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Flood Risk Management in the United States

Building flood resilience in a changing climate

June 2020

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The Geneva Association

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1. Executive summary

As the world responds to the COVID-19 crisis and governments prepare their economic stimulus plans, the potential compounding effects of weather-related extremes such as floods, tropical cyclones and wildfires could significantly challenge a country's emergency management capacities and slow down socio-economic recovery. This study is focused on building resilience to floods in a changing climate. It points to the need for a paradigm shift from reacting to crises towards a risk-based, anticipatory, holistic and all-of-society approach to managing the potential impacts of catastrophes.

Flooding is one of the most important physical climate risks in many countries, affecting households, communities, businesses and governments on a regular basis.

There are several kinds of floods:

- Fluvial floods (river floods)
- Pluvial floods (flash floods and surface water)
- Coastal floods (storm surge and coastal tidal flooding)

Each kind differs in terms of occurrence, potential damage and management measures.

Due to the major socio-economic effects of flooding, including threats to human lives and livelihoods as well as direct and indirect economic impacts, building resilience has become a priority for many countries around the world in recent years.

The costs associated with floods are growing in many places due to the combined impacts of

- Increasing concentrations of people and assets in areas of high flood risk linked to land use, urbanisation and development practices and;
- The increasing frequency and severity of weather-related events linked to climate change (e.g. changing storm and precipitation patterns and rising sea levels) (Intergovernmental Panel on Climate Change (IPCC) 2018).

Over the last decade, underpinned by three international framework agreements,[1] some governments have started to adopt a more proactive approach to disaster risk management (including for floods), engaging a variety of stakeholders (The Geneva Association 2016, 2017). Despite some progress, a number of hurdles

1 The United Nations Hyogo Framework for Action (2005–2015), Sendai Framework for Disaster Reduction (2015–2030) and The Paris Agreement, which have been adopted by over 190 member states.

remain related to policy and regulatory constraints, institutional and sectoral silos and capacities, conflicting and/or competing priorities and insufficient coordination within and across layers of government and with other key stakeholders, such as the private sector and non-governmental organisations (NGOs).

As part of its commitment to strengthening socio-economic resilience to extreme events and climate change, The Geneva Association has undertaken this study to take a deeper look at the evolution of flood risk management (FRM), particularly in light of the changing risk landscape. Specifically:

- This study offers a comprehensive review of FRM in three high-income countries with mature insurance markets: the U.S., England (a constituent country of the U.K., as defined by the Commonwealth) and Germany;
- Special attention is given to mapping the evolution of governance, institutional frameworks and the interplay of different components of FRM, including risk assessment, risk communication and awareness, risk reduction, risk prevention, risk financing, risk transfer (e.g. insurance and alternative risk transfer) and reconstruction measures;
- Trends and patterns are explored and key findings and recommendations for stakeholders aiming to improve FRM systems in any county are provided;
- The study did not set out to draw comparisons among the three countries, or to identify and promote best practices. In fact, a best practice in one country may not be so in another, as it cannot be isolated from the governance, institutional and cultural environments in which it was originally developed.

The methodology, overall findings and recommendations of the entire study are provided in The Geneva Association (2020a). Case studies for England and Germany are available in The Geneva Association (2020b) and (2020c), respectively.

This report provides a comprehensive review of FRM in the U.S. and highlights successes, lessons learned and continued challenges.

Key findings

- **Flood risks:** Flooding is one of the most frequent and costly natural disasters in the U.S. The country experiences coastal, fluvial and pluvial flooding. Flood risk is increasing due to escalating heavy precipitation events and rising sea levels caused by climate change, continued development in high-risk areas and ageing infrastructure.
- **Institutional roles and responsibilities:** FRM in the U.S. is a shared responsibility across multiple federal agencies, all levels of government, the private sector and non-governmental organisations. This creates both complementarity and duplication of efforts and some gaps in FRM remain.
- **Legislative action:** The approach to FRM in the U.S. has shifted over the past century from a focus on structural protection to building flood resilience through various approaches. The 1927 Mississippi River floods catalysed the first legislative initiatives on structural flood protection. Over the following decades, thousands of miles of levees, hundreds of dams and many other forms of structural protection were constructed. Fifty years ago, Congress broadened FRM to include non-structural measures with the creation of the National Flood Insurance Program (NFIP).
- **Risk information and communication:** At this time, nationwide, freely available flood risk information is largely only available from the Federal Emergency Management Agency's (FEMA) NFIP, in the form of Flood Insurance Rate Maps (FIRMs). However, these maps are not ideal products for risk communication and critics contend that they create a false perception of flood risk, are often outdated and do not fully capture storm-water flooding. Beyond FEMA's maps, there are substantial amounts of flood risk data in the U.S., along with multiple flood models produced by the government, academics and private sector firms. Navigating and understanding this information, however, may be confusing, particularly for less sophisticated users. Communities and households may not have access to relevant information to support their decisions. This can distort the housing market and lead to suboptimal decisions. Further advances in providing useful and decision-relevant risk information are needed.

- **Alerts and early warning:** The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) issues forecasts, warnings and advisories for weather and water-related hazards to communities across the U.S. Flood warnings originate in one of 122 Weather Forecast Field offices and are sent directly to residents' cell phones and communicated via the web, television and radio.

- **Emergency preparedness:** Flood warnings and advisories are used by local governments to make decisions about evacuations, school closures, deployment of first responders and other measures to protect lives and property. State and local governments generally have evacuation protocols in place that specify how the decision-making and evacuation processes should occur.

- **National Flood Insurance Program:** The NFIP is the primary non-structural approach to FRM in the U.S. Communities join the program voluntarily, by adopting minimum floodplain management regulations. In exchange, their residents become eligible to purchase flood insurance from the federal programme. However, many of those at risk are still not insured. Public policies to help close the flood insurance gap are being explored. Some families do not have the resources to afford flood coverage and multiple stakeholders have suggested that a federal means-tested assistance programme could help lower- and middle-income families with the cost of insurance. Congress has not designed the programme to be financially sound and the NFIP is billions of dollars in debt to the U.S. Treasury. The programme has secured flood reinsurance protection from the capital markets twice by issuing catastrophe (CAT) bonds in 2018 and 2019 and is seeking further protection with its third CAT bond issuance in January 2020. However, the programme is in critical need of financial reform.

- **Risk reduction:** Federal funding for flood mitigation is offered through a variety of agencies and programmes. These federal dollars for risk reduction are typically provided post-flood, off-budget, tied to major disaster declarations after large flood disasters and targeted at the impacted areas. There are indications of a recent shift toward allocation of more federal dollars for risk reduction pre-disaster. It is difficult to engage policymakers and other stakeholders in long-term strategic planning and investment for risk reduction and prevention. Planning to address increasing flood risks from climate change has also been difficult in the current political environment. Local interest in and approaches to flood risk reduction vary significantly around the country.

- **Post-disaster response:** Post-disaster federal aid to households is limited, and families seldom get full support for financial recovery. Federal disaster aid for local governments, however, is generally more generous. This may give local governments perverse incentives since they reap the benefits of lax floodplain land use but most of the flood costs are paid by the federal taxpayer.

- **Overall FRM approach:** Further progress on FRM is hindered by a lack of common incentives, affordability constraints, an absence of political will for long-term planning and inadequate investment in retrofitting and upgrading ageing infrastructure. Increasing flood risk, particularly in coastal areas, poses significant future challenges that should be considered now in building and land use decisions. Overall, despite the developments highlighted in this report, the FRM system in the U.S. continues to remain, in general, reactive to floods, pointing to the need for a more cohesive system-based forward-looking approach that takes into consideration the impacts of climate change. Furthermore, a process for monitoring and evaluating FRM is needed in order to improve the system.

The flood risk management system in the United States

Post-disaster response and reconstruction

- Federal involvement in post-flood recovery and reconstruction is governed by the Robert T. Stafford Emergency Relief and Disaster Assistance Act of 1988 (Stafford Act). Under the Act, the President can authorise federal assistance programs when the expected costs for recovery from a disaster exceed state and local governments' fiscal capacity.
- Post-disaster aid is administered through FEMA, the Small Business Administration, Department of Housing and Urban Development, Internal Revenue Service and U.S. Department of Agriculture.
- Post-disaster federal aid to households is limited, and families seldom get full support for financial recovery.
- Federal disaster aid for local governments is generally more generous, raising questions about possible perverse incentives.

Risk assessment and risk information

Flood risk information provided by

- Federal Emergency Management Agency (FEMA)
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Geological Survey (USGS)
- State and local governments
- Non-profit groups and academic institutes
- Private risk-modelling firms

Risk governance

- Responsibility is shared among multiple federal agencies, state and local government, the private sector and non-governmental organisations.
- Congress authorises federal spending on risk mitigation and recovery programmes.

Risk financing

- Congress appropriates dollars to federal risk reduction and recovery programmes.
- The NFIP has been seeking reinsurance and cat bonds to transfer the risk to reinsurers and capital markets.
- Residents with a mortage from a federally regulated lender on a property in a 100-year floodplain are required to purchase flood insurance for it.

Risk reduction and risk prevention

- Grants or incentives are provided by the NFIP, FEMA, the U.S. Army Corps of Engineers, among other federal agencies, and state and local governments.
- Over 90% of all federal dollars are appropriated in off-budget supplemental legislation tied to particular disasters, with much less appropriated pre-disaster.
- There are many areas at risk of flooding where the risk is not actively addressed.

Source: The Geneva Association

Risk communication

- Federal disclosure law for lenders
- Federal government programmes
- Local government programmes
- Risk awareness is highly varied within and across stakeholder groups
- State hazard disclosure laws

Early warnings linked to emergency preparedness

- The authoritative source is NOAA's National Weather Service originating from 122 field offices and shared via radio, TV, the web and cell phones (may also be packaged and delivered by private firms).

Risk transfer

FEMA's National Flood Insurance Program (NFIP), created in 1968, is the primary non-structural approach (FEMA)

Characteristics and history of the NFIP:

- Communities need to adopt minimum floodplain regulations and then residents are eligible to purchase flood insurance.
- Residential properties can be insured for up to USD 250,000 for the building and up to USD 100,000 for the contents. A business can insure both structure and contents up to USD 500,000.
- Limited take-up and highly concentrated geographically.
- Priced based on Flood Insurance Rate Maps (FIRMs) and specifications of the property, affordability is a policy concern.
- Relies on borrowing from U.S. treasury to pay claims and is deeply in debt.
- Started to purchase reinsurance in the private market in 2017.
- Two CAT bonds issued since 2018 to transfer USD 500 million and then USD 300 million to capital markets. Called for an additional USD 300 million in 2020.
- There is low demand.

Private sector flood insurance

- All peril policies for commercial and large companies.
- A small, growing residential market, targeting areas where insurance can be offered cheaper than that of the NFIP.
- There is low demand.

Other considerations for FRM

- Monitor, assess and provide ongoing feedback to improve the FRM system.
- Greater financial incentives for risk reduction are needed at all levels.
- Multi-stakeholder coordination platforms: some groups are attempting this, but initiatives are generally fragmented and small-scale.
- Educational, specialised and technical training programmes: there are local examples and examples in trade groups.
- Climate change needs to be consistently and comprehensively incorporated into all FRM policies.

Flood risk management in the United States: Pre-1950–2019

	pre-1950s	1950s	1960s	1970s
Approach to managing flood risk	Dam and levee building	Permanent federal role in disaster aid established and authority vested with the President	Growing focus on land use	Recognition of moral hazard Expansion of federal role in mitigation National flood risk mapping program established
Major flood events			**1965: Hurricane Betsy** **1969: Hurricane Camille**	**1972: Tropical Storm Agnes**
Major laws		**1950 Diaster Relief Act:** created Disaster Relief Fund **1953 Small Business Act:** provides disaster loans to households and small businesses	**1965 Water Resources Planning Act** **1968 National Flood Insurance Act:** established federal flood insurance program	**1970 Disaster Relief Act:** aid for public buildings and temporary housing **1973 The Flood Disaster Protection Act:** mandatory purchase requirement added; aid limited if community doesn't participate **1974 Disaster Relief Act:** Hazard mitigation plans required, expanded assistance
Institutional changes and noteworthy developments	Rise of federal role	President assumes more control over disater aid **1958:** Gilbert White et al. bring changes in the urban occupance of floodplains	USGS and TVA undertake floodplain mapping Release of a Unified National Program for Managing Flood Losses Multiple states adopt floodplain development laws EO 11296 – requiring federal agencies to address flood risk	**1977:** Release of A Unified National Program for Floodplain Management Creation of Federal Interagency Floodplain Management Task Force EO 11988 – agencies do not support floodplain development **1979:** FEMA established by Executive Order

Source: The Geneva Association

1980s	1990s	2000–2010	2011–present
Establishment of current federal disaster aid approach	Rise of HUD's role in recovery Growing focus on enviromental benefits of wetlands	Katrina crises	Focus shifting to resilience Rise of technology for better risk communication Growing concern that climate change will worsen flooding
	1993: Midwest flooding	**2001: Tropical Storm Allison** **2004: Hurricane Ivan** **2005: Hurricane Katrina (Rita and Wilma)** **2008: Hurricane Ike**	**2011: Hurricane Irene** **2012: Hurricane Sandy** **2016: Louisiana flooding (Baton Rouge)** **2017: Hurricane Harvey (Irma and Maria)**
1982 Coastal Barrier Resources Act: no federal expenditures or flood insurance on certain barrier islands **1988 Stafford Act:** current aid structure: IA, PA and HMGP	**1993 Hazard Mitigation and Relocation Assistance Act**	**2006 Post Katrina Emergency Management Reform Act:** national disater recovery startegy and national disaster housing strategy	**2013 Sandy Recovery Improvement Act:** streamlined aid
1983: WYO program in the NFIP established **1983:** guidelines for USACE establish National Economic Development as objective **1986:** Unified National Program for Floodplain Management	FEMA establishes Community Rating System Growing use of floodplain buyouts **1993:** First use of CDBG for disatser recovery **1999:** ASFPM creates Certified Floodplain Manager program Galloway Report: focus on role of floodplain restoration	**2002:** DHS established, FEMA moved in **2004:** Longterm Community Recovery process created large supplemental spending for Katrina due to a perceived failure in response and collapse of levees	**2011:** National Disaster Recovery Framework – statement of national recovery strategy, need for cross-scale coordination, empowers local governments **2012:** Hurricane Sandy Rebuilding Task Force Emergence of residential private flood insurance

2. Introduction

Flooding is one of the most frequent and costly disasters caused by natural hazards globally and in the U.S. The country is subject to a range of flood hazards, including overflowing rivers, storm surge along the coast, storm events exceeding local drainage, flash flooding in steep terrain and failures of flood protection infrastructure. Historically, American cities were built near waterways such as coasts and rivers as a means of transportation and energy generation, exposing them to flood risk. The country has been actively managing these threats for at least a century and communities have been grappling with them since the country was founded. Over the decades, the focus of flood management has shifted from using structural flood protection to control water to a broader approach involving building flood resilience through risk communication, investments in non-structural and structural mitigation and improving response and recovery.

The federal agency that manages disaster events, the Federal Emergency Management Agency (FEMA), advocates a 'whole community' approach to disaster management, including floods. This approach involves more coordinated engagement among all levels of government with emergency managers, community leaders, the private sector, non-profits, faith-based groups and others in preparing for and responding to disaster events in the ways that best fit a given community (FEMA 2011). The goal is to develop a shared understanding of community needs and empower multiple entities to help manage risks, thus improving preparedness and resiliency. Many stakeholders have a role in flood risk management, although coordinating roles and responsibilities remains a challenge.

This report provides a comprehensive review of flood risk management in the U.S. The review is based on applying a holistic, multi-stakeholder, forward-looking framework for FRM (The Geneva Association 2020a).

Section 3 provides an overview of flood risk across the country, how it is changing and the drivers. Section 4 introduces the overarching concept of flood resiliency as a framework for the nation's current FRM efforts. Section 5 provides an overview of flood risk information and awareness, and section 6 gives an overview of mechanisms for flood advisories and early warnings. Section 7 reviews flood insurance and other risk transfer solutions. Section 8 highlights flood mitigation programs. Section 9 offers an overview of approaches to post-flood rebuilding and reconstruction. A summary of success factors, continued challenges and lessons learned is provided in section 10.

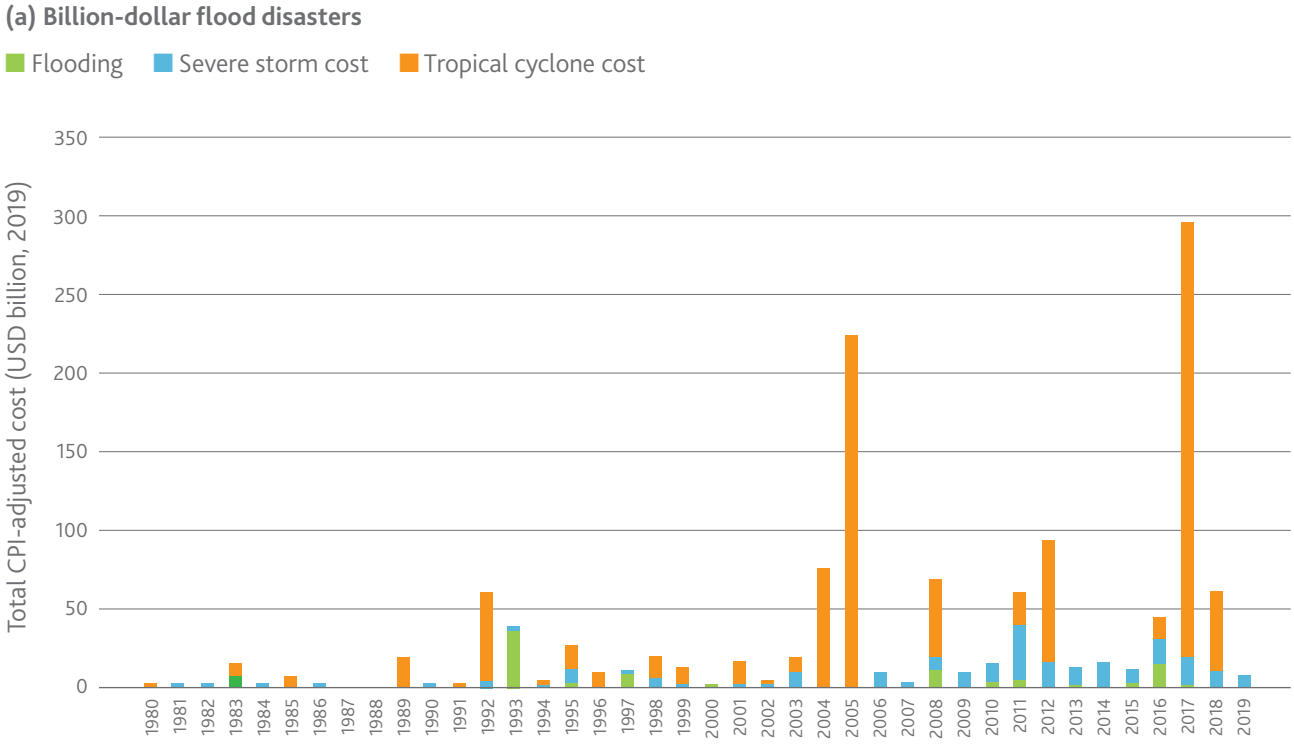
3. Flood risk

3.1. Types and impacts of flood fisk

There are three primary types of flooding, all of which are experienced in the U.S.: coastal flooding, fluvial flooding and pluvial flooding. The risk profile of each type varies, and they may require different management and financing approaches.

Data from Munich Re's NatCatSERVICE on hydrological events in the U.S. by year are shown in Figure 1. The Midwest U.S. saw severe flooding in 1993. The years of highest damage in the U.S. are attributable to hurricanes.

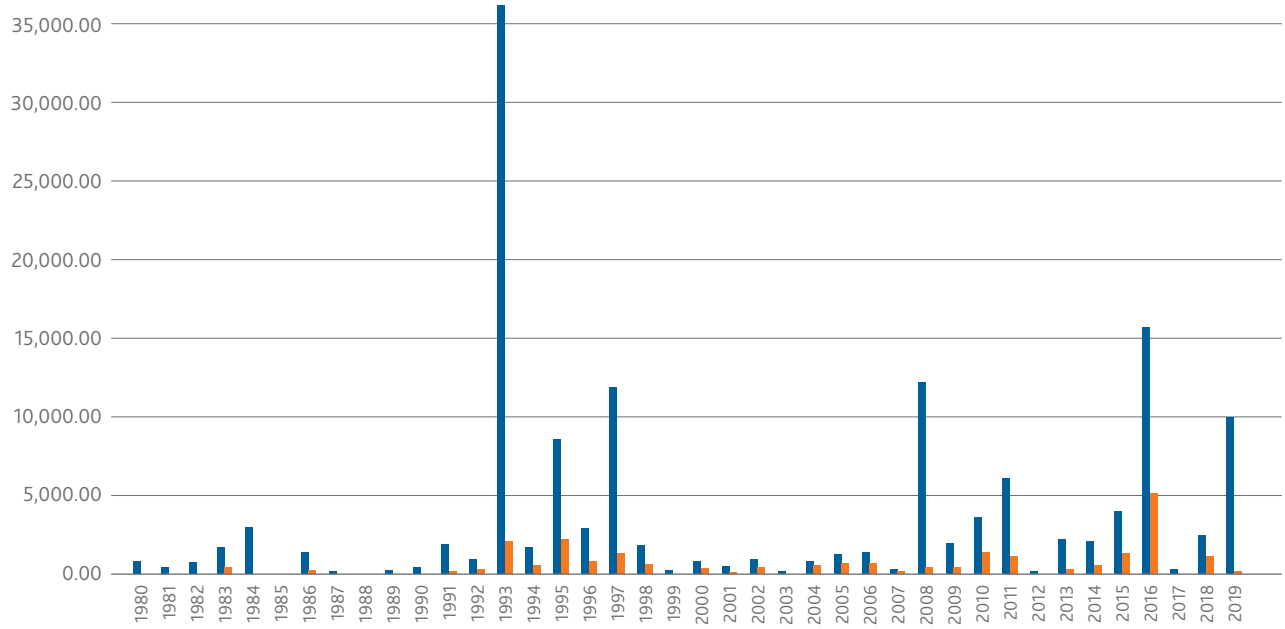
Figure 1: (a) Billion-dollar flood disasters; and (b) Overall and insured losses for floods (1980–2019)



(b) Overall and Insured losses for floods (1980–2019)

Overall losses USD million (adjusted to 2019 values based on national CPI)

Insured losses USD million (adjusted to 2019 values based on national CPI)



Sources: NatCatSERVICE Munich Re 2019 and the National Oceanic and Atmospheric Administration (NOAA)

Box 1: The costs of flood events

Floods cause both direct and indirect impacts on households, businesses and governments (Kousky 2014).

Direct costs are those resulting from the initial impact of flood waters on people and assets. For example: (i) direct loss of life and injuries; (ii) damage to buildings and their contents; (iii) damage to infrastructure; (iv) non-market damage, such as loss of family heirlooms; (v) damage to crops or livestock and destruction or damaged agricultural equipment; (v) costs of emergency response, such as evacuation and rescue; (vi) clean-up costs, such as clearing debris from streets; and (vi) interruptions to a company's production or business from physical damage.

Indirect losses are those that follow from the initial destruction and include business interruption for companies that did not sustain direct damage but may not be able to operate because, for example, their supplier was damaged, their workers evacuated or they lost power or cannot get their products to market due to failure of infrastructure. It also includes lost revenue from reductions in demand or supply due to the flood event. Furthermore, loss of or damaged infrastructure (e.g. power, sewage or water) can lead households and businesses to adopt costly measures (such as increased commuting time as a result of damaged roads or the extra costs of running a private generator when the electricity is out). There could also be mortality and injury or environmental degradation, not from the direct impact of the hazard, but from follow-on conditions. Indirect costs can also include relocation expenses and lost tax revenue, as well as a range of difficult-to-measure, but no less important costs, such as emotional distress, trauma and physical and mental health impacts.

Source: Kousky 2014

3.2. Drivers of flood risk

Flood risk in the U.S. is projected to grow over the coming decades due to a combination of an increasing concentration of people and assets in flood-prone areas; less safe development practices; changes in land use and land cover that impact infiltration; changing precipitation, storm patterns and sea level rise linked to climate change; and ageing infrastructure.

The combined effects of these factors drive an increase in flood losses. For example, a 2013 study for FEMA evaluated the impacts of population growth and climate change on flood risk in the United States by 2100 (AECOM 2013). The study estimated a 45% median increase in the area of the 100-year floodplain in riverine environments nationwide, with large regional variation. On average, roughly 30% of this increase is attributable to population growth and 70% to climate change. In coastal areas, the median growth in the 100-year floodplain was projected to be 55%.

Development

Increased development in high-risk zones is a factor contributing to rising flood losses (Cutter et al. 2017). A recent study estimated that the total U.S. population exposed to serious flooding is 2.6 to 3.1 times higher than previous estimates, and that nearly 41 million people live within the 1% annual exceedance probability floodplain, compared to only 13 million when calculated using FEMA flood maps (Wing et al. 2018). This higher estimate is due both to the authors mapping areas that do not have FEMA maps, as well as from including pluvial flood risk, which is often excluded from FEMA floodplain delineations. The same study projected an increase in floodplain population and development by 2050. It is important to also recognise the large amount of flood damages that occur outside the mapped 100-year floodplain, so estimates limited to the 100-year floodplain are not comprehensive of all flood risk.

Coastal areas are particularly attractive for development and are often drivers of economic activity. Some 23 million people (nearly 8% of the U.S. population) live in low-elevation coastal areas (Curtis and Schneider 2011). Excluding Alaska, counties directly on the shoreline make up less than 10% of the total land area in the U.S., but account for 39% of the total population (NOAA 2013). From 1970 to 2010, the population of coastal counties increased by almost 40%, and the population density in coastal areas is expected to continue increasing (NOAA 2013).

Development is regulated at the local level in the U.S. Local governments often have financial incentives to allow development of risky locations, since they benefit from the tax revenue, but pay little of the costs related to floods and the damage they cause. While development can contribute to higher flood risk and there are certain high-risk areas where no development at all may be appropriate, taking certain mitigation measures in building in the floodplain can lower expected damages.[2]

Beyond simply placing more capital at risk, increases in impervious surfaces, such as concrete and asphalt, prevent water from seeping into the soil, exacerbating the risk of pluvial flooding. As buildings, roads and housing developments replace natural landscapes, water infiltration is inhibited and flood risk can increase (Paul and Meyer 2001; Ogden et al. 2011; Du et al. 2015). This is especially problematic in urban and suburban areas where there are high concentrations of impervious groundcover. A number of cities throughout the U.S., for example, Chicago and Baltimore, are implementing green infrastructure projects or replacing impervious cover with more porous surfaces (such as permeable pavement) to reduce storm-water runoff and corresponding flood damages.[3]

Sea level rise

In coastal areas, sea level rise will inundate some areas in the coming decades (Hauer et al. 2016). A recent Zillow report suggests that nationwide almost 2% of all U.S. homes (almost 1.9 million) are at risk of being inundated by 2100 (Rao 2017)[4]. In addition, sea level rise is leading to increased probability of coastal flooding overtime (Sweet and Park 2014). As an example, a recent study on New York City found that floods which were once characterized as 1-in-500 year events in the preindustrial era are now considered 1-in-25-year floods and will probably become even more likely (Garner et al. 2017). Another recent report from the Union of Concerned Scientists identified communities under climate scenarios that would face flooding at least 26 times a year on average (every other week) over at least 10% of their land areas (Spanger-Siegfried et al. 2017). The study concludes that within 20 years, twice as many communities as today will meet this threshold, and they are not uniformly distributed around the country.[5] The combined impacts of sea level rise and storm surge are projected to lead to greater damage in the coming years, with one midrange estimate suggesting damages of USD 990 billion (2005 dollars) through 2100 (Neumann et al. 2015).

2 For example, buildings can be elevated to lower the risks of floodwaters invading. Utilities in the home can be placed on higher floors to lower the possibility of damage. Water resistant materials can be used on the lowest floors, as well.

3 For example, in 2006, the City of Chicago initiated a Green Alley program in which it replaced impervious surfaces in City alleys with permeable pavement that would reduce run-off and flooding. As of 2012, the City had completed over 100 Green Alley projects and other cities, including Baltimore and Los Angeles, had launched similar programs (Newell et al. 2013).

4 Zillow provides housing data and related research (Zillow.com).

5 Due to subsidence, Maryland and Louisiana are hotspots for the impacts of sea-level rise.

Climate-induced changes in rainfall patterns

Climate-change-induced intensification of rainfall is projected to lead to increased flooding in certain parts of the U.S. (Mallakpour and Villarini 2015; Prein et al. 2017) and this may in turn increase flood damages (Wobus et al. 2013). The frequency and intensity of heavy precipitation events in the U.S. has increased since 1901 with high scientific confidence (U.S. Global Change Research Program 2017). A 2018 study found that climate change intensified rainfall in Hurricanes Katrina, Irma and Maria by 4 to 9% (Patricola and Wehner 2018). It also predicted that total rainfall could increase by up to 30% for most extreme hurricanes and tropical cyclones. The number of heavy precipitation events in the U.S. is also expected to increase in some places in the country, even in regions where overall precipitation is expected to decline, such as in the Southwestern U.S. (Wuebbles et al. 2017). Flood damages from more intense rainfall may be particularly pronounced in communities that are not accustomed to heavy rain and lack sufficient drainage infrastructure.

Ageing and inadequate infrastructure

Across the country, communities are struggling with ageing infrastructure, such as roads and bridges and flood-protection infrastructure, such as levees and dams, is no exception. In addition, as climate change exacerbates flood risk in many places, infrastructure that was built decades ago is no longer providing the same level of protection. While upgrades and improvements will be expensive, they are increasingly necessary. For instance, the American Society of Civil Engineers grades U.S. infrastructure, with dams and inland waterways scoring a 'D' (Program 2017 #127).[6]

3.3. Stakeholders and their contributions to flood fisk

Flood risk is a combination of hazard, exposure and vulnerability. All these can be influenced by the actions of different stakeholders to increase or lower overall flood risk. This includes homeowners and businesses making decisions about where to locate and what mitigation measures to adopt; all levels of government determining funding for mitigation, enacting regulations to govern floodplains or incentivising other actors; and infrastructure operators making citing and mitigation choices, among many others (Table 1).

There are three main flood risks:

Hazard is the probability distribution of floodwater surface elevations associated with all possible floods that can occur at a particular location within a floodplain.
Exposure is the potential for people and assets to come into direct contact with floodwaters as a result of their location in a floodplain.
Vulnerability is the characteristics of people and assets that affect the likelihood that they will realize adverse consequences from exposure to the flood hazard.

Source: Scodari and Shabman 2014

As detailed in Table 1, stakeholders can increase or lower flood risk with their actions.

Flooding caused by Hurricane Katrina, 2005

6 https://www.infrastructurereportcard.org/cat-item/inland-waterways/

Table 1: Stakeholder actions that influence flood risk		
Stakeholders		**Actions**
Homeowners		• Location decision for home purchase • Risk reduction and retrofit investments (e.g. elevating home, retrofitting the pipes and sewage and drainage systems, moving valuable assets to higher levels) • Percent of lot that is pervious • Insurance decisions
Businesses		• Location decisions • Risk reduction and retrofit investments • Insurance decisions
Government	**Local**	• Land-use regulations and issuing building permits in high-risk zones
	State	• Updating and enforcing building codes • Community-level risk reduction investments (e.g. levees, green infrastructure) • Citing of infrastructure and public buildings • Incentive programs for property owners to mitigate flood risk of their properties • Availing funding for mitigation • Flood risk communication programs
	National/ federal	• Flood hazard/risk mapping • Flood risk communication programs targeted at officials and decision-makers, businesses, homeowners, etc. • Floodplain management standards, pricing and incentives • Cost-shares and requirements for flood risk reduction infrastructure • Insurance requirements • Post-disaster aid funding and reforms to incentivize ex-ante risk reduction – amount and requirements
Levee districts		• Funding and constructing levees and other flood-risk reduction infrastructure
Utilities		• Flood-proofing structures and distribution system • Water management systems such as sewage and drainage
Banks and mortgage lenders		• Insurance requirements • Risk-based loan terms in high-risk areas
Real estate developers		• Citing decisions • Risk reduction and risk prevention investments • Update building codes • Sewage and drainage projects
Critical infrastructure operators		• Citing decisions • Flood protection and risk reduction measures

Source: The Geneva Association

4. Flood resilience in the United States: An emerging concern

The approach to flood risk management in the U.S. has evolved over the years. Beginning with the Flood Control Act of 1928, and continuing through the 1950s, the dominant federal approach to flood risk management was building dams and levees to control water. In the 1960s and the 1970s, there was a shift toward concern about floodplain land use, economically efficient uses of floodplains, and an expansion of the federal role in mitigation and flood mapping. During this period, the National Flood Insurance Program (NFIP) was created.[7] With the rise of this program, approaches to flood risk in the U.S. shifted from building flood hazard control projects and to expecting those located in flood-prone areas to be more informed and responsible for bearing the costs of their decisions. This is reflected in the declining amount in recent decades spent on new federal flood hazard reduction projects and the growing importance of insurance in managing the financial risks of floods (Scodari and Shabman 2014). That said, the shift may not be as dramatic as annual appropriations suggest since the U.S. Congress has been appropriating large sums to the Corps of Engineers in post-disaster supplemental spending bills. Indeed, the Congressional Research Service estimates that between FY2005 and FY2018, Congress appropriated USD 23 billion in standard annual appropriations, but USD 45 billion in disaster supplemental bills.[8]

Recently, flood risk management in the U.S. has started to focus on building resilience. A National Research Council (NRC) report defined resilience as 'the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events' (2012). This new focus has been driven by the increased interest in resilience globally and the rising costs of natural hazards in the U.S. (Carter et al. 2018). As evidence of this shift, the government has launched multiple flood resilience programs and activities, some of which emerged after the devastating hurricanes of the last couple decades.[9]

7 For more on the early history of flood risk management in the United States, see L.R. Johnston Associates (1992) and Wright (2000).

8 https://fas.org/sgp/crs/natsec/R45326.pdf

9 When Superstorm Sandy hit in 2012, President Obama created a task force to guide federal recovery spending to promote long-term resilience. The Obama administration issued Executive Order 13653 (revoked by the Trump administration), which was titled 'Preparing the United States for the Impacts of Climate Change' and promoted the need for building resilience to disasters caused by natural hazards.

Multiple federal agencies have now incorporated resilience as an objective for various policies and programs. FEMA recently created a new resilience organisation within the agency that aims to build a 'culture of preparedness through insurance, mitigation, preparedness, continuity, and grant programs'.[10] FEMA's resilience work is led by a Deputy Administrator of Resilience and is a central component of the Agency's 2018–2022 Strategic Plan. The U.S. Army Corps of Engineers is working on climate resilience and the Environmental Protection Agency (EPA) has produced guidance on achieving flood resilience for water utilities.[11, 12] In recent years, NOAA has provided funding through the Coastal Resilience Grants Program to help states implement measures that reduce flood and storm impacts in coastal communities.

Beyond the federal government, several state and local governments have adopted flood resilience objectives in their programs, such as programs in Iowa watersheds,[13] coastal programs in the state of Maine,[14] and efforts since 2012 in New York City (Annex 2).[15] There have been many other state and local actions aimed at increasing flood resilience.

Flooding caused by Hurricane Harvey, 2017

10 https://www.fema.gov/resilience
11 https://www.usace.army.mil/Missions/Sustainability/Building-Climate-Resilience/
12 https://www.epa.gov/waterutilityresponse/build-flood-resilience-your-water-utility
13 https://www.iowawatershedapproach.org/about/
14 https://www.maine.gov/DACF/mgs/hazards/coastal/MaineFloodResilienceChecklistOverview.pdf
15 https://www1.nyc.gov/site/planning/plans/climate-resiliency/climate-resiliency.page

5. Flood risk information and awareness

Stakeholders can manage flood risk most effectively if they have access to accurate and clear flood risk information that they can act on. Flood risk information is produced and communicated to households, communities and businesses in the U.S. in different ways. This section covers 1) FEMA's flood maps, which, as of June 2020, are one of the only nationwide, consistent, free, governmental sources of flood hazard information in the country; 2) other sources of flood risk information beyond FEMA; 3) communication and outreach activities related to flood risk (beyond simply making data available); and 4) the state of flood risk awareness among different stakeholders.

5.1. FEMA's Flood Insurance Rate Maps

FEMA, as part of the NFIP, produces flood hazard maps, referred to as Flood Insurance Rate Maps (FIRMs),[16] designed to support the implementation of the NFIP. They have become the primary source of free, publicly available and consistent flood hazard information in the country (Box 2) and are now used for purposes other than NFIP regulation. The language of FIRMs, such as Special Flood Hazard Area (SFHA) and flood zones, has become the de facto language of flood risk in the U.S, and is used by many stakeholders.

Flooding caused by Hurricane Barry, 2019

16 The maps were originally produced on paper, but in the past 20 years, the nation's FIRMs have been converted into more accessible digital versions, referred to as DFIRMs. In addition to the maps for individual communities, FEMA also maintains the National Flood Hazard Layer (NFHL), a publicly available digital database with spatial flood hazard data derived from engineering and hydrological studies, FIRMs and official map revisions. For more on the mapping process, see King (2013).

Box 2: FEMA Flood Insurance Rate Maps (FIRMs)

Understanding FEMA flood zones

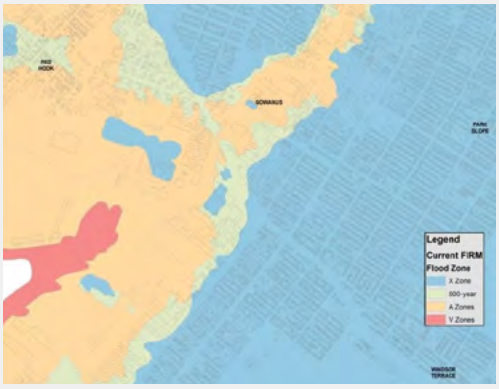
- FIRMs delineate various flood zones.
- The 100-year floodplain delineates the 1% annual chance flood and is referred to as the Special Flood Hazard Area (SFHA). The SFHA comprises two zones: the **A zone** is the inland 100-year floodplain or coastal floodplain subject to waves less than 3 feet, and the **V zone** is subject to breaking waves of at least 3 feet.
- Outside the SFHA is the **X zone**, which may be divided into the 500-year floodplain and beyond it. For certain zones, the FIRM may also show base floor elevations (BFEs), the estimated height of water in a 100-year (1% annual chance) flood.

Cooperating Technical Partners Program

In some communities, local partners assist with the production of flood maps through FEMA's Cooperating Technical Partners (CTP) Program, established in 1999. The objective of the CTP Program is to optimise limited mapping funds and incorporate unique local conditions. CTPs may be local governments, regional authorities or state agencies. Once selected, a CTP enters into a formal partnership that allows FEMA to fund activities such as program management, base map acquisition, floodplain analyses, plus up to 10% of scoping and outreach costs.

Technical Mapping Advisory Council

The Biggert-Waters Flood Insurance Reform Act of 2012 (PL 112-141) established an ongoing mapping effort to update maps. The act also created the Technical Mapping Advisory Council (TMAC) to review and make recommendations related to FEMA's mapping efforts. Council representatives come from the public and private sector and from all levels of government. The council was tasked with examining the quality and distribution of FIRMs, developing performance metrics for mapping, setting standards for mapping and data, finding ways to maintain and update FIRMs, maintaining relationships with local partners, developing approaches for improving interagency coordination and determining how to incorporate the best available climate data into mapping (Technical Mapping Advisory Council 2015; Technical Mapping Advisory Council 2016). The image below shows FEMA flood zones in New York City.



FIRM for New York City

Concerns with FIRMs

FEMA's FIRMs were not designed as risk communication products, yet they have become the de facto product for providing flood risk information to households and communities. Stakeholders have raised multiple concerns about these maps being used for risk communication:

1. The maps are often criticised for creating a false binary perception of flood risk ('in' a high-risk zone versus 'out'). For instance, while identifying the 1% annual chance flood-line is essential to NFIP program requirements, many stakeholders argue that this line suggests that outside the SFHA is safe and inside is equally at risk (ASFPM Foundation 2004). In reality, of course, flood risk varies continuously across the landscape. In an analysis of flood claims data throughout the country between 1978 and 2012, roughly 30% of claims were for properties outside SFHAs (Kousky and Michel-Kerjan 2015). Many recent storms, including Hurricanes Katrina, Ike, Sandy and Harvey, all led to flooding that extended beyond the SFHA and generated flood depths that exceeded the BFE by several feet (e.g. FEMA 2015).
2. Maps can be outdated, i.e. use outdated data or methods. Flood risk can change because of changes in pervious surface area, erosion and/or climate change. In addition, data and methods improve over time (such as the introduction of LiDAR). This creates a need to continually update FIRMs. The National Flood Insurance Reform Act of 1994 instructed FEMA to review all maps at least every five years. A 2016 report by FEMA's Office of Inspector General found that over half of stream/coast miles mapped by FEMA required updating or had not been assessed (Office of Inspector General 2017). Congress has not appropriated the needed funding for substantial upgrades to mapping.

3. There is growing concern that stormwater flooding is not well captured on FIRMs. Riverine or coastal flood hazards are the primary focus of most flood studies. FEMA flood studies may include shallow flooding with an average depth of one to three feet. Shallow flooding may be caused by ponding, sheet flow or local drainage problems, where runoff collects in yards or swales or when storm sewers back up. Generally, however, FIRMs tend to focus on riverine and coastal flooding and do not include pluvial or stormwater flooding. This may leave those at risk of stormwater flooding incorrectly thinking they are not at risk.

4. The FIRMs are designed to be a current snapshot of flood risk in a community. Since they rely on historic data and are not consistently updated, however, the flood risk depicted is inherently backward looking. With flood risk projected to increase in many places in the United States in the coming decades, this may leave users without an understanding of how their risk will be changing.

5. Not all river and coastal floodplains have been mapped and residual risk associated with flood control structures is not well depicted.

5.2. Other sources of flood risk information

Beyond FEMA maps, a variety of flood data and risk information is provided by other federal agencies, private sector firms and non-profit groups. Most provide information not included in the FEMA maps, such as future risk from sea level rise. The landscape of data providers and types of data, however, could be confusing for users to navigate, making it difficult for them to determine which source best fits their needs (Box 3). As a result, households and communities may still not have the information they need to make effective decisions.

5.3. Flood risk communication and outreach activities

Flood disclosure laws

Federal and state laws require that flood information be shared with potential property owners when they choose to locate in a flood-prone area; however, despite these disclosure laws, many potential property owners are not being given relevant and useful information about flood risk. In 1974, the U.S. Congress mandated that federally regulated lenders inform borrowers if their property is in a FEMA-mapped SFHA (100-year floodplain), since borrowers with a federally backed or regulated loan are required to purchase flood insurance. This requirement is based on the FEMA maps; it is a simple 'in' or 'out' communication. However, knowing that a property is in a SFHA may not be the most useful information to potential homeowners, as it suggests that flood risk is binary, does not communicate impacts along with probability, and does not offer any information about changing risk in the area (Kousky 2018b). Furthermore, this may not be communicated to buyers until near closing, at which point it may be too late to act on the information (Chivers and Flores 2002).

Some states have adopted their own flood disclosure laws to have information provided earlier in the home-buying process.[17] Most of these laws also mandate disclosure if the property is in or out of a SFHA. A few states also require an owner to disclose any previous floods at the property, if this information is available. However, this is difficult to enforce. As of March 2020, flood risk information is not shared on the platforms used by potential property purchasers – websites such as Zillow.com and Realtor.com.

Beyond flood risk information about a property, some states require insurers to include language in homeowners' policies, or they may choose to do so voluntarily, that flooding is not included in a standard policy.

Governmental flood risk communication programs

A variety of federal agencies and local governments provide flood risk information and/or offer risk communication programs. Some are duplicative, but some are complementary. For example, state and local officials may use both FIRMs (which provide a static view of flood risk) and tools from NOAA's Digital Coast (which provide a forward-looking view of the risk) to support long-term hazard mitigation and emergency response planning. Further, while an event is in progress, officials may monitor real-time data from the National Weather Service (NWS) and U.S. Geological Survey (USGS) to support response and evacuation decisions.

Federal flood risk communication programs

A number of federal agencies have developed and deliver flood communication programs, including these three prominent programs:

1. **FEMA** has made communication of flood risk one goal of the NFIP, through the website floodsmart.gov, floodplain mapping activities and free tools such as Hazus, a publicly available flood risk model.

17 The U.S. Natural Resources Defense Council (NRDC) has created an online map categorising the states with flood disclosure laws. https://www.nrdc.org/flood-disclosure-map

Box 3: Providers of flood risk information

Federal Emergency Management Agency

FEMA provides flood risk maps, known as Flood Insurance Rate Maps (FIRMs), as part of the National Flood Insurance Program (NFIP) (Section 4.1.).[18] FIRMs were designed to implement the NFIP and have become the chief source of free, publicly available and consistent flood hazard information across the country, used beyond the needs of the NFIP by many stakeholders.

National Oceanic and Atmospheric Administration

The NOAA provides tools to help communities understand storm surge and sea level rise risk, including an online mapping interface. NOAA also houses the National Weather Service (NWS). NWS programs provide short-range storm forecasts and real-time weather information that can be used to plan and execute emergency measures to reduce vulnerability.

United States Geological Survey

The USGS hosts a Flood Inundation Mapping Program for communities. This online, interactive mapping tool provides emergency planners with the ability to understand their immediate flood risk by providing online access to flood inundation maps and real-time streamflow data, flood forecasts, and potential loss estimates. The Groundwater and Streamflow Information Program operates more than 8,200 stream gages, often in partnership with local and state cooperators, to collect data used for flood forecasting and the modification and validation of flood models.

State and local governments

Most state and local governments do not produce their own flood hazard information, instead relying on information from federal agencies. There are, however, a couple notable exceptions. The state of North Carolina has implemented its own floodplain mapping program through which it provides high-resolution, structure level flood risk data to the public through an online portal.[19]

The website also provides base map data, imagery, LiDAR data, and hydraulic and hydrologic models that are available for download and use. They do not, however, show flood risk under climate change. North Carolina's flood risk programs are discussed in more detail in Annex 2a.

Non-profit groups

Various non-governmental sources offer flood risk information, as well, often to fill perceived gaps in governmental flood risk information products. For example, the First Street Foundation is producing pluvial, fluvial, and storm surge information for current and future risks based on peer-reviewed models. They are also creating a database of historic flood events, such that they will produce information on the past, present, and future flood risk for all homes in the country and make this available to decision-makers. As another example, Climate Central, a non-profit news organization made up of leading scientists and journalists that analyzes and reports on climate science, provides freely accessible flood risk and sea level rise mapping tools through Surging Seas.

Private-sector firms

CAT modelling firms provide flood risk information to insurance companies and other commercial clients (and sometimes governments, as well) (The Geneva Association 2018a). These firms have modeled storm surge flood risk for the United States for decades. The models are now well-developed and have been calibrated against loss events. The development of U.S. inland flood modeling; however, is in its nascent stages. The relative infancy of these models can be attributed to the presence of the NFIP and the lack of private sector demand for inland flood models until relatively recently. Now; however, multiple firms have developed inland flood models for the United States.

Academic institutions

Many colleges and universities in the U.S. have researchers that model flood risk or flood damages. This work is generally publicly available.

Source: The Geneva Association

18 The maps were originally produced on paper, but in the past 20 years, the nation's FIRMs have been converted into more accessible digital versions, referred to as DFIRMs. In addition to the maps for individual communities, FEMA also maintains the National Flood Hazard Layer (NFHL), a publicly available digital database with spatial flood hazard data derived from engineering and hydrological studies, FIRMs, and official map revisions. For more on the mapping process, see King (2013).

19 http://www.ncfloodmaps.com/

2. **The NOAA** provides tools to help communities understand storm surge and sea level rise risk, including 'sea level rise viewers'. One of these is the 'Digital Coast', which catalogues and makes readily available economic, demographic, climate, elevation, land cover and other types of data, as well as satellite imagery. It also includes tools such as a coastal flood exposure mapper, a coastal resilience mapping portal and riverine flood inundation maps.

3. **The U.S. Army Corps of Engineers** has created a levee safety program helping non-federal units of government understand changes in flood risk and take actions for levee enhancement and maintenance. They also have a Floodplain Management Services program and a Planning Assistance to States program that offer technical and financial support to lower levels of government on flood risks. The Corps has developed the Silver Jackets program to help communities appreciate their flood risk, become aware of federal programs available to them and most importantly, take action to reduce and manage that risk.

Local governments

Some local governments invest in risk communication efforts but the nature of initiatives vary around the country. The following are just two examples:

1. *New York City:* After being devastated by Hurricane Sandy, the city recognised the need to educate homeowners about their current and future flood risk as depicted on the current and updated FIRMs, and so partnered with the Center for New York City Neighborhoods to develop an easy-to-use website, FloodHelpNY.org, which allows users to enter their address on a Google-Maps-like interface. Users can toggle between a view of their current and potential zone and BFE. The website conveys risk in large-font, plain language (Annex 2a).

2. *City of Portland, Oregon:* The city is providing information in its online property database of which homes were inundated in their 1996 flood event to give residents a better understanding of flood risk than the simple in/out of the SFHA designation.

5.4. Flood risk awareness among stakeholders

Flood risk awareness within and across stakeholder groups is heterogeneous. Despite the availability of flood data and models, as well as efforts to channel this information to stakeholders, it is difficult to access levels of flood awareness among different groups. While it might take scientifically valid surveys on risk understanding and risk perceptions to provide definitive insights, there are some anecdotal findings.

Households

There are multiple lines of evidence about flood risk awareness among households.

The first is the impact of flood risk on the housing market. Multiple studies have found that flood risk is capitalised into home values, indicating some understanding of the risk and/or the cost of flood insurance among buyers. Homes in the SFHA sell for less than homes outside this zone, after controlling for multiple potential differences in the properties themselves (e.g. MacDonald et al. 1990; Bin and Kruse 2006; Kousky 2010; Bin and Landry 2013). In coastal areas, however, it can be difficult to separately identify the impacts of flood risk on housing values from the high amenities of coastal location (Bin et al. 2008). At least one study found that disclosure laws, which require information to be made available earlier than the federal disclosure requirement on lenders, lower housing values in flood-prone areas (Pope 2008). The disclosure laws then must be contributing to greater flood risk awareness to some extent.

A second piece of evidence comes from a nationwide survey. In 2013, FEMA surveyed over 1,000 homeowners in order to better understand their flood risk awareness.[20] FEMA found that about three in 10 respondents believed there was flood risk in their community and 10% thought their home was at risk. FEMA also found that 70% of respondents had undertaken at least one risk reduction measure. Without objective measures of respondents' risk, however, it is difficult to interpret these numbers. Other work – such as a survey of those living behind levees in Sacramento, California – finds that residents of risky areas can be poorly informed about their flood risk (Ludy and Kondolf 2012).

Unsurprisingly, research finds that previous experience with flooding leads to higher awareness and assessed likelihood of future flooding (Keller et al. 2006). People who have been flooded in the past are more likely to implement risk reduction measures (Laska 1986; Pynn and Ljung 1999). Relatedly, several studies have found that land prices decline immediately after the property is flooded and then recover slowly over time, although prices may not rise to the levels for comparable unflooded properties (Atreya et al. 2013; Bin and Landry 2013).

Behavioural economics and psychology research related to flood risk finds that decisions are often skewed by cognitive biases such as myopia, amnesia and optimism (Meyer and Kunreuther 2017). These biases often inhibit individuals' willingness to implement flood risk management actions. For example, optimism may cause people to underestimate

20 https://www.fema.gov/public-survey-findings-flood-risk

the likelihood that a disaster will affect them personally, leading them to view flood insurance and mitigation as too expensive relative to the benefits.

Businesses

Among businesses, flood risk awareness tends to vary by firm size. Large businesses are generally more aware of flood risk because they typically have dedicated risk officers that assess, identify and manage all types of potential risks that may impact the company, including flood risk. Additionally, commercial flood coverage is widely available and large firms generally purchase all-risk policies that insure against flood and a range of other hazards. For smaller businesses, however, the risk is less well understood and managed. Many such firms may be uninsured against flood, for example, because they are not able to afford flood coverage or may view risk management as a distraction from investing in their core operations (Collier 2016).

Traditionally, property and casualty (P&C) insurance companies invest significantly at the company and industry levels in enhancing risk modelling capacities, i.e. CAT modelling capacities, research in areas of climate change adaptation and management of extreme event risks and raising awareness (The Geneva Association 2018a, 2018b, 2020b, 2020c).

In the U.S., given that most private insurers do not underwrite residential flood risk, they may not be focusing as many resources on risk awareness and related research programs on this peril as opposed to perils that the industry is underwriting, leaving this to the federal NFIP. This is an area of opportunity for the government to leverage and engage the insurance industry as the private insurance market expands.

Utilities

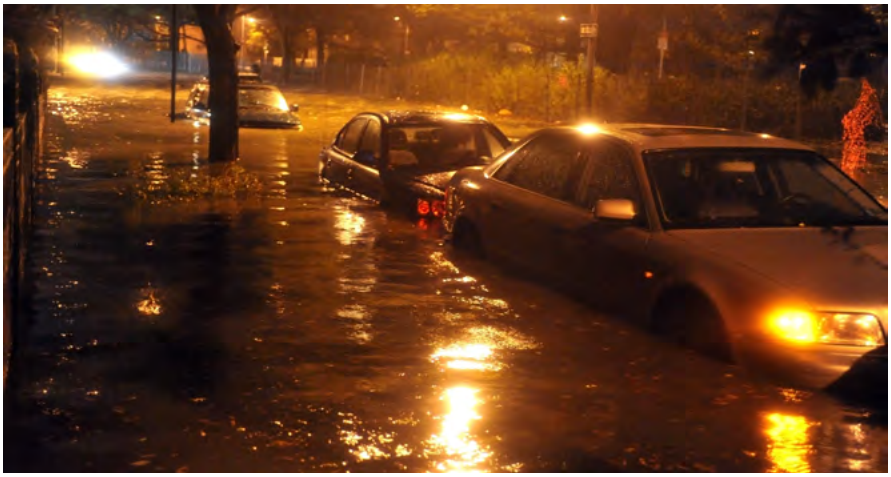
Many electric utility substations, water treatment plants and other utility infrastructure are located in flood-prone areas. When these lifelines are damaged by a flood, the economic losses cascade through communities. Recent floods of the past few years have brought this to the attention of many utility managers and more work is being done to build flood resilience at these facilities, often as part of a multi-hazard approach to building resilience to multiple hazards. Since flooding of waste water treatment facilities can contaminate water, the EPA, not typically involved in flood risk management, has prepared guidance on flood resilience for water and wastewater utilities.[21]

21 https://www.epa.gov/sites/production/files/2015-08/documents/flood_resilience_guide.pdf

6. Flood advisories and early warnings for emergency preparedness and response

The NOAA's National Weather Service (NWS) issues forecasts, warnings and advisories for weather and water-related hazards to communities across the U.S. Flood warnings originate in one of 122 Weather Forecast Field offices and are sent directly to residents' cell phones and communicated via the web, television and radio. Flood warnings and advisories are used by local governments to make decisions about evacuations, school closures, deploying first responders and other measures to protect lives and property. NOAA's National Hurricane Center issues watches, warnings, forecasts and analyses of tropical weather to protect life and property. These are the official communications about hurricane activity to be used in emergency management. The Center also conducts education and outreach activities and trainings for emergency managers and communities and provides data and tools for a range of users (Golnaraghi 2012).

Evacuation may be necessary in severe floods. State and local governments generally have evacuation protocols in place that specify how the decision-making and evacuation process should occur. State and local officials may issue mandatory, recommended or voluntary evacuation orders. They may be limited to specific neighbourhoods and communities or apply to wider regions such as multiple counties. Studies have shown that flood risk perception, perception of social and environmental cures, visual cues, flood forecasts and a home's risk level play a significant role in a household's evacuation decision (Kates and Kasperson 1983; Dow and Cutter 1998; Lindell et al. 2005; Siebeneck and Cova 2012).



Flooding caused by Hurricane Sandy, 2012

7. Flood insurance: The primary non-structural approach to flood risk management

In the U.S. the primary non-structural federal approach to FRM is the NFIP (see section 7.1.). While there is a robust private market for commercial flood insurance in the U.S., private residential flood insurance has long been limited to excess coverage for NFIP policies. That is beginning to change as a small but growing residential flood market emerges. Private flood coverage is discussed in section 7.2.

7.1. The National Flood Insurance Program

The NFIP was created in 1968 largely in response to the unavailability of private sector flood insurance.[22] Communities can voluntarily join the program by adopting and enforcing minimum floodplain management regulations. When they do so, their residents become eligible to purchase flood insurance policies through the program. As of April 2019, there were just over five million policies-in-force nationwide representing more than USD 1.31 trillion in coverage. Through the NFIP a residential property can be insured for up to USD 250,000 for the building and up to USD 100,000 for the contents. A business can insure both structure and contents up to USD 500,000.

As of February 2020, 62 insurance companies write policies and process claims on behalf of the NFIP but bear none of the risk and are not involved in rate setting. These 'write-your-own' (WYO) companies market policies and process claims (many use a vendor) in exchange for a fee. The NFIP sets pricing and issues guidance for WYO firms.

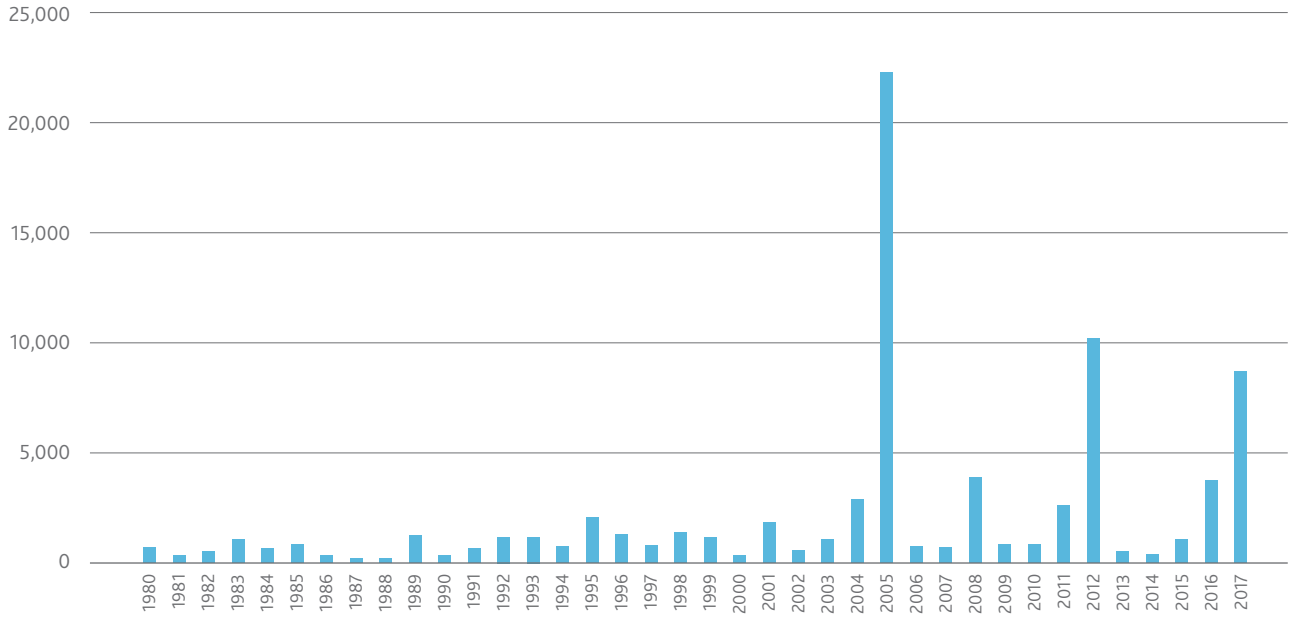
Total NFIP claims by year are shown in Figure 2. Claims appear to be growing over time. In its 50-year history, the NFIP's six costliest years have been since 2005. Table 2 provides a summary of NFIP.

Take-up rates and demand for flood insurance

Participation in the early years of the program was slow. In response, in 1973, the Flood Disaster Protection Act required communities to participate in the NFIP in order to be eligible for federal disaster aid. In addition, the law established the mandatory purchase requirement, which made flood insurance mandatory for homeowners in a 100-year floodplain with a loan from a federally backed or regulated lender. This is a requirement on the lender, not the owner.

22 An overview of the early history of the NFIP is provided by Shabman (2018).

Figure 2. NFIP claims paid in USD million



Source: NFIP

Despite the mandatory purchase requirement, many homeowners at risk of floods are uninsured against flood damages. This is due to floods occurring beyond the mapped 100-year floodplain, pluvial floods not being included in the maps (and thus not subject to the mandatory purchase requirement), and some residents of 100-year floodplains being uninsured when not subject to the mandatory purchase requirement. For example, roughly 80% of homes damaged by Hurricane Harvey lacked flood insurance (Long 2017) and in East Baton Rouge, Louisiana, nearly 90% of households were uninsured during the August 2016 floods (Calder 2016). In the U.S. as a whole, FEMA estimates that on average only about 35% of households in SFHAs nationwide have flood insurance, although take-up is much higher in coastal SFHAs, while less than 2% of households outside the SFHA are insured (FEMA 2018).

The NFIP is heavily concentrated geographically. Roughly 35% of all policies are in Florida and another 12% are in Texas. Louisiana comes in third (with almost 9% of all policies), California fourth (6%), and New Jersey fifth (just over 4.5%) (Kousky 2018a). Roughy three quarters of NFIP all policies are in only 3% of U.S. counties. This concentration is shown in Figure 3. There have been a number of studies that examine flood insurance demand in the U.S. They find that demand is greater in areas with higher flood risk, a larger share of highly educated inhabitants, a larger share of high value homes and among those with a greater perception of the risk (Kousky 2011; Petrolia et al. 2013; Atreya et al. 2015; Brody et al. 2016).

At least one recent survey finds that millennials are more likely to purchase flood insurance and think flood insurance is a good idea than older generations.[23]

Figure 3: NFIP policies by county

Source: Bradt and Kousky 2020

Premiums and affordability

Currently, the NFIP prices and policies are based on the large flood risk zones depicted on FIRMs, as well as certain characteristics of the property (such as elevation and number of stories) and whether the property has a basement. The result is large cross-subsidies within the program (Kousky et al. 2017). Given the broad zones, it is likely that households near the edge of a flood zone,

23 https://www.insurancejournal.com/news/national/2019/06/04/528323.htm

for example, are paying more than their risk for the exact same property deeper in the floodplain where flooding is more frquent. Additionally, current NFIP rating approaches do not include the value of the structure or insurance to value in setting premiums (with a minor exception of some properties in the V zone, a narrow strip along the coast); this creates a perverse cross-subsidy from low- to high-value homes.

Under its Risk Rating 2.0 initiative, FEMA is changing the way it calculates insurance premiums to more accuratley reflect the level of flood risk at a specific property. The new methodology will combine the NFIP's existing data with commercial flood CAT models and geographic and structural characteristics of individual properties. Rates calculated under the new system are scheduled to take effect on 1 October 2021.[24] This effort will make progress toward modernising NFIP pricing, improving communication about risk and eliminating the perverse cross-subsidy by accounting for home values.

Since 2014, the NFIP has also been phasing out some historic premium discounts for older structures. These price increases have called attention to the affordability of flood insurance as an important policy concern. A recent report from FEMA (2018) revealed that just over a quarter of NFIP policyholders in SFHAs are low income and just over half of non-policyholders are low income. Several reports and papers have proposed and examined possible federal policy solutions, all centred around some form of means-tested assistance for both insurance premiums and hazard mitigation investments (Kousky and Kunreuther 2014; National Research Council 2015; Dixon et al. 2017). Congress has yet to adopt such a program and a few local governments are creating their own programs to assist residents with flood insurance (Sherman and Kousky 2018).

Program financing and reinsurance

The NFIP largely relies on borrowing authority from the U.S. Treasury to pay claims in high loss years. The losses from 2005 and subsequent storms, however, were so severe that it sent the program deeply into debt, from which it has yet to recover. Many stakeholders argue that this debt should be forgiven since both FEMA and the Government Accountability Office estimate there is no way for the program to ever repay the debt. To help improve its financing, since 2017, the NFIP has purchased reinsurance on the private market. As of Q1 2020, 28 reinsurers participate in the program, up from 25 in 2017.

In 2017, the NFIP paid a USD 150 million premium to cover 26% of losses between USD 4 billion and USD 8 billion for any single event, up to a total possible payout of USD 1.042 billion. That policy paid out in full following Hurricane Harvey, but that did not deter reinsurers from continuing their participation in the program. More companies participated in the 2018 contract, which provides even greater coverage: 18.6% of losses between USD 4 billion and USD 6 billion and 54.3% of losses between USD 6 billion and USD 8 billion for any event, up to a total of USD 1.46 billion. The 2018 premium is USD 235 million.

Alternate risk transfer solutions for flood have been slowly gaining traction in the U.S. After Hurricane Sandy caused widespread damage to New York City's subway and transportation infrastructure, the Metropolitan Transit Authority (MTA) had difficulty finding sufficient financial protection in traditional insurance markets.[25] Faced with USD 4.8 billion in repair costs caused mostly by Sandy's storm surge, the MTA issued a USD 200 million CAT bond to protect against future surge-related damages.[26] The bond, first issued prior to the 2013 Atlantic hurricane season, provided coverage for three years and featured a parametric trigger based on surge levels at specific locations, allowing the MTA to access funds quickly if those surge conditions were met. The bond expired on 5 August 2016, providing a USD 27 million return to investors. The MTA issued a new, but similarly structured, USD 125 million CAT bond that will cover surge losses from 2017 to 2020.[27]

Following the MTA's lead, FEMA diversified its reinsurance program by issuing its first CAT bond, FloodSmart Re Ltd. (Series 2018-1), in August 2018, transferring USD 500 million of the NFIP's financial risk to capital markets.[28] The bond provides coverage for three years and, for a named storm, is designed to cover 3.5% of losses between USD 5 billion and USD 10 billion, and 13% of losses between USD 7.5 billion and USD 10 billion. For the first year of coverage, FEMA will pay a USD 62 million premium.[29] It is a per-occurrence, indemnity-based bond. This was followed by a smaller, USD 300 million transaction in 2019.[30] Finally in January 2020, FEMA has sought a further USD 300 million of flood protection from capital markets, with the issuance of its third CAT bond, FloodSmart Re Ltd (Series 2020-1).

24 Originally this was intended for October 2020, but it was moved to October 2021. For more information see https://www.fema.gov/nfiptransformation
25 http://www.mta.info/press-release/mta-headquarters/mta-secures-200-million-insurance-protection-future-sandy-storms
26 https://www.wsj.com/articles/SB10001424127887323681904578640401075075198
27 ttp://www.swissre.com/media/news_releases/nr20170602_metrocat.html
28 https://www.artemis.bm/deal-directory/floodsmart-re-ltd-series-2018-1/
29 https://www.fema.gov/news-release/2018/07/31/fema-expands-its-reinsurance-program-transferring-500-million-flood-risk
30 https://www.artemis.bm/deal-directory/floodsmart-re-ltd-series-2019-1/

Table 2: Overview of the National Flood Insurance Program	
Risk-based approach	• Historically, the NFIP was priced based on large zones with discounts for certain policyholders. • Beginning in 2021, it will also calculate and offer property-level risk-based rates.
Compulsory terms	• Flood insurance is mandatory for loans, federally backed or provided by federally regulated lenders, on properties located in the FEMA-mapped 100-year floodplain.
Policyholder programs	• Flood protection is usually offered as a standalone policy for residential properties.
Incentivising risk reduction	• The NFIP incentivises risk reduction by offering lower premiums for residential policyholders that have elevated their homes and for a limited number of other measures. • Residents in communities that participate in the NFIP Community Rating System are also rewarded with lower premiums.
Market penetration	• On average, take-up rates for flood insurance in the FEMA-mapped 100-year floodplain is around 35% but there is high regional variation. • Take-up rates on the hurricane-prone coast are much higher.
Insurance-backed securitisation	• The NFIP has purchased reinsurance and a CAT bond on the private market.
Finances	• As of Q1 2020, the NFIP is in debt to the U.S. Treasury as it relied on borrowing to pay high-loss years. • This debt is unsustainable, warranting financial reform of the program.

Source: The Geneva Association

7.2. Private-sector flood insurance

Commercial private flood insurance has long been available, often as a part of comprehensive, all-peril policies for large companies. In the last few years, a small but growing, private residential flood insurance market has emerged in the U.S. For many years, private insurers were primarily underwriting the so-called 'excess' policies above the NFIP coverage. There is also a market for lender-placed policies, or those forced on borrowers by their lenders for failure to comply with the mandatory purchase requirement. What is new, however, is a growing private-sector presence in underwriting stand-alone flood policies or offering flood endorsements on homeowners' policies. It is estimated that less than 5% of all residential flood policies in the U.S. were written by the private sector in 2018, with the rest in the NFIP, although the private market is growing (Kousky et al. 2018).

In the U.S., given the dominance of the NFIP, many supporting functions such as mapping and actuarial expertise normally provided by private sector insurers, have not been developed outside the government, although that may be starting to change. For example, inland flood models for the U.S., as discussed earlier, have only recently been developed by CAT modellers to support the nascent private flood insurance industry. Similarly, industry-funded centers and platforms, such as the Institute for Building and Home Safety (IBHS),[31] typically did not focus on flood-risk reduction since this was not a peril covered by the private sector.

Private insurers are targeting areas where they can offer coverage more cheaply than the NFIP. The NFIP is required to write a policy for any property in a participating community, such that the private sector must be, by default, in competition with the program. There is variance in where companies can find a niche and the terms of the policies they offer (Kousky et al. 2018).

As with the NFIP, one of the biggest challenges facing the private residential market is low demand. Unlike the NFIP, however, the private sector may be able to create products that better respond to customer needs and preferences. Believing they can be competitive, firms are offering different coverages, targeting different types of properties and using different pricing and underwriting strategies to make cheaper and broader coverages available. Yet, while the number of private policies is growing, it is unclear what effect this has had on increasing the total number of insured households. Firms believe their portfolios include both newly insured homeowners as well as those switching from the NFIP; however, there is no data to quantify the net effect (Kousky et al. 2018).

31 https://ibhs.org/

8. Flood mitigation programs

In the U.S. flood mitigation is funded and incentivised through multiple federal programs. These funds and incentives, along with additional local resources, provide states and municipalities with opportunities to implement flood mitigation programs. Some programs target households and businesses with opportunities to retrofit their own structures.

8.1. Federal flood mitigation efforts

Several federal agencies provide grants or incentives for hazard mitigation. FEMA funds a range of hazard mitigation efforts by local governments, the Corps of Engineers builds large flood infrastructure and the Department of Housing and Urban Development (HUD) offers block grants to local governments for long-term recovery that often also involve risk reduction.

A review of federal flood mitigation spending reveals that over 90% of all federal dollars are appropriated in off-budget supplemental legislation, tied to a particular disaster, with much less appropriated pre-disaster (Kousky and Shabman 2017). Much of the post-disaster spending may be used to reduce future risk; however, it is only available to the impacted areas. While this targets funds at incorporating mitigation measures into rebuilding, a new 2018 law aims to shift more spending on mitigation efforts to pre-disaster.

Flood mitigation and the NFIP

The NFIP has three approaches to promoting and incentivising flood-risk reduction:

1. In order for communities to participate in the NFIP, they must adopt minimum floodplain management regulations in the SFHA. The most notable is that all new construction, or substantially improved or damaged properties in SFHAs, must be elevated such that the lowest floor is at or above the BFE, which is the estimated height of floodwaters in a 100-year flood (non-residential structures can also be dry flood-proofed). In V zones, additional building requirements apply to address the force of waves.

2. The NFIP also creates incentives for communities to undertake additional actions through the Community Rating System (CRS). This voluntary program, established in 1990, rewards communities with lower flood insurance premiums for voluntarily reducing their flood risk. Eligible activities are grouped into four categories: (1) public information, (2) mapping and regulation, (3) flood damage reduction and (4) flood preparedness. As of 2014, only 5% of NFIP communities participated in the CRS, but they accounted for 67% of all policies-in-force (FEMA 2014). Only five communities nationwide have attained one of the two highest classes.[32]

3. The NFIP offers financial incentives for households. Premium reductions are given when homes are elevated. Additionally, through the NFIP's Increased Cost of Compliance Coverage (ICC), NFIP policyholders can receive additional funds with a claim payment to help bring their flood-damaged structures into compliance with current state and local floodplain management regulations designed to reduce future flood risk. For residential properties, ICC provides up to USD 30,000 for homeowners to elevate, relocate or demolish their properties after a flood; total payouts cannot exceed the maximum coverage limit. In recent years, the program has been criticised because it is not well understood by homeowners, and because it often fails to cover the full cost of eligible mitigation measures.

What is the Community Rating System?

The CRS is an incentive program of the NFIP. Communities are awarded points when they undertake flood-risk reduction or outreach activities. As they move up in the program, residents may become eligible for discounts on flood insurance.

Flood mitigation grants from FEMA

FEMA has several grant programs that provide funds for flood-risk reduction, collectively referred to as the Hazard Mitigation Assistance (HMA) programs. These include the Flood Mitigation Assistance (FMA) program, the Pre-Disaster Mitigation (PDM) program, and the Hazard Mitigation Grant Program (HMGP) (Box 4).

Across FEMA's HMA programs, state agencies submit proposals to FEMA, including sub-applications from local governments. State and local government applicants must have FEMA-approved hazard mitigation plans in place to apply for a grant. For FMA, local government sub-applicants must also have a plan that addresses flood hazards specifically. All properties included in an FMA application must be insured by the NFIP, and structures that receive mitigation funding must be insured against flood damages in perpetuity, even if the property is sold. If the property owner fails to maintain insurance coverage, they will be ineligible for federal disaster aid in the case of future floods.

FEMA's HMA programs provide funds for the following types of flood mitigation measures:

- Property acquisition and structure demolition (or relocation)
- Structure elevation
- Mitigation reconstruction
- Dry flood-proofing of historic residential structures
- Localised flood-risk reduction projects (e.g. culverts, stormwater management facilities, retention and detention basins, floodwalls, dams, etc.)
- Structural retrofitting of existing buildings
- Non-structural retrofitting of existing buildings and facilities
- Infrastructure retrofit
- Soil stabilisation
- State- and local-mitigation planning[33]

32 These include Roseville, California; Tulsa, Oklahoma; King County and Pierce County, Washington; and Fort Collins, Colorado. Several studies have examined reasons for communities participating in the CRS and the activities they chose to pursue (Brody et al. 2009; Landry and Li 2012; Highfield and Brody 2017).

33 For additional information on each of these measures, see FEMA's Hazard Mitigation Assistance Guidance, pages 34-38 at https://www.fema.gov/media-library/assets/documents/103279

Box 4: FEMA's mitigation programs and grants

- **Flood Mitigation Assistance (FMA)**: provides funding annually to NFIP-participating communities and policyholders to implement actions that reduce future flood damages and claims to the NFIP. FMA is funded entirely by NFIP premium revenue rather than discretionary appropriations from Congress. The FMA program prioritises Repetitive Loss[34] and Severe Repetitive Loss[35] properties, i.e. structures that have repeatedly suffered flood damages and have proven to be the costliest to the NFIP.[36]

- **Pre-Disaster Mitigation (PDM)**: provides funds for hazard mitigation that reduce damages from floods and other types of disasters. PDM funds projects located in SFHAs only if the community participates in the NFIP. PDM is funded annually by Congressional appropriations. Grants are subject to a cost-sharing arrangement in which non-federal partners are required to contribute 25% of project costs. However, FEMA may cover up to 90% of costs for small, impoverished communities.[37] Among the flood mitigation measures eligible for PDM, most funding between FY 2000 and FY 2016 has been received for mitigation planning (20%), property acquisitions (18%) and flood control (12%).

- **Hazard Mitigation Grant Program (HMGP)**: funds to state and local governments to implement mitigation measures following a federally declared disaster. HMGP provides funding to states, tribal governments, local governments and non-profit organisations that have been affected by a major disaster to carry out risk-reduction actions intended to reduce the adverse consequences of floods and other hazards. Applicants (and sub-applicants) must have a FEMA-approved state or tribal hazard mitigation plan in place at the time of the major disaster declaration and at the time the award is obligated. The amount of HMGP funding available to an applicant is determined by the overall amount of federal assistance FEMA allocates under the major disaster declaration (excluding administrative costs) and on whether their approach is an 'enhanced' mitigation plan. HMGP is subject to a cost-sharing requirement in which FEMA may contribute up to 75% of eligible activity costs and applicants/sub-applicants are responsible for the remaining 25%. Of the USD 13.2 billion in HMGP funds committed between 1989 and 2016, 81% was attributable to floods and flood-related events.

Source: The Geneva Association

In October 2018, the President signed into law the Disaster Recovery Reform Act of 2018 (DRRA), which makes several changes to FEMA programs and operations with the aim of reducing the rising costs of disasters caused by natural hazards.[38] One of the most significant changes DRRA makes is providing for greater investment in pre-disaster hazard mitigation. Specifically, the bill allows up to 6% of the disaster assistance provided under FEMA's Public Assistance and Individual Assistance programs to be deposited into a 'National Public Infrastructure Pre-Disaster Mitigation Fund'.[39] According to FEMA, under a program called Building Resilient Infrastructure and Communities (BRIC), grants made from this fund will be awarded on a competitive basis to public infrastructure projects designed to promote resilience. DRRA also allows state and local governments to use PDM funds to establish and enforce stronger building codes. Further, DRRA expands the criteria for PDM assistance to include the extent to which a state or local government applicant has facilitated the adoption and enforcement of the most recent hazard-resistant building codes, providing an incentive for state and local governments to adopt such codes.

34 A Repetitive Loss property is an NFIP-insured structure that (a) has incurred flood-related damage on two occasions in which the average cost of repair equaled or exceeded 25% of the structure's market value, and (b) at the time of the second incidence of flood-related damage, the flood insurance policy contained ICC coverage.

35 A Severe Repetitive Loss property is an NFIP-insured structure that has incurred flood-related damage for which four or more separate claims payments (building and contents) have been made, each exceeding USD 5,000; or, for which at least two separate claims payments (building only) have been made, with the cumulative amount exceeding the market value of the insured structure.

36 A 2004 Government Accountability Office study found that RL properties made up just 1% of policies, but 38% of claims payments from 1978 to 2004. And according to a study from the Natural Resources Defense Council, SRL properties accounted for 0.6% of policies- in-force, but 10.6% of claims payments from 1978 to 2015 (Eastman 2016).

37 For a complete definition of 'small impoverished community', see Page A3 of FEMA's Hazard Mitigation Assistance Cost Share Guide For Applicants, Subapplicants, and FEMA, available at https://www.fema.gov/media-library/assets/documents/117020

38 DRRA is Subdivision D of H.R. 302, the 'FAA Reauthorization Bill of 2018'. See https://www.congress.gov/bill/115th-congress/house-bill/302/text

39 Specifically, the bill authorises a set-aside of up to 6% of disaster assistance provided under sections 403 (Essential Assistance), 406 (Repair, Restoration, and Replacement of Damaged Facilities), 407 (Debris Removal), 408 (Federal Assistance to Individuals and Households), 410 (Unemployment Assistance; Emergency Grants to Assist Low-Income Migrant and Seasonal Farmworkers), 416 (Crisis Counselling Assistance and Training) and 428 (Public Assistance Program Alternative Procedures) of the Stafford Act.

Flood mitigation and the U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) plans and constructs infrastructure projects to mitigate the impacts of riverine and coastal flooding in communities throughout the U.S. USACE's FRM and coastal storm risk management (CSRM) projects include the construction of levees, floodwalls, dams, reservoirs, beach berms and sand dunes, as well as the channelisation of rivers and tributaries. Projects are directed by Congress through a Water Resources Development Act, usually passed every two years. These bills authorise water resources studies and projects, including flood control projects, and set policies for the USACE.

FRM and CSRM projects typically begin with a request for assistance from a non-federal co-sponsor. They must next go through a feasibility study. The study evaluates an array of alternative project plans and identifies the plan that provides the greatest net economic benefits to the nation, subject to an environmental protection constraint. The selected plan may then be recommended for Congressional authorisation and funding.[40]

Over the six-year period from FY 2011 to FY 2016, regular funding for flood project studies and construction averaged roughly USD 490 million annually with about USD 40 million dedicated to feasibility studies and USD 450 million to construction. Following Hurricane Sandy, the Disaster Relief Appropriations Act of 2013 provided USD 3.5 billion in supplemental appropriations to USACE, approximately 99% of which was earmarked for CSRM construction projects in the USACE North Atlantic Division, mostly for beach nourishment. This follows a recent trend of the USACE receiving much more funding for construction from off-budget disaster supplemental legislation than through annual appropriations.

The USACE also runs a levee safety program to assess the integrity of levees and recommend actions as needed to manage risks. As part of this, the USACE maintains a database and inventory of constructed levees and has developed methodologies for technical risk assessments of levees. Under Public Law 84-99, the USACE can help communities repair levees that are damaged in a flood.

Flood mitigation and other federal agencies

The Coastal Zone Management Act was passed in 1972 to 'preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone'. The Act includes a National Coastal Zone Management Program, a National Estuarine Research Reserve System and the Coastal and Estuarine Land Conservation Program. While not explicitly developed to manage flood risk, in focusing on protecting the coastal environment, it may address flood risk through protective actions taken in the coastal zone.

The Coastal Barrier Resources Act (1982) was passed in response to growing concerns regarding development on coastal barriers, i.e. areas with both high risk of flood and storm damage as well as high ecological value. Coastal barriers also provide a protective function to the coast, reducing winds and storm surge. In recognition of this, Congress designated certain areas as part of the Coastal Barrier Resources System.[41] There are a number of restrictions related to federal spending, disaster aid payments and use of the NFIP.[42]

NOAA houses the Coastal Resilience Grants program, which provides annual funding on a 2:1 match basis for projects supporting coastal storm and flood resilience, as well as restoring marine and coastal ecosystems. The program is relatively new and has a small budget. Many of the grant awards are for risk information and planning. Those that support project implementation focus on the ecological restoration of wetlands, with storm-surge reduction as one possible benefit.

The Flood Apex Program within the Department of Homeland Security's Science & Technology Directorate funds work to reduce the threats of flooding to the nation.

State and local flood mitigation

Across the U.S. there are various state and local efforts to mitigate flood risk and these take a number of forms. Generalisations are difficult, as some communities engage heavily in flood-risk reduction and others not at all. For those that do pursue flood mitigation, there are also a wide range of activities, such as property acquisitions, structure elevations and implementing engineered and ecosystem-based, disaster risk-reduction measures.

40 Feasibility studies are required to evaluate the extent to which each alternative plan reduces economic and life-safety risks, as well as anticipated, remaining residual risks from implementing an alternative plan. A probabilistic risk assessment explicitly characterises and considers uncertainties. A feasibility study may end with a recommended plan or the decision to take no action. If Congress authorises a specific project, it becomes eligible for inclusion in the President's annual budget request, and then construction appropriations in the annual Energy and Water Appropriations Act. Congressional authorisation does not necessarily mean that Federal construction funds will be forthcoming; many authorised FRM and CSRM projects never receive Federal funding and do not proceed to construction.

41 The U.S. Fish & Wildlife Service maps the Coastal Barrier Resources Act boundaries.

42 Within this system, federal spending on infrastructure is prohibited, as are disaster-aid payments. Additionally, NFIP policies cannot be implemented in the system. Communities are allowed to continue to develop in these regions independently but without federal support, including subsidies for development in high-risk areas that provide important services while undeveloped. However, FEMA assistance is allowed when emergency work is needed to protect against immediate safety threats, as well as for applicants located in these areas who need temporary housing assistance, medical assistance or crisis counselling, provided they meet the eligibility requirements.

Many are partially funded through the federal programs discussed above. Examples are provided in two case studies, New York City and North Carolina in Annexes 2a and 2b, respectively.

There is a growing recognition of the flood challenges associated with stormwater and multiple communities are addressing higher stormwater flood risk. For example, in 2012, the Metropolitan St. Louis Sewer District (MSD) launched a USD 4.7 billion campaign to update St. Louis' neglected storm-sewer infrastructure over several decades, which includes a USD 100 million green-infrastructure initiative. As part of this campaign, in 2016, voters approved funding MSD's stormwater system with a uniform districtwide property tax rate to give it more flexibility to fund infrastructure updates and mitigation projects where there is the greatest need.[43] As another example, in 2017, Miami, Florida passed a USD 400 million bond, the 'Miami Forever Bond', to invest in flood mitigation measures and other resilience measures.

Several states and local governments have established buyout programs, which acquire flood-prone property and then preserve it as open space. For example, in Charlotte-Mecklenburg County, North Carolina's Storm Water Services office has worked since 2000 to acquire land through strategic buyouts of flood-damaged properties. The state of North Carolina has also pursued buyouts of flood-prone land using dollars from the grant programs discussed above. In fact, over the past 25 years, FEMA has funded the acquisition of over 5,600 homes in the state. There have also been buyouts in many other local jurisdictions, from New Jersey, through their Blue Acres program, to St. Louis, Missouri, to Portland, Oregon. Buyouts tend to be used for riverine flood risks more than in coastal locations, such as the program in Cedar Rapids, Iowa after their 2008 floods (Tate et al. 2016). Local governments can sometimes harness additional benefits from buyouts by using the land for recreational or conservation purposes (Environmental Law Institute and UNC Institute for the Enviornment 2017).

Before many of these activities are funded and implemented, they are typically documented in a state or local government's multi-hazard mitigation plan. Plans are required as a precondition for receiving certain types of federal disaster assistance. In developing these plans, state, local, and tribal governments must carefully assess the potential impacts of a range of natural hazard risks, including flood. This typically involves collecting flood-risk information and conducting risk assessments; establishing a long-term mitigation strategy, including identifying specific actions and activities to reduce losses; and establishing a coordinated process to implement and maintain the plan over time. As of December 2018, all 50 states and nearly 21,000 local governments had current, FEMA-approved mitigation plans in place.[44]

Despite the active flood risk management by select states and local governments, there are also many areas of the country at risk of flooding where the risk is not actively addressed. In many places, building codes and land-use regulations are only the bare minimum required by the NFIP (if they are a participating community). These minimum floodplain regulations, as discussed, are constantly outdated in areas of increasing flood risk since they are based on backward-looking maps, not future projections of an evolving threat. Further, there is little financial incentive for local governments to be more aggressive with limiting development in high-risk areas since they receive all the benefits from higher tax revenue and share minimally in the disaster costs.

43 https://www.stltoday.com/business/local/voters-approve-msd-bonds-stormwater-tax/article_21d0274d-c051-5373-90ba-1aa33142c400.html
44 https://www.fema.gov/hazard-mitigation-plan-status

9. Post-flood response and reconstruction

Impacted households, businesses and local governments must typically manage recovery from small-scale and localised flood events on their own. For large events, the federal government has played an increasing role in helping coordinate and fund recovery and reconstruction.

Federal involvement in post-flood recovery and reconstruction is governed by the Robert T. Stafford Emergency Relief and Disaster Assistance Act of 1988 (Stafford Act), which authorises the President to provide federal assistance when the expected costs for recovery from a disaster exceed state and local governments' fiscal capacity to respond or recover. When a flood event is so severe state and local governments cannot effectively respond on their own, the President may issue a major disaster or emergency declaration. For more detail on the process, see McCarthy (2014). Figure 4 shows major federally declared disasters since 1980. The number of declarations has grown somewhat over that time period. The overwhelming majority are for flood-related events.

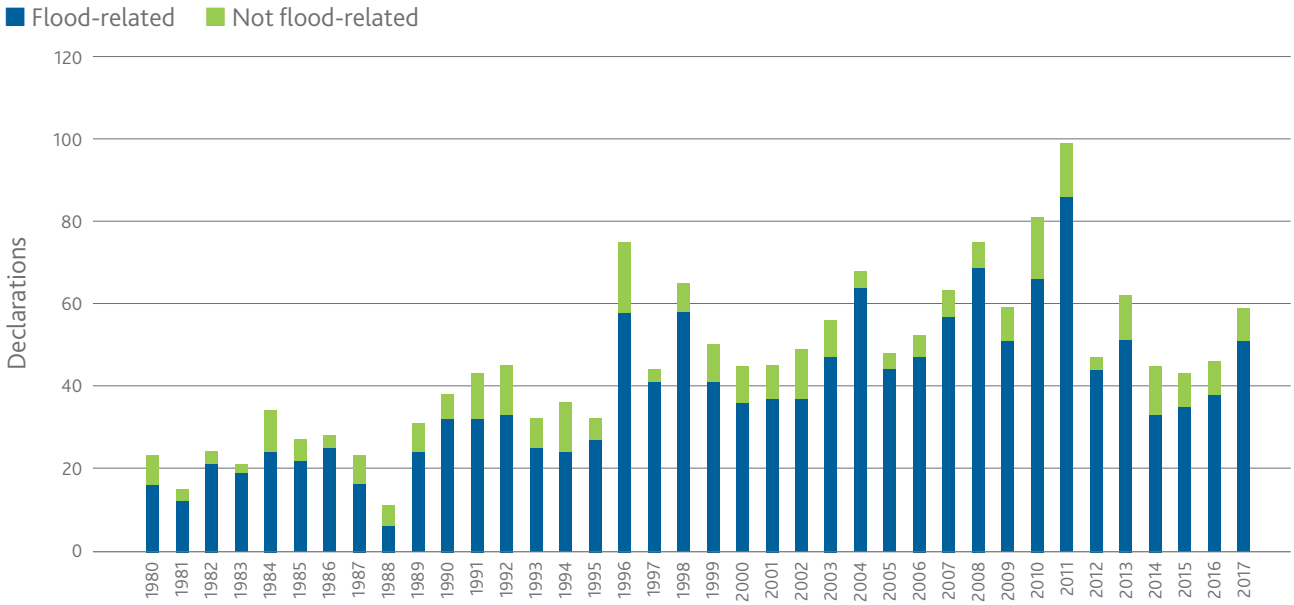
9.1. FEMA

When a President issues a disaster declaration, s/he can choose to authorise one or both of two programs: Individual Assistance (IA), providing assistance to households, and Public Assistance (PA), providing assistance to state and local governments. These are post-disaster grant programs administered by FEMA. From 2005 to 2014, IA was authorised in only 35% of major disaster declarations.[45] Major disaster declarations have resulted in IA in 57% of hurricanes, 36% of severe storms and 25% of floods. PA has beenauthorised much more frequently. Major disaster declarations provided PA in 92% of severe and coastal storm declarations, 94% of flood declarations and 98% of hurricane and typhoon declarations.[46]

45 According to FEMA data, IHP was only authorised under two emergency declarations between 2005 and 2014: once in 2011 for Hurricane Irene in Connecticut and again in 2013 following a fertilizer plant explosion in Texas.

46 According to FEMA data, IHP was only authorised under two emergency declarations between 2005 and 2014: once in 2011 for Hurricane Irene in Connecticut and again in 2013 following a fertilizer plant explosion in Texas.

Figure 4. Major federally declared disasters



Source: Data from FEMA as of 1 February 2018

Individual Assistance

Through the Individuals and Households Program (IHP), FEMA provides financial assistance to disaster victims. There are two types of assistance available under IHP: Housing Assistance (HA); and Other Needs Assistance (ONA). HA provides limited funding for the repair or replacement of damaged homes or temporary housing needs; ONA provides funding for expenses caused by the disaster, such as replacing personal property, transportation, medical and dental expenses, child care expenses and funeral costs.[47]

IHP grants are focused solely on recovery and intended to help disaster victims meet basic needs when those needs are not covered by insurance or provided by another source. According to FEMA, 'IHP is not a substitute for insurance and cannot compensate for all losses caused by a disaster; it is intended to meet basic needs and supplement disaster recovery efforts' (FEMA 2016). As such, IHP assistance is capped at an inflation-adjusted amount every fiscal year, based on the Consumer Price Index. It was set at USD 33,300 for FY 2017, but the average grant is usually only a few thousand USD.[48]

In accordance with Section 408 of the Stafford Act, ONA is subject to a cost-share in which FEMA covers 75% of eligible expenses and the state, territorial or tribal government covers the remaining 25%. HA, however, is funded entirely by FEMA with no cost-sharing requirement. Furthermore, as a condition of IHP assistance, and in order to receive any future federal assistance for flood damages, applicants living in the SFHA must purchase and maintain a flood insurance policy for at least the amount of assistance received.[49]

Public Assistance

The PA program provides funding for state, local and tribal governments post-disaster. To be eligible for PA funding, work must 'be required as a result of the disaster, be located within the designated disaster area and be the legal responsibility of an eligible applicant'.[50] The PA program provides funding for three eligible purposes: emergency work, permanent work and management costs.[51, 52]

As a prerequisite for receiving permanent work assistance, eligible recipients must have a FEMA-approved state or

47 Before receiving HA and certain types of ONA, applicants must be able to prove that they occupied the damaged property as their primary residence prior to the disaster.

48 This aid is not counted as income and is tax-free. FEMA may provide IHP grants for up to 18 months after the declaration date; this period may be extended in extraordinary circumstances.

49 This applies only to real and personal property that can be insured by the NFIP. Flood insurance coverage must be maintained at that address for as long as it exists, as the requirement is reassigned to the next owner.

50 44 C.F.R. §206.223(a)

51 Permanent work is organised into five categories: roads and bridges; water control facilities; buildings and equipment; utilities; and parks, recreational, and other facilities.

52 As established in Section 406 of the Stafford Act, the federal government covers a minimum of 75% of PA project costs, leaving the grant recipient responsible for a maximum amount of 25%. The non-federal cost-share may be reduced or waived at the discretion of the President, typically with a recommendation from FEMA. For declarations issued from 2004 to 2011, the recipient's cost-share was reduced or eliminated in 20% of all declarations (GAO 2012).

tribal mitigation plan in place.[53] Recipients must also agree to purchase and maintain an insurance policy for the type of hazard that damaged the facility and for which grant funds are being used for repair.[54, 55] For all hazard types, grants are reduced by the amount of eligible insurance coverage in force when a disaster strikes. This applies to PA grants, as well, for repairing public property. This requirement aims to incentivise governmental property owners to purchase flood insurance prior to a disaster.[56, 57]

9.2. Small Business Administration

For most disaster victims, SBA loans are the principal source of government assistance. Under the Small Business Administration's (SBA) Disaster Loan Program, the SBA provides low-interest loans to business owners, homeowners and renters to 'repair, rehabilitate or replace property, real or personal, damaged or destroyed by or as a result of natural or other disasters'.[58] SBA's disaster loan program is supported by annual Congressional appropriations and by occasional supplemental appropriations made for major catastrophes. Although the program is available through the SBA, the vast majority of disaster loans (approximately 83%) are provided to individuals and households (Lindsay 2015).[59]

The program allows homeowners to borrow up to USD 200,000 to restore disaster-damaged homes to pre-disaster condition.[60] Homeowners and renters may borrow up to USD 40,000 to repair or replace personal property lost or damaged in a disaster. Eligible items include cars, clothing, appliances and furniture. Funds cover only uninsured or under-insured losses and may not be used to make upgrades, expansions or improvements to a property unless required by local building regulations. However, homeowners may receive additional funds to carry out hazard mitigation measures to reduce losses from similar future disasters. Mitigation funds may total up to 20% of homeowners' physical losses, though the maximum loan may not be more than USD 200,000.

SBA offers two types of loans to businesses located in disaster areas: Business Physical Disaster Loans and Economic Injury Disaster Loans, the latter of which are targeted at small businesses that cannot obtain credit elsewhere.[61] The loans only cover damages not covered by insurance. The economic injury loans are for businesses that are not able to meet obligations and pay ordinary expenses due to a disaster.[62]

9.3. Department of Housing and Urban Development

Since 1992, Congress has used HUD's Community Development Block Grant – Disaster Relief (CDBG-DR) program to provide flexible grants to support recovery from federally declared disasters, with a focus on lower-income areas. The program requires supplemental appropriations from Congress; it does not have standing funding. Entities eligible for CDBG-DR funds may include states, local governments, tribes and other governmental units designated in a major disaster declaration. Grantee communities must have significant unmet needs and limited capacity and resources to recover.

Eligible activities are typically identified in appropriations legislation, but state and local governments have significant flexibility in how they spend grants. Most funds are dedicated to housing repair and reconstruction, restoration of public facilities and infrastructure and economic development activities to revitalise disaster-stricken areas. Beyond these, CDBG-DR funds are also used for mitigation measures that lessen the likelihood of future disaster damages.[63] As with many of the other

53 Plans must include a description of the planning process, risk assessments, a risk-reduction strategy, coordination of local/state planning, a plan maintenance process, a plan adoption process and assurances of compliance with federal laws. Plan funding varies by state, tribe and municipality. PDM, HMGP, and FMA funds can and have been used to fund them.

54 At the very least, property owners are required to maintain coverage equal to the amount of aid they have received through the PA program. For all hazard types, grants are reduced by the amount of eligible insurance coverage in force when a disaster strikes.

55 42 U.S.C. §5172d. See https://www.fema.gov/pdf/government/grant/pa/9580_3.pdf. This reduction is not applied to PNPs located in communities that do not participate in the NFIP. However, for these facilities to receive PA funds, the community must agree to join the NFIP within six months, and the PNP must obtain the required flood insurance.

56 In 2015, FEMA modified this policy to allow applicants (in certain cases and with FEMA approval) to comply with the insurance requirement through a self-insurance plan. See https://www.fema.gov/media-library-data/1436442397459-a1a4197f9528308d6d190ceb14418327/FP206-086-1_PublicAssistancePolicyInsurance_062915.pdf

57 This policy has been difficult to implement. See https://www.oig.dhs.gov/assets/GrantReports/2015/OIG_15-19-D_Dec14.pdf

58 Small Business Act of 1953, see Tile 15 of the United States Code, Chapter 14A, available at: https://www.law.cornell.edu/uscode/text/15/chapter-14A

59 The maximum interest rate is 8% per year or 4% if SBA determines the borrower cannot obtain credit elsewhere. Applicants must meet criteria to show they are creditworthy.

60 Second homes and vacation properties are ineligible for the program.

61 The physical disaster loans can be up to USD 2 million for qualified businesses or non-profits and used to repair or replace real property, machinery, equipment, fixtures, inventory or leasehold improvements.

62 They can be up to USD 2 million with the loan amount based on actual economic losses and financial needs.

63 For funds appropriated in response to Hurricane Sandy, HUD put a strong emphasis on mitigation and resilience efforts, much more so than for previous appropriations (Gundlach and Jones 2016). Recent appropriations have also required that properties in the SFHA be elevated one or two feet above the BFE.

federal assistance programs, a HUD-assisted homeowner with a property located in a Special Flood Hazard Area (SFHA) must obtain and maintain flood insurance.

Since 1993, there have been 24 CDBG-DR appropriations in total, providing nearly USD 60 billion to disaster-affected communities across the United States. While funds support recovery from all types of hazardous events, more than 90% have been appropriated in response to floods, storms and hurricanes.[64]

Beyond CDBG-DR, HUD has several other programs. HUD's Section 203(h) program provides loans to rebuild or replace damaged homes. The loans are given through the Federal Housing Administration (FHA) to those whose homes are located in a federally declared disaster area. A down payment is not needed, but the mortgage insurance is not free and includes an up-front insurance premium. Additionally, HUD limits the amount that may be insured and FHA caps the dollar value of the mortgage that can be covered through the program in order to ensure that programs can serve low- and middle-income individuals.

Additionally, the FHA operates a foreclosure moratorium program, which stops the beginning of a foreclosure or delays a foreclosure that may be underway. Typically, the foreclosure moratorium 'pauses' the process for 90 days for borrowers who live within the geographic area of a federally declared disaster area, whose ability to make mortgage payments was directly impacted by the disaster, whose mortgage was less than 60 days past due prior to the disaster and who have not already been approved for a forbearance or other loss mitigation program.

HUD also operates a housing counselling service for those impacted by disasters caused by natural hazards. These counsellors can help residents navigate between various stakeholders, including FEMA, banks, insurance companies and aid organisations, understand the housing disaster recovery process, protect against mortgage defaulting and foreclosure and avoid predatory loans.

9.4. Internal Revenue Service

The Internal Revenue Service (IRS) allows taxpayers to make deductions for casualty losses, and since 2017 tax reform, is limited to only those in presidentially declared disaster areas. The IRS defines these casualty losses as those resulting from 'the damage, destruction, or loss of property from any sudden, unexpected, or unusual event such as a flood, hurricane, tornado, fire, earthquake, or volcanic eruption'.[65] In general, casualty losses are deductible in the tax year in which they occurred. However, if a taxpayer suffers a casualty loss in a presidentially declared emergency or major disaster area where FEMA's IA or PA programs have been authorised, they may choose to treat the loss as having occurred in the preceding tax year to receive a faster refund.[66]

9.5. U.S. Department of Agriculture

To help protect farmers against crop losses from floods and other disasters caused by natural hazards, crop insurance is provided through the U.S. Department of Agriculture (USDA). Private insurance companies write the coverage and must provide crop insurance to any eligible farmer. Rates and policy terms are set by the Risk Management Agency within the USDA.[67] The federal government reinsures the program, subsidises the premiums for farmers and reimburses the private companies for administrative costs. Between 2007 and 2016, crop insurance cost the federal government USD 72 billion, of which USD 43 billion went to producers.[68]

In addition, to help farmers after floods damage their crops and structures, the USDA offers several assistance programs. The USDA has an emergency loan program to provide eligible farmers with low-interest loans, up to a maximum of USD 500,000, to fund recovery from physical and production losses from flooding (or other disasters caused by natural hazards).[69]

64 After Congress makes appropriations, HUD determines how much to provide each state grantee based on damage estimates and unmet needs. CDBG-DR Grantees then prepare Action Plans for HUD's approval detailing how they will use the funding. Funds may be allocated in phases, with potentially different requirements and amounts applying to each tranche.

65 The tax deduction applies to real and personal property as well as business and income-producing property. For more information, see https://www.irs.gov/taxtopics/tc515

66 https://www.irs.gov/publications/p547#en_US_2016_publink1000225410

67 As early as 2005, RMA invested in developing CAT risk modelling methodologies from the insurance sector to assess and manage agricultural losses caused by natural events such as hail storms.

68 https://www.everycrsreport.com/reports/R45193.html

69 Loans can be used to restore or replace property, cover production costs, pay living expenses, reorganize farm operations, or refinance certain debt. The USDA has several other programs to assist post-flood, including a Livestock Indemnity Program, the Non-insured Crop Disaster Assistance Program, the Tree Assistance Program (to replace lost trees), the Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program, and the Environmental Quality Incentives Program. For more information, see: https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2017/emergency_loan_program_oct2017.pdf

10. Conclusions: Successes, continued challenges and lessons learned

The United States has been actively managing flood risk for over a century. During that time, the approach has shifted from one of attempting to control water to a focus on a broader range of flood risk management tools, including use of natural infrastructure, multi-stakeholder preparedness and use of financial incentives, including insurance. The federal government has also taken a more active role in disaster recovery and in funding risk reduction investments, although most mitigation spending tends to be post-disaster. More recently, the policy focus has shifted towards developing flood resilience among households, communities and businesses. This is true not just at the federal level, but for many local governments and non-governmental organisations.

In recent years, there has been a dramatic improvement in abilities to measure and model flood risk at fine spatial scales. This information is increasingly made available to all stakeholders and has led to more emphasis on best practices for risk communication. However, the level of flood risk awareness and effective utilisation of this information in decision-making by households, small businesses and communities is still limited. For example, despite flood disclosure laws, many potential property owners are not provided relevant, useful and timely information to guide their decisions on where to live and how to mitigate flood risk to their homes.

Flood risk management and efforts to build flood resilience are shared across multiple federal agencies, state governments, local governments, the private sector, non-profits, businesses and households. Authorities involved in flood risk management are spread across levels, agencies and sectors, which can lead to fragmented approaches, conflicting incentives, duplication of efforts and gaps in policies. On the other hand, this can also create synergies and robustness in the system. Improved coordination would be useful, but is difficult to organise and sustain.

With increasing flood risk linked to continued floodplain and watershed development, ageing infrastructure, sea level rise, and changing precipitation and storm patterns, many stakeholders have been calling for more aggressive investments in forward-looking flood mitigation measures. The most recent evidence of this is a piece of 2018 legislation that allocates a greater share of federal disaster aid to pre-disaster mitigation. However, more aggressive mitigation efforts are necessary for properties that repeatedly suffer flood damage and more investments are needed to upgrade ageing infrastructure and adapt it for climate change.

There has also been a proliferation of efforts to better understand and communicate changing flood risk to stakeholders. Several organisations have been created in the last few years with the goal to improve understanding of escalating flood risk and make data and modelling available to a wide range of stakeholders. While the available information is growing, there are not always supporting local public policies to guarantee that developers consider flood risk before breaking ground and that purchasers of property are made aware of how flood risk could evolve over their life in a structure. This could soon change with the integration of such information into property listings.

The last 50 years has seen the rise of the NFIP as a key non-structural flood risk management approach. The NFIP supports flood mitigation and the availability of risk information, as well as provides flood coverage for over five million properties. However, this is only a small share of those at risk from floods and a large flood insurance gap remains in the U.S. This gap can impede financial recovery, as federal disaster aid programs are either insufficient for rebuilding (such as the IA grants) or do not make their way to property owners until months, or more typically years, after the disaster (as in the HUD CDBG-DR program). A larger driver of lack of flood insurance is the cost. As discussed above, multiple stakeholders have recommended means-tested assistance for lower-income families to afford insurance, but Congress has yet to adopt such a program.

The private insurance industry has recently begun to write residential flood coverage, although the NFIP remains the dominant provider. While there was always a more robust commercial flood insurance market (largely through multi-peril policies) and some 'excess flood' coverage for residences above the NFIP coverage cap, there are now more insurers writing primary residential flood policies. That said, today it is likely only a bit more than 5% of the residential market. This has, however, led to advancements in services, such as inland flood models, to support the industry, which could inform public-sector programs and policies.

While there are advancements in developing flood resiliency among households and communities, challenges remain, particularly in light of escalating flood risk from climate change. It is difficult to get policymakers and other stakeholders to engage in long-term strategic planning and investments for risk reduction and prevention of future risk. The majority of flood risk reduction dollars are appropriated after large flood disasters, targeted at the impacted areas. Forward planning to address increasing flood risks from climate change at the national level has also been difficult to motivate in the current political environment. However, although some localities are moving forward on their own, FRM in the U.S. remains, in general, reactive to floods, pointing to the need for a more cohesive, system-based, forward-looking approach to addressing this growing risk. There is also a need for a more coordinated approach to monitoring and evaluation in order to improve the system.

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Annexes

Annex 1: Questions used for mapping and analysing the evolution of flood risk management

1. **What is the evolution of flood risk in the country?**
    a. What are the types of flood risk, who is at risk and why?
    b. What are the underpinning causes of flood risk?
    c. What are the socio-economic impacts?
    d. Is flood risk growing? What are the drivers of rising flood risk in the country?
    e. Has addressing financial and social risks associated with floods become a national concern for people, businesses and the government? In what ways?
2. **Is reliable flood risk information available and accessible to support decision-making?**
    a. What are the underpinning data sources for flood risk analysis (hazard, exposure and vulnerability)?
    b. Are there official flood risk maps and are they publicly available? What types of information are being developed? What are the strengths and weaknesses of the official flood risk maps? How often they are updated?
    c. Are there other sources of flood risk information? Who is processing and providing flood risk information? What types of information is being developed? To whom is this information provided? How is this information provided to target stakeholders?
    d. Is flood risk information provided to target stakeholders? E.g. people, businesses, community organisations, different government agencies, local government and utilities? Are these maps decision-relevant?
    e. Has the level of risk (e.g. high, medium, low) been identified in different regions? Is this information used to zone the regions according to the level of risk? What are the fundamental assumptions?
    f. Are there targeted risk communication programmes? If yes, who provides them?
    g. What are the benefits, challenges and concerns associated with available risk information and the way it is being provided?
    h. What is the level of flood risk awareness in the country among different stakeholders? Is risk information impacting decisions (e.g. by people, businesses and government)?
    i. Are there any mechanisms for monitoring, assessing and incorporating the changing risk landscape (hazards, exposures, and vulnerability) in the risk maps? Are the underpinning causes of the changing risk landscape investigated and monitored (e.g. climate change, development patterns and practices?) What are the main challenges and concerns?
3. **How is FRM governed in the country, and how is it evolving? How are different stakeholders engaged in the system?**
    a. Who are the key stakeholders with official responsibility to manage floods and their impacts?
        i. Who has official responsibility for FRM in the country? Is this reflected in national to local legislative processes (e.g. government at national, state and local levels, the insurance sector, banking and mortgage lenders, public utilities, the media, NGOs and other community-based orgs, homeowners)? What are their roles?

ii. Who is responsible for addressing the needs and challenges faced by the most vulnerable groups of the population?

iii. What is the perception of homeowners, businesses and other stakeholders in terms of who is responsible? Does the existing system require that homeowners and business owners manage their own flood risks? Please describe.

4. **What is the approach to risk reduction (existing risks) and risk prevention (new risks), particularly in relation to rising risks associated with climate change and other socio-economic drivers?**

   a. Is FRM considered an integral element of socio-economic planning, budgeting and development in the country? Is FRM an integral element of climate adaptation policies and decisions, as opposed to being a stand-alone objective?

   b. Have (or are) disaster risk reduction and risk prevention plans been (or being) developed, implemented and supported/enforced by public policy and regulatory frameworks (at all levels of government)?

      i. Who is responsible for the development and implementation of these measures? Are the interlinkages of these measures considered part of the overall development and risk management strategy? Or are they implemented in isolation?

      ii. Is there a dedicated budget supporting these plans? How is the budget allocated between levels of government?

      iii. Are there incentive mechanisms to promote and enable the implementation of risk reduction and risk prevention by different stakeholders (homeowners, businesses, community-based organisations, local, state and federal governments, public and private utilities, etc.)?

      iv. Is there a process for monitoring and evaluating the impacts of these measures to improve them over time (what level, by whom, how)? For example, monitoring the impact of retrofitting for residential homes, businesses, government assets, infrastructure (public or privately owned) and communities; or the impact of floods on homes and buildings built based on new building code standards versus old ones?

5. **Are early warning systems and emergency preparedness in place and if so, how is this helping to reduce risks (reducing loss of life, livelihoods and economic damage)?**

   a. Who is responsible for developing and issuing the alerts and warnings? Are these warnings accessible, understood and responded to by different stakeholders?

   b. Who is responsible for ensuring alerts and warnings are linked to emergency preparedness on the ground?

   c. What is the receptivity of the general public, businesses and communities to these warnings?

   d. Are warnings leading to increased risk awareness, reduction of property damage and expedited response to and recovery from flooding?

   e. What types of actions are being taken by government (at all levels), businesses, communities and people, based on warnings, to reduce risk?

6. **Are those directly impacted by floods incorporating risk financing and contingency planning in their budgets and plans to increase financial resilience and expedite their ability to respond to floods (e.g. government (all levels), businesses, people)?**

   a. Is the government taking a strategic approach to its financial protection by combining financial instruments? E.g. prioritising cheaper sources of funding, ensuring that the most expensive instruments are used only in exceptional circumstances, using pre-planned budgetary instruments, contingent financing and risk transfer measures (e.g. risk pools) and insuring public assets?

   b. How has post-disaster aid funding been approached and appropriated?

   c. Does the country remain reactive (focused on post-disaster response and recovery) or is it strategically considering the need to build resilience to reduce current risks and prevent new risks? Describe in more detail with examples.

   d. Have post-disaster aid programmes undergone any reforms or modifications to incentivise and/or enable risk reduction and prevention and help with the expansion of insurance for the protection of people, businesses and government?

e. Does the government arrange for any contingency plans to protect its budget to ensure access to cheaper funds in case of disasters?

7. **Is there an active flood insurance market in the country? Is the value proposition of the insurance sector leveraged in building flood resilience in the country? Is the value proposition of the insurance sector understood by governments, businesses and people?**

   a. What is the status of insurance in the country? Is it provided as a national government service, through the private insurance market or as a combination (public–private partnerships, PPPs)?

   b. What is the nature of the insurance programmes (insurance pools, integral part of home insurance or separate insurance products)? Is the insurance delivery

      i. Risk-based?

      ii. Mandatory versus voluntary?

      iii. Incentivising risk reduction through reduced premiums or other mechanisms (please describe)?

      iv. Aimed at residents, SMEs, businesses, government?

      v. Market-based or enabled through policies and regulatory frameworks (if so, how)?

   c. Is there insurance-backed securitisation of CAT and green bonds?

   d. What is market penetration and coverage?

   e. Is the insurance programme sustainable?

   f. What is the receptivity of government in engaging with the insurance sector?

   g. Is the insurance industry proactively engaged with government and other stakeholders to address strengthening of flood resilience? Please describe.

      i. Is the insurance industry engaged with government in reviewing flood risks to residents, business, government, and infrastructure and identifying innovative market-based solutions?

      ii. Is the insurance industry developing innovative risk transfer measures (with or without collaboration with the government?). Are these solutions available, accessible and affordable and are they being used by those at risk to distribute or pool the residual economic risks?

      iii. Are insurance solutions (by industry, government or both) incentivising behavioural change (e.g. insurance solutions available to residents, SMEs, etc.)?

   h. Are the government (at all levels) and/or the insurance industry engaged with customers and businesses to educate about risks, preventive mechanisms and the benefits of insurance?

8. **Following a disaster, are there systematic mechanisms to revisit, re-evaluate and decide on reconstruction plans and decisions?**

   a. Are there formal mechanisms and legislation in place to enforce the need to build back smarter (e.g. build back using updated building codes, relocate and do not build at all if the region(s) has been identified as a high-risk zone)?

   a. Are there efforts to reconsider land zoning in high-risk regions that experience recurrent risks? Are there any government plans for buyouts and relocation from high-risk zones? Have these programmes and their impact been assessed?

9. **Are there monitoring and review processes in place for assessing/measuring the impact of risk communication, risk reduction, risk prevention, risk financing and risk transfer decisions and for providing feedback to improve the different components of FRM in the country?**

10. **FRM approach**

   a. Is the FRM approach transitioning toward a greater focus on flood resiliency? E.g. Is the approach focused not only on reducing current risks but also prevention of future risks linked to factors such as climate change?

   b. Is the approach characterised as fragmented (i.e. engaging many organisations with different but disconnected roles and initiatives) or is it evolving towards a holistic all-of-society approach (leveraging all components of the system)?

   c. Is there any evidence of cultural/behavioural change towards active management and reduction of risk (e.g. people, businesses, communities and all levels of government)? Is it linked to the level of risk? Are there incentives for this change?

Annex 2a: Local case study – New York City, NY

Overview

The mid-Atlantic region of the United States has seen accelerated rates of relative sea level, increasing flood risk (Ezer and Atkinson 2014). One study estimated that the annual expected flood damage to buildings in New York City is USD 59–129 million (Aerts et al. 2013). Floods that were once characterised as 1-in-500 year events in the preindustrial era are already occurring at a 1-in-25-year interval and are likely to drop to a 1-in-5-year event in the next 30 years (Garner et al. 2017). In 2012, the city was heavily impacted by Hurricane Sandy. The frequency of Hurricane Sandy type flooding is likely to increase over the 21st century (Lin et al. 2016) and storm tides have increased (Talke et al. 2014).

As in most U.S. communities, flood risk management and communication activities in New York City have largely been carried out under the auspices of the National Flood Insurance Program (NFIP). As an NFIP-participating community, New York has implemented minimum floodplain management regulations and FEMA flood maps are a primary source of flood risk information for city residents. That said, since Hurricane Sandy in 2012, New York has taken a more proactive and multi-faceted approach to flood risk management by investing more heavily in hazard mitigation and resilience planning, strengthening flood protection for buildings and infrastructure, taking steps to enhance New York City's coastal defenses and improving risk communication to residents about flood risks. Much of this was funded by federal appropriations after Hurricane Sandy.

Planning and building codes

Over the last several years, New York City has issued several planning documents to guide flood risk reduction efforts as well as flood-resilient design and construction of facilities throughout the city. These include *OneNYC 2050: A Livable Climate*,[70] which outlines the city's climate resilience action plan and the *Lower Manhattan Coastal Resiliency Study*,[71] the findings of which the city has used to identify USD 500 million worth of investments and develop a series of projects to protect Lower Manhattan from flood and storm damages. The city has also issued *Climate Resiliency Design Guidelines*,[72] which provide guidance on how to incorporate future climate data into the design of capital projects; *Retrofitting Buildings for Flood Risk*,[73] a wide-ranging guide to help building professionals retrofit the city's most vulnerable buildings; and *Urban Waterfront Adaptive Strategies*,[74] which provides a framework for communities to evaluate how effective and appropriate different coastal protection measures may be for different areas. At the community scale, the Resilient Edgemere Community Plan led by the Department of Housing Preservation and Development (HPD) presents a long-term vision and community development framework for a higher quality of life for residents.

The Department of City Planning (DCP) has also engaged with communities throughout the city to develop and implement new zoning regulations to reduce flood risk for buildings and neighborhoods in New York City's most vulnerable coastal areas. DCP recently issued a set of zoning recommendations – Zoning for Coastal Resiliency – that will undergo a formal public review process in 2019.[75] These proposed regulations include provisions that remove zoning barriers that previously inhibited flood-resistant reconstruction and retrofitting of damaged buildings, and allow all buildings in areas at risk of current or future coastal flooding to proactively implement risk-reduction measures, even if they are not required.

In addition to the proposed zoning changes and guidance documents noted above, New York City amended its construction codes in 2013 to require buildings in the SFHA to be elevated beyond what is required by their preliminary new flood map. Under the new codes, one–two family homes are required to have at least two feet of additional freeboard protection above flood elevation, while most other buildings are required to have at least one foot.

70 https://onenyc.cityofnewyork.us/wp-content/uploads/2019/05/OneNYC-2050-A-Livable-Climate.pdf
71 https://www.nycedc.com/project/lower-manhattan-coastal-resiliency
72 https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v3-0.pdf
73 https://www1.nyc.gov/site/planning/plans/retrofitting-buildings/retrofitting-buildings.page?tab=5
74 https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf
75 https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/flood-resiliency-update/zoning-for-flood-resiliency.pdf

Mitigation investments

Coastal defenses are also an integral part of New York City's approach to flood risk management and will continue to be as the city carries out its resilience strategy. As of 2014, roughly 25% of the city's 520 miles of shoreline were protected by bulkheads (NYC Emergency Management 2014). Surge barriers and floodwalls are key components of the East Side Coastal Resiliency Project and other projects planned for Lower Manhattan, Staten Island and the Rockaway Peninsula in Queens.[76]

To reduce the impacts of stormwater flooding, the Department of Environmental Protection collaborates with other city agencies such as the Departments of Transportation, Sanitation, and Parks and Recreation, to enhance drainage systems, make better use of green infrastructures, provide floodwater storage and manage surface water more effectively.[77]

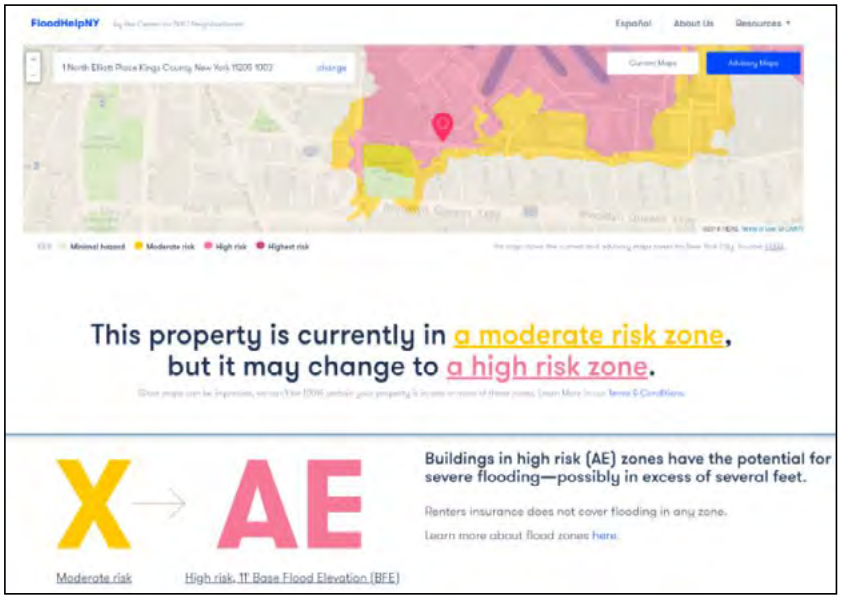
Site-specific mitigation of scattered private residences was completed in more than 35 neighborhoods through the Build It Back housing recovery program. Mitigation actions included new construction, elevation retrofits, and elevation of critical utilities. Additionally, post-disaster buyout programs led by both Build It Back and the New York State Governor's Office of Storm Recovery have converted a scattered portfolio of single-family homes in Queens and Staten Island into permanent open space. Where feasible, these former housing sites will be integrated into new and existing coastal defense, stormwater mitigation and open space assets.

Communication and outreach

To better educate homeowners about current and future flood risks, the city partnered with the New York Governor's Office of Storm Recovery and non-profit housing organisation, the Center for New York City Neighborhoods (CNYCN), to create a Google-maps-style platform, www.FloodHelpNY.org, that reveals the flood risk to a specific property. The site provides plain-language information to users about the current flood risk and how it may change as flood maps are updated. For example, for the address highlighted in Figure A1, the site explains that the property is in a moderate flood risk zone, but may be in a high-risk zone in the future. The site also notes that 'Buildings in high risk (AE) zones have the potential for severe flooding – possibly in excess of several feet' and that 'Renters insurance does not cover flooding in any zone'.

Further, the website provides a flood insurance rate estimator that allows users to see current and potential future flood insurance rates. It also enables low- and moderate-income homeowners to check their eligibility for a free home resiliency audit to identify feasible risk-reduction measures that would lower flood insurance costs for the homeowner. Nearly 700 homeowners have received a free resiliency audit since November 2016.[78] Beyond the website, there have also been over 200 events since Hurricane Sandy related to flood insurance and flood risk management, including community events and trainings. A consumer education campaign ran from October 2016 to March 2017.

Figure A1: Screenshot from FloodHelpNY.org



76 https://www1.nyc.gov/site/escr/index.page
77 https://www1.nyc.gov/site/dep/water/stormwater-management.page
78 https://www.floodhelpny.org/en/homeowners

Annex 2b: Local case study – North Carolina

Overview

North Carolina is subject to pluvial, fluvial and coastal flooding. Flood risk along the coast is expected to grow over the coming decades. The sea is rising three times faster on the North Carolina coast than it did a century ago. The North Carolina Coastal Resources Commission Science Panel expects a one-meter increase by 2100.[79] The state has been a leader in flood risk communication and flood risk management. The State Department of Emergency Management has overseen data collection and flood risk communication and worked with counties and local communities on floodplain management.

Risk communication

After Hurricane Floyd devastated North Carolina in 1999, the state prioritised the production of accurate, up-to-date flood hazard maps. In 2000, North Carolina became a Cooperating Technical Partner State, formalising its flood-mapping partnership with FEMA and taking primary responsibility for all flood hazard analyses and mapping efforts in communities throughout the state. As a result, North Carolina launched its own floodplain mapping program and information platform that is widely regarded as a model for states and communities around the U.S.

The state has invested significantly in developing high-resolution, structure-specific flood risk data that is publicly available via an online portal.[80] Through the website, Flood.NC.gov, users can enter an address and view a structure's flood risk profile, which includes information on the nature of the hazard (flood zone location and base flood elevation), potential damage costs, insurance premium estimates and potential mitigation options. Figure A2 is an example of what a user would see when they enter the address for a specific property.

Figure A2: Screenshot from Flood.NC.gov

79 http://ncdenr.s3.amazonaws.com/s3fs-public/Coastal%20Management/documents/PDF/Coastal%20Hazards%20Storm%20Information/NC_Sea_Level_Rise_Assessment_Report_2010_CRC_Science_Panel.pdf

80 http://www.ncfloodmaps.com/

Components of a structure's flood risk profile shown in Figure A2 (hazard, impact, insurance and mitigation) have adjustable parameters that allow a user to see how these components, and the overall risk, would change under different circumstances. For example, by clicking on 'Impact', a new window opens that allows users to edit structure-specific information such as heated square feet, number of stories, foundation type, building and contents value and simulated flood depth to better understand potential flood impacts under different scenarios.

Additionally, North Carolina's Flood Risk Information System (FRIS) – accessible through a similar online platform – provides advanced tools and information useful to city planners, emergency managers, industry stakeholders and property owners.[81] The website provides flood hazard data, models, maps, risk assessments and reports, as well as imagery, LiDAR data and hydraulic and hydrologic models.

Flood warnings

North Carolina also provides real-time flood risk information through its Flood Inundation Mapping and Alert Network (FIMAN).[82] The FIMAN website provides data on stream elevation, rainfall and weather parameters from gages across the state, including those managed by the North Carolina Division of Emergency Management, the U.S. Geological Survey, local government agencies and private organisations. The key objective of the FIMAN system is to provide emergency managers and the public with flood warnings and advisories to protect life and property.

81 https://fris.nc.gov/fris/Home.aspx
82 https://fiman.nc.gov/Map.aspx#

As the world deals with the COVID-19 pandemic crisis, the potential compounding effects of weather-related extreme events, such as floods, tropical cyclones and wildfires, could significantly challenge a country's emergency management capacities and slow down its socio-economic recovery. Floods are among the most concerning and costly weather-related events globally. Part of a major study on flood risk management (FRM) in five mature economies, this report takes an in-depth look at the FRM system in the United States – governance, institutional frameworks and stakeholder engagement – against an analysis of the changing risk landscape.

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