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Introduction: rising waters

On June 20, 2006, a heavy summer storm dumped over 10 inches (25.4 cm) of rain on the Houston, Texas, metropolitan area: several bayous overflowed and there were over 500 emergency calls for help from motorists stranded on flooded roads. On October 16 of the same year, only 6.5 inches (16.5 cm) of rainfall was enough to submerge a highway underpass leading to a major interstate under almost 12 ft (3.66 m) of water. As a consequence of the storm, schools closed and four people died when they became trapped in their cars. Three years later, in April 2009, the same amount of precipitation fell across Houston, once again flooding homes and major roads. This time, approximately 200 motorists were marooned in a parking lot, 80% of streets were under water in several neighborhoods, and five children were among those who died. This chronic pattern of flooding, property damage, and human casualties is not unique to Houston, but is replicated in thousands of towns and cities across the U.S. Rapid population growth in low-lying coastal areas, sprawling development patterns, and the alteration of hydrological systems are just three of the factors shaping the development of flood-prone communities in which more people are being placed at risk.

The little-known fact is that, among all natural hazards, floods pose the greatest threat to the property, safety, and economic well-being of communities in the U.S. More property is lost and more people die from flood events than from tornados, earthquakes, and wildfires combined. And, despite federal policies created to guide both structural and non-structural mitigation initiatives, property damage and human casualties continue to mount across the nation. Apart from the sheer disruption caused to people's lives, the economic impact alone is estimated in billions of dollars annually (Association of State Floodplain Managers [ASFPM], 2000; Pielke, 1996). According to data extracted from the Spatial Hazard Events and Losses Database for the United States (SHELDUS), damage from floods has increased over time. In the 1960s, flood damage averaged $45.65 million a year; by the 1990s, average annual property damage from flooding increased to

$19.13 billion dollars a year (inflation adjusted at 1960 dollars (Brody *et al*., 2007a: 330–345). One reason for the tremendous increase in property damage may be the occurrence of floods: according to SHELDUS, the average annual flood count has increased sixfold, from 394 floods per year in the 1960s to 2444 flood events per year in the 1990s.

It is not necessary to conduct a national study of flood events and their impacts to elucidate what local decision makers and residents have tacitly understood for decades: Floods pose a major risk to the health and safety of U.S. communities and this problem is only becoming worse. Perhaps the real threat comes not from major storms, but from the multitude of chronic, small-scale floods that barely make headlines. Catastrophic events such as the great floods of the Midwest in 1993 and Tropical Storm Allison in 2001 are well documented and quickly addressed. But the relatively small storms that come and go almost undetected by the media and the public add up to billions of dollars in losses over time. A single event, such as the 2009 late afternoon thunderstorm described above, which passed over Houston, is not by itself a cause for alarm. Rather, it is the cumulative impact of these repetitive, small-scale events that weigh down local economies, tear at the fabric of community well-being, and disrupt the daily lives of millions of residents.

In *Disasters by Design*, Mileti (1999) argues that disasters do not simply occur as acts of God, but are instead largely the result of how we build and design human communities. This notion has helped many scholars and decision makers realize that disasters are literally human-constructed events that can be mitigated through thoughtful land use policies. However, this concept has gone largely untested from an empirical perspective among researchers over the past decade.

This book builds on Mileti's theory by offering systematic, empirical evidence that the location, intensity, and pattern of the built environment are critical factors in determining the impacts of floods. Our underlying premise is that the rising cost of floods is not solely a consequence of increasing mean annual precipitation, population growth, or inflationary monetary systems. It is also driven by the manner in which we plan for and subsequently develop the physical landscape. Individual and community-based decisions pertaining to the distribution of buildings and impervious surfaces, and the degree to which hydrological systems are altered, are exacerbating losses from repetitive floods. Increasing development associated with residential, commercial, and tourism activities, particularly in coastal and low-lying areas, has diminished the capacity of hydrological systems (e.g., watersheds) to naturally absorb, hold, and slowly release surface water runoff. As a result, private property, households, businesses, and the overall economic well-being of coastal communities have become increasingly vulnerable to the risks of repetitive flooding events.

In the U.S., decisions about planning and development reside at the local level, and therefore effective flood mitigation lies in the hands of county commissions, zoning boards, mayors, planning departments, and other local governmental entities. From this perspective, flood control and avoidance can no longer be considered the sole province of the federal government. The twenty-first-century vehicles for preventing loss of property and life may not be based only on federal disaster relief or large dams and levees, but also on county and citywide land use plans, development and construction codes, zoning and subdivision ordinances, technical assistance, community-based outreach, and other locally based non-structural programs.

Our book rigorously examines the causes, consequences and policy implications of repetitive flooding in the U.S. This book is the culmination of over five years of empirical research funded by the National Science Foundation on how local communities can reduce both property damage and human casualties associated with flooding. Focusing on two of the most vulnerable states in the nation, Texas and Florida, we have fully investigated the factors contributing to the degree of flooding and how local planning and development decisions may be critical elements in determining the extent of damage experienced by local communities. It is our proposition that, over time, local communities in the U.S. have increasingly borne the responsibility for flood problems. By adopting and implementing both structural and non-structural mitigation measures, localities have taken important steps to reduce property damage and human casualties associated with localized flood events. With this understanding, we examine the effects of past decisions on floods and flood damage, in order to offer future solutions that could more effectively mitigate the adverse impacts of flood events.

Research questions

Recognizing that now, more than ever, scientific knowledge is needed to better comprehend the impacts of development-based decisions on flooding, we posit that, with better knowledge, local decision makers can reduce loss of both property and human lives in the future. While much research has catalogued the amount of damage caused by floods in the U.S., there is comparatively little work on the local-level causes, consequences, and policy implications associated with repetitive flooding events. The inquiry that exists is largely argumentative, focused on a single time period, and based on isolated case studies. This research approach makes it difficult to externalize findings that may be useful to a broader community of policy makers. In fact, over the past decade, no systematic, large-scale, quantitative study has been conducted that can move the field of flood mitigation and planning in the U.S. forward.

This book directly addresses this research need by providing empirically driven, evidence-based results that can directly inform local decision makers and scholars about effectively reducing the adverse impacts of floods. We employ multiple methods of inquiry, including geographic information systems (GIS) analytical techniques, multivariate modeling, and surveys to thoroughly investigate the characteristics, causes, consequences, and policy implications of flooding throughout coastal Texas and Florida. The primary research questions addressed in the following chapters are:

- What is the spatial pattern of local flooding in coastal Texas and Florida?
- What is the effect of development on the degree of flooding and flood damage?
- To what degree does the alteration of naturally occurring wetlands along the coast contribute to riparian flooding and property damage from floods?
- How well are coastal communities preparing themselves to mitigate repetitive flooding events?
- To what degree are local flood mitigation and planning working in terms of saving lives and property?
- How does local organizational capacity influence the level of preparedness and mitigation to reduce the adverse impacts of floods?
- What are the major factors driving households to insure themselves against flood risks?

Study areas: why Texas and Florida

For the study areas, we selected coastal Texas and Florida (Figure 1.1) to examine the characteristics, causes, and consequences of flooding and flood mitigation for several reasons. First, both states are situated within the coastal zone of the Gulf of Mexico, where population growth and development make communities vulnerable to the effects of flooding. Given the recreational, aesthetic, and economic opportunities available on the coast, this geographic area has historically been the focus for extensive population growth and land use change. In 2003, for example, it was estimated that approximately 153 million people (53% of the U.S. population) live in the 673 coastal counties, an increase of 33 million people since 1980 (Crossett *et al.*, 2004). With increasing population come more structures located in areas susceptible to flooding from severe storms that routinely strike coastal areas. From 1999 to 2003, 2.8 million building permits were issued for the construction of single-family housing units (43% of the nation's total) and 1 million building permits were issued for the construction of multi-family housing units (51% of the nation's total) within coastal counties across the U.S. (Crossett *et al.*, 2004). Because communities positioned along a coastline or within a coastal watershed are especially

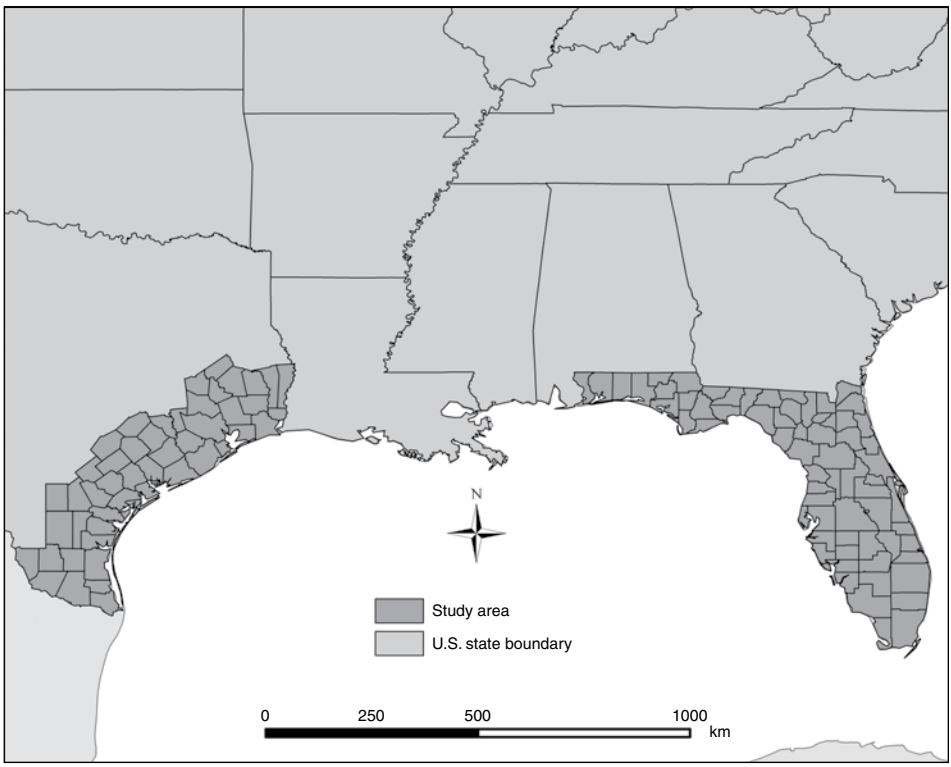

Figure 1.1 The study areas.

vulnerable to flooding from both severe and chronic storm events, this upward trajectory of growth has created the ideal conditions for human catastrophe.

In Texas, between 1980 and 2003, approximately 2.5 million people more moved into the coastal areas, representing a 53% increase. Only California and Florida ranked higher in the addition of coastal population (Crossett *et al*., 2004). Surprisingly, from a total land area perspective, the Texas coast remains relatively undeveloped, with the population centered in the Houston–Galveston area, Corpus Christi, Beaumont, and Brownsville. However, these populated areas have recently become places of intense growth. For example, from 1980 to 2003, Harris County, where Houston is located, had the second highest coastal growth rate among all counties in the U.S. (Crossett *et al*., 2004). Today, the Houston–Galveston–Brazoria region remains one of the fastest growing areas in the country, with over 2100 persons per square mile.

Florida has historically been a place of intense population growth and development, and its pace continues to rank among the top in the nation. For example, in 2000, Florida, along with California and New York, comprised 41% of the total housing units added among all coastal counties. Florida also had the largest number

of seasonal housing units, over 24% of the total for all coastal counties (Crossett *et al*., 2004). According to the U.S. Census Bureau, Florida and California combined made up 37% of all permits issued for single-family units and 42% of all multi-family units in coastal counties.

Population projections place both study states among the top in the nation for future growth. For example, Florida and Texas are predicted to be among the five fastest-growing states between 2000 and 2030, with 80 and 60% increases, respectively. The Texas Gulf coast region population alone is expected to increase by over 40% between 2000 and 2015 (Texas State Data Center and Office of the State Demographer, 2008). Of the 10 leading counties in population change, eight are expected to be in Florida. Population growth in the next decade will be most prominent in the southernmost portion of Florida, with Broward County expected to increase by 167 000 persons and Palm Beach County expected to increase by 151 000.

A second rationale for selecting our study areas is that both states contain low-lying coastal areas, which makes them extremely prone to flooding. For example, Texas consistently incurs more deaths (double the total for the second-highest state, California) and insurance losses per year from flooding than any other state in the U.S. According to Federal Emergency Management Agency (FEMA) statistics on flood insurance payments from 1978 to 2001, Texas reported approximately $2.25 billion dollars in property loss. These losses amount to more than California, New York, and Florida combined, the next three states on the list of the most property damage (National Flood Insurance Program [NFIP], 2007). Florida also experiences significant annual economic losses from floods due to its low elevation, large coastal population, and frequent storms. For example, based on a composite flood risk measure combining floodplain area, population, and household values, Florida ranks the highest among all states (FEMA, 1997). Recent estimates indicate that from 1990 to 2003, the state suffered losses of almost $2.5 billion (in current U.S. dollars).

A third reason for selecting Texas and Florida as our study areas is that while both states are similarly susceptible to flooding and flood damage, their different policy settings and development patterns allow for an insightful comparative analysis. For example, with the passage of the Florida Growth Management Act in 1985, Florida adopted a statewide mandate requiring all local jurisdictions to adopt a legally binding, prescriptive comprehensive land use plan (Chapin *et al*., 2007). Under this requirement, cities and counties within the state must adopt in their plans flood mitigation and coastal natural hazard policies. Florida's top-down mandate and regulatory environment for development has long been considered one of the strongest in the nation. Rule 9J-5, adopted by the Department of Community Affairs (DCA) in 1986, requires that specific elements and goals be included in

local plans and prescribes methods local governments must use in preparing and submitting plans. Despite this "checklist" approach to land use planning, there is evidence of wide disparities in the breadth and quality of local environmental policies in Florida (see Brody, 2003a, for more detail).

In contrast, Texas has no comparable state-level planning mandate. Land use planning, development regulations, and flood mitigation are largely the responsibility of local jurisdictions. As a result, flood planning and mitigation activities are spotty along the Texas coast. A Texas culture of strong private property rights combined with a lack of government regulations concerning development patterns versus the centralized Florida model provides an ideal comparative setting in which to examine the effectiveness of flood plans and policies.

Outline of the book

The book is categorized into four related parts. Part I examines the consequences of flooding in the U.S. Chapter 2 addresses trends in flood damage and casualties from a national perspective and at multiple spatial scales. We cover past studies on the status of flooding, and provide new data enabling us to make more current and spatially specific damage estimates. Chapter 3 focuses on local communities within the study area states of Texas and Florida. Here, we provide more detailed information regarding property damage, injuries and fatalities, insurance purchase amounts, physical risk variables, etc. In this chapter, we focus the reader's attention on specific geographic areas, which serve as the representative target for the rest of the book. After examining the trends and status of flood impacts across the country and within the study area, Chapter 4 critically examines the existing legal and policy frameworks associated with flood mitigation. Special attention is paid to the role of the NFIP, FEMA's community rating system (CRS), and specific local mitigation initiatives.

Part II of the book concentrates on the major factors influencing the amount of flooding, property damage, and human casualties from flood events. Chapter 5 lays the groundwork for explaining the causes and consequences of flood impacts, and the policy implications of hazard mitigation at the local level. Specifically, we identify and discuss the major factors influencing flooding and flood damage, including the natural environment, socioeconomic factors, the built environment, and mitigation. In Chapter 6, we focus on the degree to which naturally occurring wetlands mitigate flooding and the human impacts of the floods. First, we trace the policy and regulatory history behind wetland development in the U.S. Second, we discuss the current permitting process administered by the Army Corps of Engineers (ACE), which includes different types of permits suited for specific development conditions. Third, we present the results of our own inquiry on the

spatial pattern of wetland development over a 13-year period, the different types of wetland altered along coastal Texas and Florida, and most importantly the contribution of wetland permit issuance to flooding and flood damage across the study area. Chapter 7 focuses on the role of FEMA's CRS as a proxy for non-structural local flood mitigation activities. After providing an overview of the program, we describe the extent to which local policies are adopted within the study areas and explain the relationship between policy implementation and reduced property damage from floods. We also report the results of a survey of planners and managers conducted in both states on the effectiveness of specific policies implemented at the local level. In Chapter 8, we examine the effects of contextual community and development factors on flooding. Empirical analyses identify the effects of structural mitigation, such as dams and levees; the role of impervious surface resulting from increased urban development; socioeconomic variables, such as community wealth and education; and demographic variables, including population, population growth, and housing density.

Part III of the book focuses on the role of learning in terms of reducing the adverse impacts of floods within our study area. By taking a longitudinal approach, we unravel policy learning and adjustment at the community, institutional, and household levels. Chapter 9 investigates the drivers of policy change instituted by governments, as well as household adjustments associated with insurance purchasing. Quantitative models demonstrate the degree to which communities are improving their mitigation capabilities in the face of continual flood events and the reasons localities and households are willing to make these changes. Because policy change and learning, in response to repetitive flood events, comprise such a complex issue based on contextual characteristics, in Chapter 10 we supplement quantitative findings with case studies. Several cases based on secondary documentation and interviews with planning officials from jurisdictions within the study areas add depth to the arguments based on statistical analysis made in the previous chapter.

Finally, Part IV of the book discusses the policy implications of the research findings and presents a set of integrated planning recommendations for improving the ability of local communities to reduce the negative effects of flooding across the U.S. In both Chapters 11 and 12, we extend our results for Texas and Florida to coastal communities in general and set forth a policy agenda for flood mitigation in the twenty-first century, focusing on local level initiatives. We also identify specific future research needs that can help move the U.S. closer to building more resilient communities in the future.

Part I

The consequences of floods

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Rising cost of floods in the United States

The U.S. is assaulted by a variety of natural hazards every year, totaling tens of billions of dollars in direct damages. Hurricanes along the coasts, earthquakes in California, blizzards in the Midwest, tornadoes, wildfires, and drought are just some of the hazards contributing to persistent, economically damaging adverse impacts. What is virtually unknown and rarely discussed in the public domain is that among all natural hazards, floods pose the greatest threat to the property, safety, and economic well-being of local communities across the nation. While these events rarely make the national news for their drama and intensity, in total, economic impacts from floods alone are estimated in billions of dollars each year (ASFPM, 2000; Pielke, 1996).

Floods have always plagued metropolitan areas in the U.S. because cities tend to be located along major river bodies and in coastal areas for better access to commerce. But, a casual glance at any flood dataset shows that the problem is getting worse, despite the fact that Americans have steadily moved out of urban centers into sprawling suburban environments. For example, data from SHELDUS show that the number of floods per year has increased sixfold, from an average of 394 floods per year in the 1960s to 2444 in the 1990s. This dataset also reveals that floods in the 1960s caused approximately $41 million of property damage a year compared with over $378 million dollars a year in the 1990s (inflation adjusted to 1960 dollars).

This chapter lays the foundation for the remainder of the book by examining direct damages attributed to flooding in the U.S. using multiple sources of data. Specifically, we investigate the magnitude and trends for human causalities, crop damage, and property damage caused by floods at both national and state levels. We report on past flood studies and provide new data, enabling us to paint a more current and spatially specific picture of the consequences of floods nationwide. Our objective is not to rewrite or replace previous studies calculating the impacts of floods, but rather provide a descriptive basis to support the content of the remaining chapters, which discuss how to respond to the increasing threat of floods.