable global flood insurance market (Statistica, 2024). This dissertation explores why some insurance institutions remain fiscally sustainable while the NFIP is not. The literature review shows that many factors contribute to the NFIP's fiscal challenges. Factors that include absence of a management structure dedicated to insurance operations, high overhead costs, failure to implement modern actuarial practices for rate setting, reliance on cross-subsidies, neglect of behavioral economics in policy pricing, lack of preparedness for catastrophic events such as Hurricane Katrina, and inadequate funding for subsidized rates, as discussed in Chapter 2. The comparison of the challenges faced by the NFIP to the success strategies of private insurance firms suggested that flood insurance would be attractive to the private market under the right conditions, as discussed in Chapter 3.

Given the NFIP's financial challenges, a critical question emerges: If the program is not sustainable in its current form, what alternative configuration could make it fiscally sustainable?

This dissertation suggests a new framework for community insurance to overcome the current system's deficiencies. By critically assessing the various aspects of flood insurance operations, including risk management practices, actuarial methods, and consumer behavior, this research identifies implementable solutions to closing the insurance protection gap, particularly for smaller communities.

Examining the characteristics of insurability generally helps in understanding the conditions under which floods are insurable. This dissertation categorizes insurability criteria along actuarial, societal, and market dimensions to identify properties of flood risk that make insurance viable. Each challenge to insurability is paired with opportunities, such as using catastrophe models, open-source data, and parametric insurance. According to Kousky (2022), flood insurance requires a thoughtful balance, akin to a Goldilocks arrangement, where risks must not be too high or too low. Premiums must be sufficiently high to ensure financial feasibility for insurers yet low enough to remain attractive to consumers. Investigating conditions that make flood risk insurable provides insights for developing flood insurance solutions that achieve this delicate balance.

A framework of three-tiered insurance was developed through an examination of insurability. Tier 1, the "It Takes a Village" tier, addresses behavioral economic challenges discouraging individuals from purchasing flood insurance. It offers a modest recovery payment to all property owners within the assessment district to quickly address immediate household needs immediately following a flood for accommodations, any short-term clean-up and repair, and other actions that reduce and address immediate flood disruptions and damage. It is funded, in part, with a Proposition 218 assessment. Tier 2, the "Affordable Property Insurance" tier, aims at affordability issues that prevent many from obtaining flood insurance. Tier 3, the "Concierge" tier,

is designed to address additional needs not covered by the first two tiers. Together, these three tiers ensure compliance with mandatory purchase requirements and can provide $250,000 or more in flood insurance coverage while addressing immediate and long-term flood recovery and damage reduction. Dividing the risk into these three tiers overcomes insurability challenges, creating a flood insurance program that should be more attractive to consumers than the NFIP.

After creating the tiered program, the next step was to explore its potential through a case study in the Sacramento-San Joaquin Delta community of Isleton. The initial phase of implementation involved forming a GHAD. Two years ago, the city council established the Delta Region GHAD (DR-GHAD), which meets every two months to finalize Tier 1 program arrangements. A grant from DWR helped fund flood coordination and advance negotiations to purchase a $2 million parametric insurance policy. Under this Tier 1 insurance arrangement, floodwaters are anticipated to trigger a sensor at the town's lowest point near the wastewater pumping station if the levee fails. Activation of this sensor will result in a $2 million insurance payout distributed among Isleton's 530 property owners. DWR has allocated an additional $100,000 for next year. This year’s policy is flexible, aiming to identify contractual details and define the administrative process. However, next year’s funding is conditioned upon a successful Proposition 218 vote. To the author's knowledge, this arrangement is the first of its kind implementation of community-level flood insurance.

One of the most surprising findings is the governance gap in flood protection and insurance. Current flood management in the U.S. consists of either working to keep the floodwaters away from people by building stronger levees and higher dams or by keeping the people away from floodwaters through land use restrictions and building requirements, as well as flood warnings and evacuations. Together, these options ignore cases where households may occupy flood-prone areas

because it is all they can afford, it is the neighborhood they grew up in, or it provides workforce housing for industries like the agricultural industry in California's Central Valley. The current arrangement neglects the reality that when most households do not purchase flood insurance in a flood-prone area, it can jeopardize the entire community's stability to recover for generations. Engineers, acting as flood risk managers can help communities address the protection gap, but only if they have a governance framework that can organize and act.

The second surprising finding is the potential role of the GHAD in the CoDFiRM framework. The GHAD, a professionally managed organization led by an engineer, provided the space for conversations about low-probability, high-consequence events like the flood of an entire community. Knowing that insurance could be purchased and the financial consequences of the catastrophe could be addressed helps eliminate confusion when communities believe there is nothing they can do about a future problem.

A third finding is the significance of liquidity. A fundamental reason for implementing a Tier 1 program is to provide households with quick post-disaster liquidity to meet basic household needs and reduce immediate flood disruptions and damages. Liquidity is also needed at the community level. For example, the city of Isleton is on the verge of bankruptcy because payments promised by FEMA to help cover the expenses from the wastewater evaporation pond failure have not been forthcoming in a timely manner. City officials mortgaged the city hall to obtain the cash needed to pay for the emergency work. It contributed to their need to declare bankruptcy. Although this dissertation focused on household insurance, the CoDFiRM framework provides a mechanism to examine ways to ensure there is sufficient liquidity to fund immediate community disaster response.

Lastly, this project showcased the power of action case study research and public-private partnerships. Through this research effort, a $900,000 grant was obtained to bring added resources into the community to help them financially recover from the 2022 storms that caused their wastewater evaporation pond levees to fail. Small communities like Isleton often lack the technical expertise or staff capacity to navigate the post-disaster federal bureaucracy or manage major infrastructure repairs. Integrating academia into the community provides a dual benefit to academia, as it results in actionable research.

Contributions to the Field

This thesis makes several important contributions to the understanding and advancement of flood insurance and management frameworks.

Comprehensive Analysis of NFIP Limitations. The thesis examines the challenges of the NFIP by examining its changes over time through an insurance lens, as opposed to the traditional government program or land use management lens. This lens identifies and discusses the governance and insurance management gaps—the disconnect between a privately run insurance company and the NFIP. It also addresses the difference between federal flood insurance and local flood insurance management, which represents a novel conceptual contribution.

*Innovative Flood Insurance Approache*s. The thesis explores a variety of emerging ideas for flood insurance and how this financial tool can be better integrated with broader flood risk management strategies. The discussion of the GHAD presents a novel approach to closing the governance gap.

Flexible Flood Insurance Structure. A key contribution of this thesis is the proposed structure for more flexible flood insurance products. This framework is designed to support both

community-level flood management and individual property protection. The flexibility and multi-scalar nature of this approach represent an important theoretical advancement in the field.

Practical Application and Implementation. Perhaps most notably, this thesis provides a detailed and practical discussion of how the proposed flexible flood insurance structure could be applied to a small, flood-prone town in California. This in-depth case study analysis offers valuable insights for practitioners and policymakers seeking to implement innovative flood insurance and management solutions at the local level.

Overall, this thesis contributes to the evolving understanding of flood insurance, its limitations, and the need for more integrated and adaptable approaches to flood risk management. The findings and proposals put forth have the potential to inform policy, guide future research, and shape the practical application of flood insurance and related flood mitigation strategies.

Recommendations For Future Study

This research leads to several suggestions for future research.

- *Explore responses to precipitation extremes*. Investigate the adequacy of financial protection mechanisms in the face of projected extreme precipitation events in California. If physical protection is inadequate, research shoul focs on determining optimal levels and forms of financial safeguards to mitigate climate-induces risks effectively.
- *Examine the governance gap and the role of a Chief Resilience Offi*cer. Evaluate the efficacy of California's JumpStart program, which provides funding for small communities to enhance their competitiveness in grant acquisition. Assess the program's impact and explore potential adaptations to improve its effectiveness in addressing the governance gap. Additionally, examine the potential benefits of establishing a Chief Resilience Officer position to coordinate and streamline disaster resilience efforts.
- *Examine the role of ergodicity in making communities disaster-resilient*. Further investigate the role of ergodicity in enhancing community disaster resilience. Recent research by Wang et al. (2024) suggests that non-ergodic flood responses accumulate over time, potentially exacerbating local poverty. Building on the work of Peters and Adamou (2017), which highlights the benefits of examining risk through time-averaged growth rates, explore the potential expansion of insurance coverage using this analytical framework.
- *Examine how a Tier 1 program might be developed for every California household*. Conduct a feasibility study on implementing a comprehensive Tier 1 flood insurance program for all California households. Given the state's diverse geographical expanse,

research should focus on opportunities to distribute risk statewide, potentially reducing flood insurance costs. This investigation could serve as a foundation for developing a state-supported flood insurance program, addressing coverage gaps and enhancing overall resilience.

Recommendations for California State Government

The research leads to several recommendations for the California Department of Insurance and the California Department of Water Resources.

California Department of Insurance

- *Enhance local officials' comprehension of flood risk insurability strategies*. Although community leaders typically strive to achieve 100-year flood protection to exempt citizens from NFIP requirements, this approach is often economically infeasible. Concurrently, the insurance industry is innovating with novel insurance forms and insurance-linked securities. Educating local officials about potential partnerships with insurance providers and increasingly available options creates an opportunity to develop cost-effective risk reduction measures that close the insurance gap. This collaborative approach may yield more sustainable and financially viable flood management solutions.
- *Educate local officials on the risk management services of insurance*. Communities often reduce insurance costs by participating in an insurance pool to cover items such as municipal buildings and equipment. They are familiar with risk pooling, reserves, and mitigation to reduce insurance costs. These risk management pools often provide risk mitigation training to participating agencies as a condition of providing insurance. The CDI should facilitate opportunities to create similar arrangements that reduce flood risk costs for communities and citizens.
- *Educate local officials on risk transfer tools*. Insurance is just one risk transfer tool. Helping community officials understand the range of risk transfer options will help them identify situations where insurance may be the best option where it is not. Educational material should include information on the availability of parametric insurance products, the creation of a captive or ways to accumulate reserves.
- *Promote public-private flood insurance collaborations*. Collaborations between the community and insurance can lead to flood risk mitigation. Establishing these partnerships requires initial investment in capacity building. CDI should promote grant programs that furnish initial financing to the insurer and the community to offset the expenses of forming these partnerships (GAO, 2020b).
- *Encourage the growth of professional organizations that combine insurance and floodplain management.* Organizations like the Floodplain Managers Association (FMA) and the Central Valley Flood Control Association (CVFCA) provide information to members on flood management and flood control actions. CDI can help its members transition from flood management to flood risk management, where insurance is part of an integrated financial management package.
- *Encourage the dissemination open and transparent insurance and flood loss data.* CDI should partner with DWR and CalOES to accurately quantify the location and amount

of flood losses and potential flood losses. This information can provide a benchmark for measuring the effectiveness of mitigation and insurance programs. Areas needing special attention can be identified, and actions can be taken to improve flood resilience.

- *Conduct a targeted survey of leading risk management firms* (e.g., Lloyd's of London, Swiss Re, Gen Re, Munich Re, FM Global) to:
    - Evaluate barriers and information requirements for pricing risk instruments in California's Central Valley
    - Gauge interest in providing private insurance coverage for the region
    - The Central Valley presents unique challenges for risk assessment due to its complex levee system and intricate water supply infrastructure. While global reinsurers' risk pricing methodologies remain opaque, DWR possesses detailed modeling data, primarily developed to justify USACE levee investments. To bridge this information gap, the CDI should facilitate a framework enabling insurance providers to utilize DWR's modeling data effectively, thereby enhancing risk assessment accuracy and potentially expanding insurance options in the region.

- *Facilitate cost reduction in insurers' reserves and reinsurance*. CDI should investigate and implement strategies to alleviate the financial burden on insurers providing flood coverage, particularly in high-risk and underserved areas. This multi-faceted approach may include:

    - Tax incentives: Explore the possibility of offering tax breaks or credits to insurers who maintain substantial reserves for flood-related claims or provide coverage in traditionally underserved regions.
    - Financial backstop: Develop a state-backed reinsurance program or catastrophe fund specifically for flood risks, similar to existing models for earthquake or terrorism coverage in other jurisdictions.
    - Reinsurance tax reform: Advocate for reducing or eliminating taxes on reinsurance purchases, which currently inflate the cost of insurance provided by private insurers. This could lower premiums for end consumers.
    - Regulatory sandbox: Establish a controlled regulatory environment that allows insurers to test novel flood insurance products or pricing models without the full regulatory burden, encouraging innovation in the sector.

  By implementing these measures, CDI can create a more favorable environment for insurers to offer flood coverage. This could potentially increase market participation, lower consumer costs, and ultimately reduce the flood insurance gap in California's high-risk areas.
- California might consider implementing its own flood insurance program. The NFIP is required to offer coverage for all U.S. properties, even though climate change may make hurricanes uninsurable. Although California faces unique challenges due to climate change, particularly the increased risk of levee failure in urban areas, California voters have consistently supported investing in levee improvements to reduce risk. Given these factors, now may be an opportune time to set up a state-led insurance

program. The political landscape adds urgency to this idea, as the new federal administration has previously expressed reluctance to provide disaster relief to California, casting doubt on the reliability of future federal assistance. A state-managed flood insurance program could potentially provide cheaper flood insurance, prompting more people to buy, ultimately reducing the need for state-funded disaster aid. It could also serve as a "sandbox" for exploring NFIP reforms.

California Department of Water Resources

- *Encourage the creation of flood risk information that insurers and communities can use*. California's flood risk is challenging to model, partly because our flood control system is tightly linked to our water supply system. Even large events can result in little damage if they follow a very dry period, whereas small rainfall events can cause much damage when reservoirs are full. DWR can help make flood risk more appealing to insurers by helping them develop detailed risk information.
- *Encourage public/private flood insurance arrangements*. Public-private partnerships between the community and insurers can reduce flood risk. DWR should collaborate with CDI to encourage funding for public/private partnerships. DWR could leverage Small Community Flood Risk Reduction Studies as a starting point for public/private partnerships that help small communities.
- *Encourage the growth of professional organizations that bring insurance and floodplain management together*. DWR is an active participant in the FMA. FMA's Extreme Precipitation Forum can provide an opportunity to bring floodplain managers and insurers together to improve flood risk modeling
- *Reexamine recommendations by the Agricultural Floodplain Ordinance Task Force*. Floodplains are commonly used for agriculture. However, many NFIP regulations burden the agricultural economy, affecting the financial viability of agricultural production. The Agricultural Floodplain Ordinance Task Force (CA DWR, 2017b) report includes several recommendations for reducing regulatory burdens and implementing community choice flood insurance programs. DWR and CDI should jointly revisit the recommendations and act to advance certain insurance-related recommendations.

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