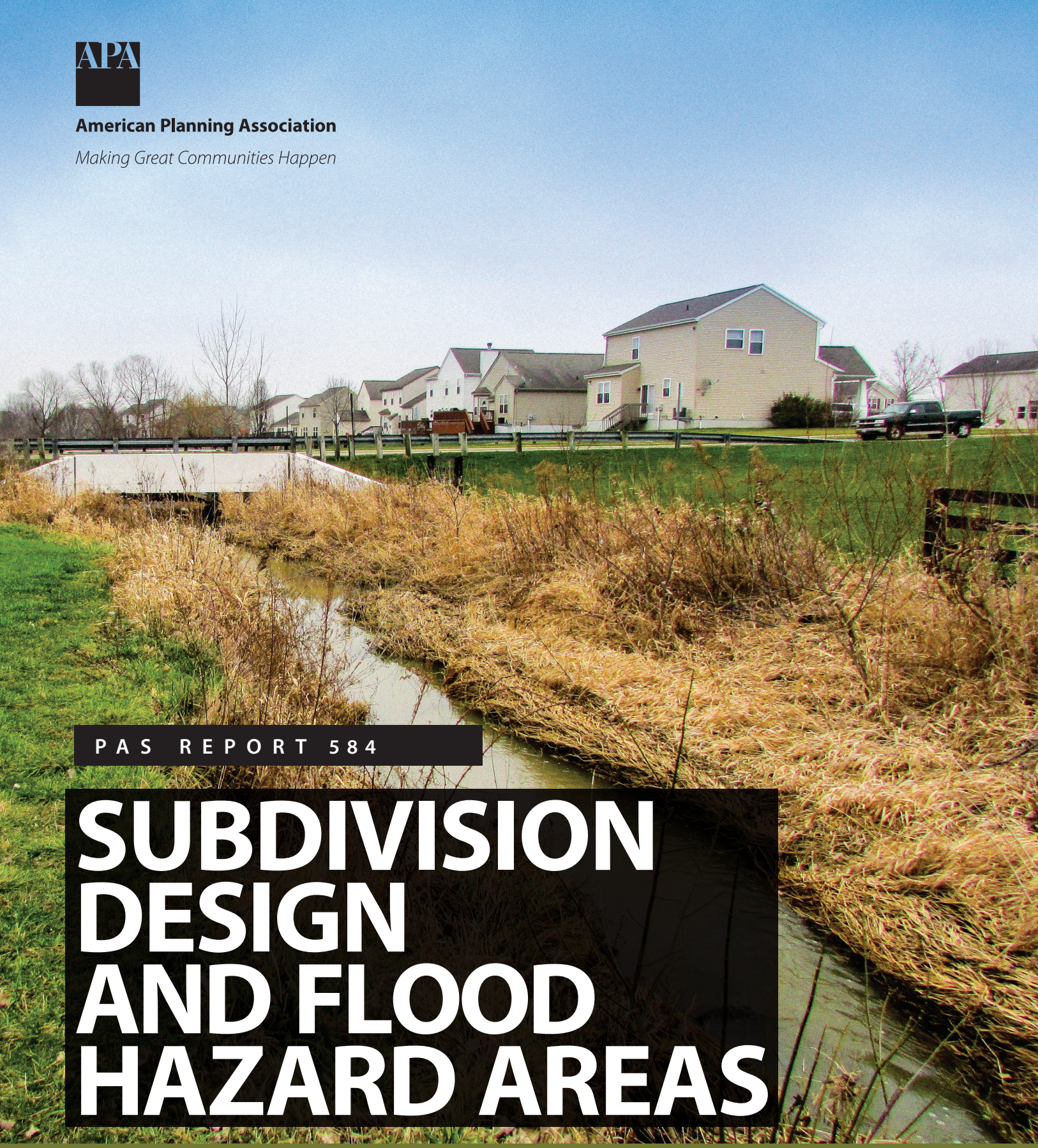
American Planning Association
Making Great Communities Happen



PAS REPORT 584

SUBDIVISION DESIGN AND FLOOD HAZARD AREAS

James C. Schwab, FAICP, Editor

TABLE OF CONTENTS

FOREWORD

Since 1968, the National Flood Insurance Program (NFIP) has enabled property owners in participating communities to purchase insurance as a protection against flood losses. In exchange, communities adopt and enforce floodplain management regulations that reduce future flood damage to homes and businesses. Participation in the NFIP is a community decision and based on an agreement between communities and the Federal Emergency Management Agency (FEMA). FEMA provides many forms of assistance to states, communities, and tribal nations as well as small amounts of support to property owners facing flood hazards. However, more than five million households purchase flood insurance through the NFIP as an alternative to disaster assistance. This investment reduces the escalating costs of damage to buildings from floods in communities.

As we approach the 50-year mark since the NFIP's creation, the program needs to build on its successes and address some of its gaps. To this end, FEMA is focusing on both the insurance product and the value of the program by doing the following:

- Make the flood insurance product more closely align with familiar insurance products, provide more coverage choices, and increase the sense of value in the product by better matching policyholder needs at the time of loss
- Simplify policy language for policyholders and guidance for our partners
- Use new ways of working with stakeholders through clear communications and outreach during program and map changes
- Shift to a structure-based understanding of risk, simplify communications of flood risk to policyholders, encourage increased mitigation activities, and measure risk by leveraging new technologies
- Focus on redesigning the claims and appeals process as a result of lessons learned and policyholder feedback from the process
- Interact with 22,000 communities to support FEMA's mission to boost resilience and mitigate the impact of future disasters

So what does this mean for local planners, community officials, elected officials, and the developers within those communities? In the last 20 years, experiences in places affected by devastating disasters such as Hurricanes Katrina and Sandy resulted in changes to the NFIP through legislation and the way the program is implemented.

Community officials are at the heart of the success of these changes. The decisions that are made today about where we build, how we build, and what types of building codes and local ordinances drive development will have long-term impacts on our flood risks in the future. Reducing the potential for flood risks to new development will allow community officials, first responders, and property owners to focus on reducing the risks to existing development and redeveloped areas. This report, *Subdivision Design and Flood Hazard Areas*, provides an additional tool to community planners to help drive local decisions and future development and to be more resilient in the face of changing flood conditions.

I would like to recognize the American Planning Association (APA) for its continued partnership in focusing research and professional growth on flood hazard reduction and community resilience. Since 1993, FEMA and APA have collaborated to improve the planning profession's understanding of natural hazards and the role that planners play in reducing the risks of natural hazards through hazard mitigation planning and actions. This partnership is critical to our whole-community approach to improving the long-term resilience of communities and the people that they serve.

Further, I would like to offer my gratitude to a particular member of the APA staff, James Schwab, FAICP. For more than 20 years, he has promoted community resilience to natural hazards and disaster recovery, and his personal and professional contributions to advancing the planning profession in these subject areas are profound. He was singular in advancing APA's support for multiple hazards research publications, including the pivotal 1998 PAS Report *Planning for Post-Disaster Recovery and Reconstruction*. He has become the authoritative APA representative for federal initiatives that seek input from and engagement with professional organizations on hazard and disaster recovery-related topics. His experience and knowledge about the intersection between community development and natural hazards are highly regarded not only by FEMA but numerous other federal agencies as well. For his long-standing commitment and advancement of the profession, I say, *Thank you, Jim*.

Roy E. Wright
Deputy Associate Administrator for Insurance and Mitigation
Federal Emergency Management Agency

EXECUTIVE SUMMARY

MAKING THE CASE TO BETTER MANAGE FLOOD RISK

Much has changed in the 19 years since the publication of *Subdivision Design in Flood Hazard Areas*, PAS Report 473 (Morris 1997). Billion-dollar flood disasters have grown in frequency and regularity, and these increases likely will continue well into the future. Hurricanes Katrina and Sandy provide convenient touchstones for truly massive flooding disasters—both exceeded $200 billion in losses. The federal taxpayer now bears a disproportionate share of disaster costs, with federal aid rising precipitously over the past decade. Demographic shifts are placing more people and property in harm's way, as natural hazards are either ignored or downplayed in the development process.

Meanwhile, the concept of resilience has emerged as a focus of planning practice. Significant time, money, and attention are being dedicated to understanding how cities can withstand and rapidly recover from disasters. Far more accurate tools, models, and methods for assessing and defining specific flood risks are now available, which allows local planners and practitioners to go well beyond the limited focus of Federal Emergency Management Agency (FEMA) flood zone maps. Adapting to the multiple cascading risks associated with a changing climate is a primary focus of planners today. However, while the profession as a whole is gradually incorporating these concepts into long-term planning practice, subdivision design practice has changed comparatively little.

The intent of this report is to complement PAS Report 473 by providing an expanded and updated second volume. This report reflects an evolved way of thinking about planning and hazards that allows for a more comprehensive approach to saving lives, protecting property, and building a future that is free from, or has a reduced risk to, flooding hazards.

Defining Flood Risk

A commonly used expression of flood risk is probability multiplied by consequences. The probability element of the flood risk equation is commonly expressed through flood maps.

FEMA's Flood Insurance Rate Maps (FIRMs) are the most commonly used resource for assessing flood risk in planning practice. Their primary purpose is in determining flood insurance rates based on variable levels of mapped risk. FIRMs are also used as a standard reference for local policy makers and regulators. They are used to establish zoning and land use, to plan for the location and protection of infrastructure, and to develop emergency preparedness and evacuation plans. FIRMs are the essential default standard for communities nationwide. Yet they are also quite limited tools for assessing true risk, especially in recently subdivided areas where maps may be far out of date or incomplete, or may only include the most basic risk information.

Floodplains and watersheds are extraordinarily dynamic environments where risk is neither static nor beholden to mapped boundaries. Thus, there are a number of factors related to floodplains that must be taken into account when considering subdivision design and development practices:

- Flood risk is not static. Communities must consider how hypothetical development may shape future risk for the existing built and natural environments. Similarly, climate change and sea-level rise data are at a point where the data can and should be used for planning purposes.
- There is value to the floodplain and watershed purely as a complex natural system. Green infrastructure, low-impact development, and effective land-use regulations can help protect and preserve the natural and beneficial functions of the floodplain and the wider watershed.
- Coastal areas are often notoriously difficult to regulate because of comparably high land value and development demand. Takings challenges often threaten robust regulation from practitioners. Conversely, a more permissive approach toward floodplain development can lead to legal challenges from existing residents, especially if flooding is worsened by new development.

THE PRINCIPLES OF SUBDIVISION DESIGN IN FLOOD HAZARD AREAS

During a 2015 symposium at the American Planning Association (APA)—which included subject matter experts and staff

from APA, FEMA, and the Association of State Floodplain Managers—participants developed an overarching vision for subdivision design in flood hazard areas:

> Adopt a comprehensive and integrated approach to protecting floodplains and other natural areas and aligning development with community goals, in order to increase community resiliency and reduce flood hazard risks.

Subdivision design in flood hazard areas has become increasingly important due to the high social and physical costs associated with flood damages. Now, more than ever, communities must adapt to the ever-growing threat of human-made and natural disasters.

General Principles

These five general principles lay the foundation for mitigating flood hazards within subdivision design:

1. Maintain natural and beneficial functions of the floodplain.
2. Adopt a No Adverse Impact approach to floodplain management.
3. Avoid new development in the floodplain whenever feasible.
4. Focus on data-driven decision making, using only the best available data to assess risk and inform decisions.
5. Consider future conditions of the floodplain, including development impacts and climate change.

Planning and Design Principles

Together with the general principles, the following six planning and design principles can help communities develop a comprehensive and integrated approach to protecting floodplains by aligning development with community goals:

1. Communicate with and inform stakeholders and community members throughout the planning and design process in order to facilitate coordination and community buy-in.
2. Apply multiple tools and techniques for structural and nonstructural flood mitigation measures.
3. Allow for creativity in design and, where possible, adopt a "watershed-scale approach" to design and an "ecosystem-based approach" to disaster risk reduction.
4. Design new infrastructure and adapt existing infrastructure, including stormwater facilities and transportation networks, to be resilient to both high- and low-frequency flooding events.
5. Protect open space and incorporate green infrastructure into development patterns.
6. Ensure that subdivision and related development regulations include provisions for enforcement personnel.

INTEGRATED COMMUNITY APPROACH

As outlined in *Hazard Mitigation: Integrating Best Practices into Planning*, PAS Report 560, effective hazard mitigation is best achieved through coordinated plans, complementary goals, and collaborative efforts (Schwab 2010). The following discussion focuses on three key categories of planning actions within which subdivision design for flood hazard areas takes on special importance: (1) comprehensive plans, (2) other types of community plans, and (3) implementation tools.

Comprehensive Planning and Visioning

According to *Sustaining Places: Best Practices for Comprehensive Plans*, PAS Report 578, the traditional focus of the comprehensive plan has been on the long-term physical development of a local government municipality (Godschalk and Rouse 2015). Comprehensive plans tend to be made up of discrete planning elements such as land use, transportation, and community facilities—though many contemporary plans have expanded in scope and focus to address such topics as long-term global sustainability. Recent advances in both technology and the planning process allow contemporary comprehensive plans to address a wider and more creative range of possibilities, and they are generally less beholden to the generic format of past plans.

Recent innovations include the integration of local hazard mitigation into the comprehensive planning process. This integration can be achieved in various ways. In some instances, the mitigation plan may feature as a planning element within the comprehensive plan, as an addendum, or as an appendix. Deeper integration is possible as well. Analyses and policy recommendations developed for the mitigation plan or hazards element can be tied to specific land-use actions in the comprehensive plan. With regard to subdivision design, high-risk areas of the floodplain (perhaps land in a levee or dam failure zone) may be subject to a stricter regulatory regimen than land elsewhere in a community. Additionally, a focus on hazards should not preclude addressing complementary goals within the floodplain or watershed, such as open space preservation or wildlife conservation.

Other Planning Tools and Linkages

Most communities have a combination of plans aside from the comprehensive plan, and each is an opportunity to align planning with subdivision policy and hazard mitigation. Consideration of future conditions is vital to an effective integrated community approach to subdivision design in flood hazard areas. Quantifying future development potential, the loss of open space buffers, and the significantly higher flood elevations associated with sea-level rise can be extraordinarily useful in various special purpose plans of a community.

Functional plans such as parks plans, transit plans, or water supply plans introduce some difficulties when integrating hazard mitigation plan elements, as they are often produced by regional agencies or special planning districts. These policies can have a significant bearing on subdivision design that is outside of the ability of the community planner to influence, especially if subdivision design approval comes from the special planning district and not the municipality.

Area plans may be extraordinarily well suited for integration with hazard mitigation for subdivision design. These plans have a narrower geographic focus than comprehensive plans, which allows for a far greater level of detail with respect to local flood hazards.

Policy drivers in the form of federal and state laws effectively drive local governments to implement certain measures. These drivers can be leveraged to overcome tepid political will and develop more stringent regulations (for instance, maintaining wetland or open space buffers as a condition of meeting federal Clean Water Act standards) for subdivision planning and development.

Regional plans are useful in establishing a larger context for watershed management and floodplain management that goes well beyond the boundaries of a single subdivision. Regional plans are a step removed from comprehensive plans, and they may not have the force of municipal policy that a comprehensive plan does. However, they can create the needed context for connectivity between communities within the same watershed.

Implementation Tools

Implementation tools are the most important link between the various plans a community may develop and good subdivision design. Implementation can happen through code enforcement, public investment, creation of new regulations, programmatic efforts, or local incentives for property owners, developers, and investors. Capital improvements policy within a planned subdivision, the encouraging or requiring of conservation development (clustering residential development while preserving natural areas), and the benefits conferred by active participation in the Community Rating System all can function as effective implementation tools.

SUBDIVISIONS: ROLE AND PROCESS

A key to implementing comprehensive subdivision standards for flood loss reduction and preservation of floodplain functions is to have a comprehensive and integrated approach to subdivision review, competent inspections, and ongoing maintenance of any flood loss reduction infrastructure. The subdivision development review and approval process should be consistent with all local plans and standards and informed by the full array of flood hazard data, resulting in resilient design and lessened damage.

Effectively reducing flood risk requires sound planning principles and consistent flood reduction strategies on a day-to-day basis. This includes developing staff floodplain management capability; identifying and gathering all relevant flood hazard information; ensuring consistency of subdivision design across the spectrum of local plans, programs, and policies; proactive communication with developers, partner agencies, and local elected officials; and communication with local owners associations about a variety of flood risk management topics, especially in cases where infrastructure is managed and maintained by the association.

The subdivision design review process is the primary avenue for ensuring that the proposed development is consistent with flood risk management principles and any local, regional, or national plans and policies. Each step in the process can help to incorporate flood risk management into the final subdivision design proposal:

- **Due diligence/pre-sketch plan meeting stage:** This is an early opportunity to influence design and inform the applicant of the community's development regulations, including its flood loss reductions standards.
- **Sketch plan stage:** This is an opportunity to more effectively discuss feasibility and plan elements such as general layout, topography, existing conditions, known utilities, and existing storm drainage features.
- **Preliminary plan:** This should include applicable engineering design elements, including precise hydrologic calculations and analyses, the location of flood hazard areas, subdivision entry and exit points, and preliminary construction drawings for any infrastructure that may be necessary.

- **Commencement of construction:** A final plat will be submitted to the planning department and should be used to convey vital flood risk information, recordation of flood hazard areas, base flood elevations, or physical monumentation of the flood boundary (if required by the city).
- **Proper inspection and oversight:** After approval, these activities are important to ensure that floodplains are not degraded, flood risk is not increased, and applicable regulations have been followed. Periodic inspection by the community and the design professional is important to ensure compliance, and oversight is especially important to ensure subdivision stormwater facilities are in proper working condition.

SUBDIVISION STANDARDS

In contrast to the prescriptive approach to subdivision standards in PAS Report 473, this report categorizes recommended standards based on five considerations for all subdivisions. This approach is intended to give the practicing planner a menu of standards that can be used individually or collectively to decrease the risk of flood impacts to subdivisions and to minimize the impact of subdivisions on the floodplain.

Natural and Human-Made Geographic Features

Flooding can result from any number of natural and human-made features. Flooding of rivers and streams and along coastlines is familiar. However, other geographic features are also susceptible to flooding: gulches that are dry most of the year can become raging torrents during heavy rainfalls in the Southwest, alluvial fans can have unpredictable and undefined flow areas, and shallower lakes with large surface areas can have wind-driven flooding due to storms or frontal systems. Additionally, a number of human-made features can result in flooding. One of the most common flooding events is urban stormwater flooding in older areas of cities.

Recommended standards for natural and human-made geographic features include the following:

- Map waterbodies without identified floodplains (e.g., ditches, ponds, lakes), lower lot or area minimum thresholds to trigger more detailed flood studies, and perform future flood conditions analyses (for both land use and hydrology).
- Protect, inventory, and restore riparian areas. Maximize riparian buffers.
- Identify dam failure areas on preliminary plans and final plats. Perform an impact analysis of any proposed development in the dam failure inundation zone.
- Identify levee protection areas on subdivision plans and plats. Require maintenance easements, buffers, and setbacks along the side of the levee facing the subdivision.
- Protect alluvial fans by prohibiting newly created lots and prohibiting improvements to existing structures using fill.

Layout and Design

Depending on the size of the subdivision, the stormwater created by the development itself can result in increased flood risk to on-site buildings and infrastructure as well as offsite impacts. For practicing planners, a persuasive argument to elected officials is that new development must not create conditions for future problems for those property owners, nor should it result in higher flood risks for existing residents of the community.

Recommended standards for layout and design include the following:

- Ensure that conservation subdivisions protect and preserve natural features. Prohibit the creation of new lots in the floodplain, or require that new lots have adequate buildable areas above the 100-year flood elevation.
- Perform an impact analysis and mitigation by prohibiting the subdivision of land that is unsuitable for development due to flooding, poor drainage, or other conditions that may endanger health, life, or property. Require evaluation of communitywide impacts. Adopt a No Adverse Impact standard.
- Require use restrictions prohibiting the platting of land for uses that may increase dangers to health, life, or property. Prohibit new lots in the floodplain without a natural grade elevation above the regulatory floodplain. Prohibit the use of fill. Do not allow critical facilities in the floodplain extent or the flood of record extent, whichever is greater. Do not locate land reserved for schools or fire stations in the floodplain.
- Require new private or public streets in the subdivision to access an existing "dry" road during the 100-year flood and/or be constructed above the 100-year floodplain.

Infrastructure

Where flood risk is present, infrastructure should be carefully considered and protected accordingly. A great deal of

infrastructure may be considered "critical" in that is it is needed during a flood emergency, and additional standards and safeguards should be applied to such facilities.

Recommended standards for infrastructure include the following:

- Require local road systems, including culverts and bridges, to be built to a 100-year storm elevation.
- Do not exempt utilities from flood protection standards. When possible, require utility easements to be located outside the floodplain or build redundancy into utilities that cannot be located outside the floodplain. Require transmission lines containing toxic or flammable materials to be buried to at least a depth below the calculated maximum depth of scour for a 100-year flood.
- Require that all stormwater and flood protection infrastructure owned by an owners association be turned over to the local government for maintenance. Require a study to identify ongoing maintenance costs of all stormwater and flood protection infrastructure, which incorporates reasonable life cycles and sea-level rise projections. Require the developer to identify annual maintenance costs of stormwater and flood protection infrastructure and fund the maintenance of such facilities until the owners association is established.

Platting

While subdivision plats may not ever be viewed by subsequent buyers of lots, they nonetheless can serve an important function in providing information on flood risk. However, thought should be put into how this information is conveyed so that it is not implied that a flood hazard never changes (e.g., not putting a flood elevation on a plat unless it is also accompanied by an explanation that flood risk can change over time).

Recommended platting standards include the following:

- Require flood hazard information on plats and plans. This includes 100-year and 500-year flood elevations and boundaries, specific references to FIRM panels, and relevant information about elevation and flood insurance requirements.
- Permit density bonuses when coupled with restrictive covenants and easements. Require conservation and drainage easements in floodplain communities where lots may not be developed.
- Require physical monumentation of floodplain boundaries.

Watershed Management

Perhaps nowhere have the science and techniques evolved more over the last 20 years than in the area of watershed management, especially for flooding. Powerful new models can now precisely show causation of flood events due to improper or undersized stormwater features. New techniques such as low-impact development and green infrastructure can result in more stormwater being held and infiltrated on site. With even a few small changes, a community's subdivision standards can significantly promote these better practices.

Recommended standards for watershed management include the following:

- Require green infrastructure and low-impact development techniques for stormwater management and design. Require submittal of a stormwater control plan. Require post-development peak storm flows and runoff for the 100-year storm to be no higher than was the case prior to development. Require retention and detention facilities based on the 24-hour, 100-year storm.
- Identify conservation land priorities. Within a certain distance of a desired habitat protection area, prepare a habitat assessment. Protect existing ecosystems by implementing a riparian buffer based on habitat protection, and prohibit or minimize clearing, grading, and filling in these areas.

THE ROAD AHEAD

Change is a virtual certainty. Planners and floodplain managers must be prepared to help shape the future in both practice and policy terms. The following are nine specific issues related to the flood risk mitigation measures needed to ensure better public safety in the coming decades.

Incorporate climate change considerations into planning standards for land use and development. Climate science will continue to advance. Data at the regional level are now allowing scientists to provide impacts within certain ranges that can inform land-use policy in areas like floodplains. Within the lifecycle of buildings and infrastructure, it is now possible to build in a margin of safety with regard to likely precipitation, the likelihood of extreme coastal events, and the general heights of floodwaters. Therefore, access to and the availability of data are crucial to planners.

Improve technology and visualization tools for subdivision design. Many communities want and need assistance in using and deploying advanced scenario planning and

design visualization tools. It is important that cutting-edge tools be mainstreamed into planning practice in the context of resilience. Better visual and mental representations of the outcomes of decisions will help ensure that developments affected by flooding will be better designed in the face of environmental hazards.

Expand the use of future-conditions analysis to include subdivision standards. Analysis of future conditions based on projected land-use development and flood risk is possible today. These analyses can assess future buildout under existing land-use ordinances and policies as it relates to flood threats. Relatively static data, such as FEMA's flood maps, are useful as general signifiers of risk, but more dynamic analysis is necessary if communities are to comprehensively plan for future development and flood hazards.

Strengthen attention to local planning capacity for floodplain management and subdivision design. Funding and resources in many communities, especially rural communities, is tight. State, regional, and metropolitan area technical assistance and policy guidance are crucial to strengthening local capacity.

Develop best practices and tools for local government to use green infrastructure and No Adverse Impact strategies to improve subdivision design in flood hazard areas. Green infrastructure has emerged as a specific area of interest for local planners, in part to mitigate the impacts of riverine and urban flooding. The recent surge of interest in both green infrastructure and No Adverse Impact principles will hopefully lead to mainstreaming of these approaches in local planning practice. This is likely to be an increasingly fertile area of investigation in the coming years.

Educate and inform stakeholders in the subdivision design approval process. The subdivision design process should not escape notice as FEMA adjusts to a broader, more deliberate engagement with communities. Outreach, tools development, and planning are crucial in this effort. As more infrastructure maintenance and ownership shifts to local owners associations, direct outreach is vital to ensuring sound subdivision flood risk management.

Increase professional development of city staff on floodplain management and its relationship to good subdivision design and plan review. Floodplain management principles and their relationship to good subdivision design must be more deeply integrated into the planner's educational and training regimen. It is the role of APA, its chapters, and other organizations to make such training available. Additionally, local governments must take the initiative to highlight and encourage these opportunities.

Increase the focus on hazard management to broaden the view of impacts from development. Good floodplain management is about how we manage the landscape. It is vital to develop a more comprehensive understanding of how development in the floodplain affects the watershed and the wider built environment. Without a more holistic understanding of the topography and of our communities, we are doomed to repeat mistakes of the past.

Incorporate the review of subdivision standards in local and regional hazards plans. The role of land use in reducing flood hazards is undeniable. A review of the role played by subdivision design standards and the subdivision approval process within the hazard mitigation plan is long overdue. Pre-disaster and post-disaster resiliency plans are a prime opportunity to incorporate lessons learned as they relate to subdivision design. Ultimately it is essential that these plans, along with the comprehensive plan, work together to ensure a stronger, safer, and more resilient community.

Ultimately, most of these goals work toward a common theme in APA Hazards Planning Center's work: the integration of resilience and hazard mitigation throughout the planning process. It is best to make various plans work in concert toward this end. The precise issues may vary from one community to another. What matters is the willingness to use the available tools as best they apply and to keep in mind an adage from *Planning for Post-Disaster Recovery: Next Generation*, PAS Report 576: *We cannot know when a community will encounter its moment of truth, but procrastination is not an option.*

CHAPTER 1

MAKING THE CASE TO BETTER MANAGE FLOOD RISK

Prior to the publication of *Subdivision Design in Flood Hazard Areas*, PAS Report 473 (Morris 1997), there was scant information related to subdivisions and their impact on flood risk. State floodplain management offices—also called state National Flood Insurance Program coordinators—may have compiled some best practices, and communities had examples of these adopted in their local codes. However, until this report, no single resource was available that focused on the process of subdividing land.

Today PAS Report 473 and its recommendations, tools, and ideas are still relevant. However, in the almost two decades since the publication of the report, much new knowledge has been gained, technology has evolved, and, perhaps most importantly, flood losses have continued to rise. Either the knowledge gained has not been adopted or more needs to be done.

The intent of this PAS Report is to complement PAS Report 473—in effect, to act as a second volume elaborating on new information or tools that have been developed since 1997—and to reflect new ways of thinking; this new report will cross-reference PAS 473. At its foundation, this PAS Report is about working toward a more comprehensive system for saving lives and protecting property and about building communities that are free from, or at least have a reduced risk to, flooding—the nation's number one natural hazard.

So what has changed over the last 19 years?

ERA OF THE BILLION-DOLLAR DISASTER

Weather-related disasters are becoming increasingly frequent, due largely to a sustained rise in the numbers of floods and storms. From 1995 to 2015, flooding alone accounted for 47 percent of all weather-related disasters worldwide, affecting 2.3 billion people (United Nations Office for Disaster Reduction 2015).

Since PAS 473, large flood disasters in the United States—including those caused by severe storms and tropical cyclones—have increased significantly. Aggregating the billion-dollar disasters attributable to what the National Climactic Data Center categorizes as flooding, tropical cyclones (flooding is a large component), and severe storms (flooding is a component) shows the number of events climbed from 38 between 1980 and 1997 to 86 between 1998 and 2014. Recent research has suggested a trend of about a 5 percent increase per year in the number of billion-dollar disasters (Smith and Katz 2013). In the 1990s, the nation experienced approximately $5.4 billion in flood losses annually. This jumped to over $10 billion annually in the 2000s (ASFPM 2013a). The two obvious conclusions are that (1) flooding is increasingly occurring as part of extreme weather events that involve other hazards and (2) the approach we are taking as a nation is clearly not reducing losses.

Given the brief period of history in which flood losses have been tracked in the United States, it is fair to say we have not seen the "probable maximum flood" for most areas. While Hurricanes Katrina and Sandy have caused over $200 billion in losses, both events could have been worse—and some future events likely will be. Trends indicate that federal taxpayers are bearing a greater share of disaster costs than ever before. A recent analysis showed that from 1989 to 2004, federal aid as a percentage of all economic costs from major hurricane events averaged 26 percent. Since 2005, the federal aid proportion jumped dramatically to 69 percent (ASFPM 2013a). Even if the climate stabilizes, millions of people are still at risk, especially for flood-related incidents. And that risk is still growing because natural hazards continue to be ignored when development decisions are made (Thomas and Turner 2011).

Demographic trends are also putting more people and more property in harm's way. The National Oceanic and Atmospheric Administration (NOAA) anticipates that by 2020, 47 percent of the nation's population will live in counties

that are adjacent to shorelines (approximately 10 percent of the nation's land area, not including Alaska). That means it is projected that approximately 133.3 million people will live in our nation's coastal areas. NOAA does not expect these projections to diminish anytime soon.

THE RISE OF RESILIENCE, CLIMATE CHANGE, AND ADAPTATION

In 1997, "sustainability" and "resilience" were just words found in the dictionary and not necessarily a concentrated focus of land development, as they are today. No one had begun to recognize or had given much thought at all to our ever-changing climate—much less how to adapt to it. More recently, several federal agencies have become involved in resiliency by, for example, sponsoring competitions and developing tools for communities to better plan and implement resiliency actions. In 2015 the US Department of Housing and Urban Development's National Disaster Resilience Competition (NDRC) resulted in grants to states and municipalities around the country totaling almost $1 billion (US Department of Housing and Urban Development 2015a). The Rockefeller Foundation is promoting the concept worldwide with its 100 Resilient Cities initiative (www.100resilientcities.org).

A good working definition of resilience for land-use planners can be found on the NDRC fact sheet: "A resilient community is able to resist and rapidly recover from disasters or other shocks with minimal outside assistance" (US Department of Housing and Urban Development 2015b). This definition includes both the elements of resistance and rapid recovery—so the focus is not exclusively on recovery but also on risk-reduction activities—and the notion of doing it with little external help.

Using this definition then, how would a planner ensure a flood-resilient new subdivision? The following are two possible scenarios that highlight the specific ways communities and planners could think about resilience in this context.

Example Scenario 1. A tract of land that is proposed for a large residential subdivision has several streams running through it, and the land in the area is also known to be highly erodible. Instead of just relying on Federal Emergency Management Agency (FEMA) flood maps that do not identify flood hazards on the site, the community requires the collection of flood hazard data for all of the watercourses affecting the property. Additionally, the community requires the evaluation and protection of potential erosion zones associated with those same watercourses. The potential for impact of structures located outside the regulatory floodplain can occur in riverine erosion zones, and erosion can occur not only during the larger 100-year event but also during the smaller events. Therefore, the community requires these flood hazard areas to be identified, dedicated as reserve areas, and protected as open space.

Example Scenario 2. A new subdivision is proposed downstream of a large, high-hazard dam. The community and developer work to identify flood hazard areas within the proposed development, including those resulting from the activation of the emergency spillway and possible dam failure zones. The community requires configuration of the subdivision lots to avoid the dam failure inundation zone and the emergency spillway inundation area. In addition, the developer is required to provide data about the proposed subdivision to the dam owner in order to allow updating of the community's emergency action plan for the upstream dam in case of dam failure.

Inherent in the definition of resilience is the acknowledgment that there may be areas that are too hazardous for development. Resilience is different from sustainability primarily in terms of the end goal. For resilience, it is the ability to withstand large shocks to the system. For sustainability, it is to ensure the protection of a benefit for current and future generations. Resilience also goes beyond the physical environment; recent social science research shows the need and value of ensuring that social systems are resilient as well (Davidson 2010).

Few issues have been more politically charged in the last two decades than climate change. But as time has passed and scientific data have accumulated, it is clear that climate change is occurring. From a flood-risk perspective, climate change is resulting in the following conditions:

- Sea-level rise will affect communities on every coastline in the United States. Also in coastal areas, the warming oceans are resulting in more energetic tropical cyclone systems, increasing the frequency and range of high-hazard events.
- Inland flood risk is changing with more frequent extreme precipitation events. The distribution of rainfall is changing, and more rain is being concentrated in shorter, more intense storms.
- The traditional precipitation regime in the western United States is changing, particularly in the intermountain area of the West. Generally, snowpacks are decreasing and snowmelt is occurring earlier. The carefully managed water systems calibrated to meet several competing water-use

objectives must account for increased springtime temperatures, which result in rainfall events versus snowfall events.

The focus of most planners dealing with hazards and land use is to adapt to these changing conditions. Key to adaptation is identifying what the future condition might be and the appropriate adaptation technique to use. The Intergovernmental Panel on Climate Change describes climate change adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2014). Adaptation seeks to lower risks posed by the consequences of climate change. This is not to be confused with climate change mitigation, which is focused on addressing root causes like reducing greenhouse gas emissions. Nor is it to be confused with hazard mitigation, which is a sustained action to reduce or eliminate the long-term risk to life and property from hazard events. However, many climate change adaptation techniques may also be good climate hazard mitigation techniques.

In the past two decades, communities have shifted from a general focus on limited resources, untrained personnel, and lack of adequate information to topics such as sustainability, resilience, and climate change. These topics are at the forefront for planners, floodplain managers, hazard mitigation specialists, and other related professionals all aimed at understanding vulnerabilities, assessing risks, and reducing the susceptibility to human-made and nature-induced hazards. Meanwhile, subdivision practices have seen relatively little change, especially in terms of comprehensive floodplain management and resilience of the subdivision itself.

CHANGES IN TECHNOLOGY

Since 1997 the technology and models used to identify and assess flood risk have changed substantially. The following discussion examines a couple of these developments in more depth.

One of the primary inputs into any flood mapping is the topography of the land. Lidar, which stands for light detection and ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to Earth. These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. Terrestrial Lidar (using the same light pulses) can be used for land surface analysis of flood risks, such as small cracks or imperfections in dam or levee walls. The advantages of Lidar over traditional photogrammetric methods for collecting elevation data include high vertical accuracy, fast data collection and processing, and robust datasets that can be used to generate many different products.

The US Geological Survey (USGS) is leading the 3D Elevation Program (3DEP) initiative (http://nationalmap.gov/3DEP/). It is being developed to respond to growing needs for high-quality topographic data and a wide range of other three-dimensional representations of the nation's natural and constructed features. The primary goal of 3DEP is to systematically collect Lidar elevation data for the conterminous United States, Hawaii, and the US territories, with the data acquired over an eight-year period.

Another factor affecting flood hazard identification is the advancement in flood models. Today, two-dimensional flood models are replacing older one-dimensional models. In coastal areas, far more precise models—such as those generated by the ADCIRC system (http://adcirc.org/)—are effective at predicting hurricane storm surge and flooding. Also, the ability of models to quickly generate data has been enhanced using faster, more powerful computer workstations. Flood modeling is improved by the use of the rich Lidar datasets to create increasingly precise flood boundaries. Finally, researchers are using less expensive methods of auto-generating flood elevations that are model based, in areas with lower flood risk. Much of this modeling technology did not even exist in 1997.

IMPROVEMENTS IN DEFINING FLOOD RISK

A commonly used expression of flood risk is probability multiplied by consequences. The probability element of the flood risk equation is commonly expressed through flood maps. In the United States FEMA Flood Insurance Rate Maps (FIRMs) are the most widely available. However, these maps only depict certain flood risk areas—the 100-year flood zone, the 500-year flood zone, and high-hazard floodways and velocity zones. FIRMs typically do not identify all of the following flood risks: higher frequency flood zones (such as the 10-year or 25-year flood zones), fluvial erosion zones, dam failure and emergency spillway inundation zones, levee failure zones (for levees certified to provide 100-year protection), and tsunami and tropical cyclone surge zones (in excess of the 100-year frequency flood).

Also, FIRMs only cover approximately 1.2 million miles of the 3.5 million miles of streams, rivers, and coastlines contained in the USGS's National Hydrography Dataset. FEMA's floodplain mapping programs to date have chosen to prioritize limited resources for those areas of existing population and flood insurance policies. The impact for newly subdivided land is clear. There is likely not adequate existing flood mapping for newly developed areas since, prior to being subdivided, the areas were considered low risk due to lack of development and minimal population.

Flood maps are used for many purposes. FIRMs are used to determine flood insurance rates, guide development regulations, and promote flood protection in areas at risk for floods. Government officials use them to aid in establishing zoning, land-use, and building standards; to support land-use, infrastructure, transportation, flood warning, evacuation, and emergency management planning; and to prepare for and respond to floods. Insurance companies, lenders, realtors, and property owners depend on these maps to determine flood insurance needs. For citizens, businesses, and communities, FIRMs are essential tools for reducing flood losses and are the nation's default source of flood hazard information.

Accurate flood maps are dependent on precise and high-quality flood hazard data, and premium quality topographic information is essential. Further, quality topographic data has multiple uses and can be used by various programs and agencies. Communities can then use other datasets in addition to the flood maps and topographic data to determine safe evacuation routes for citizens, support first responders in emergencies, account for changes in the tax base, and update a variety of local plans (e.g., hazard mitigation, comprehensive land-use, and capital improvement plans). Such data can reduce the need to conduct field surveys by agencies, such as departments of transportation, and can help officials plan for resilient community growth.

Maps depicting flood hazard areas are not only the foundation of the National Flood Insurance Program policy rating but are also the basis of sound floodplain management policies at the local, state, and federal levels. Adequate, accurate, and current maps are essential for the program to function adequately. If a potential flood-prone area is not mapped, the community has no tool to adequately guide development to be safer in that particular area or to mitigate future flood losses. If a potential flood-prone area has outdated flood maps, or there are areas where development has far exceeded updated mapping information, the community has an inferior tool for development and mitigation planning.

The consequences of flood events on individuals have been well documented and include lost wages and agricultural products, expenses for evacuating, and significant health and mental health issues for years following the event. For businesses, the effect is pronounced. According to FEMA (2016), almost 40 percent of small businesses do not reopen after a disaster and another 25 percent fail within one year. Similar statistics from the US Small Business Administration indicate that over 90 percent of businesses fail within two years after being struck by a disaster. Businesses also experience lost revenues from being closed, which in turn means lost taxes, lost jobs, and lost wages throughout the community. Businesses can be affected by employees being unable to get to work due to transportation system failures or their own homes being devastated. Supply lines can be disrupted. All of this has a direct and significant impact on where we live and how we live. Without a source of income from employment, many homeowners are unable to pay their mortgages, and if the business interruption is sustained, it may result in widespread foreclosure in the flood-affected area.

Communities also suffer. Beside the loss of taxes from closed businesses, local funds earmarked for other uses must instead go to flood repair and recovery, physical and mental health services, and the use of community resources (staff, equipment, and infrastructure) for response, rescue, and recovery. Community infrastructure can be severely affected, including the most costly and vital-to-the-public elements, such as water and wastewater treatment facilities. Debris collection and environmental cleanup can be significant and lengthy. Local taxes, such as income and property taxes, are reduced, both in the short and long terms. Roads, bridges, and other infrastructure, such as emergency facilities, can be damaged or completely destroyed. The impacts of flooding on a state include a diversion of resources from necessary programs to response and recovery programs. State taxes, such as income and property taxes, decrease, and impacts can be severe enough that recovery can take years.

All taxpayers pay for the consequences of flooding, whether or not they live or work in a Special Flood Hazard Area. If property owners do not have flood insurance, taxpayers provide assistance through disaster relief. This may take the form of tax deductions, grants, or loans and can include short-term emergency assistance to ensure that victims have basic necessities, such as food, clothing, housing, transportation, and medical assistance (including psychological counseling) as well as longer-term aid, depending on the severity

of the event. The casualty loss deduction allowance and the loss of tax revenue due to lost wages surrounding a business closure result in forgone tax revenue (the difference in earnings or performance between what is actually achieved and what could have been achieved with the absence of specific fees, expenses, or lost time). Insurance subsidies, through either crop or flood insurance, result in costs to the US Department of the Treasury.

Nonstationarity and Future Flood Risk

Both within the National Flood Insurance Program and more generally, flood risk has traditionally been determined by examining past occurrences only. Models generate flood elevations for any given area by using stream gauge data, historical events, and statistics. Nearly all of the methods and models developed for the planning, management, and operation of water resource systems assume stationarity—that historical stream flows will remain unchanged in the future. However, nonstationarity can result from myriad human influences, ranging from agricultural and urban land-use modifications to climate change to modifications to water infrastructure (Vogel et al. 2011). Over the past 15 years, communities, engineers, and modelers have begun to examine the impacts of future flood conditions and nonstationarity—primarily due to climate change—on current mapped flood elevations and flood damages. These future-condition scenarios have then been incorporated by communities into their flood maps and land-use management programs. In some cases, the changes resulting from future-conditions scenarios have been dramatic.

One factor for future flood risk is future land use. Intensification of land use in a watershed increases impervious surfaces, which increases runoff and changes the timing of the flow of stormwater. Planners can use future land-use maps and buildout analysis to get a better understanding of the potential impacts of development (Godschalk 2006).

Another factor for future flood risk is climate change. In riverine areas, this factor is seen in hydrology—namely changes in the intensity, frequency, and type of precipitation. In coastal areas, it is seen in the warming of the oceans and sea-level rise. The science of climate-change-induced future flood risk in coastal areas is at the point where data such as sea-level rise scenarios for planning purposes can and should be used. A recent report, *In Deep: Helping Sandy-Affected Communities Address Vulnerability and Confront Flood Risk* from New Jersey Future (2015, 15), made a number of recommendations for dealing with the reality of future flooding risks along the New Jersey coastline, including the following: "The state and each county and municipality should map areas likely to be flooded today and in 2050 and adopt these maps as part of their land-use plans."

RECOGNIZING THE BENEFITS OF PROTECTING THE FLOODPLAIN RESOURCE

The nation's floodplains continue to be affected by development and, in turn, the natural and beneficial functions of floodplains are affected as well. A floodplain is a part of a larger watershed; a watershed is a region or area that drains into a particular river or other water body. Watersheds can encompass thousands of acres and can cross numerous political jurisdictions. Activities that disrupt one part of the watershed, such as land clearing and development, have multiple effects on other parts of the watershed, affecting areas both upstream and downstream.

Improvements in Quantifying Natural and Beneficial Functions of Floodplains

Floodplains are among the most productive of the planet's ecosystems. Table 1.1 (p. 16), from PAS Report 473, provides an excellent summary of floodplain resources and the natural functions of floodplains. At the same time, the nation's rivers and other bodies of water have been highways for exploration, migration, and commerce, as well as disposal systems for the byproducts of our industrial society. Almost all major cities are located on a river or at the mouth of a river. Most smaller communities have at least one stream that helps define local character and is an important source of community identity (Federal Interagency Floodplain Management Task Force 1992).

Since the last PAS Report on subdivision design and flood hazards, much has been learned about managing the natural and beneficial functions of floodplains as research and new techniques have emerged. For the planning practitioner, these new data may be helpful in making the argument for strengthened land-use, subdivision, and zoning standards or may provide ideas for developers to consider when proposing new subdivisions or redeveloping old ones. Several advances have been made in the ability to quantify the value of environmental benefits. FEMA's current Benefit-Cost Analysis Tool used for its Hazard Mitigation Assistance grant programs now incorporates values for a number of environmental benefits, as summarized in Table 1.2 (p. 17). As the table illustrates, riparian land, where

TABLE 1.1. NATURAL AND CULTURAL RESOURCES OF FLOODPLAINS

Water Resources
Natural flood and erosion control
• Reduce flood velocities
• Reduce flood peaks
• Reduce wind and wave impacts
• Stabilize soils
Surface water quality maintenance
• Reduce sediment loads
• Filter nutrients and impurities
• Process organic and chemical wastes
• Moderate temperature of water
• Reduce sediment loads
Maintain groundwater supply and quality
• Promote infiltration and aquifer recharge
• Reduce frequency and duration of low flows (i.e., increase/enhance base flow)
Living Resources
Support flora
• Maintain high biological productivity of floodplain/wetland vegetation
• Maintain productivity of natural forests
• Maintain natural crops
• Maintain natural genetic diversity
Provide fish and wildlife habitat
• Maintain breeding and feeding grounds
• Create and enhance waterfowl habitat
• Protect habitat for rare and endangered species
Cultural Resources
Maintain harvest of natural and agricultural products
• Create and enhance agricultural lands
• Provide areas for cultivation of fish and shellfish
• Create and enhance forest lands
• Provide harvest of fur resources
Provide opportunities for recreation
• Provide areas for active and consumptive uses
• Provide areas for passive activities
• Provide open-space value
• Provide aesthetic value
Provide areas for scientific study and outdoor education
• Provide opportunities for ecological studies
• Provide historical and archaeological sites

Source: Morris 1997

most floodplains exist, is very valuable when maintained primarily as a floodplain.

Organizations such as Earth Economics have found that floodplains provide a multitude of ecosystem services, including natural places for recreation and enjoyment; scientific and education opportunities to learn about the planet; hunting, fishing and wildlife viewing; and habitat and ecosystem diversity—to name a few of the many benefits. The value of each of these areas depends on the "position, pattern (size and shape), and connectivity of habitat elements" that all factor into the number of ecosystem services they provide (Earth Economics 2015, 47). In other research, Highfield and Brody (2006, 123) found that "after controlling for environmental and socioeconomic variables, the number, type, and location of wetland permits are a significant predictor of flood damages," further reinforcing the importance of protecting floodplains and riparian areas.

Stream Restoration Gains in Popularity

Stream restoration has the ultimate goal of restoring a functional ecosystem, reestablishing the processes and functions between the aquatic and associated riparian ecosystems. It repairs damage caused by human activities. After World War II, policies tended to shift toward economic management over environmental river management, resulting in thousands of miles of streams and rivers being channelized, paved, buried, or otherwise altered. Since 1998, the number of stream restoration projects has exploded. Concrete-lined channels or buried streams are giving rise to restoration projects that often use natural channel design principles to create stable streams.

A restoration strategy called "two-stage channel systems" can be part of a natural channel design approach or done outside of it, and it provides improved physical and ecological performance over the traditional trapezoidal channel approach (Figure 1.1). It includes a channel-forming discharge channel and a floodplain bench or floodplain channel which can handle very large flows (i.e., Q100+). Currently, however, the science is inconclusive as to which stream restoration approaches work best, and experience suggests that effective designs are highly site specific. Planners may encounter stream restoration as part of new subdivisions containing channelized farm ditches or in the redevelopment of older, established subdivisions.

No Adverse Impact Approach

The No Adverse Impact (NAI) floodplain management approach developed by the Association of State Floodplain

TABLE 1.2. ANNUAL ESTIMATED MONETARY BENEFITS OF GREEN SPACE AND RIPARIAN AREAS PER ACRE

Environmental Benefits	Green Open Space ($)	Riparian ($)
Aesthetic value	1,623	582
Air quality	204	215
Biological control		164
Climate regulation	13	204
Erosion control	65	11,447
Flood hazard reduction		4,007
Food provisioning		609
Habitat		835
Pollination	290	
Recreation/tourism	5,365	15,178
Stormwater retention	293	
Water filtration		4,252
Total Estimated Benefits	**7,853**	**37,493**

Source: FEMA 2013a

Managers (ASFPM) helps communities identify the potential impacts of development and implement actions to mitigate those impacts before they occur. In essence, NAI floodplain management is an approach that ensures that the action of one property owner or a community does not adversely affect the properties and rights of other property owners, as measured by increased flood peaks, flood stage, flood velocity, erosion, sedimentation, and costs now and in the future. Addressing these adverse impacts protects the natural and beneficial functions of floodplains as well. If a community values a particular natural function of the floodplain, it can be included in the list of potential adverse impacts that must be addressed.

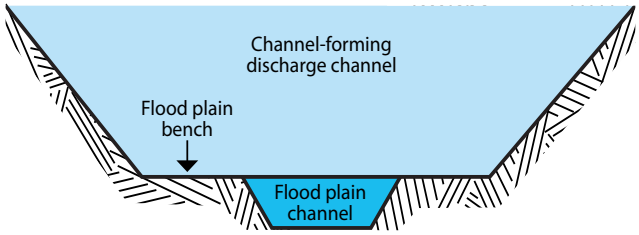


Figure 1.1. Conceptual design for two-stage channel system (National Resources Conservation Service 2007)

The true strength of the NAI approach is that it encourages local decision making to ensure that future development impacts will be considered and mitigated—leading to a comprehensive strategy to reduce flood losses. NAI floodplain management is not a "no development" approach, but rather a process of regulating and permitting proposed development in a manner that ensures existing and future property owners are protected from adverse impacts *before* the development occurs.

ASFPM has been developing NAI tools for the past 15 years. More recently, a series of NAI how-to guides has been developed, which profile at least five NAI-level tools or actions for seven common classes of community activities: hazard identification and floodplain mapping, education and outreach, planning, regulations and development standards, hazard mitigation, infrastructure, and emergency services (ASFPM 2016). Planners can incorporate NAI tools into community plans, adopt specific regulatory or policy language, initiate individual projects, prepare master plans with NAI principles, or start or revise entire programs.

LEGAL ISSUES FOR SUBDIVISIONS AND FLOODPLAIN MANAGEMENT REGULATIONS

Government has an affirmative duty to prevent harm. The jobs of planners, floodplain managers, stormwater professionals, and professionals in disciplines related to water resources—especially those working in, for, and around government—are all centered around harm prevention. As simple as that sounds, it is much more difficult to put into practice. A few years ago, NOAA commissioned a report based on interviews with community development officials around the nation. The conclusions reveal two basic reasons why we are not doing more to lessen the severity of disasters. The primary reason is economics. De-

PLANNING FOR FUTURE FLOOD RISK IN NORTH CAROLINA

The following is based on an excerpt from *No Adverse Impact Floodplain Management: Community Case Studies* of a case study of Mecklenburg County, North Carolina (ASFPM 2004):

Mecklenburg County faces overbank flooding from its many streams, stormwater drainage problems, erosion, channel degradation, and occasional flooding caused by hurricane-related rainfall. The county includes Charlotte and six other towns and covers over 500 square miles in south-central North Carolina. Its population of 2.1 million is growing steadily.

In 1999 Charlotte-Mecklenburg Stormwater Services embarked on a new approach to update its 1975-era flood maps. Instead of an update to minimum National Flood Insurance Program standards, Charlotte-Mecklenburg undertook a series of studies and research that ultimately led to new flood maps for a future-conditions floodplain that is now the consistent basis of regulation throughout the county. The research and modeling showed that the average flood elevations based on ultimate buildout of the watershed were 4.3 feet higher on average than those on the old maps (based on 1975 land use). About half of that increase resulted from land-use changes between 1975 and 1999, and the rest is from changes projected to occur between 1999 and full buildout. The study of cumulative impacts indicated that filling in the floodplain fringe, as allowed by National Flood Insurance Program minimum standards, could result in increases in flood elevations of almost 2.5 feet.

The new floodways are based on ultimate buildout and a 0.1-foot allowable rise (versus one foot allowed under National Flood Insurance Program minimum standards). These new floodways averaged 454 feet wide versus floodways averaging 290 feet wide on the 1975 flood maps. Setting aside lands for filtering pollutants was calculated to decrease flood heights by 0.5 feet. Water quality buffer locations were overlaid on the floodplain maps and, where appropriate, either the water quality buffers or the new floodplain boundaries set the limits for development in and around the floodplain.

The staff proposed, the development community supported, and the governing bodies accepted that proposed regulatory flood elevation guiding further development in and around the floodplain would be based on ultimate development in the watershed plus one foot of freeboard and a 0.1-foot allowable floodway rise. Based on a flood loss economic study of the new county-wide floodplain maps and associated regulations, it is estimated that over $330 million in structure and content losses (for a single 1-percent annual chance event after ultimate buildout) have been avoided with the new approach.

COLUMBIA VENTURE, LLC V. RICHLAND COUNTY (2015)

The opinion from the South Carolina Supreme Court in the case *Columbia Venture, LLC v. Richland County* (No. 27563, 2015) is one of the strongest endorsements of the legitimacy of land-use controls for flood loss reduction to date and is important because most past floodplain takings cases applied an outdated analysis. In *Lingle v. Chevron USA Inc.* (544 US 528, 2005), the US Supreme Court shifted considerations of a takings analysis away from due process considerations and more heavily factored the severity or magnitude of the burden on the landowner. The role of harm prevention as a valid aspect to consider was not clear.

Thus, in a unanimous decision, the South Carolina Supreme Court upheld Richland County's floodplain regulations, which were even more restrictive than the Federal Emergency Management Agency (FEMA) minimums against a regulatory takings claim. The importance of this case, post-*Lingle*, is that the court clearly and unequivocally recognized that floods are dangerous and costly and the harm-preventing purpose of floodplain regulations is an important consideration.

The Association of State Floodplain Managers (2014) filed an amicus brief in the case. It is recommended reading for any community's legal counsel (and for practicing planners and floodplain managers) on the matter of land-use controls for flood loss reduction and takings. It provides an excellent review of previously existing case law and rationale supporting local regulatory standards.

Columbia Venture purchased land to develop along the Congaree River in Richland County. It planned for a $1 billion development called the Green Diamond on the property. Columbia Venture knew at the time of the purchase that FEMA was in the process of revising the area flood maps and designating most of the property as lying within a regulatory floodway. Under federal law and Richland County's own local regulations, development was generally not permitted in a regulatory floodway. In 2002 FEMA revised the floodplain maps in the area and placed 3,130 acres of Columbia Venture's property within a regulatory floodway. Columbia Venture appealed FEMA's findings in federal court but was unsuccessful. Columbia Venture then filed suit, claiming the county's regulations constituted an unconstitutional taking.

The county had been a participant in the National Flood Insurance Program before Columbia Venture purchased the property. At the time of the purchase, Columbia Venture was aware of the revised FEMA flood map's floodway designation and the fact that such designation carried with it extensive regulatory implications affecting over 70 percent of the property. Although Columbia Venture may have subjectively believed that, in spite of all this, it would nevertheless be allowed to develop the extensive Green Diamond project, the court found any such expectation was not objectively reasonable.

Further, the court found that the county's limitations on development in flood-prone areas reduce the inherent risk of flood-related property damage and benefit all county taxpayers and residents by reducing the county's potential liability incurred in emergency response, rescue, evacuation, and other actions taken during a flood. Importantly, the court further said that "in light of the potential public costs of extensive development in the regulatory floodway, we reject the argument that the County's floodway development restrictions constitute anything but responsible land-use policy" (South Carolina 2015). Also notable is that the court upheld floodplain regulations that were more restrictive than National Flood Insurance Program standards. This case should provide floodplain managers and land-use planners across the country a firmer constitutional footing for communities to enact more protective floodplain or floodway regulations.

Ultimately, the court concluded that Columbia Venture's lack of reasonable investment-backed expectations coupled with the legitimate and substantial health- and safety-related bases for the county's floodplain development restrictions outweighed Columbia Venture's economic injury, and under *Penn Central Transportation Co. v. New York City* (438 US 104, 1978) no regulatory taking occurred.

velopment near the water is more valuable, and local governments covet these high-value properties. The second reason is fear of regulatory takings challenges (Thomas and Turner 2011).

The courts give careful consideration to the prevention of harm. Even our system of law and government, going back thousands of years, revolves around the fact that people do not have the right to use their property in a way that harms other people. A maxim of Roman law was *sic utere tuo ut alienum non laedas*—use your property so that you do not harm others.

Individuals damaged by flooding or erosion are increasingly filing lawsuits against governments claiming that the government has caused the damages, knowingly allowed actions that contributed to the damages, or failed to provide adequate warnings. Courts and legislative bodies have expanded the basic rules of liability to make governments responsible for actions which result in, or increase, damages to others. While still commonly held by some local officials as valid, the "act of God" (sovereign immunity) defense has dramatically reduced over time. To successfully establish an act of God defense, a governmental unit must prove that a hazard event was both large and unpredictable. This is becoming increasingly difficult because technology has allowed us not only to foresee future events but also to identify their impacts.

Most successful suits against communities result from actions such as construction or inadequate maintenance of dams, levees, roads, and bridges that increase flood damages on other lands. Other successful suits against communities come from communities not adequately or consistently administering their floodplain management ordinances or regulations. Communities are far more likely to be sued for issuing a permit that causes harm than they are for denying a permit, especially if health, safety, and public welfare are the basis for denial of the permit.

The courts have broadly and consistently upheld performance-oriented floodplain regulations, including those that exceed the minimum standards of the National Flood Insurance Program. Regulations that protect the public—such as requiring additional freeboard (additional elevation above the base flood elevation), imposing tighter floodway restrictions, or very tightly regulating high-risk areas such as coastal V-zones—have consistently been upheld by the courts. Courts have also consistently upheld the validity of floodplain regulations that have been reasonably, fairly, and uniformly administered and enforced and that are aimed at hazard prevention. In recent years, the US Supreme Court has issued a series of opinions strongly endorsing planning and land-use regulations aimed at preventing damage that could be potentially caused by hazardous, unsafe, or unwise development.

Takings, Liability, and No Adverse Impact

ASFPM research shows that communities that take a NAI approach will decrease the potential for successful liability suits from a broad range of government activities, such as building roads and bridges, installing stormwater facilities, building flood control works, grading, constructing public buildings, approving subdivisions and accepting dedications of public works, and issuing building permits. From a constitutional law perspective, courts are likely to provide strong support in upholding community regulations that adopt a NAI performance standard against claims of unreasonableness or "takings" of private property without payment of just compensation. The NAI standard is consistent with overall common law rights and duties.

Actions that local governments can take to reduce the possibility of a successful takings challenge to regulations include the following:

- Apply performance standards fairly and uniformly to all properties.
- Include special exception and variance provisions in regulations that allow the regulatory agency to issue a permit where a denial will deny a landowner all economic uses of the entire parcel and the proposed activity will not have nuisance impacts.
- Adopt large-lot zoning for floodplain areas, which permits some economic uses (e.g., residential uses) on the non-flood-prone portion of each lot (this approach is detailed in PAS Report 473).
- Allow for the transfer of development rights from floodplain to non-floodplain parcels.
- Do not pursue an act of God defense as an excuse for inaction—particularly where studies or local data show potential for future flooding, especially resulting from other development in the watershed.

STRUCTURE OF THE REPORT

The remainder of this report continues from the general introduction in this first chapter to the very specific and then back again with a look at the future. Chapter 2 outlines a se-

ries of general principles and planning and design principles related to subdivision design and flood hazard areas. These principles were developed during an expert symposium held around the outset of the project that produced this report. Chapter 3 underscores the value of a broader, integrated approach to planning for natural hazards as a basis for supporting efforts to improve subdivision regulations and design for flood hazards. Chapter 4 then describes the process for establishing good subdivision design procedures. This discussion is followed by Chapter 5, which outlines good recommended practices for establishing standards for such development. Finally, Chapter 6 then distills the best forward-looking ideas from the preceding chapters to project a "road ahead" that offers a glimpse into the future of community planning for better floodplain management.

CHAPTER 2

THE PRINCIPLES OF SUBDIVISION DESIGN IN FLOOD HAZARD AREAS

In February 2015, the American Planning Association (APA) convened a two-day symposium at its Chicago office that brought together five subject matter experts as well as staff representatives of APA, the Association of State Floodplain Managers (ASFPM), and the Federal Emergency Management Agency (FEMA). Over the two days, participants worked to define the general principles and the planning and design principles explored in greater detail in this chapter and throughout the report.

During the symposium, participants also developed an overarching vision for subdivision design in flood hazard areas to inform these principles:

> Adopt a comprehensive and integrated approach to protecting floodplains and other natural areas and aligning development with community goals, in order to increase community resiliency and reduce flood hazard risks.

GENERAL PRINCIPLES

Subdivision design in flood hazard areas has become increasingly important due to the high social and physical costs associated with flood damages. Now, more than ever, communities must adapt to the ever-growing threat of human-made and natural disasters. Five general principles lay the foundation for mitigating flood hazards within subdivision design.

General Principle 1

Maintain natural and beneficial functions of the floodplain. Finding a balance between human needs and environmental sustainability can be a difficult undertaking for communities of all sizes. When a subdivision development is proposed, it is the job of the local municipality to consider the effect it may have on the surrounding environment. Interfering with the natural processes of a floodplain increases the risk of a flood hazard. Communities located within a floodplain are subject to periodic inundation caused by direct precipitation, fluctuating groundwater levels, coastal storm surges, and other weather events. This periodic flooding and the related processes of erosion and deposition determine the shape, soils, vegetation, and other physical features of the floodplain. Together, these functions are often referred to as natural and beneficial functions of the floodplain (Kusler 2011).

Surface water, ground water, floodplains, wetlands, and other features do not function as separate and isolated components of a watershed but rather as a single, integrated natural system. Disruption of any one part of this system can have long-term and far-reaching consequences on the functioning of other system components and on the system as a whole (Wright 2007). As a result, it is important for planners and all parties involved in a subdivision development to understand the role of a floodplain within the natural environment.

A document initially prepared by the US Water Resources Council in 1979 titled *A Unified National Program for Floodplain Management* divides riverine and coastal floodplain resources into three categories: (1) water resources, such as natural flood and erosion control, surface water quality maintenance, and groundwater recharge; (2) living resources (habitat), such as biological productivity and fish and wildlife habitats; and (3) cultural resources, such as harvesting of wild and cultivated products, recreational opportunities, and areas for scientific study and outdoor education (FEMA 1986). (FEMA 1986). Each of these resources provides numerous contributions to the environment. Disrupting the aforementioned hydrologic/hydraulic, geomorphic, and biologic processes will not only have negative effects on the natural environment, but also on the development that has caused the disruption. By changing the ecological process, structural developments increase the risk for a hazard to take place.

Hazard events can also cause financial hardship for individuals who live within or near the floodplain and for the local municipality. As a result, it is important for the local author-

ity to take into account and maintain the natural and beneficial functions of the floodplain. For example, in Westernport, Maryland, cooperation led to successful community planning efforts that reduced flood losses and restored the natural functions of the floodplain. This was done through a buyout of existing structures in the floodplain and the restoration of the Georges Creek to a stable form of flow capacity (US Department of Housing and Urban Development 2002).

In order to regain and maintain the sustainability of water-based ecosystems and resources, local, state, and federal agencies should consider new approaches to floodplain management. ASFPM encourages a floodplain management strategy that includes the following: "Set a policy that the natural functions and resources of flood-prone areas are worthy of protection and should not be sacrificed for human development, . . . rehabilitate and restore degraded riparian and coastal resources, [and] incorporate into all public and private activities at all levels a respect for and understanding of the functions and resources of flood-prone areas along our coasts and waterways" (ASFPM 2008a, 5).

General Principle 2

Adopt a No Adverse Impact approach to floodplain management. In the United States, damage caused by flood hazards has increased steadily, as described in Chapter 1. Direct average annual flood damage costs have risen from approximately $5.6 billion per year in the 1990s to nearly $10 billion per year in the 2000s (ASFPM 2013b). Even still, development has continued to intensify in flood-prone areas for reasons including constraints in land availability, lack of flood mitigation techniques in comprehensive plans, and land-use regulations that do not sufficiently address flood hazard areas. This can result in flood damage even for property owners who have taken action to mitigate flood hazard risks.

By adopting a No Adverse Impact (NAI) approach to floodplain management, communities can minimize flood risks: "[NAI] takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners. These adverse effects or impacts can be measured in terms of increased flood peaks, increased flood stages, higher flood velocities, and increased erosion and sedimentation" (ASFPM 2008b, 2). Other impacts communities might consider important may include negative effects on economic health and livability, risks to human safety and property, and alterations of the natural environment.

Currently, management actions are intensifying the potential for flood damage by allowing development to alter water velocities and divert flood water onto other properties downstream (ASFPM 2008b). Adopting an NAI approach to floodplain management provides local governments with a legally defensible tool to support people and property by addressing risks in the planning and proposal stages of development through the regulations and standards stages (ASFPM 2008b). With NAI tools in place, developers are provided guidance about the necessary arrangements for construction of structural developments, such as subdivisions near floodplains, and there is clarity in the development process.

Local governments can use this approach to shape certain elements within a comprehensive plan and provide a regulatory framework that identifies acceptable levels of impacts, specifies appropriate measures to mitigate those adverse impacts, and establishes a path for implementation, resulting in numerous benefits in both the long and short term. These benefits include (1) increased community resilience by reducing flood risks and private-sector costs, (2) decreased litigation by way of the courts due to deference to regulations that seek to prevent harm, and (3) near-term benefits that can include reduced conflicts and flood insurance rates and increased predictability in planning (NOAA and ASPPM 2007).

The most important overall aspect of implementing an NAI approach to floodplain management is decreasing a community's risk of experiencing a major flood hazard, which in turn reduces future associated costs when a flood event occurs. It can also change the mentality that floodplain management is solely a federal responsibility. This is important because it promotes local accountability (ASFPM 2008b).

One community that has adopted an NAI approach to floodplain management is Fort Collins, Colorado. Fort Collins emphasizes the importance of cumulative impacts by focusing on avoiding damage to property and people, both upstream and downstream. This is done through regulations and development standards, hazard identification and mapping, public education and outreach, planning, and mitigation (ASFPM 2004).

General Principle 3

Avoid new development in the floodplain whenever feasible. Structural development has encroached onto floodplains in nearly every community within the United States. This has caused flood disasters to occur more frequently, resulting in excessive property damage that causes financial strain on counties, municipalities, and property owners.

Not all development is good development, especially when it is in the floodplain. It is important for planners and local governments to adopt measures to avoid new develop-

ment in floodplains, when feasible. Allowing the water system to process naturally by preventing development that interferes with natural system functions will greatly reduce the risk of flooding.

Maintaining and protecting the valuable services that floodplains provide people and nature are important because the landscape we depend on is formed in part by water moving through it. Avoiding development in the floodplain provides many benefits, including improved water quality, recharged aquifers, flourishing wildlife habitats, increased recreational activities, reduced flood insurance, and flood protection.

By developing in the floodplain, we add to existing impervious surfaces, causing an increase in water flow. Water that travels too quickly to creeks and streams worsens erosion and escalates the risk of flooding. It also can pick up and carry much more sediment and other pollutants. Streams and rivers need space to adjust to their capacity and to come into symmetry so they can flow into their floodplains when needed. Peak flows of water need places to spread and slow down—by using the floodplains they have shaped over thousands of years. The more development that takes place, the more heavily channelized or engineered a floodplain becomes. This impinges on the natural system.

When a new structural development, such as a subdivision, is built near or within a floodplain, it may raise the projected FEMA 500-year and 100-year floodplain, due to erosion, unnatural drainage, and other factors. One community that has installed measures to limit new development within a floodplain is Charlotte-Mecklenburg County, North Carolina. In response to the impacts of Hurricanes Bertha and Fran, the North Carolina Department of Public Safety's emergency management division launched the Hazard Mitigation Planning Initiative (HMPI) in 1996. The ultimate goal of the HMPI was to reduce community vulnerability to natural hazards through mitigation policy and projects (Schwab 2010).

A policy that contributed to reducing community vulnerability was the Surface Water Improvement and Management (SWIM) Program. Through SWIM, county commissioners established a goal of improving water quality to a high level. Although this initiative was established to improve water quality in streams and creeks, over time it developed into a program to protect water quality through flood hazard mitigation. By means of a cooperative approach, a coalition of environmentalists, citizens, developers, and local officials created a stream buffer plan that defined buffer widths based on the acreage drained by each creek or stream. Therefore, the larger the drainage area, the larger the buffer required. If the buffer area exceeded the mapped FEMA 100-year floodplain, new development was not allowed within the buffer, even though it was outside the floodplain. By keeping the buffer free of development, the existing vegetation filtered pollutants, while the open space provided for additional water storage (Schwab 2010).

General Principle 4

Focus on data-driven decision making, using the best available data to assess risk and inform decisions. Data-driven decision making refers to the collection and analysis of data to guide decisions that improve success (US Department of Education 2009). From large cities to communities and the neighborhoods within them, the use of data to assess risk and inform decisions is an important tool. The benefits of data-driven decision making include the following: adapting to trends in a community, measuring and comparing results to similar projects done by others, understanding local context and risk, and having the ability to track development outcomes to make better decisions in the future.

By applying data-driven decision making to subdivision design in flood hazard areas, the replication of situational best practices and the collection of data over time may decrease the probability of a flood hazard from occurring. As part of its efforts and stated strategic priority to reduce disaster risk nationally, FEMA is leveraging its partnerships, programs, risk information, and tools to catalyze efforts to advance risk-based decision making across the nation to enable risk reduction through mitigation (FEMA 2014a).

The focus of this report is to provide the data for greater risk-informed decision making. Improving the quality, accessibility, and use of risk information will allow for more data-driven decision making and provide local planners the necessary tools for decreasing the risks associated with flood hazards. By developing flood risk data and maps that supplement the flood insurance study data provided by FEMA and other hazard mitigation organizations, communities can earn premium discounts for every individual flood insurance policy holder in a jurisdiction through Community Rating System incentives from the National Flood Insurance Program (FEMA 2014a). The goals of the Community Rating System are to (1) reduce flood damage to insurable property, (2) strengthen and support the insurance aspects of the National Flood Insurance Program, and (3) encourage a comprehensive approach to floodplain management (FEMA 2015).

Replicating best practices throughout the country provides tools to communities implementing measures that reduce flood risk. It is important that the public and private

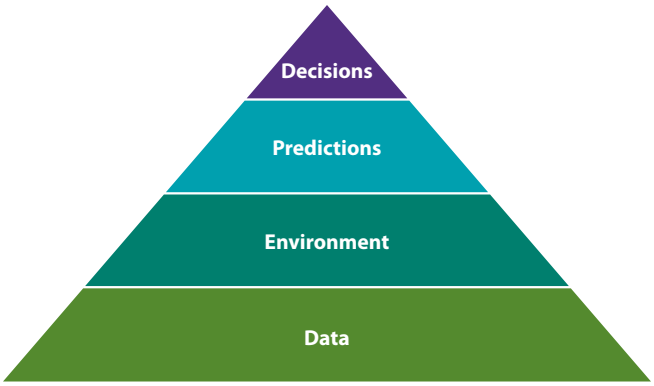


Figure 2.1. Data-driven analysis pyramid (George Homewood)

sectors (e.g., homeowners, engineers, developers, insurers, urban planners, and emergency managers) cooperate, assess risk, and make informed decisions based on similar successful projects. Moreover, by applying FEMA's portfolio of existing risk assessment tools—which includes Hazus, the nation's flood maps, and the Threat and Hazard Identification and Risk Assessment—integration and understanding of flood risks has greatly improved (FEMA 2014a).

Norfolk, Virginia, has adopted this approach. From 2009 to 2010, in the midst of its Coastal Flood Mitigation Program, data-driven analysis and decision making were used to define the physical environment and variations in water levels in the city based on storm conditions. The city developed a data-driven analysis pyramid, shown in Figure 2.1, that consisted of the steps taken to identify where to place its tide gauges. Figure 2.2 shows the locations of the tide gauges as a result of the data-driven decision-making process.

Collecting quantitative data to assess risk and inform decisions can be an innovative way to mitigate flood risks in a community. An example of this can be found in the Clear Creek watershed in southeast Texas, where Brody et al. (2013) examined the impact of land-use and land-cover characteristics on flood losses. Statistical results indicated that the local configuration of land use plays an important role in predicting the amount of property damage caused by floods at the parcel level. Innovative research and analysis such as this provides tools for planners to improve their hazard mitigation programs through data-driven decision making.

General Principle 5

Consider future conditions of the floodplain, including development impacts and climate change. The United States is an increasingly urbanized nation. With most US cities located near waterways and coastlines, development has interfered with the natural process of floodplains. Projects proposing development in the 25-year and 100-year floodplains have the potential for placing citizens and their property at risk of flooding and producing changes in floodplain elevations.

As urbanization intensifies pressure on floodplains, flood hazards are more likely to occur. This has resulted in hundreds of millions of dollars in structural damage and, in some instances, loss of life. Therefore, it is important for communities to consider the future conditions of a floodplain, such as climate change and the impacts of developing in or near the floodplain. Over time, climate change will increase the frequency of heavy rainstorms, putting many communities at risk for devastation from floods. However, by adapting to climate change and limiting development in the floodplain, a community can become more resilient.

To increase resilience by limiting development in a floodplain and addressing climate change, the City of Chapel Hill, North Carolina, and its public works department acquired a useful tool known as a future-conditions hydrology. As defined by the stormwater management division of Chapel Hill (2015), future-conditions hydrology models the

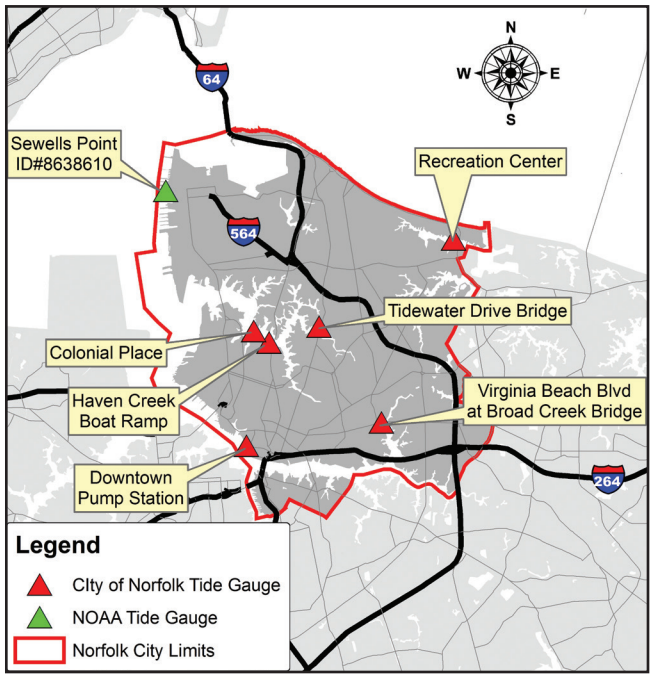


Figure 2.2. Initial tide gauge program in Norfolk, Virginia, 2009–2010 (George Homewood)

flood discharges associated with projected future land-use conditions based on a community's zoning maps or comprehensive land-use plans. Projected future land-use conditions may be based on 10, 20, or even 30 years into the future. However, future-conditions hydrology does not take into consideration projected future construction of flood detention structures or projected future hydraulic modifications within a stream or other waterway, such as bridge and culvert construction, fill, and excavation.

Adopting future-conditions hydrology decreases vulnerability from the dangers and risks that a flood hazard poses. As outlined by FEMA (2001), using future-conditions data on FEMA flood maps can provide numerous essential benefits for a community. These benefits include increased support from FEMA when using stricter floodplain management regulations or more informed decisions about where to locate structures near the floodplain. Also, fewer revisions to National Flood Insurance Program maps would be needed, thereby reducing FEMA costs in the long term as well as flood insurance fees and costs to taxpayers. If a community decides to adopt future-conditions hydrology, the Community Rating System could be used to reduce flood insurance rates. This approach allows future land-use conditions to be determined by the community, therein reducing damage to structures and loss of life due to the less amount development that would likely occur in the floodplain (FEMA 2001).

For instance, in Texas, the City of Plano, a suburb north of Dallas, has seen substantial growth since 1990. According to the US Census Bureau (1995, 2010c), Plano had 128,713 inhabitants then and in 2010 the population had reached 259,841. Following flood insurance studies for many of the city's large streams in the 1980s, developers were required to use future-conditions discharges in the analysis of their projects, and they must provide the associated floodplain maps to the city (FEMA 2001). Therefore, based on the maps that the developers provide, the city regulates floodplain development using future-conditions hydrology maps. The city does not allow new construction in the floodplain. This forward and imaginative thinking has allowed cities such as Plano to minimize damage if a major flood event were to occur.

PLANNING AND DESIGN PRINCIPLES

These six Planning and Design Principles, together with the General Principles discussed previously, can help communities achieve a comprehensive and integrated approach to protecting floodplains and other natural areas by aligning development with community goals, in order to increase community resiliency and reduce flood hazard risks.

Planning and Design Principle 1

Communicate with and inform stakeholders and community members throughout the planning and design process in order to facilitate coordination and community buy-in. Floods are the most costly natural disaster in the United States, occurring during all four seasons and in all parts of the country, with estimated damages of $10 billion annually (see General Principle 2, p. 24). While the link between flood damage and development patterns may seem straightforward, communicating with local officials and community members about flood hazard risks and the measures that can be taken to avoid and mitigate these risks may prove more challenging.

It is important to have a clear communications strategy in order to communicate with and inform community members and stakeholders throughout the planning and design process. An effective communications strategy can facilitate coordination among partners and stakeholders, including local government officials, developers, the business community, community organizations, and community members. It can also provide important education on flood risks and mitigation measures, and result in support and from community members.

General outreach and education about flood hazards and related risks, and the measures that can be taken to avoid or mitigate these risks, are important to ensuring that community members are aware of potential flood risks, basic efforts that they can take to mitigate those risks, efforts being undertaken by the local government, and what to do in an emergency. For example, in Iowa, the City of Cedar Falls, which experienced catastrophic flooding in 2008, publishes a stormwater management best practices brochure (Cedar Falls 2016). The brochure provides residents with information on issues such as yard waste and streambank protection, as well as flood protection and flood safety information and information regarding flood insurance.

Planning and design processes should have a communications plan specific to that process or project, with clearly defined goals and strategies. This plan should identify key messages and stakeholders, and it should also be used to guide outreach efforts (APA 2013). Engaging stakeholders and community members effectively throughout the process is key to addressing local conditions and needs and building public support for implementation of various actions.

Figure 2.3. Yard signs commenting on the city's property buy-out program (James C. Schwab)

Figure 2.4. A home elevation project in progress, November 2008 (James C. Schwab)

In 2011, Lewes, Delaware, a small town located on the Delaware Bay across from Cape May, New Jersey, completed its *Hazard Mitigation and Climate Adaptation Action Plan* (Lewes 2011). Building on previous hazards planning efforts, the town engaged stakeholders—including numerous public agencies, businesses, and homeowners associations—in a planning process that focused on future conditions related to climate change and sea-level rise and their impacts on the community. The process focused on the impacts of floods to homes, businesses, and community infrastructure, and the plan included six primary actions, including addressing these issues in the comprehensive plan and zoning code, improving education and outreach, and increasing participation in FEMA's Community Rating System program (ASFPM 2013b).

Planning and Design Principle 2

Apply multiple tools and techniques for structural and nonstructural flood mitigation measures. Effective planning and design in flood hazard areas applies multiple tools and techniques, which fall into two categories: nonstructural and structural. According to ASFPM, nonstructural flood mitigation measures increase the resiliency of new or existing developments by either preserving or restoring floodplain function. Structural mitigation measures, on the other hand, work to prevent flood damage (ASFPM 2007).

Nonstructural measures are those that reduce flood damage by minimizing disruptions to floodplains and other flood-prone land. These include floodplain zoning regulations, floodplain management regulations, relocation of structures in the floodplain, building codes, conservation measures, and efforts to restore natural features.

Structural measures, on the other hand, are generally engineered features that are designed to increase flood resistance. Federal, state, and local governments have invested heavily in these measures, which hold back rising flood waters but also affect the function of watershed features (Opperman 2014). Structural measures include dry proofing for commercial buildings and the elevation of structures in flood hazard areas, as well as dams designed to store flood waters and levees designed to hold back flood waters.

When used alone, structural measures may, paradoxically, cause an increase in development in the floodplain, which can in turn increase the potential for flood losses (ASFPM 2007). As a result, communities should seek to find a balance of tools and techniques that focus first on avoidance of the floodplain and, as that is not always possible, next on resistance to flooding. In 2013, Lyons, Colorado, experienced a major flood disaster and required tools and techniques to resist future flooding (the town sits within a floodplain). With the help of an American Planning Association Community Planning Assistance Team, the town has identified and is seeking to implement structural and nonstructural measures to resist flooding (see "Case Study: Lyons, Colorado," p. 30).

Cedar Falls, Iowa, located on the banks of the Cedar River, has experienced many major flood events, including

catastrophic flooding that took place in 1993 and 2008. Beginning after the 1993 floods, the city adopted an approach that includes both avoidance of the floodplain (nonstructural) and resistance to flooding (structural). Measures include the adoption of the 500-year floodplain as its locally regulated floodplain and a strategy of property buyouts in the floodplain. Relying primarily on federal and state funding, the city has acquired 331 properties since 1993 that will be preserved as open space. While most residents live to the south and the better-protected downtown lies to the south as well, there was some controversy around the buyouts that mostly occurred north of the Cedar River, a low-lying area without levee protection (Figure 2.3). A number of homeowners in northern Cedar Falls whose properties were not acquired chose to elevate their homes (Figure 2.4).

The city has also updated its subdivision ordinance to complement the floodplain ordinance and include measures such as a prohibition on the establishment of new building lots in the floodplain. On the structural side, the city is expanding the existing levee, designed for 100-year flood protection, to meet 500-year flood protection standards (Musiol and Ryan 2013). The city authorized funding to begin the project in January 2014.

Planning and Design Principle 3

Allow for creativity in design, and, where possible, adopt a watershed-scale approach to design and an ecosystem-based approach to disaster risk reduction. Watershed-scale approaches to design and ecosystem-based approaches to disaster risk reduction seek to take a holistic look at the watershed features and their natural functions. Allowing for creativity in design while adopting a watershed-scale or ecosystem-based approach allows communities to address local needs and conditions while seeking to maintain the natural and beneficial functions of the floodplain (see General Principle 1, p. 23). These functions include providing rich habitat areas for plants and animals, floodwater storage and conveyance, and groundwater recharge.

An NAI approach (see General Principle 2, p. 24) allows communities to take a more holistic view of floodplain management at the watershed scale. This approach examines the impacts that proposed development will have on new or existing development elsewhere in the watershed. These impacts are measured in quantifiable terms, such as increased flood peaks and higher flood velocities, and the related mitigation measures are provided to prevent negative impacts (ASFPM 2007, 2008b).

A watershed-scale approach can also include regional-scale green infrastructure planning and protection. Regional-scale green infrastructure planning can coordinate across jurisdictions to integrate green infrastructure into regional land-use patterns (Rouse and Bunster-Ossa 2013). This enables a look at valuable green infrastructure resources within the watershed, rather than fragmented assessments within jurisdictional boundaries. A watershed-based approach to planning and design also takes a long-term look at watershed conditions (ASFPM 2013b). This means examining both past flood events and future conditions, including impacts that future development will have on the watershed and potential impacts of climate change on the floodplain (see General Principle 5, p. 26).

Houston's Bayou Greenways initiative is working to add 4,000 acres of interconnected green space, including 300 miles of multiuse greenway trails, to Houston's bayous. The countywide initiative draws on Houston's 1912 master plan, which proposed a park system with the bayous at its core. The Bayou Greenways initiative is focused on improving equitable access to parks and green spaces in Houston, while also protecting habitats, improving water quality, and reducing flooding using the natural bayou landscape (Houston Parks Board 2015).

Planning and Design Principle 4

Design new infrastructure and adapt existing infrastructure, including stormwater facilities and transportation networks, to be resilient to both high- and low-frequency flooding events. Infrastructure—or the facilities that support human activities, including roads, bridges, railways, sewer and water systems, and communications facilities—is important for safety, access during emergency events, and recovery. As a result, communities should work to design and adapt infrastructure to be resilient to both high- and low-frequency flooding events.

Addressing infrastructure resiliency is complicated due to the extensive range of agencies involved in the ownership and operation of these systems. For example, roads are generally built and maintained by the public sector, while electric systems and communications systems are usually owned and operated by private companies. In order to build resilient infrastructure, it is necessary to have a clear understanding of the risks involved. This includes identifying flood hazard areas, vulnerability of systems, level of risk, and what activities will be affected in a flooding event (e.g., access, communications) (Crouch et al. 2014).

Avoidance of the floodplain protects critical infrastructure by limiting its presence in high-flood-risk areas (Roths

CASE STUDY: LYONS, COLORADO

Nicholas A. Walny, American Planning Association

On September 12, 2013, the town of Lyons, Colorado, situated 12 miles north of Boulder, experienced devastating floods that severely altered its landscape. The town was among the hardest-hit communities along the Colorado Front Range. Lyons lies at the junction of the North and South St. Vrain Creeks, and large parts of the town were in the direct path of the flood. The historic rainfall, topping over 17 inches of rain, brought yearly precipitation to more than 30 inches—the most in 120 years of hydrological recordkeeping. The estimated river volume of the St. Vrain River was 10 times its normal amount, reaching 100-year flood levels and surpassing the 500-year and 1000-year flood levels in certain areas (Lyons 2014).

With a population of 2,033 (US Census Bureau 2010b) and a land area of 1.2 square miles, low-income households of Lyons suffered after the flood from the loss of affordable housing and the lack of developable land. During the flood, 168 homes and 43 mobile homes were damaged or destroyed, displacing 15 percent of the population (Punchard 2015). The total amount of damage to the town was estimated at $50 million, including $5 million in temporary measures and $45 million in permanent work (Lyons 2014).

As of April 2016, the process of rebuilding was ongoing. According to Andrew Rumbach (assistant professor, College of Architecture and Planning, University of Colorado Denver, pers. comm.) many of the homes that were most severely affected were acquired using federal funds, and the land will be returned to natural states. Other homeowners repaired their houses, most elevating out of the floodplain. The mobile home parks that were destroyed were closed, and the land is either part of the buyout or being used for other purposes.

Two and a half years earlier, in December 2013, with the difficult road to recovery already underway, a Community Planning Assistance Team (CPAT) from the American Planning Association provided technical assistance to Lyons for redeveloping in a way that would support community goals for sustainable neighborhood design, affordable housing, environmental preservation, resilience, and economic sustainability (APA 2014). The following are highlighted action items regarding subdivision design in flood hazard areas taken from the town's *Recovery Action Plan* (Lyons 2014), with the hope being that these items will be brought to fruition in the form of stronger floodplain management standards:

HOUSING GOAL 1

Recognize and accommodate the housing needs of a diverse population.

Housing Objective 1.1

Promote safe, stable, diverse neighborhoods throughout Lyons that provide a range of housing options and link residents to destinations to learn, work, and shop.

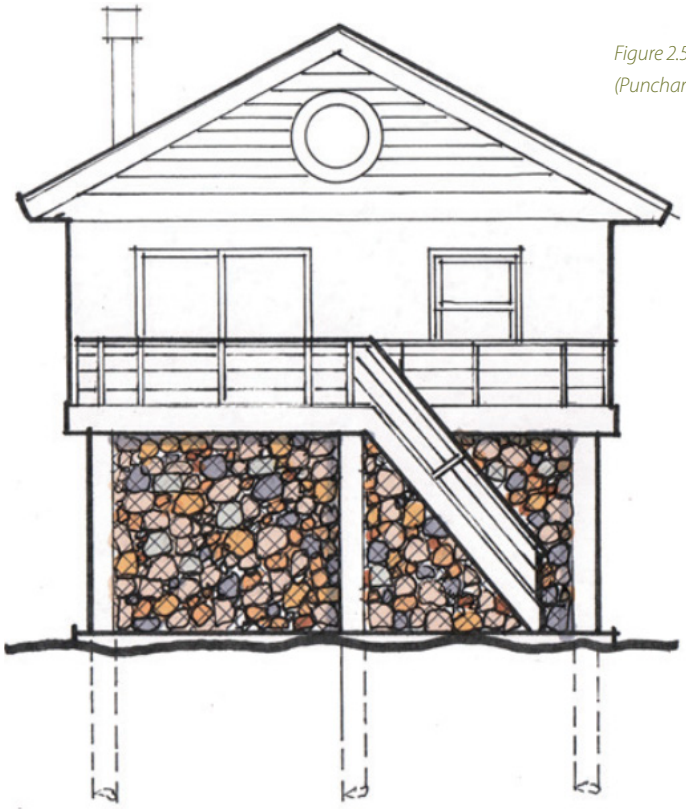


Figure 2.5. Gabion wall system (Punchard 2015)

Housing 1.2.3

Evaluate and modify existing regulations and codes regarding construction of residential structures in floodplain areas.

Resilience and Building Regulation

Regulations evaluation: Propose an evaluation of current building regulations specifically regarding building in floodplains. Send a message to political structure that the community needs to impose and enforce tougher building regulations, especially when evaluating new developments and structures.

Miracle Village Improvements

Background: Miracle Village improvements expand on streetscape improvements to offer sustainable natural drainage rain gardens, curb cuts, planted swales on contour, and food forest clusters for stormwater retention and flood prevention. With an acre, there can be 12 dwellings surrounding a shared center of amenities, of which some would provide lodging entrepreneurship and others would offer value-added products to the Lyons local economy.

Because most of the town is located in the floodplain, the CPAT recommended a more resilient approach to include foundations that allow water to pass under housing structures. One option, shown in Figure 2.5, is a Gabion wall system (interconnected wire boxes filled with river stones), which would allow water to pass through without compromising structural integrity (APA 2014).

The CPAT also recommended that the Town of Lyons restrict and remove development in the regulatory floodway and establish a policy to gradually remove all buildings and infrastructure in this area with the exception of bridges, infrastructure used to convey stormwater, and other facilities that can sustainably operate in a floodway (APA 2014). This provision should be included in the town's comprehensive plan and flood damage prevention regulations.

GREEN INFRASTRUCTURE

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments (Figure 2.6). One definition refers to a network of open space and natural resources at the city and regional scales (Benedict and McMahon 2006, 1):

> [Green infrastructure is] an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife. . . .Green infrastructure is the ecological framework for environmental, social, and economic health—in short, our natural life-support system.

Figure 2.6. Stormwater management infrastructure in Henderson, Nevada (Carolyn Torma)

Developed by the US Environmental Protection Agency (2016), the other definition refers to green stormwater infrastructure at the site or neighborhood scale:

> An adaptable term used to describe an array of products, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. As a general principle, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff.

Both definitions are relevant to subdivision design. At the scale of the neighborhood or site development, green stormwater infrastructure techniques include the following:

- Pervious pavement and asphalt that reduce stormwater runoff and increase groundwater discharge
- Rain gardens or bioretention cells to collect and absorb runoff from rooftops, sidewalks, and streets
- Bioswales that provide treatment and retention as they move stormwater from one place to another (vegetated swales slow, infiltrate, and filter stormwater flows and, as a linear feature, are particularly suitable along streets and parking lots)

More and more, the term *green infrastructure* is being used interchangeably with the term *low-impact development*. Communities can incorporate green stormwater infrastructure practices into zoning districts, subdivision regulations, planned unit developments, stormwater management standards, or erosion and sediment control standards. At the larger scale of the city or region, floodplain areas and other sensitive lands within developments can be preserved as part of larger open space networks using techniques such as conservation subdivision design.

The Center for Neighborhood Technology (2009) has developed the National Green Values Calculator to help users compare costs, benefits, and performance of green infrastructure and low-impact development to those of conventional or "gray" stormwater infrastructure. Various "green interventions" can be entered into the tool, including disconnecting downspouts and draining the roof to rain gardens; using porous pavement on driveways, sidewalks, and other non-street pavement; and using vegetated drainage swales in lieu of drainage pipes. The calculator is meant for a single site or a campus of buildings on a single site.

2008). New infrastructure should be designed to account for both high- and low-frequency flood hazard events and be located outside of the 100-year floodplain or mapped flood hazard area. While locating infrastructure outside the floodplain is ideal, it is not always possible. In some cases infrastructure, for reasons such as access, must be located in flood hazard areas. At other times, it is not practical to relocate existing infrastructure.

When considering whether to retrofit or relocate existing infrastructure, communities should assess risks and costs, both of relocation and of systems failure. If the infrastructure is retrofitted in place, it is also necessary to retrofit related components that may fail in a flood event (ASFPM 2013a). Designing and adapting infrastructure systems to be more resilient should be seen as a continuing process as communities assess and prioritize flood hazard risks (and other hazard risks).

Planning and Design Principle 5

Protect open space and incorporate green infrastructure into development patterns. Green infrastructure—which can refer both to networked open spaces that protect ecosystem services and biodiversity and to a set of development practices that preserve, restore, or simulate the natural stormwater management functions of a site (see "Green Infrastructure," p. 32)—can be an important tool for addressing flood hazards. On a larger scale, a green infrastructure network can play an important role in protecting the natural and beneficial functions of the floodplain (see General Principle 1, p. 23). On a smaller scale, green infrastructure can improve stormwater infiltration by reducing peak stormwater flow and pollutant loads. Green infrastructure also provides additional social, health, and recreational benefits for communities.

Residential cluster development through open space, conservation, or cluster subdivisions can be a valuable tool for protecting open space and incorporating green infrastructure into development patterns. These approaches concentrate development on a smaller percentage of the developable land, protecting networks of open spaces and environmentally sensitive areas, including floodplains (Arendt 2015). By concentrating development, residential clustering not only preserves open space, but it also results in less impervious surface cover and reduces the amount of the site that is graded for development, which in turn reduces soil compaction. These differences between cluster development and traditional subdivision development result in lower runoff volume and preserve stormwater infiltration and runoff capture capabilities of the site. An example of a residential cluster development can be found at the Evia subdivision on Galveston Island, Texas, where developers used new urbanism design techniques to create a flood-resilient community (see "Case Study: Evia Residential Development on Galveston Island, Texas," p. 34).

Ordinances for critical or sensitive areas are designed to protect environmentally sensitive locations, including frequently flooded areas, wetlands, and riparian corridors. These can be standalone ordinances or overlay zones (Morris 2009; Turner 2012). Overlay zones are another tool for protecting open space and incorporating green infrastructure into development patterns. They add additional requirements to the underlying zoning district regulations.

For example, Anne Arundel County in Maryland has an open space conservation overlay. Its defined purpose is for "protecting and preserving floodplains and wetlands associated with floodplains in their natural state, protecting and preserving streams and bogs in their natural state, protecting and preserving wildlife habitat associated with streams, wetlands, floodplains and bogs, preventing soil erosion and sedimentation in tidal and nontidal waters by protecting steep slopes, protecting and preserving scenic values, and protecting and preserving wildlife habitat" (§ 18.9.204.B, Anne Arundel County Code).

Portland, Oregon, has the Pleasant Valley Natural Resources Overlay Zone (Portland 2015), which resulted from the *Pleasant Valley Natural Resources Protection Plan* (Gresham and Portland 2004). This plan, adopted by the cities of Portland and Gresham in 2004, included an inventory of resources and their significance. The purpose of the overlay zone, which applies to all development or division of land, is to protect and restore these resources, including floodplains and wetlands. The overlay zone prohibits new development, with exceptions for (1) lots that have at least 3,500 square feet outside of the new overlay zone and (2) new lots for existing homes where the existing home located entirely within the overlay zone will remain and the portion of the lot located in the overlay zone is not larger than required for the house, garage, and setbacks. It also prohibits new disturbance with the exception of rights-of-way (streets, common greens, pedestrian infrastructure) and utility lines. The remaining area of the "overlay zone that is outside of new lots and outside of the right-of-way must be placed entirely within environmental resource tracts" (§ 33.465.165, Portland Zoning Code).

CASE STUDY: EVIA RESIDENTIAL DEVELOPMENT ON GALVESTON ISLAND, TEXAS

Samuel D. Brody, Department of Marine Sciences, Texas A&M University at Galveston

Evia is a residential development situated on Galveston Island, along the Gulf of Mexico coastline. This community is located on a barrier island historically afflicted by hurricanes and tropical storms moving in from the Gulf. Both storm surge and rainfall-based inundation are significant factors affecting the safety and well-being of the community. The most recent storm was Hurricane Ike in 2008, which was accompanied by historic levels of storm surge that flooded much of the island and surrounding areas, causing over $25 billion in damage.

Figure 2.7. Mixed-use, walkable subdivision design (Mitigation Best Practices, Region VI, Mitigation Division, FEMA)

Figure 2.8. Evia site plan (Mitigation Best Practices, Region VI, Mitigation Division, FEMA)

Developers established Evia in direct response to the threats posed by tidal flood events, rising waters, high winds, and heavy precipitation. The goal for development was to create a community based on new urbanism principles that also has a strong commitment to reducing environmental impacts, while at the same time being resilient to flood events (Figure 2.7). This 93-acre, mixed-use subdivision contains 361 lots and multiple commercial spaces configured to promote walkability and resilience to flood impacts (Figure 2.8).

Flood-Resilient Strategies by Scale

Evia implemented flood-resilient strategies at multiple scales to minimize impacts from flood hazards.

Island: Location

The subdivision is located behind an existing 17-foot seawall erected in response to a Category 5 storm, which devastated the island in 1900. The development is also positioned on the island's interior, where it is less likely to be affected by wave and tidal action. Both of these location-based strategies greatly reduce Evia's exposure to damaging storm-surge events.

Neighborhood: Land Design

Recessed roads, lakes, and a five-acre constructed wetland serve as a secondary water-detention system that helps ameliorate flooding. In particular, the streets in the subdivision are intended to flood during storm events and convey stormwater runoff into the lake and wetland areas. These community design features also provide ecological and aesthetic benefits (Figure 2.9).

Site: Elevation

The entire development was originally elevated to 11 feet above sea level, making it one of the highest spots on the island. Fill from constructing the three lakes was used to further raise the building sites. Building pads were additionally elevated to at least 13 feet above sea level. Because the home sites themselves were elevated, there is no need to use pilings, stilts, or other supports that can more easily fail during a storm. The streets, carved into the landscape around the home sites, are specifically designed to collect and convey runoff from each parcel.

Structure: Building Design

Evia was the first Texas residential project to use the tie-down system from Florida's Dade County building code, which requires metal clips, cable tie-downs, and fortified wind construction. The loss of a roof during periods of heavy rainfall is one of the major causes of flood damage in coastal areas. Other flood reduction techniques used at the structural level include the following:

- Elevation of major utilities (e.g., HVAC systems) above ground to the second story level to avoid loss of critical heating and cooling systems
- Application of blown-in foam insulation that not only provides energy efficiency but also maintains its function when saturated by flood waters
- Pressure-activated venting systems in garages and crawl spaces that allow flood waters to pass through the structure without causing it to fail
- Passive survivability features in several homes, including solar panels, wind turbines, and backup generators that allow them to function even if power is lost at the main grid.

Figure 2.9. Residential structures adjacent to detention (Mitigation Best Practices, Region VI, Mitigation Division, FEMA)

Household: Storm Planning, Preparation, and Recovery

Evia residents commit to both storm preparedness and recovery plans. For example, during pre-storm conditions, homeowners are required to remove anything that could become flying or floating debris, such as lawn chairs, trash cans, and flower pots. Residents are also educated on flood threats and encouraged to move valuable contents to second floors before a storm hits. After a storm, contracts are already in place so that cleanup and reconstruction can begin immediately, even before evacuated residents return to the community.

Evidence-Based Assessment

As mentioned previously, the flood resiliency of Evia was first tested in 2008 when Hurricane Ike made landfall just northeast of Galveston Island. Significant storm surge battered the island from the Gulf side, while rising water from the surge forerunner inundated the island from its backside. Galveston experienced major losses from flooding and is still today in a period of recovery. While virtually every residential neighborhood sustained losses from the storm, Evia experienced only superficial damage (e.g., blown-over street signs, displaced wood bridges), allowing evacuated residents to return as soon as possible. Not only did homeowners avoid flood losses from the hurricane, but property values and resale potential actually increased after the storm.

Overall, Evia offers a strong example of how a subdivision can be developed in an extremely flood-prone area without its residents suffering the adverse impacts of flooding events.

Planning and Design Principle 6

Ensure that subdivision and related development regulations are supported with adequate enforcement personnel. For subdivision and related development regulations to be effective, they require not only provision for enforcement but also enforcement personnel. It is important to ensure there is sufficient staffing within a local agency with the qualified personnel, such as floodplain managers and zoning officials, to enforce the regulatory requirements related to the floodplain and subdivision and related development regulations.

Port Orange, Florida, participates in the National Flood Insurance Program and the Community Rating System. The city adopted the State of Florida's model floodplain ordinance in 2014, and its land development code specifies floodplain development permit requirements, which include acceptance of as-built drawings (Port Orange 2016). Additionally, substantial improvements (those equaling or exceeding 50 percent of the building's assessed market value) are required to meet the same standards as new construction. The city has a site inspector who inspects all construction activity from when a silt fence is erected to when construction is completed, ensuring that development is in accordance with submitted plans.

Port Orange has seen a resurgence in subdivision development, including both previously approved subdivisions and new applications. Much of this development is taking place outside the mapped FEMA flood hazard area. As a result, the city is also working with a consultant to identify the base flood elevation.

In addition to ensuring that there are provisions for enforcement personnel, localities should consider capacity building to make sure that enforcement personnel have the necessary skills and resources to do their jobs. This is a particularly important consideration in this time of constrained budgets, as local governments try to do more with less. Reducing spending on training and skill development for enforcement personnel may appear to save money but instead results in higher costs related to a lower quality of enforcement.

CONCLUSION

Floods occur across the United States and during all parts of the year, making them both a common and costly natural disaster. The five General Principles and six Planning and Design Principles in this chapter outline a comprehensive and integrated approach to addressing flood hazard risk and increasing resiliency. These principles draw from floodplain management and planning toolboxes and provide guidance for using data to assess risk, considering future conditions, and understanding impacts of development, as well as working with natural systems to increase resiliency to flood hazards. Chapter 3 builds on these principles, examining an integrated community approach to reducing vulnerability to flooding through subdivision design through the comprehensive plan, other community plans, and implementation tools.

CHAPTER 3

INTEGRATED COMMUNITY APPROACH

Planning at its best is a holistic enterprise. Planners tend to realize that, to one degree or another, everything in a community is connected to everything else. Siloes are not the best approach for understanding these mutual impacts. That is why the American Planning Association (APA) took an integration-oriented approach to hazard mitigation in *Hazard Mitigation: Integrating Best Practices into Planning*, PAS Report 560 (Schwab 2010).

The driving concept behind that PAS Report was that effective hazard mitigation could best be achieved through coordinating plans to achieve complementary goals and through collaborative efforts between agencies and stakeholders working from a common agenda to make their communities safer, smarter, and more resilient in the face of natural disasters. Given this long-standing priority, it makes perfect sense for APA to apply this logic to the problem of devising subdivision standards for areas of the community subject to flood hazards.

After all, subdivision design for these areas is merely a subset, albeit an important one, of the larger problem of community planning for hazard mitigation. However, it is clear to first responders that some parts of a community can be more vulnerable and generate more demands on emergency services as a result of those vulnerabilities. It should be equally clear to planners that good building codes and land-use regulations, including subdivision design controls, can reduce those vulnerabilities significantly—although they may never eliminate them completely. Preventing injuries and losses of life and property are among the paramount responsibilities of the planning profession. In that context, this chapter focuses on applying that approach to three key categories of planning actions within which the subject of subdivision design for flood hazard areas takes on special importance: (1) comprehensive plans, (2) other types of community plans, and (3) implementation tools.

COMPREHENSIVE PLANNING AND VISIONING

The comprehensive plan, also referred to in some states as the general or master plan, is intended to express development policy objectives of the community (Godschalk and Anderson 2012; Godschalk and Rouse 2015). In general, the idea is that zoning and development decisions should be consistent with those policies, although states vary in how strictly they apply this concept (Ohm 2005).

Regardless of those differences, a community's vision to ensure safe living spaces for its residents is a consequential decision only if it results in policies that help to ensure public safety and if these are in turn reflected in implementation actions that make that vision a reality. Best practices in this regard include maintaining the natural and beneficial functions of floodplains and discouraging development in floodplains. But the starting point for such an outcome is the vision itself accompanied by meaningful goals incorporated into the comprehensive plan.

Hazards in the Comprehensive Plan

APA previously outlined a comprehensive approach to making hazard mitigation an essential element of the local planning process (Schwab 2010). The central element in this approach was to establish direct ties between the local hazard mitigation plan (LHMP) and a hazard-related element in the comprehensive plan. LHMPs are prepared under the federal Disaster Mitigation Act of 2000, which provides the incentive of establishing eligibility for federal mitigation grants once the Federal Emergency Management Agency (FEMA) approves the plan as complying with the act and its associated regulations. Those programs—including the Hazard Mitigation Grant Program, which provides mitigation grants as part of post-disaster assistance, and Flood Mitigation Assistance—can provide significant federal aid for underwriting local mitigation strategies.

USING LOCAL HAZARD MITIGATION PLANS TO ADDRESS SUBDIVISION DESIGN

Although comprehensive plans can take a much broader approach to issues of subdivision regulations, local hazard mitigation plans can address some critical issues that can help guide comprehensive plan policy with regard to flood hazards and their implications for subdivision design. If properly integrated into the process of preparing comprehensive plans, mitigation plans can play a valuable role in highlighting some flood safety issues that might otherwise go unrecognized. How can the local hazard mitigation plan (LHMP) help?

First, it is not just Flood Insurance Rate Maps (FIRMs) that matter in defining flood risk. In fact, FIRMs were never intended to be the sole determinant of flood risk. Instead, they were intended to merely demarcate zones within which it is determined there is at least a 1-percent annual chance of flooding. Here is a short list of potential topics for inclusion in a discussion of flood risk in the LHMP as it pertains to new subdivision development:

- **Dam failure zones:** While not typically mapped in FIRMs, if there is in fact an upstream dam, there is always some potential for failure or overtopping. Mapping how that affects developed and developable land downstream would be important in delineating areas of potential risk. Depending on the terrain and the size of a reservoir behind the dam, this risk could either be minor or quite significant, but it is worth considering in any case. One must also, however, be aware of potential regulatory or security considerations (such as terrorism) that may discourage or inhibit communities from mapping such areas.
- **Levee failure consequences:** Levees fail and when they do, development behind those levees is often at greater danger than if the levees had never existed. Historically, there has been an unfortunate tendency to assume that these areas are adequately protected, an assumption that went sadly awry in New Orleans after Hurricane Katrina. The LHMP can explore both of the potential issues in levee failures: (1) the existing certification or accreditation of local levees and (2) the potential consequences of levee failures. That latter analysis can include an examination of the impact of allowing development in such areas where subdivisions may not yet exist, but land is zoned to permit it.
- **Clusters of National Flood Insurance Program claims:** Not necessarily revealed on a FIRM, mapping these clusters and identifying "hot spots" may also serve to reveal that an area ripe for potential development may also be one that deserves closer scrutiny to determine the reason for such a cluster.
- **Repetitive losses:** In communities with any significant number of repetitive loss properties, this too can be a salient indicator of one or more locations worthy of closer scrutiny to avoid aggravating existing flood losses. The Federal Emergency Management Agency (FEMA) defines repetitive loss properties as "any insurable building for which two or more claims of more than $1,000 were paid by the National Flood Insurance Program within any rolling ten-year period, since 1978" (FEMA 2005). The issue is one of recurrent rather than episodic damage.
- **Higher standards:** If the community has already adopted standards stricter than the minimum required under the National Flood Insurance Program, it is important to detail in the LHMP how those standards affect the safety of potential future subdivisions. Showing why these standards are important and what they have achieved is important in underscoring the value of good floodplain management and planning. This can include both higher freeboard standards and restrictions beyond the 100-year floodplain. For instance, a few communities have adopted the 500-year level as their locally regulated floodplain. On the other hand, if the community has simply adopted minimum standards of the National Flood Insurance Program, the LHMP could become an effective vehicle for exploring how higher standards could beneficially affect flood safety.
- **Areas deserving special protection:** The LHMP can reinforce or even influence comprehensive plan provisions concerning designation of natural or sensitive areas by clarifying what is risk and where those risks are located. Ideally, the result is that the jurisdiction will establish those designations where needed based on the evidence compiled in the LHMP.

Second, planners should be involved in developing the LHMP. Because the natural inclination of FEMA and state emergency management agencies is to work with their counterparts at the local level, and because many local officials still tend to see the LHMP as an assignment belonging to emergency managers, those agencies tend to be the lead entities in developing the plans. That

does not mean there is not a role for planners, including potentially the lead responsibility for developing the LHMP if that makes the most sense.

No matter who is in charge, planners ought to be at the table in the preparation of the LHMP because, especially with regard to subdivision design, many of the most effective hazard mitigation strategies require or implicate land-use regulations, which should be a planner's forte. If planners are not involved, important points regarding the impact of land-use policy on risk reduction can and probably will be missed in the process. Planners can make the LHMP a very different document from what sometimes results—and almost always for the better.

In the first years after the passage of Disaster Mitigation Act of 2000, one critical problem was that most mitigation plans were being prepared by emergency management agencies with little direct involvement from community planners. This was a result both of emergency managers not reaching out to planners for their perspectives and of planners often failing to assert their own roles in the process. In many cases, this was because planners did not see its relevance, although land-use policy clearly shapes the impacts of natural hazard events, especially where flooding is concerned.

The APA project that resulted in the publication of PAS Report 560 was an attempt to alter this dynamic in favor of a more integrated approach that treated land-use regulations such as zoning, planned unit development, and subdivision codes as essential elements of a successful approach. As part of that strategy, the report included a Safe Growth Audit as a tool that would allow communities to identify and remedy the weak points in their plans, policies, and ordinances with regard to hazard mitigation.

Although PAS Report 560 took the approach of integrating hazard mitigation priorities into all aspects of the local planning process, there is no question that the inclusion of a hazards-related element in the comprehensive plan is a cornerstone of this strategy. It establishes a focal point for policy making based on a thorough assessment of the circumstances facing the community. It also establishes a means for linking the comprehensive plan to the LHMP, which is important for achieving implementation because the local comprehensive plan typically has legal standing as an expression of municipal policy in a way that other plans do not. At least 10 states require some such element in local comprehensive plans. (It should be noted that the hazards element can and often does have other names—for example, the safety element in California.)

There are at least three important options for accomplishing this integration:

- Using the same document as both the LHMP and the hazards element
- Adopting the LHMP as part of a more expansive hazards element
- Referencing the LHMP in the hazards element

In fact, in May 2010, the same month when APA's report was published, the Iowa General Assembly passed the Iowa Smart Planning Act (§ 18B.1, Iowa State Code), which described a newly prescribed hazards element as the following:

> Objectives, policies, and programs that identify the natural and other hazards that have the greatest likelihood of impacting the municipality or that pose a risk of catastrophic damage as such hazards related to land use and development decisions, as well as the steps necessary to mitigate risk *after considering the local hazard mitigation plan approved by the federal emergency management agency*. (italics added)

The Iowa law grew directly out of that state's experience with flood recovery after the events in 2008 that massively affected cities like Cedar Rapids, with a recognition that land-use policy played a clear role in creating many of the state's vulnerabilities. Subdivision design clearly falls within the parameters of local land-use policy and directly affects outcomes of flood-related disasters.

However, the report went much further than simply advocating the inclusion of a hazards element in the comprehensive plan. It also discussed the need for linking the analysis and prescriptions of that element to other relevant elements throughout the plan—for example, land use, housing, and transportation. By doing this, the plan, in the land-use element, could not ignore data and prescriptions in the hazards element that might point to the need for avoiding or restricting development in more hazard-prone parts of the community, such as floodplains, steep slopes, or the wildland-urban interface. Subdivision design, as a vital element of land-use policy, could then take account of the need to locate development in less hazardous areas. That, in turn, could reduce the exposure of needed infrastructure—such as roads, bridges, and utility lines—to those same hazards, an issue that ought to be addressed also in a transportation or infrastructure element as a policy consideration.

Thinking beyond Hazards

Before moving to other factors in this integrated approach, it is important also to consider that a focus on hazards should not preclude a wider focus on other important issues in smart subdivision design. Good planning will usually consider multiple objectives served by the same approach, among which wildlife conservation and biodiversity are often crucial elements of smart development. In arguing for sound policy to support ecologically sound subdivision practices, Hostetler (2012, 22) notes, "Policy and planning considerations set the stage for 'smart growth.'" He goes on to outline why a larger vision of connectivity is essential to larger biodiversity goals, in part because even well-intentioned developers may not be considering issues outside the

boundaries of their own development projects, making local and regional coordination a primary responsibility of planners and policy makers.

OTHER PLANNING TOOLS AND LINKAGES

The comprehensive plan and LHMP are not the only opportunities to address flood risk and the ways in which land use can mitigate the problem. Nor should the comprehensive plan limit itself to traditional assessments of flood risk based on historical projections, which are likely to prove inadequate in coming decades as a result of changes in both development patterns and climate change. Most communities have a combination of other plans that afford opportunities to be much more specific about localized issues or those related to specific public services and functional capacities. Each of these provides an opportunity to align such planning with zoning and subdivision policies aimed at reducing exposure to flood hazards or, conversely, to identify potential shortcomings in such policies that other plans can help address.

Future Conditions

Flood risk maps are among the most misunderstood tools in the planner's arsenal for addressing hazards. The very language we use, such as "the 100-year flood," suggests to many people that floods of a certain magnitude ought to happen only once a century, producing consternation when they occur more often. In fact, the term really means only that there is a 1-percent annual chance of a flood reaching the lines drawn on such a map and that same chance is present again in the year immediately following such a flood.

If that were the only public misperception, the planner's or floodplain manager's task of public education might still be relatively easy. Some communities and flood mitigation advocates have learned to reframe the issue as the level of risk during the term of a 30-year mortgage, so that people understand the odds of flooding during their probable tenure in a home. The US Geological Survey describes it as follows: "During the span of a 30-year mortgage, a home in the [100-year] floodplain has a 26-percent chance of being flooded at least once during those 30 years! The value of 26 percent is based on probability theory that accounts for each of the 30 years having a 1-percent chance of flooding" (Holmes and Dinicola 2010).

What compounds popular misunderstanding, however, is the notion that the lines on the floodplain map are, or should be, relatively static. In fact, as any geographer or floodplain manager knows, nothing could be further from the truth. Even under purely natural conditions, rivers sometimes migrate, as did the Mississippi under the powerful impact of the New Madrid Fault earthquakes from 1811 to 1812.

Humans often radically influence those patterns, not only by building dams and channeling rivers, or even by building levees that push floodwaters downstream, but simply by building at all. Buildings, with rare exceptions, create hardscapes that force rainwater and riverine flood waters to move around them. The paved roads and parking lots that serve those developments further reduce the pervious surface ratios of land in urban areas. Impervious surface increases flow rates by reducing the absorption capacity of the land, in the process expanding the floodplain and rendering flood insurance rate maps obsolete in a matter of years.

The end result is that the 100-year, or 1-percent annual chance, flood is in fact much more frequent and extensive than the maps suggest, and the National Flood Insurance Program will probably never have the capacity to keep all its flood maps up to date in a nation with approximately 3.5 million miles of rivers. Moreover, our historical experience with flooding is limited, and FEMA thus updates flood maps routinely after major disasters to reflect those new experiences. This, in turn, often creates a public outcry as property owners find themselves on the "wrong" side of the line in a flood map, when in fact that map may merely reflect flood risk that already existed before the new flood or hurricane forced a reevaluation. Objecting to the new maps thus resembles killing the messenger. The impacts of sea-level rise and climate change serve to exacerbate the situation even further.

In light of these realities, the future-conditions analysis undertaken by the stormwater services department of the City of Charlotte and County of Mecklenburg in North Carolina in the decade after 2000, discussed in a case study in PAS Report 560 (Schwab 2010) and previously cited in Chapter 1, stands out as an example of a large jurisdiction mounting a remarkable effort to tackle the problem of explaining shifting floodplain boundaries to a skeptical public. Much of the initial impetus for reexamining the problem came from Hurricanes Fran and Floyd in the late 1990s, leading to pilot studies of two creek watersheds and engagement with developers and real estate interests to demonstrate the extent of the problem as it related to future conditions—that is, the size of the floodplain if full buildout occurred under existing land-use codes. Sharing that data with the community ultimately resulted in endorsement of the remapped floodplains by development

interests and the avoidance of serious public backlash against stricter floodplain regulations.

The analysis focused on quantifying the impacts of allowing full buildout under existing development codes in an urban area subject to flash flooding along numerous streams and tributaries flowing out of the mountains into the North Carolina Piedmont. By making its analysis transparent and sharing it with key stakeholders, most notably the real estate and development communities, officials succeeded in winning critical support for changes in development regulations that would help to mitigate those problems and limit future expansion of the floodplain into newly vulnerable areas. A number of other jurisdictions have also undertaken future-conditions analyses. Even by 2001, FEMA (2001) cited examples such as Fairfax County, Virginia; Plano, Texas; and the Urban Drainage and Flood Control District of Denver among others who have employed future-conditions hydrology as the basis for strengthening local floodplain management ordinances.

Charlotte-Mecklenburg's experience leading up to 2000 was in many ways a classic example of the problems of rapid growth in accelerating expansion of the floodplain, even when mapping does not keep up with the new reality. An analysis by American Forests (2003) showed that Mecklenburg County had lost 22 percent of its tree cover and 22 percent of its open space between 1984 and 2001, with a 127 percent increase in impervious surface cover. A later report found that by 2008 the loss of forest canopy since 1985 had grown to 33 percent, with a consequent "loss of the tree canopy's ability to naturally manage 252 million cubic feet of stormwater" (American Forests 2010, 2).

Such numbers have clear implications for stormwater runoff but also for subdivision design, which are discussed in the "Implementation Tools" section (p. 45) as well as in the next two chapters. Severe flood events in 1995 and 1997 resulted in damage outside the 100-year floodplain, which in turn contributed to a realized need to model flood elevations based on future buildout conditions to capture the full extent of the problem. The result was the creation of a future land-use map and future-floodplain initiative, with substantial stakeholder participation, to address these issues (Schwab 2010).

Climate change is another aspect of future conditions that communities can address, but one that has seemed less clear in its implications than a buildout analysis, which can make assumptions based on allowable densities in the zoning code. Nonetheless, the usability of regional projections for local planning has been improving steadily to the point where some communities are pioneering in the incorporation of such data into hazard mitigation planning. One distinct example in that regard was the decision by the City of Baltimore to merge its climate adaptation plan with its local hazard mitigation plan, allowing the city to examine what future needs its mitigation efforts ought to address (Baltimore 2013). This establishes the planning basis for a more consistent overall effort to address both current and projected future conditions.

While the plan does not directly address issues surrounding subdivision design—not surprising, perhaps, for an already densely built urban area—its discussion of strategies does take into consideration the city's goal for 40-percent tree canopy cover and the contribution it may make to hazard mitigation and green building and infrastructure standards, all of which can at least play a role in subdivision design in jurisdictions where new subdivision applications are still occurring. The larger point is that this merger of climate adaptation and hazard mitigation planning provides a model for a more holistic framework within which to develop public policy regarding subdivisions.

Functional Plans

Functional plans deal with planning for specific functions of a community or region, such as parks and open space, water supply, wastewater and sewage treatment, and transit. They introduce some complexities into the problem of coordinating hazard mitigation planning because they are often produced by regional agencies or special districts, such as a transit authority or water reclamation district. As such, maintaining relationships with these independent authorities poses a challenge to planners (Schwab 2010). At the same time, their policies and strategies can have a bearing on subdivision design to the extent that they affect issues like open space preservation or the design and extension of public services like water and sewer lines.

An example would be the planning of a levee district along a river corridor, with clear implications for land use behind the levee. In Louisiana, for instance, levee districts have authority to approve subdivision plats within their areas of jurisdiction. In California, the Subdivision Map Act requires a general drainage plan for agencies (such as a flood control and water conservation district) imposing fees within a subdivision to support proposed drainage facilities (Title 7, Division 2, California Government Code). It is important to understand how state law drives the relationship between subdivision plat applications and the responsibilities of such special districts, as these relationships take many forms.

Area Plans

Area plans deal with specific subsections of a jurisdiction and thus are geographically defined. However, the nature of the geographic definition can vary from neighborhoods to commercial districts to corridors along arterial roads. In a sense, some watershed plans could even be considered area plans, although often watersheds transcend municipal boundaries and take on more of the nature of regional plans. Area plans need not be urban, either; they can deal with rural subsections of a county, for instance. In areas within or near the extraterritorial zoning authority of an incorporated community, these may very well entail land-use planning for areas subject to future subdivision.

The important factor in such plans related to subdivision design and flooding is that the narrower geographic focus of such plans allows for the inclusion of much greater detail with respect to local flood hazards than would often be possible in community-wide comprehensive plans (Schwab 2010). However, as noted in the APA case study of Charlotte-Mecklenburg, that potential for incorporating hazard mitigation in area plans is not always realized (Schwab 2010). Another highly functional approach is a greenway plan specifically focused on a stream corridor, such as the Two Rivers Area Greenway Plan for Northampton County, Pennsylvania (Northampton County 2005). These plans afford opportunities to outline co-benefits of protecting stream corridors, such as recreation and habitat protection, thus strengthening public support for flood hazard mitigation in the process.

Policy Drivers

Policy drivers are those federal or state laws and regulations that effectively "drive" or impel local governments to implement certain measures. When not accompanied by grants or other aid to pay for implementing the requirements, they are often referred to as "unfunded mandates."

Funded or not, however, such laws or regulations can become effective arguments at the local level for taking action in instances where political will might otherwise be lacking. They have often been cited as factors aiding local planners and urban foresters in making the case for implementing various green infrastructure measures, including forested riparian buffer zones, as a means of meeting federal Clean Water Act requirements for managing stormwater runoff (Schwab 2009). This argument can obviously be applied in seeking to maintain open space in special flood hazard areas along river and stream corridors in the process of platting a new subdivision.

Other factors that can come into play are the requirements of the Endangered Species Act, state environmental policy acts, federal transportation planning mandates, and, most obviously, the floodplain management requirements for participation in the National Flood Insurance Program. With regard to endangered species, riparian corridors generally have a much higher density of biodiversity and wildlife habitat than most other areas precisely because of the availability of water.

Regional Plans

As noted earlier, although developers may think primarily in terms of conservation and stormwater management within the context of their own subdivision boundaries, it is the responsibility of local and regional planners to establish the larger context for watershed management and biodiversity. Regional plans lack the force of municipal policy contained in comprehensive plans and are at least one step further away from subdivision regulations. However, they can, as Hostetler (2012) notes, help create some policy context for needed connectivity between communities in the same watershed, affected by the same or very similar stormwater runoff and environmental quality considerations.

The issue is really one of scale and recognizing that flood hazards rarely end at municipal boundaries. In short, subdivision design is important for effective flood mitigation but so is the larger policy context in which it happens. Too often in the past, communities in the same watershed have even worked at cross purposes and undermined each other's objectives.

In this context, it is also worth mentioning that many local hazard mitigation plans are themselves regional in nature because of provisions in the Disaster Mitigation Act for multi-jurisdictional plans. Many involve county-level aggregations of municipalities with the county, but some, such as Nebraska, are also specific to watersheds.

IMPLEMENTATION TOOLS

In the end, perhaps the most important link in the larger set of linkages connecting plans and good subdivision design to achieve a safe community is the one driving implementation of the policies created in the plans. Implementation tools come in a variety of forms, but basically they consist of any means of ensuring that the intent of plan policies is actually carried out. This can happen through code enforcement, of course, but also occurs through sound public investments, the crafting of regulations to be

CASE STUDY: THE CHICAGO REGION

Nicholas A. Walny, American Planning Association

Chicago is the most urbanized area in the state of Illinois and the third-largest metropolitan area in the United States, with a population of 8,431,385 (US Census Bureau 2010a). This seven-county region (comprising Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties) is home to more than 284 municipalities, making the area a hotbed for political activity. With many overlapping districts—such as counties, cities, townships, and villages—enabling effective urban planning measures and policies can be a difficult challenge. However, coordinated strategies by the Chicago Metropolitan Agency for Planning (CMAP), the area's official regional planning organization, and the Illinois Department of Natural Resources (IDNR) help the region's communities address planning issues that deal with transportation, housing, economic development, open space, and the environment. These issues include stormwater management and mitigation of flood hazards.

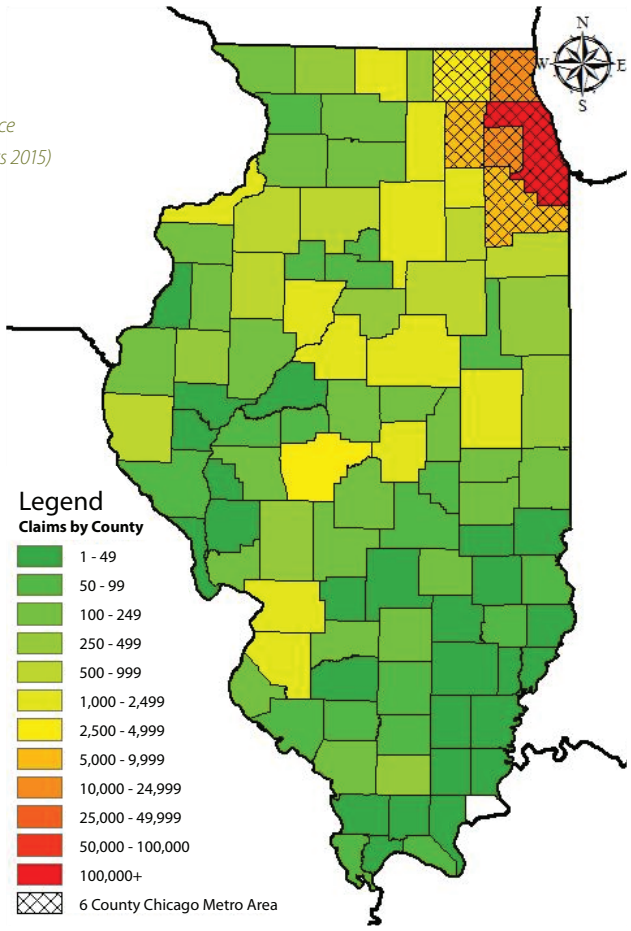


Figure 3.1. Illinois insurance claims by county (Winters 2015)

The Chicago region has become vast and dense as a result of increased urbanization and a growing population. This dense environment has caused floods to occur frequently because the region sits on broad floodplains and clay-based soils and it experiences increased runoff from impervious surfaces such as roofs, parking lots, and streets. Figure 3.1 shows the resulting high number of insurance claims due to flooding. To address the problem, CMAP's predecessor, the Northeastern Illinois Planning Commission (NIPC), introduced preventative measures for communities to adopt and both organizations continued to modify them.

One of the first measures was a model floodplain ordinance. NIPC created the ordinance in 1996 to reflect the Federal Emergency Management Agency's minimum requirements for National Flood Insurance Program eligibility. The ordinance is also intended to protect the hydrologic and hydraulic functions of floodplains and watercourses and their related water quality and habitat functions, as well as to protect structures and their inhabitants (INDR and NIPC 1996). However, because the region's population continues to increase, mitigating potential flood hazards has become extremely important. The model floodplain ordinance was a crucial first step. Nonetheless, further measures were needed.

In 2003, NIPC (2003) introduced the *Conservation Design Resource Manual*. The manual is for use by local governments interested in modifying local comprehensive plans, zoning and subdivision ordinances, and other ordinances to accommodate the principles and practices of conservation design. Con-

servation design has been defined as a design strategy where "half or more of the buildable land is designated as undivided, permanent open space" (Arendt 1996, 6).

Chapter 3 within the manual offers approaches to integrating conservation design into local plans, zoning codes, and subdivision ordinances. The following are a few of the highlights related to subdivision design in flood hazard areas:

- Minimize development on and destruction of sensitive natural resource areas and wildlife habitats.
- Reduce the quantity and improve the quality of stormwater runoff from expected development.
- Provide a wider range of feasible sites to locate stormwater best management practices.
- Minimize impervious surface area.
- Reduce potential pressure to encroach on resource buffer areas.
- Reduce soil erosion potential.

By adopting these principles, communities may decrease the risk of flooding and increase the quality natural assets that floodplains offer.

However, flooding has continued to worsen due to the increase of impervious surfaces, an aging sewer system, and the effects of climate change. In 2015 the Illinois General Assembly under the Urban Flooding Awareness Act (effective August 3, 2014) gave IDNR the assignment of preparing a report on the extent, cost, prevalence, and policies related to urban flooding in Illinois and to identify resources and technology that may lead to mitigation of the impact of urban flooding (Winters 2015). The report specifically identifies the key findings related to minimizing damage to property from urban flooding:

- The three most common types of urban flood damage reported in the survey of Illinois community officials are basement water seepage, basement sewer backup, and water coming in through basement windows.
- Strategies to mitigate the problems vary based on the local conditions. Thus, effective mitigation generally is implemented at the community, neighborhood, and/or property levels.
- A number of flood damage reduction strategies can be used to reduce damages experienced by property owners, including many that are inexpensive. Identification of the source of flooding is fundamental to successfully mitigating future damages.
- Education and outreach on identification of root causes are necessary to empower homeowners to solve flooding issues that can only be addressed on their property.
- Neither green nor gray infrastructure should be considered a single solution to urban flooding. Both complement each other while being subject to their own limitations.
- Development of a comprehensive stormwater management plan is a key component in reducing urban flood damage at the neighborhood or community scale.

These strategies and key findings, along with many others outlined in the Urban Flooding Awareness Act, provide communities essential measures for preventing extreme flood damages from occurring in a subdivision.

Incorporating mitigation measures such as the ones outlined in this case study are important steps toward creating resiliency in the face of a flood hazard. With the many units of government in metropolitan Chicago, it is critical that organizations such as CMAP and IDNR continue to provide communities the ability to adopt and implement sound planning measures on a local scale. Chicago is a prime example of a region working to get things done.

enforced, programmatic efforts to protect ecological and other features, and, finally, through incentives. These incentives can take the form of local incentives to property owners and private investors but also of state and national incentives driving local policy.

Local incentives can take the form of subsidies, low-interest loans, and tax breaks, while state and national incentives often take the form of grants and technical assistance. In the latter case, those incentives may drive local governments to create their own incentives that then influence the behavior of individual residents and property owners. With subdivision design, the influence is aimed at developers. The adage that "time is money" suggests that one incentive might involve streamlining approval for desired types of development while making approval for less desired outcomes more challenging.

Capital Improvements

The famous line from the movie *Field of Dreams*—"If you build it, they will come"—has occasionally found its application with regard to the extension of urban infrastructure. Conversely, not building new infrastructure may serve as a deterrent but not always. Because developers are typically underwriting the cost of much new infrastructure, such as roads, in new subdivisions, the issue has less to do with communities budgeting for such capital improvements than with the requirements they include with regard to both construction and location of infrastructure in subdivision regulations as well as provisions for long-term maintenance and operations. (Chapter 5 specifically discusses the latter points with regard to homeowner associations.) Nonetheless, at some point, a community needs to coordinate both its own capital expenditures and existing infrastructure and those connected with new development.

An important point is that numerous studies and communities have found that a more compact development form that preserves greater open space—presumably in more hazardous areas that are best avoided as building sites—makes infrastructure less expensive to develop and maintain by reducing sprawl and shortening water, sewer, and other lines. At the same time, while undergrounding utility lines may add costs, the infrastructure is better protected from wind and water hazards, reducing losses from future events.

Floodplain Management Regulations

Floodplain management ordinances enacted by local government as a condition of National Flood Insurance Program participation are an example of the policy drivers discussed earlier. The program has clear requirements for such ordinances, but they are minimum requirements that communities are free to enhance or exceed with stricter requirements of their own. PAS Report 473 noted that most of these ordinances establish overlay zones with particular requirements that apply within that prescribed zone, often mapped as the 100-year floodplain for the National Flood Insurance Program (Morris 1997).

It is important to recognize, however, that states and communities are free to undertake their own mapping and to use such techniques as future-conditions mapping to develop a more inclusive overlay district for the purpose. Some, like Cedar Falls, Iowa, have used the 500-year floodplain boundary as a guideline for siting critical facilities and as the locally regulated floodplain. The city requires structures located within the boundary to be elevated one foot above the 500-year flood elevation (Musiol and Ryan 2013). PAS Report 473 also noted something that is even truer today—namely, the wisdom of basing such regulations on a participatory planning process, which not only builds stronger public awareness and support for flood hazard mitigation but also can earn credits under the Community Rating System, a special incentive system discussed in a following section (Morris 1997).

One major sign of changing times was the Executive Order by President Obama, issued January 30, 2015, amending Executive Order 11988 and directing changes in the Federal Flood Risk Management Standard. The order states that its intent is to "improve the Nation's resilience to current and future flood risk." Although the order pertains to federal actions in the floodplain, it makes clear that its aim is partly to address climate-induced changes "informed by the best-available and actionable science." While the order does not address regulatory changes at the local level, it sets a tone and standard for national consideration.

At the very least, asthe Association of State Floodplain Managers recommends, communities can establish 500-year flood standards for critical facilities and developments. ASFPM's model language describes "critical development" as "that which is critical to the community's public health and safety, [is] essential to the orderly functioning of a community," involves hazardous or toxic materials, or "house[s] occupants that may be insufficiently mobile to avoid loss of life or injury" (ASFPM 2010, 5).

It is also possible for communities to incorporate their floodplain standards directly into building codes and zoning and subdivision ordinances (Morris 1997). In either case,

communities use these regulations to establish standards for siting, density, lot configuration, and flood-resistant construction (including freeboard requirements) in order to minimize flood losses. Chapters 4 and 5 will discuss these issues in greater detail.

Wetlands Protection

Hostetler (2012) cautions against simply trying to protect all wetlands, no matter how fragmented, instead of focusing on larger areas. The larger focus allows for building in more compact patterns that minimize sprawl. He notes that simply focusing on wetlands may result in building in a fragmented pattern in between designated wetlands without achieving compact form. There may be times when it is wiser to focus on the larger goals, including moving development out of harm's way. The result may be both better public safety and a higher degree of biodiversity integrity.

Hostetler (2012) offers the example of the Harmony community near St. Cloud, Florida, where developers used a community development district bond costing the average homeowner about $200 annually to finance preservation of lakefront land that included wooded wetlands along the lakeshore. The result was higher real estate values for the homeowners and better habitat protection, lakefront park amenities, and protection of water quality.

Given the documented stormwater filtration benefits of forested riparian buffer zones, flood reduction benefits can be assumed in most riverfront settings in addition to similar amenity values. Baltimore County, Maryland, has used such strategies successfully for a number of years (Schwab 2009).

Conservation Development

The clustering of development to preserve open space, particularly in sensitive or hazardous areas, is an idea that has been in circulation for more than two decades. But it received a significant push in popularity in the planning field, beginning in the 1990s, with the work of Randall Arendt (see Arendt 2015). The underlying idea is to replace what is often known as "cookie cutter" plat design, in which a subdivision plat is simply cut up into lots of roughly equal size without significant regard to natural features, with a plat that concentrates, or clusters, residential or other buildings in more buildable areas and reserves sensitive, historical, or more natural areas as common open space.

In ordinances permitting or enabling such zoning and subdivision design, communities either allow the transfer of density to safer, more appropriate spaces within the subdivision boundaries or sometimes allow density bonuses in exchange for more innovative approaches that enhance the aesthetic or environmental appeal of the resulting space. Once less common, conservation subdivisions by now are commonly recognized as a more sensitive development approach, not only with regard to flood hazards, but for a number of purposes related to environmental protection and reduced sprawl.

Community Rating System

Since 1990, the National Flood Insurance Program has provided incentives for more effective local floodplain management through the Community Rating System. Participation by communities is optional but offers substantial benefits in the form of reduced flood insurance premiums for residents. Those reductions come in 5 percent increments based on the community achieving any of nine classifications in a system in which points are awarded for completing any of a wide variety of activities. Consequently, Class 9 provides a 5 percent premium reduction while Class 1 provides a 45 percent reduction, something achieved by Roseville, California, as the result of very deliberate policy decisions on the quest to achieve such status (Schwab 2010).

The Community Rating System *Coordinator's Manual* is the most useful tool for determining both what activities are most applicable overall in a particular community for earning credits, and which are most specifically applicable in improving and supporting effective subdivision design for flood hazard mitigation (FEMA 2013b). The list of activities that are valid for earning points is both broad and very specific and lends itself very well to an integrated approach to hazards management. With reference to floodplain management in the context of subdivisions, those activities include the following:

- Providing map information to the public with regard to flood hazards, including subdivision plats
- Maintaining and updating maps to keep them current—for example, by accounting for new subdivisions and annexations
- Posting flood warning signs in subdivisions
- Developing open space preservation regulations that meet criteria spelled out in the manual, which include prohibiting buildings in the regulatory floodplain
- Ensuring that building sites in a new subdivision are on natural high ground
- Requiring evacuation plans for larger subdivisions

- Adopting stormwater management regulations as a condition of subdivision approval

While it is beyond the scope of this report to delve into the details of the Community Rating System activities and credits, the essential point is that the community can benefit its own property owners and residents with lower flood insurance premiums while undertaking efforts that will make the community safer and lead to better subdivision design for limiting flood hazards. In addition, participation can become a vital part of an integrated citywide approach to achieving flood resilience.

CONCLUSION

This chapter's review of various potential elements of a larger context for hazard mitigation was intended to highlight the wisdom of undertaking a review of subdivision design rules at the local level within a more comprehensive framework and to underscore the value of placing those considerations within a wider approach to hazard mitigation rather than treating them in isolation from other planning goals. The rest of this report will focus largely on the process and standards for considering subdivision design with respect to flood hazards.

CHAPTER 4

SUBDIVISIONS: ROLE AND PROCESS

At their core, subdivision regulations and processes control the creation of buildable lots, both residential and commercial. A key to successfully implementing comprehensive subdivision standards for flood loss reduction and preservation of floodplain functions is to have a comprehensive and integrated approach to subdivision review, competent inspections, and ongoing maintenance of any flood loss reduction infrastructure. Subdivisions can also include additional important features such as wetlands and floodplain areas (including any wetlands discovered and any floodplains created during the development process), easements for conveyance of stormwater and the overall stormwater system, and areas of greenspace and public use.

It is important to remember that sustainable subdivision regulation and implementation is really part of a much larger community development and flood loss reduction effort that involves multiple agencies; several sets of codes, standards, regulations, and requirements; a multitude of community staff, agencies, and departments; and local decision makers (from the council or commission, as applicable). Ultimately, the subdivision development review and approval process should be consistent with all local plans and standards and informed by the full array of flood hazard data, resulting in what is hoped to be resilient designs and lessened damage. Achieving this requires various steps throughout the subdivision life cycle.

ROUTINE ACTIVITIES OF THE PLANNING DEPARTMENT

To effectively reduce flood risk through the community's subdivision review process, it is critical not only to take an integrated and holistic approach, but also to undertake sound planning and consistent flood reduction actions on a day-to-day basis. Consistency in an integrated approach to planning and floodplain management will facilitate better understanding by the public, reviewing agencies, and decision makers; foster cooperation with developers and design engineers; and engage the whole community in the planning and flood reduction process. Transparency of information is key to successful implementation, along with utilization of all available modern-day methodologies, techniques, and data. This ensures that the development coming out of those processes will ultimately lead to new subdivisions that minimize susceptibility to future flooding and flood losses.

Development of Staff Floodplain Management Capability

In more than 22,000 communities throughout the country, the community floodplain manager is identified as the individual who administers the flood loss reduction standards that are adopted in order to participate in the National Flood Insurance Program. The Association of Floodplain Managers (ASFPM) has conducted research on just who is the floodplain manager in a given community. The findings indicate that they can be a diverse set of community officials, including mayors, clerks, and emergency managers. The top three positions include local building/zoning code administrator (33.2 percent), planner (11.6 percent), and engineer (11.3 percent). Overwhelmingly, floodplain managers have other primary duties (Berginnis and Brown 2016).

It is preferable to have floodplain management functions and subdivision planning functions located in the same agency. For example, a county planning agency that has both of these under its purview will have an easier time with integration and coordinated development reviews. In smaller communities, both functions may be done by the same staff person who is also responsible for several other planning activities. However, many communities lack personnel with the proper skill sets to serve as floodplain managers. Even communities that participate in the National Flood Insurance Program may not have a Certified Floodplain Manager on staff.

Inasmuch as the development community is depending on advice and information from the planner or floodplain manager to make decisions, it is incumbent on those staff to ensure there is within the agency a level of competency and knowledge about an array of topics related to floodplain management, including floodplain management standards, flood insurance issues, levee considerations certification, flood mapping/map changes, and flood hazard mitigation techniques. Luckily each state has a floodplain management office that provides free training and tools to local floodplain managers. ASFPM also has 36 chapters in 41 states that conduct different levels of training and outreach. In addition, ASFPM offers the Certified Floodplain Manager credential, which tests competency on a broad array of floodplain management knowledge and requires continuing education.

Necessary Data

It is important for the planner or floodplain manager to identify, gather, and maintain all available flood hazard information for the jurisdiction to inform subdivision reviews as well as promote flood hazard reduction. As noted in Chapter 2, however, only one-third of the nation's streams, coastlines, and rivers have flood hazard areas identified and mapped by the Federal Emergency Management Agency (FEMA), and only half of those identified flood hazard areas have detailed flood hazard data. Thus, the community's Flood Insurance Rate Maps are merely a starting point and certainly do not come close to identifying the entire flood risk, especially in newly developing areas. Urban infill or redevelopment areas may have better FEMA flood risk data.

What other flood hazard data exists? The following data sources are just a start:

- **Historical flood information:** These data can be gathered by talking to the original property owner or owners in the area. Resources in the local library or historical events memorialized in local newspapers can also contain this information. One variable to be especially aware of is potential ponding areas either in rural areas or in older urban neighborhoods with inadequate stormwater infrastructure that would not be identified by other data sources.
- **Soil maps:** These maps identify hydric and other soils typically found in floodplain areas. The Natural Resources Conservation Service now has 95 percent of the nation's soil maps available online. However, more detailed onsite soil investigations may be found at state departments of geology or agriculture (or similar agencies) as well as local universities.
- **US Geological Survey maps:** Besides topography, these maps show hydrography (rivers, streams, and other water features). If it is depicted as a "blue line stream" on the US Geological Survey (USGS) map, it has flooding potential! Additional hydrography information is available through USGS, the state department of water resources or natural resources, or similar agencies.
- **Dam/levee failure zones and emergency spillway areas:** This information may be gathered from local emergency management offices or the state's dam/levee safety program. Recent large flood events in South Dakota and South Carolina resulted in damage to several homes in newer subdivisions due to the activation of the emergency spillway of a dam, improper operation of the dam spillway, or the failure of the dam altogether. These are losses that could have been avoided or prevented.
- **Flood insurance claims:** The local floodplain manager, through the state floodplain management office, can obtain claims data as long as it is for official use for floodplain management purposes. Historically, one-fourth of the claims to the National Flood Insurance Program fall outside mapped flood zones.
- **Amount and age of impervious surfaces (roads and rooftops):** The local geographic information systems (GIS) department may be a good source of these data.
- **Climate/climate change models:** Many communities, universities, regional planning agencies, and states maintain these data.

Planning departments with more technical capability or more significant flood hazards may try to integrate all of these datasets into a GIS system. However, even if it is not integrated into a system, maintaining and being knowledgeable of these data sets separately can be helpful during the early stages of subdivision planning and review.

Ensuring Consistency

It is important for the planner or floodplain manager to ensure consistency of subdivision proposals with all local and regional plans by inventorying and cross-referencing all applicable plans, hazards data, and local and regional development goals and policies. Traditionally, planners ensure subdivision proposals are consistent with the community's comprehensive plan. However, a variety of other plans and development goals need to be reviewed and consulted. Chapter 3 detailed some of the plans that need to be integrated to truly achieve reduced flood risk. These plans, programs, and policies should be inventoried, and information essential to

either increasing or reducing flood risk needs to be identified. The following are examples of types of plans and pertinent issues and questions that should be considered:

- **Comprehensive plan/zoning:** Do the comprehensive plan and future land-use map show high-density development in known flood hazard areas?
- **Hazard mitigation plans:** Not only may the risk assessment in the local hazard mitigation plan have additional flood data, but the mitigation strategy may contain actions or policies that pertain to flood hazard reduction. For example, is there a goal that shows a particularly flood-prone area will eventually be bought out and converted into a park? Would a particular subdivision proposal jeopardize that goal?
- **Community housing plans:** Where is low-income housing located or proposed? What about essential services? How are potential environmental justice issues being addressed so that the community's subdivision processes are not placing the most vulnerable in high-hazard areas?
- **Capital improvements plans:** Where is the infrastructure going? Does it have the potential to promote development in flood hazard areas? Will a particular subdivision proposal have the practical impact of encouraging development in a risky area? Are important facilities planned within vulnerable locations?
- **Parks/open space plan:** Are parks located or planned in areas that may have the co-benefits of flood loss reduction? Good examples of this are the linear parks along streams and rivers. But note that not all parks are appropriately placed in or suitable for flood hazard areas. For example, parks with intricate infrastructure may need to be located entirely outside of high at-risk-for-flood areas, while some may need to only have critical infrastructure located outside of the flood hazard area.

Ensuring Effective Coordination

It is important for the planner or floodplain manager to proactively reach out to land developers, sister agencies, and local elected officials to inform them of land development policies and procedures related to flood risk and ensure consistency with the community's standards. In the majority of communities, most development is undertaken by developers who have a history of previous subdivision activities. Proactive work with these entities can facilitate a much smoother subdivision review and approval process. Similarly, it is important to coordinate early with newly elected officials to ensure they are aware of the community's development goals and policies.

A program of outreach to these stakeholders, as well as others in the community involved in development, increases flood risk awareness and can ensure greater acceptance of the community's overall flood loss reduction goals. Some best practices include the following:

- **Talk to the economic development office.** Which sites are being marketed for future commercial or industrial development? What is the flood risk of those sites?
- **Hold annual informational meetings for newly elected officials.** This is particularly important in counties where there may be many more newly elected officials on an annual basis.
- **Present at trade association meetings for homebuilders, surveyors, architects, realtors, and other development-related professions.**
- **Proactively contact land developers who purchase large tracts of land, such as farms, and provide them data showing any known flood risks on the site.** Typically, state real estate disclosure laws (even those that only require the disclosure of known issues by the seller) would then require the developer to pass on that knowledge to prospective buyers. This may be especially important if the subsequent land divisions are exempt from the planning department's review process.

Outreach to Property Owners

It is equally important to proactively reach out to owners associations (OAs) on a variety of topics related to flood risk management. According to the Community Associations Institute (2016), 20.7 percent of the US population, or 66.7 million Americans, live in 333,600 common-interest communities. Approximately 55 percent of these common-interest communities are homeowners associations, with the others being primarily condominium or community associations. Allowing the creation of OAs is almost universal in community subdivision regulations. The reasons for this vary, but a primary reason is that the community may not have the interest or resources to maintain the infrastructure in the subdivision. Depending on the infrastructure for which it is responsible and the degree of flood risk in the subdivision, the OA may have significant responsibilities related to ensuring that residents are safe and protected from flooding. Yet, most OA board members, association management companies, and on-site staff have no expertise in flood risk management.

Planners know the challenges OAs face in keeping up with maintenance of common areas and infrastructure, but

what happens when an OA is responsible for maintaining highly sophisticated, engineered systems like dams, levees, or seawalls? Berding and Weil (2012) developed an excellent primer on community associations and the inherent risks with disasters. The bottom line is that planning departments or other agencies can help provide anything from technical training to disaster preparedness or post-disaster plan development assistance. Appendix A shows a county-sponsored workshop notice for homeowners associations and property owners about maintaining detention ponds, wetlands, and natural areas.

The Stormwater-Flood Management Connection

Many communities manage stormwater in response to the Clean Water Act, but very few consider the linkages between stormwater and floodplain management. Stormwater runoff is responsible for a vast majority of flood events. If runoff can be better managed in the areas outside designated Special Flood Hazard Areas, flood risks could be maintained or reduced. Stormwater management typically only looks at the more recurrent rainfall events that carry pollutants into streams and rivers while floodplain management generally looks only at the extreme flood events which are typically associated with extreme or prolonged precipitation events.

Ironically, many of the practices that limit pollution from reaching a waterway can also help mitigate flood risk increases by attenuating runoff rates and reducing runoff volumes. These functions to "clean" the water can incrementally reduce flood risk as well. Integrating stormwater management with floodplain management creates a linkage between a source of the flood risk and the flood risk itself. Even with the best floodplain management operations, if stormwater from areas outside the Special Flood Hazard Areas is not managed properly, flood risks will continue to increase.

Due Diligence and the Pre-Sketch Plan Meeting

The wise developer includes due diligence (also referred to as feasibility analysis) in the development process, and the community's subdivision process may include the step of a pre-sketch plan meeting (sometimes called a pre-application conference). Due diligence is an informal evaluation, analysis, and discussion to explore and confirm the development feasibility of a particular piece of property for an intended use, generally before spending money on design engineering. If planning staff can meet with the developer early in the process to explain the community's development regulations, chances are higher that the developer will adhere to those regulations, including all standards that relate to flood loss reduction.

Applicable due diligence elements for flood loss reduction include the following:

- Historic data and information about the subject property
- Use of aerial photogrammetric mapping to assess existing features; use of GIS or existing topographic maps to assess "the lay of the land," and thus the feasibility of the proposed development
- A site visit or site investigation; this can identify possible constraints to development, especially those not evident within a report or on a map, and planning staff should participate in this site investigation
- Analysis/discussion of all of the community's regulations and ordinances (zoning; site plan regulations; subdivision regulations; stormwater regulations; water and sewer regulations; US Department of Transportation or traffic regulations; board of health regulations or requirements; and other local, regional, state, and federal requirements, as applicable) affecting the property
- Soil suitability analysis based on local soil surveys, previous studies, or reports involving the property or independent testing performed (or previously performed) on the property
- Assessment of wetlands and floodplains and other flood hazard areas on or adjacent to the subject property; this is where a robust inventory of flood hazard data maintained by the community is particularly helpful (as noted above, not often considered but important are dam failure and emergency spillway inundation zones)
- Identification of sensitive areas such as riparian buffers and brownfields
- Parcel information, including any liens on the property and any easements that may affect the property; in particular, be on the lookout for easements related to FEMA's hazard mitigation grant program on parcels that have been acquired by the local government, as these properties have permanent easements that only allow open space compatible uses (conservation easements may hinder development, as well; these types of easements are generally on file with the clerk of court for the municipality and the tax assessor's office)

While often not required, the pre-sketch plan meeting is strongly recommended. At that meeting, planning staff can explain all of the community's regulatory processes, including community floodplain management standards that go beyond the National Flood Insurance Program minimums, and the planner or the floodplain manager can explain the

differences (as most will be familiar with the minimums). For example, if the community requires the creation of 100-year flood data for any area that could potentially convey water (which may also be discovered when staff conduct an initial site visit), requirements can be discussed. Also, it is not uncommon that a developer would look to develop a flood-prone site by first filling it to remove it from the floodplain. However, planning staff can make the developer aware if the community either has standards prohibiting filling of the floodplain or requires that lots be laid out where only natural land above the 100-year flood elevation is allowed for the building envelope.

Sketch Plan

Much like the pre-sketch plan meeting, the submittal of a sketch plan may not be required as part of the subdivision review process. However, it can be very effective as a low-cost planning tool used by the developer in early meetings with community officials about the feasibility of the proposed project in conjunction with the community's regulations and requirements for design, through the permitting process, and on to implementation (construction). Many of the facts and findings from the due diligence process are included in the sketch plan itself or are used in preparing the sketch plan.

Applicable sketch plan elements for flood loss reduction include the following:

- A general layout (property boundary, proposed subdivisions, known easements of record, and any information that would have a bearing on the proposed project)
- Topography, preferably at two-foot intervals at most (although, usually at this stage, it is from the community's GIS information or an old topographic survey and has not been field verified); it is helpful to identify all perennial and intermittent streams
- Wetlands, floodplains, and any other sensitive areas (again, at this stage, wetlands are generally taken from the community's GIS information or an old topographic survey and have not been field verified)
- Existing structures, adjacent roadways, and general access points and alignments
- Known utilities and how the developer plans on providing water supply and sewage disposal
- Existing storm drainage features and a conceptual plan of how stormwater on the site is to be handled
- Site-specific characteristics of the property that would impact site development (e.g., a grave site or a riparian buffer)

Sketch plans usually do not require engineering details. The sketch plan review is usually conducted by the planning department staff; however, it is not uncommon to include review and design staff from other community departments. Key review questions of the sketch plan for the purposes of flood loss reduction include:

- Are floodplain boundaries correctly identified? For example, is the developer using current data?
- Does the subdivision area include any parcels previously acquired by FEMA under its hazard mitigation grant programs that may be permanently deed restricted? Is the proposed land use consistent with those restrictions?
- Are the proposed access points in or out of the subdivision flood prone?
- Are there any watercourses for which the flood hazard is unknown and needs to be identified?
- Is the proposed development consistent with not only the comprehensive plan and zoning but also with the community's hazard mitigation plan?

An effective technique often used in subdivision review that is particularly important for flood risk reduction is the creation and use of a technical review committee. The committee may include representatives from the following departments: planning, public works/engineering, fire, police, parks, health, and emergency management. Having a technical review committee increases the likelihood that a particular flood risk will be discovered through the process. For example, public works may be aware of an area where citizens reported flooding of utilities and roads, or it may be aware of future planned stormwater management projects.

Preliminary Plan

The preliminary plan (sometimes referred to as a tentative plan, development plan, or preliminary plat) should incorporate applicable engineering design elements, include any analyses or studies that are required, and account for all applicable regulations and ordinances for the community. Usually, the preliminary plan is the stage in the process where variances are requested (if needed), and it is usually reviewed and approved by the planning board or commission. When it comes to flood loss reduction there are several points in the preliminary plan stage that need attention.

Elements of a preliminary plan submittal that are important to flood loss reduction include the following:

- Hydrologic and hydraulic analyses, either to develop new flood hazard data that may be required or to verify no impact to the floodplain and no encroachment into floodways
- Stormwater management calculations and designs to ensure proper stormwater conveyance
- Location of all flood hazard areas
- Location of reserve or open space areas
- Locations and elevations of access points in and out of the subdivision
- Preliminary construction drawings for all infrastructure improvements (improvement plan), including erosion control plans

During this phase in the subdivision process, it is critical that the community have the competency to review any hydrologic and hydraulic engineering analyses that may need to be completed. In some communities, staff within the planning department or outside (e.g., the floodplain manager, who may be an engineer; the engineering department; another agency that works in the community) may be able to perform these reviews. If that is not possible, the community may wish to retain the services of an experienced consulting engineer. The National Flood Insurance Program only requires such analyses to be certified by a registered professional engineer to a certain specification (i.e., that a proposed floodway encroachment will cause no rise) and allows acceptance of these types of certifications by local floodplain managers. However, this does not guarantee that the analysis will be correct, especially if the engineer performing the analysis is not familiar with doing these types of flood studies.

The vast majority of variances to subdivision standards are heard by the planning board during the preliminary plan stage. Yet the threshold to issue a variance to typical subdivision issues—such as frontage, lot size, and roadway width—is often lower than if a variance were being considered to a community's floodplain management standards, even allowing for the consideration of hardship. Review standards are much stricter for floodplain variances, the evaluation of which centers on life-safety issues and impacts to the applicant's property and nearby properties. Therefore, it is important that if a community chooses to put flood loss reduction standards such as those suggested in Chapter 5 into its subdivision regulations, consideration also be given to include variance evaluation standards that are more typically found in floodplain management regulations (see "Factors for Variance Requests," p. 59) within its subdivision regulations as well.

Planning staff need to be aware of the boundaries of the floodway, especially when reviewing any improvements resulting in land disturbance to the site, such as new infrastructure or grading. It is a good idea to require that floodway boundaries be clearly shown on improvement plans to ensure that no encroachment (fill or new construction) in floodway areas is occurring. If such an encroachment does occur, then a hydrologic and hydraulic engineering analysis is required to demonstrate that any permitted floodway encroachment meets National Flood Insurance Program requirements per §60.3(d)(3) of the Code of Federal Regulations. Many communities require a No Rise Certification for floodways to document the analyses.

Final Plat Approval

Usually, at the commencement of construction and after satisfactory completion of all inspections of all constructed infrastructure, a final plat will be submitted to the community's planning department for formal review and approval. Formal plats should be in substantial conformance with the approved preliminary plan. A formal application is generally required along with documents deeding roadways, detention, stormwater infrastructure, water, and sanitary sewer, as applicable, to the local community. Other documents, such as maintenance agreements, may be required.

From a floodplain management standpoint, final plats should also be used to convey important flood risk information. Many communities require recordation of flood hazard area boundaries on final plats. In addition, some communities require the recordation of the base flood elevation on each lot that may be affected by flood hazard areas. Others additionally require that each lot have physical monumentation of the boundary of the flood hazard area as well as the base flood elevation. All of these techniques are effective best practices in communicating flood risk to potential buyers and also help the engineering and building department staff in knowing where the flood hazard is on each lot as improvements (e.g., infrastructure, buildings) are taking place.

Post-Approval Management

Proper inspection and oversight of improvements are important to ensure that floodplains are not degraded and that flood risk is not increased. Construction of improvements may take weeks to months (but generally less than two years, which in many communities is the life expectancy of the land disturbing permit), depending on the size of the subdivision. Generally, but not always, construction of structures does not occur during this phase. What does occur is placement of best

FACTORS FOR VARIANCE REQUESTS

Many states' model floodplain regulations include 11 factors upon which to base variance requests. These factors are comprehensive and require evaluation of possible adverse impacts of at-risk development—to the development itself, its inhabitants, neighboring property owners, and the community:

1. The danger that materials may be swept onto other lands to the injury of others
2. The danger to life and property due to flooding or erosion damage
3. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the individual owner
4. The importance of the services provided by the proposed facility to the community
5. The availability of alternative locations not subject to flooding or erosion damage for the proposed use
6. The necessity to the facility of a waterfront location, where applicable.
7. The compatibility of the proposed use with existing and anticipated development
8. The relationship of the proposed use to the comprehensive plan and floodplain management program for that area
9. The safety of access to the property in times of flood for ordinary and emergency vehicles
10. The expected heights, velocity, duration, rate of rise, and sediment transport of the floodwaters and the effects of wave action, if applicable, expected at the site
11. The costs of providing governmental services during and after flood conditions, including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, and water systems and streets and bridges

These 11 evaluation factors have stood the test of time since they were first developed in the 1970s and are still in use, with little deviation, in many communities across the United States today.

management practices, grading of the land, and construction of roads, storm sewer, detention, water and sewer, and any underground utilities (e.g., gas, electric, cable). Building pads for future construction of structures may be prepared during the construction phase or with the actual building of the structure, after final plat approval.

Periodic inspections by community staff occur as well as periodic inspections by the design professional to ensure compliance with the approved development plan. Great care should be taken during the construction phase for protection of wetlands, floodplains, and riparian buffers as well as prevention of erosion and sedimentation leaving the development site. Many codes include specific standards for protection during active construction activity as well as to ensure infrastructure improvements perform as designed.

Maintenance of Stormwater Facilities

Determining who will manage the stormwater facilities in a subdivision is important to the long-term operations of such facilities. As noted earlier, it is not uncommon for OAs to be formed as part of creating a new subdivision. In dealing with flood risk, it is important to understand the financial risk to the OA for stormwater infrastructure that could be damaged or that is not properly and routinely maintained and the ability of the OA to successfully pay for and maintain that infrastructure.

For example, an OA of a newly developed subdivision may be responsible for maintaining stormwater ponds or even a seawall or levee. After several years, those facilities may fall into disrepair if the OA has insufficient financial resources and no expertise in or understanding of the maintenance needs of such infrastructure. In a similar way, if a pond or other impoundment has a dam, the OA may be unprepared for costly upkeep or repairs needed for dam maintenance. In recent years, what is also becoming more common is the need to upgrade the dam to higher standards because the downstream risk has increased through new development.

It is critical that long-term operations and maintenance of such facilities are considered as thoughtfully as is the approval of them in the first place. Bonding of such facilities prior to construction (if their construction is a condition of approval of the plat) amply covers the costs of construction. Requirements for owners of such facilities should be included as part of the subdivision approval. Finally, after construction, a robust inspection and maintenance program should seek to discover problems early before they become much larger and costly.

Figure 4.1. Platted subdivision (note the watercourse appears to have a buffer and/or roadways largely parallel to the flood risk area) (Google Earth)

Other Considerations

Two other considerations planners need to keep in mind involve the handling of minor subdivisions and lot splits and the enforcement of restrictive covenants. These are somewhat different matters from the overall process of subdivision review and approval, both legally and substantively, and hence they are discussed in more detail in the following sections.

Minor Subdivisions/Lot Splits

The purpose for minor subdivisions to be distinguished from major subdivisions in state-enabling law is to allow for a more efficient process. These "lot splits" typically do not have the more extensive review requirements or standards associated with major subdivisions. So what can be done about flood risk?

Minor subdivisions are a common process in rural areas and outside the territorial jurisdiction of cities and towns. The seller has to make a minimal investment in engineering (if any), planning, and improvements (generally, there are none), and they can recoup any costs associated with the land development quickly, since normally only the services of a registered land surveyor are used. Unfortunately, this can lead to very poor, if any, stormwater design overall, an absence of information for future property owners, and costly improvements that ultimately need to be made by future property owners. States such as South Carolina exempt lots of five acres or more from any review process whatsoever. Flood hazard areas may not be identified (for example, they are not required to be on final plats in Georgia), and flood-prone lands will be more likely to have at-risk-for-flood improvements placed on them. Unsuspecting property owners may believe that access driveways that they believe to be roads will be maintained by the local gov-

Figure 4.2. Lot-split subdivision (note the proximity of structures to the watercourses, more numerous watercourse crossings, and lack of any discernable buffer area) (Google Earth)

ernment (including road crossings over streams). They can face very difficult circumstances after a flood degrades the road and washes out the crossing. Figure 4.1 and Figure 4.2 show the treatment of such areas in a platted subdivision versus a lot-split subdivision in Arizona.

The strategy for dealing with minor subdivisions depends on what elements that state-enabling authority allows local governments to review or require as part of the minor subdivision process. It is generally important to have adequate standards contained in zoning codes and standalone floodplain regulations to compliment the subdivision standards, especially when a full platting process is not required. To the greatest extent possible, provisions for identification of all flood hazards and setbacks or buffers (see Chapter 5) from flood hazard areas should be included as part of the minor subdivision process.

Restrictive Covenants

Restrictive covenants (commonly called deed restrictions) are those placed on a property by the property owners and are usually found in individual deeds or in a separate recorded document. They run with the land, regardless of ownership, and developers use these to provide controls that go beyond the local agency's controls and powers. From a flood loss reduction standpoint, restrictive covenants are used to achieve a variety of floodplain-compatible uses. For example, hazard mitigation projects funded by FEMA and the US Department of Housing and Urban Development (HUD) may require the placement of a restrictive covenant on land that the community has acquired. In fact, HUD has developed a sample restrictive covenant for floodplains and wetlands (US Department of Housing and Urban Development 2014).

It is important to understand that while a particular restriction can be a very sensible standard for the parcel and flood risk, the most significant problem comes with enforceability of the restrictions within the covenants. Absent a homeowners association, the only course of action is often a civil action by another homeowner unless the community has, as part of its codes and standards or within the covenant itself, retained the right to be a party to any enforcement action when needed. Occasionally a state or federal agency may also have standing to take an enforcement action if it is identified within the covenant. With a homeowners association, enforcement may become easier as the association could lead the enforcement effort—such as imposing fines and suspending membership in the homeowners association. However, it is important that the association's organizing documents, which are usually submitted and approved as part of the subdivision review process, include the requisite authority to take an enforcement action.

CONCLUSION

While floodplain management is implemented by a wide variety of community staff, planning offices and planners can have a key role. This is especially true when it comes to subdivisions. In the planning department's day-to-day operations, planners can help educate stakeholders, including the development community, on flood risk and management techniques. Through each step in the subdivision process, planners should be aware of the types and locations of development that can increase flood risk and take necessary steps to ensure that flood risk is minimized. By incorporating these concerns into the subdivision review, approval, and management processes, adverse impacts can be minimized.

CHAPTER 5

SUBDIVISION STANDARDS

This report is intended to complement the standards and approaches recommended in PAS Report 473 (Morris 1997), rather than repeating them. It also provides practicing planners with a number of possible standards that can be used individually or collectively to decrease the risk of flood impacts in subdivisions through subdivision regulations or unified development codes, without necessarily requiring the adoption of special ordinances or zoning (e.g., stormwater low-impact ordinances). However, as mentioned several times earlier in this report, to effectively manage flood risk in a community, all of the available land-use and planning tools should be aligned with the goal of reducing or minimizing flood risk. Therefore, the standards listed in the following sections may also be appropriate in zoning, building, or special-purpose regulations. The recommended standards are categorized based on five considerations for all subdivisions: (1) geographic features, (2) layout and design, (3) infrastructure, (4) platting, and (5) watershed management. Appendix B supplements the discussion in this chapter with examples of ordinance language from communities nationwide dealing with each of these considerations.

NATURAL AND HUMAN-MADE GEOGRAPHIC FEATURES

Flooding can result from any number of natural and human-made features. Beyond familiar rivers, streams, and coastlines, gulches that are dry most of the year can be raging torrents during heavy rainfalls in the southwest, alluvial fans can have unpredictable and undefined flow areas, and shallower lakes with large surface areas can have wind-driven flooding due to storms or frontal systems.

Additionally, a number of human-made features can result in flooding. One of the most common flooding events is urban stormwater flooding in older areas of cities. Most of these flood areas are not identified on any maps, yet they cause some of the largest floods in terms of financial cost damage. Similarly, inundation areas downstream of dams or adjacent to levees are often not mapped but can be flooded in sudden, catastrophic events.

Waterbodies without Identified Floodplains

While the National Flood Insurance Program's Flood Insurance Rate Maps (FIRMs) are the nation's most comprehensive inventory of flood hazard areas, they are not complete. Only one-third of rivers, streams, shorelines, and coastlines—waterbodies with clear floodplains—have flood hazards identified along them. And only half of those have detailed flood data. Further, because funding for mapping is limited and focused on existing areas of high flood risk (as defined by areas of existing development), the lands most likely to be subdivided have been traditionally areas of low priority for flood mapping. Over 20 percent of flood insurance claims and one-third of federal disaster assistance payments are for damages outside the mapped 100-year floodplains of the Federal Emergency Management Agency (FEMA). Planners need to look beyond conventional flood maps and take a more encompassing approach to identifying and mitigating potential flood risk within the landscape.

Recommended standards for waterbodies without identified floodplains include the following:

- Require mapping of the 100-year floodplain and floodway for any area that could hold or convey water where a floodplain has not already been mapped. The basis for identifying these features can include but is not limited to US Geological Survey (USGS) blue line streams and identified waterbodies, as well as historical flooding areas.
- Use lower thresholds than National Flood Insurance Program minimum standards (50 lots or five acres) for triggering the need to undertake a detailed flood study. For example, the threshold could be reduced to five lots and two acres, which would be much more effective in most major subdivisions.

CASE STUDY: LICKING COUNTY, OHIO

Jerry Brems, Former Planning Director, Licking County, Ohio

Licking County is a growing county located adjacent to and east of Columbus, Ohio. While generally rural in nature, it is undergoing rapid suburbanization. A new four-lane divided highway bisects the county, potentially increasing these growth pressures.

When the initial Flood Insurance Rate Maps (FIRMs) were presented to the county in the early 1980s, the board of county commissioners adopted only the basic and minimal requirements of the National Flood Insurance Program. This was a struggle because the commissioners felt they were under a federal mandate, and they were not happy in their belief they had no real choice in the matter.

Over the course of the next 10 years or so, the number of subdivision proposals grew exponentially, and a series of small localized (mostly stormwater) flood events occurred. Unlike in previous years, large developers from the "big city"—with no local roots or political connections—were proposing and building these many new developments. At the same time, local residents became increasingly vocal at planning commission hearings about their concerns that downstream flooding was exacerbated by the new developments upstream.

In response to these pressures, the board decided in the mid-1990s to review and update the county's subdivision regulations and to adopt some level of stormwater regulations. Within this context, the notion of protecting existing and new residents from harm took hold. In fact, it was the No Adverse Impact strategy before its time! The ensuing process included several years of tumultuous hearings, debates, and public hearings. The end result was a series of new standards and regulations that the Licking County planning commission adopted and the county commissioners ratified by a vote.

The crux of the new requirements was an understanding that the FIRMs were to some degree inaccurate and, more importantly, extremely limited in their coverage. The obvious answer to this dilemma was to require the developer to conduct studies for all streams on land proposed for development in order to determine the 100-year flood elevation. At this point, no standards were tied to these data.

As mentioned earlier, Licking County was primarily a rural county undergoing development pressure. In this context, a considerable amount of developable land was in the county. The logical solution to the issue was to stay out of flood-prone areas. However, the agricultural interests and realtors were not particularly enamored with this proposal. The response, however, was clear. The response of farmers was based on the fact that they were in fact acting as developers, not farmers, when selling their land for development (or developing the land themselves). The response of realtors was posed as a question: "How many of you want to advertise you are selling a home that we know will be flooded some day?" Their silence was deafening.

In a somewhat ironic twist, it was frequently residents of new developments who voiced their strong opposition to additional new developments. They pushed the notion of greater protection and the idea that the county needed to consider what would happen in the future if development continued unabated. This led to a decision to require developers to consider future conditions when undertaking their engineering analyses of unstudied streams on or adjacent to their proposed developments. Because predicting the future is fraught with uncertainty, the commission decided that the most legally defensible way of determining future conditions was to use current zoning and assume full buildout at the allowed densities.

With the codification of the requirement for detailed studies looking at future conditions, the stage was set for adopting requirements that used these new and available data. The overriding principle that guided the discussions and eventual adoption of additional regulations was that any new development should not increase hazards upstream or downstream of the site to be developed and that any new development should not put its residents or public safety officials in harm's way.

With this fundamental concept now rooted in the minds of the planning commission and county commissioners, it was a natural progression to require the following standards:

- All streets within platted subdivisions must be elevated one foot above base flood elevation (with minimal exception for flood routing).
- No area subject to the 100-year flood may be used for building sites, wells, or septic fields.
- Permanent markers must be placed on lots indicating the extent of flooding during the 100-year flood event.
- Stream bank buffers are required, the extent of which is dependent upon the upstream drainage area.

- The stream bank buffer areas must be kept in natural or scenic condition, with the exception of allowing for passive recreational uses such as hiking, biking, horseback riding, hunting, and fishing.
- Essentially no development is permitted in the floodplain on newly created lots, including fill.
- Easements of access are required to be placed along all streams allowing for, but not requiring, the maintenance of such streams (such as clearing of log jams).
- Development can occur on lots of record at the time of adoption of these regulations, but a freeboard of two feet is required and compensatory storage is required if fill is to be placed in the 100-year floodplain.
- Dredging, mining, excavation, or similar activities are prohibited in a floodplain unless a technical evaluation by a registered professional engineer certifies there will be no increase in erosion, sedimentation, or turbidity upstream or downstream of the site.

Once the proposition of "do no harm" took root, these standards and regulations were deemed to be common sense. In the politically conservative environment in which they were ultimately adopted, it became difficult, or even impossible, to rationally oppose them, and they have withstood the test of time. Having adopted these standards, the county has been able to participate in the Community Rating System program, achieving a Class 7 rating. The flood insurance rate discounts provided by taking part in the program have fostered a "special interest group," which would make walking back these rules contentious at best.

The members of the planning commission, its staff, and the county board chose to put the interests of residents before the short-term interests of the development community. In the process, they have reaped a more profitable environment for developers and a more economically sound, safe, and sustainable community.

- Require the use of future conditions—both land use and hydrology—when undertaking new flood mapping.

Licking County, Ohio, combines two standards that have been extremely effective in eliminating any new flooding problems as development occurs: (1) developing 100-year flood data on all water bodies as shown on USGS quadrangle maps and (2) requiring any newly created lot have enough buildable land on natural ground outside the floodplain for the primary structure plus any associated improvements (see "Layout and Design" (p. 70) for considerations). More details about Licking County's program is included in "Case Study: Licking County, Ohio" (p. 64).

Riparian Areas

The National Academies of Sciences defines riparian areas as transitional between terrestrial and aquatic ecosystems and distinguished by gradients in biophysical conditions, ecological processes, and biota (National Research Council 2002). They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., zones of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines.

While comprising less than 5 percent of the land area in the United States (National Research Council 2002), riparian areas considerably outperform ecological, hydrological, and geomorphological functions per unit area as compared to non-riparian areas. Scientific research has strongly established the harm to water quality, the increased flooding, and the damage to the ecosystem that result from failure to protect riparian buffers (Pennsylvania Land Trust Association 2014). From a floodplain management point of view, riparian zones dissipate energy, which results in less soil erosion and flood damage. By definition, riparian areas should generally be inclusive of the fluvial erosion zone and the stream meander belt width.

Protection should be the goal for riparian areas in the best ecological condition, while restoration is needed for degraded riparian areas. However, while many riparian areas can be restored and managed to provide many of their natural functions, they are not immune to the effects of poor management in adjacent uplands. Upslope management can significantly alter the magnitude and timing of overland flow, the production of sediment, and the quality of water arriving at a downslope riparian area, thereby influencing the capability of riparian areas to fully function. Therefore, upslope practices contributing to riparian degradation must be addressed if riparian areas are to be improved (National Research Council 2002).

Recommended standards for riparian areas include the following:

- Prohibit development immediately adjacent to streams, rivers, lakes, wetlands, and other water bodies. Avoid land

TABLE 5.1. RANGES OF BUFFER WIDTHS FROM SCIENTIFIC STUDIES

Function	Range of Riparian Buffer Widths		Minimum Recommended Buffer Width
	Environmental Law Institute (2003)	Fischer and Fischneich (2000)	
Stream stabilization	30–170 feet	30–65 feet	50 feet
Water quality protection	15–300 feet (remove nutrients) 10–400 feet (remove sediment)	15–100 feet	100 feet
Flood attenuation	65–500 feet	65-100 feet	FEMA 100-year floodplain plus an additional 25 feet
Riparian/wildlife habitat	10 feet–1 mile	100 feet–0.3 miles	300 feet
Protection of coldwater fisheries	>100 feet (5 studies) 50–200 feet (1 study)		150 feet

Data from Pennsylvania Land Trust Association and Brandywine Conservancy 2014; Rhode Island 2011

disturbance, pavement, and other impervious cover. Require restoration of any disturbances.
- Require and maximize the width of riparian buffers. While the minimum width needed depends to some extent on what benefits or ecosystem services are deemed important by the community, virtually all sources recognize that the wider the buffer the better the ecoservices performance.
- Inventory riparian areas as part of the subdivision process and preserve unimpaired riparian areas in natural conditions.
- Require restoration of impaired riparian zones as a condition of subdivision approval.

The State of Rhode Island undertook an extensive analysis of buffer recommendations in its *Rhode Island Low Impact Development Site Planning and Design Guidance Manual* (RIDEM and CRC 2011). The manual referenced an analysis by the Environmental Law Institute of over 150 scientific studies of recommended buffer widths for a variety of biological, hydrological, and physical functions (Table 5.1).

The State of Montana's Fish and Wildlife Recommendations for Subdivision Development recommend buffers of 300 feet for rivers, 200 feet for perennial streams, and 130 feet for other water bodies (Montana 2012). In Rhode Island, low-impact development guidelines recommend buffers from 50 to 300 feet (depending on the objective the community is trying to achieve) and a buffer of the FEMA 100-year floodplain plus 25 feet for flood attenuation (RIDEM and CRC 2011). In 2015, the State of Minnesota passed a requirement establishing perennial vegetation buffers of up to 50 feet along rivers, streams, and ditches (Subd.3(1)(i), Chapter 85, S.F. 2503). The new law provides financial support for landowners to install and maintain buffers and will not become effective until the state has mapped all of the buffers. The Borough of Raritan, New Jersey, includes a riparian zone restoration requirement as a condition for major subdivision or site plan approval (§ 315-51, Code of Borough of Raritan, New Jersey).

Alluvial Fans

Alluvial fans are gently sloping, fan-shaped landforms created over time by deposition of eroded sediment, and they are common at the bases of mountain ranges in arid and semiarid regions such as the American West. Given that alluvial fans tend to occur in apparently dry conditions, homeowners are often shocked to find that they can be the sites of destructive floods. Floods on alluvial fans, although characterized by relatively shallow depths, can strike with little warning, can travel at extremely high speeds, and can carry tremendous amounts of sediment and debris (National Resarch Council 1996).

Although alluvial fans are often thought to occur mainly in the western United States, they occur in a wide range of environments, including the Appalachian Mountains, western Canada, and various mountain, arid, and volcanic regions around the world. In North America, most fans that are subject to controversy are in the West because it is a rapidly urbanizing region and fans—with their relatively gentle terrain and views of the mountains—are appealing building sites (National Research Council 1996).

Active alluvial fan flood zones are characterized by flow path uncertainty, high flow velocity, erosion, sediment transport and scour, channel avulsions, and debris and mud flows. Flooding on active alluvial fans poses an ultra-hazardous condition because of the convergence of flow path uncertainty, presence of sediment, and active sedimentation and erosional processes.

Recommended standards for alluvial fans include the following:

- Require the mapping of alluvial fan areas as part of the subdivision process.
- Prohibit the creation of new lots on active alluvial fans.
- Prohibit construction of any improvement using fill on active alluvial fans.

Dams

There are approximately 85,000 dams in the United States, and more than half of them are over 50 years old. One source of flood risk associated with dams is planned releases, such as large flows from the principal spillway or usage of the emergency spillway. The other source of flood risk is the overtopping and/or structural failure of any type of dam (even those considered low hazard).

The failure of a dam can lead to cascading impacts, creating flood flows too heavy for downstream dams to handle and causing subsequent failures. Even planned releases can be deadly to those downstream, if they are not properly warned. Dam failures can also destroy critical utilities servicing a community and are often larger and more violent than the 100-year flood shown on the community's FIRMs. The advancing age of dams can make them more susceptible to failure. Some common problems of older dams include the following (ASDSO 2012):

SOUTH CAROLINA 2015 FLOODS: FORTY-SEVEN FAILED DAMS AND COUNTING

The confluence of a frontal system and Hurricane Joaquin resulted in prolonged heavy rain and significant flooding in South Carolina during the first week of October 2015. With up to 31 inches of rain falling over several days (Figure 5.1), the destruction of the storm resulted in the failure of at least 47 dams, including seven high-hazard dams, 16 significant-hazard dams, and 24 low-hazard dams. Sixteen of the dam failures may have been influenced by a dam breach upstream on the same watercourse.

The dam failures highlighted several issues:

Figure 5.2. Cary Lake dam failure (when this dam breached, 15 properties lost roadway access to the properties) (Maria Cox Lamm)

- Very few of these dams had inundation mapping associated with them, and downstream property owners did not understand that there was any flood risk.
- Some of the failed dams had a road traversing them and, in a few instances, the road was the only point of ingress and egress to some properties or lots (Figure 5.2).
- Areas where dam failures washed out roads has resulted in the need to take alternate routes that in some instances result in more than an hour of additional driving time or required owners to negotiate with other property owners to obtain access through private property.
- Emergency action plans associated with dam failures were not understood by owners association representatives and were not communicated to residents of the developments that owned the dams.

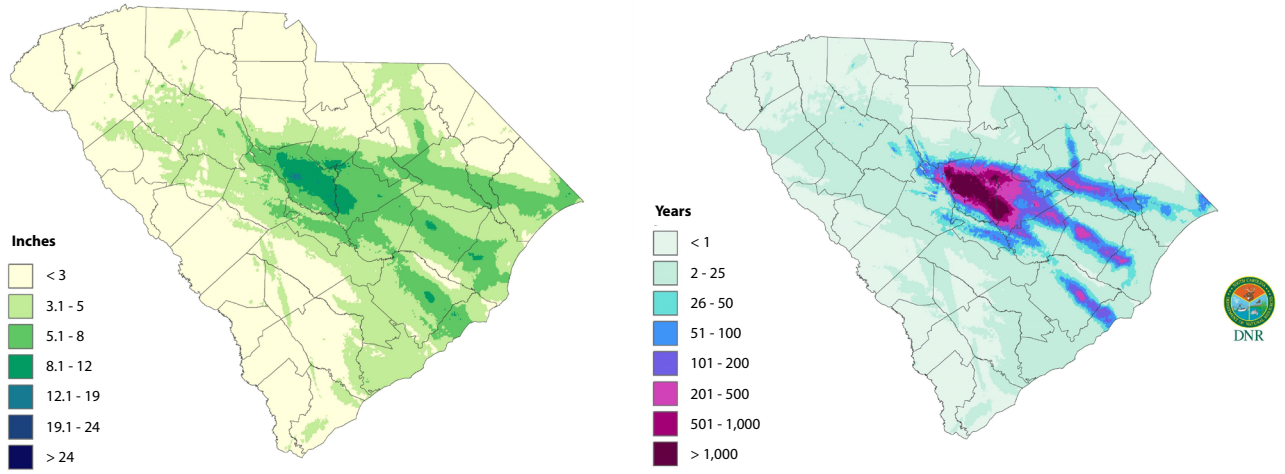


Figure 5.1. South Carolina, September 30 to October 7, 2015, storm totals (left) and innundation relative to predicted flood frequency on FEMA maps (right) (South Carolina Department of Natural Resources)

- Deteriorating metal pipes and structural components (after 50 years, metal rusts and fails)
- Sediment-filled reservoirs (this reduces the volume of water that the reservoir can accommodate); in addition, some sediment may have contaminants from chemicals in runoff from upstream areas
- Subdivisions and businesses built upstream (roofs and concrete streets and sidewalks increase the volume of runoff to the reservoir)

Another issue associated with dams is that most dam safety construction standards tie construction design specification to the downstream risk at the time when the dam is built. Where potential loss of life may occur due to a possible dam failure, the dam is classified as high hazard. (However, the term can be misunderstood because potential loss of life could mean either one life or 1,000 lives; the classification does not make any further distinction.) If there is no risk of loss of human life at the time of dam construction, then the design specifications will be minimal. However, if appropriate land-use controls are not in place downstream of the dam in its failure inundation zone, risk could intensify, resulting in the need for costly upgrades to the dam and addition of an emergency spillway. These costs can exceed $1 million.

Finally, the identification of dam failure zones across the United States is not complete for existing dams. Of the total number of dams, it is estimated that approximately 14,000 are considered high hazard. Yet the creation of emergency action plans and dam failure inundation mapping exists only for approximately 60 percent of those and the percentage is even less for lower-hazard dams (ASDSO 2012). While these dam-related flood risk zones do not currently appear on FIRMs, they very well could be present on a site.[1]

Recommended standards for dams include the following:

- Require identification and inclusion of any dam failure or levee failure/overtopping areas on preliminary plans and final plats (Roswell, Georgia).
- In areas downstream of dams, require an impact analysis of any proposed development in the dam failure inundation zone on the spillway design flood. If the proposed development will change the spillway design flood standards, it cannot be approved unless it is modified or the development contributes a payment for the necessary upgrades to the impounding structure (Fairfax County, Virginia).

In 2008, Virginia adopted legislation (HB 837) to address development in dam break inundation zones of state-regulated dams. The legislation directs developers to assist dam owners with required upgrades and requires additional disclosure and notification procedures for dam owners. The requirements apply only to proposed development downstream of a dam for which a dam break inundation zone map is on file.

Levees

According to FEMA, a levee is a human-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding. Its primary function is flood protection (44 CFR 59.1). Levees reduce the risk of flooding, but no levee system is flood proof and can eliminate all flood risk. There is always the chance that a flood will come that exceeds the capacity of a levee, and levees do not always perform as intended (ASCE 2010).

The primary flood risks associated with levees are due to levee overtopping by an event that is larger than the levee was designed for; the structural failure of a levee, which can occur even in small floods; increased flooding on adjacent lands due to the failure to consider adverse impacts of the levee's footprint (i.e., increased flooding on the opposite side of the river from the levee where there is no protection); and the failure of the drainage system behind a levee during an intense rainfall event. Depending on the size and location of a levee, the failure or overtopping of a levee can actually reduce flood risk on subsequent levees proximate to or downstream of the failed levee.

As with any engineered flood control system, levees need continual monitoring and maintenance. But like dams and other stormwater infrastructure, levee maintenance—especially for privately owned levees—is frequently turned over to owners associations (OAs), which as noted in Chapter 4 has been very problematic. Later in this chapter, a more extensive discussion of issues surrounding OA responsibilities to maintain infrastructure is presented.

It is estimated that there are over 100,000 miles of levees in the United States and, of those, approximately 85 percent are locally owned. In some places like California, massive subdivisions containing thousands of homes are created in flood-prone areas protected by levees (and some of those levees may even be turned over to OAs for maintenance). Unlike dams, areas protected by a levee to the 1-percent annual chance flood event may be shown as such on the community's FIRMs. However, buyers of lots and homes protected by the

levee may have little or no awareness of the levee or the risk associated with it.

Recommended levee standards include the following:

- Identify levee protection areas on subdivision plans and plats.
- Allow for maintenance easements to exist along the side of the levee facing the subdivision.
- Prohibit newly created lots from extending onto the levee itself (the toe of the levee). Also allow for a buffer or setback from the toe of the levee for levee maintenance.
- Identify all owners, sponsors, and operators of the levee to avoid future uncertainty during the platting process.

LAYOUT AND DESIGN

Addressing flood risk for new subdivisions should start with the mindset that: (1) FEMA flood maps provide an initial identification of risk areas and (2) there may be additional flood hazard areas on the tract of land that need to be identified. Depending on the size of the subdivision, the stormwater created by the development itself can result in increased flood risk to the buildings and infrastructure on-site as well as offsite impacts. For the practicing planner, a persuasive argument to elected officials is that new development must not create conditions for future problems for those property owners, nor should it result in higher flood risks for existing residents of the community. There are a number of approaches to subdivision layout and design that can aid in minimizing the creation of new flood risks for new and existing residents.

Cluster/Conservation Subdivisions

A cluster subdivision, also known as an open space subdivision, is a technique allowing for the modification of dimensional requirements of the zoning law to group or "cluster" structures or lots at a higher density on the most suitable portion of land. This clustering leaves other areas open to preserve the natural and scenic quality of open lands. A conservation subdivision is a type of cluster subdivision that focuses on protecting large portions of a site with important environmental value. Usually, half or more of the site is preserved as open space.

From a flood risk perspective, there is no other approach that has as much ability to reduce flood damages while simultaneously protecting the integrity of the floodplain ecosystem. Indeed, PAS Report 473 recommends conservation subdivisions with no lots in the floodplain as the best policy for communities (Figure 5.3). Nothing has changed in the past 19 years to alter that view. However, it is recognized that some communities may have more dif-

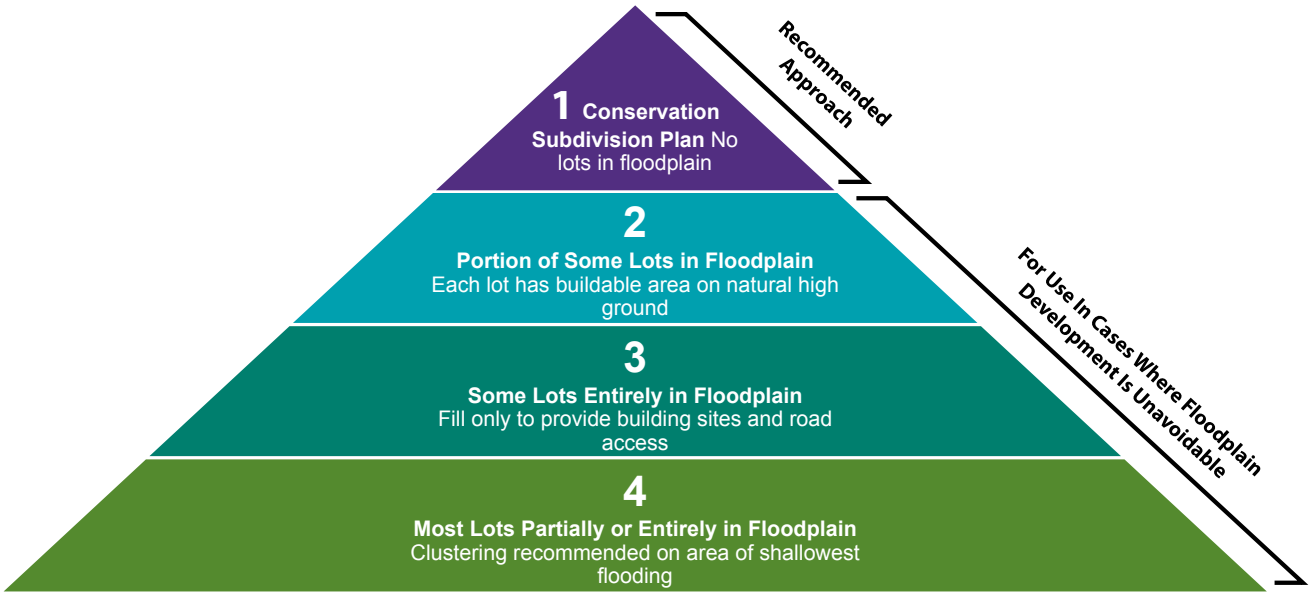


Figure 5.3. Subdivision design hierarchy (Morris 1997)

ficulty implementing such an approach due to their geography or the fact that any remaining developable land is at higher risk from flooding.

The basic principles of conservation subdivision design that also apply in reducing flood risk and enhancing natural floodplain functions include the following:

- Ensure that floodplain areas are non-buildable, either laid out as areas that are non-buildable on lots or set aside reserve areas entirely (i.e., not contained within lots).
- Preserve riparian areas in perpetuity by making them reserve areas protected through easements. This, in turn, protects or enhances the conservation of wildlife and aquatic resources.
- Develop smaller lots.
- Allow for increasing density in developable areas to ensure a roughly equivalent lot yield that would otherwise be allowed if a more conventional subdivision design was applied to the site.
- Promote flexibility in reducing setbacks from roads and increasing setbacks from floodplains or water bodies.

If a community has a special conservation subdivision ordinance or standards that are optional, the planner may want to consider at least applying some of the conservation design principles required for all subdivisions near or in flood hazard areas.

Recommended standards for conservation subdivisions include the following:

- Prohibit creation of new lots in the floodplain and require that any flood-prone land not be included as part of any lot. Require that floodplain land be set aside as designated open space on the subdivision plat and preserved in perpetuity through permanent easements.
- If floodplain development is unavoidable, require that all lots created have adequate buildable area on natural high ground above the 100-year elevation.
- Require a flood protection elevation of at least two feet above the 100-year flood elevation for any buildings or improvements on a lot (Portland, Oregon).
- Ensure that conservation subdivision submittals are meeting these three goals, at a minimum: (1) protecting natural streams, water supplies, and watershed areas; (2) maintaining and enhancing the conservation of wildlife, natural, or scenic resources; and (3) promoting conservation of soils, wetlands, and other significant natural features.

Augusta, Georgia, has developed a conservation subdivision ordinance that has been very successful (see "Case Study: Conservation Subdivisions in Augusta, Georgia," p. 72).

Impact Analysis and Mitigation

Development typically adversely affects the natural functions of floodplains and can affect properties adjacent to, downstream, and even upstream of the development area. The physical impacts of floodplain development include increased flood peaks, higher flood stages, increased flood velocity, faster erosion rates and new erosion locations, and increased sedimentation. Floodplain function (ecosystem and natural function) impacts include diminished flood storage capacity, decreased groundwater recharge, and reduction in diversity and higher stress on existing terrestrial and aquatic species. It is important to identify and then mitigate these impacts.

This is the central message of the Association of State Floodplain Managers' No Adverse Impact (NAI) initiative. In contrast, the minimum floodplain management standards adopted by most communities only require analysis and mitigation of very few adverse impacts—namely, in floodways to ensure that no rise occurs—and assurance of the flood-carrying capacity of watercourses, but only in FEMA-mapped floodplains.

Recommended impact analysis and mitigation standards include the following:

- Prohibit the subdivision of land that is determined to be unsuitable for subdivision development due to flooding, poor drainage, or other conditions that may endanger health, life, or property and where the subdivider has not proposed adequate mitigation.
- Require assessment and evaluation of impacts to which the community is particularly susceptible (e.g., fluvial erosion, log jams).
- Adopt a No Adverse Impact (NAI) standard for evaluating and mitigating most, if not all, physical and ecosystem impacts of development and impacts on critical habitat.

To achieve a Community Rating System Level 1 rating (the highest achievable level), a community must demonstrate that it has an NAI program by receiving a certain number of points for designated activities. The City of Brevard, North Carolina, requires an NAI determination that not only requires applicants to submit an NAI narrative (explaining impacts in a non-technical way), but also requires an NAI certification document prepared by a profes-

CASE STUDY: CONSERVATION SUBDIVISIONS IN AUGUSTA, GEORGIA

Terri L. Turner, City of Augusta, Georgia

In order to curb the growing national trend toward developing sensitive areas such as floodplains, wetlands, and riparian buffers, Augusta, Georgia, in June 2003 chose to enact a strong Flood Damage Prevention Ordinance and include provisions allowing conservation subdivisions in its zoning ordinance. The aim of the Conservation Subdivision Ordinance was to offer a cost-effective solution that would not only keep residential structures out of the Special Flood Hazard Area and wetlands, but also yield the same number of lots (though of reduced size) within the development; permanently protect floodplains, wetlands, riparian buffers, and other sensitive areas; reduce impervious surfaces, such as roads; minimize stormwater runoff; and potentially treat all or part of the stormwater generated within a development in the greenspace and open space created within the project itself.

Augusta's ordinance applies to projects with a minimum area of 20 acres and requires the permanent protection of at least 40 percent of the overall acreage of the tract as green space or open space. Further, the ordinance notes that if more than 50 percent of the proposed greenspace is area that could have been developed under the present federal, state, and local statutes, rules, and regulations—such as floodplains and wetlands; habitat for threatened or endangered species; or historic, cultural, or archeological areas—then the minimum green space requirement can be reduced to 30 percent of the overall acreage of the tract (§ 28-D-5, Comprehensive Zoning Ordinance of Augusta-Richmond County).

Permanent protection of this newly designated greenspace or open space could come in the form of deed restrictions or perpetual conservation easements held by the homeowners association or a third party such as a land trust or conservation agency. These restrictions or easements must run with the property (and its successors and assigns). If this is the case, a greenspace management plan must be a part of the conservation subdivision plan approval and must provide for the use, ownership, maintenance, and permanent protection of the newly created greenspace or open space area. It must also outline the responsibilities for maintenance and operation of the greenspace or open space and any facilities located on it. Finally, it must include financial provisions for stewardship, maintenance, repairs and operation, and long-term capital improvements, if there are to be any.

Green space or open space areas may be landscaped or left with a natural vegetative cover, but these must be areas where no roadways, parking areas, or improvements may be included, with the exception of recreational facilities, gazebos, wildlife observation facilities, boat docks and similar facilities, landscaped stormwater and drainage areas, or other uses that are compatible with the intent of the ordinance.

The "incentive" for the developer is the ability to construct detached housing with lots that have no minimum lot size—though lot sizes less than 60 percent of the minimum size permitted in the base zoning classification require special exception approval and the total number of lots cannot exceed the number of lots that would be permitted by the base zoning classification in a conventional subdivision. Additional benefits of this kind of development lie in the reduction of the length of roadway surfaces and the associated curb-and-gutter infrastructure; the reduction in length of water, sewer, and other related utility lines; the reduction of other impervious surfaces such as sidewalks and driveways; and the massive reduction in stormwater pipes and ponds, if not the outright elimination of most or all of the stormwater detention ponds.

Impacts on the environment, especially on water resources, are drastically reduced by minimizing land disturbance and reducing the amount of impervious surface. The open space can serve as a filtering and infiltration area for the subdivision's stormwater runoff, thus improving water quality. It can also act as a buffer for nearby ponds, wetlands, and similar water bodies.

Greater still, for anyone wishing to locate in one of these subdivisions, are the financial gain realized in increased property values within conservation subdivisions, especially in those lots immediately adjacent to the preserved greenspace or open space; the recreational opportunities that can be a part of these green spaces or open spaces; and the viewsheds often created by all of that unspoiled environment. The clustering of homes within the subdivision can encourage walking and more frequent interaction with the subdivision's neighbors, fostering a stronger sense of community, or what is described by many as a "sense of place" among the residents living there. Conservation subdivisions work well because they use the right combination of techniques—in the right places, at the right time—to achieve the right results. Preserved green spaces or open spaces within conservation subdivisions can make subdivisions more

enjoyable and sustainable places to live and recreate.

They not only preserve land and enhance aesthetics within the community, but also provide for more efficient stormwater management, often dramatically driving down the cost of stormwater infrastructure installation and maintenance. At the same time, these conserved green spaces and open spaces, and their natural ecosystems, provide a huge return in flood control, increased water quality, enhanced groundwater recharge, promotion of nutrient cycling, and enhanced erosion control—just to name a few of the many long-term benefits. Maybe the most important quality of conservation subdivisions is that they allow residential living to coexist with nature, so that a community's natural heritage is preserved for the enjoyment of current residents and the environment is protected for future generations.

sional engineer to show that any proposed encroachment into the floodplain will not create adverse impacts upon any other property owner (§ 34-33, City of Brevard Code of Ordinances).

Use Restrictions

While use restrictions are typically found in either zoning or floodplain management regulations, use restrictions have also found their way into subdivision standards as they relate to allowable uses of lots or land in the floodplain proposed to be subdivided. Regardless of where such standards are located, they can be very helpful in managing flood risk.

Critical facilities present a special situation that should be approached carefully. Critical facilities are those for which even a slight chance of flooding is too much, and they are usually characterized by any of the following criteria:

- Storage or production of volatile, flammable, explosive, or toxic materials
- Occupants that may not be mobile to avoid injury or death during a flood (e.g., hospitals, nursing homes, schools)
- Facilities needed for flood response activities before, during, and after a flood (e.g., police and fire stations, emergency communication centers, other emergency facilities)
- Utility facilities vital to restoring normal services to flooded areas before, during, and after a flood

Development of these facilities may trigger subdivision standards by creating a new easement of access or as a major development. Such facilities, even if owned or operated by the community, should adhere to much higher flood standards than other floodplain development and ideally be kept out of the floodplain altogether.

Finally, communities occasionally require or accept the dedication of land areas within a subdivision for public facilities and services. The community should ensure that these dedicated sites are not within the floodplain if the future use is for facilities such as schools and fire stations. For parks and other recreational uses, floodplain locations may be quite compatible.

Recommended standards for use restrictions include the following:

- Prohibit land subject to flooding to be platted for residential use or any other use that may increase the danger to health, life, or property.
- Prohibit land division or structures (dwellings or nonresidential structures) in the floodway or velocity zones.
- Prohibit the creation of new lots in the floodplain unless they have a minimum area (usually equivalent to the full building envelope) with a natural grade elevation above the regulatory floodplain.
- Prohibit fill to create building sites.
- Prohibit critical facilities in the 100-year or 500-year floodplain.
- Protect critical facilities to the 500-year flood level or flood of record, whichever is greater, and ensure that any critical facility has dry-land access (see the following section).
- Prohibit the location of reserved lands within a subdivision for new school sites and fire stations within the floodplain.

Ingress and Egress

Fire prevention, evacuation, and rescue operations are common emergency response activities associated with flooding. The effectiveness and success of these efforts greatly depend on readily available access. However, streets and roads are usually the first things to be inundated in the event of a flood. Thus, ingress and egress from a building, including driveways, is an important consideration.

Occupants may be trapped and unable to reach safer ground during a flood. Emergency responders and vehicles must be able to access buildings during flood events. In 1978, a flood in Rochester, Minnesota, killed four people in a nursing home when this critical facility was isolated by high-velocity floodwaters, and firefighters could not rescue the occupants because there was no dry-land access (Figure 5.4).

Figure 5.4. In 1978, four people died in a flood at this critical facility, a nursing home, in Rochester, Minnesota, when firefighters could not access the building with necessary rescue equipment (Federal Emergency Management Agency)

Dryland access standards can ensure safe access for vehicles to habitable buildings.

Recommended ingress and egress standards include the following:

- Require new streets, public or private, within a subdivision have access to an existing "dry" road during the 100-year flood.
- Require the surface of new streets within subdivisions to be built to at least the 100-year flood elevation.
- Prohibit building of segments of new driveways below the 100-year flood elevation.

INFRASTRUCTURE

"Where infrastructure goes, development follows" is a truism for practicing floodplain managers and planners. Where flood risk is present, infrastructure should be carefully considered and protected accordingly. A great deal of infrastructure may be considered "critical" in that is it is needed during a flood emergency. Additional standards and safeguards should be applied to such facilities. For example, consider a new wastewater treatment plant needed to support a development. Not only should the plant be protected to the 500-year flood elevation from any flood hazard that may exist at the site, but the road, especially if it is the only point of access to the facility, should be similarly protected so service personnel can maintain it during an event.

Local Road Systems

The term local road system is used broadly to refer to the local transportation infrastructure, consisting of a network of components (e.g., roadways, bridges, culverts) that is owned and maintained privately by an OA or by a city, county, or other municipal transportation agency.

Flooding has significant impacts on local road systems. Composed primarily of paved and unpaved roads and various types of structures that cross waterways, road systems can experience a range of damage. Flood damage to the physical road and drainage infrastructure is costly to restore, interrupts the flow of traffic, affects local businesses, and limits access by fire and emergency vehicles. The National Weather Service reports that over half of all flood-related fatalities in the United States are vehicle related. Roads themselves can contribute to increased flooding that adversely affects adjacent lands (America Lifelines Alliance 2005).

From the standpoint of new subdivisions, the default standards for bridge and culvert design for local roads often comes from the state department of transportation. These standards require 10-year to 50-year design storms, only occasionally requiring sizing of bridges and culverts to handle 100-year storm events (and this is typically only done when there is a community-adopted floodplain and floodway as is found on the FIRM). However, in most cases, communities may adopt standards that exceed state department of transportation standards.

Some community subdivision standards may allow up to six inches of flood water over a roadway, provided flow velocities will not endanger people or vehicles. However, if the water flowing over the roadway is murky or turbid, there is a risk of an unseen hazard if a roadway is undermined or a bridge is washed out. In fact, the leading cause of flood deaths in the United States is due to vehicles driving over flooded roadways.

Recommended local road systems standards include:

- Size culverts and bridges (other than driveway culverts) to a 100-year storm frequency.
- Require road surfaces to be elevated to or above the base flood elevation or allow only a nominal amount of water to flow over the road during the 100-year flood event.

Utilities

While most utilities are inherently protected against flooding (they are either underground or overhead), there is often

Figure 5.5. Non-elevated, pad-mounted transformer in the floodplain very close to the flooding source (Chad Berginnis)

ground-level equipment associated with these utilities in subdivision proposals that is vulnerable to flood damage:

- **Electric:** Pedestals, transformers, and medium-voltage switchgear for underground electric connections serving lots. Sometimes, there are limitations on the ability of some components, like pad-mounted transformers (Figure 5.5, p. 75), to be elevated due to the need to limit the voltage drop. For larger subdivisions or for commercial or industrial subdivisions, an electrical substation might also be constructed.
- **Gas:** Local natural gas compressor stations.
- **Water/wastewater:** Wellheads for water and on-site sewage disposal components for individual lots, pumping stations for water and wastewater, and package plants for wastewater serving a subdivision.

Under the National Flood Insurance Program minimum standards, utilities for subdivisions are addressed; however, the standard essentially requires protection through elevation or floodproofing to ensure proper functioning of the utility. Planners should think about utilities from a hierarchical perspective. Seek to avoid the floodplain first. If that is not possible, elevate. And finally, floodproof. Both elevation and floodproofing are problematic from the standpoint of accessibility, especially in areas where long-duration flooding occurs. However, it should be noted that buried utility transmission lines could be susceptible to flood damage and endanger nearby occupants if they are exposed during a flood by scouring of the floodplain.

Also, planners should consider whether the at-risk utility or ground-level equipment serves a single home or is critical to the functioning of several homes, businesses, or subdivisions. If it may indeed be a critical facility, higher standards—such as locating it outside the 500-year floodplain or protecting it to several feet above the 100-year flood level (also see the previous discussion on use restrictions)—may be most appropriate.

For example, a wastewater treatment package plant likely represents the most costly infrastructure investment for a major subdivision. When one is proposed, any drainage way into which it discharges should be analyzed to determine the flood risk, and then the plant should ideally be located outside the 500-year floodplain or be protected to two to three feet above the 100-year flood elevation. In coastal areas, considerations for using a freeboard should factor in sea-level rise. The State of Ohio requires that public water wells be protected to three feet above the 100-year flood elevation or the flood of record, whichever is higher (§ 3745-9-02(H)(1), Ohio Administrative Code).

Figure 5.6. Wood debris stored in a stormwater retention area could clog the drainage outlet, threatening the integrity of the retention area berm and causing more significant flooding (Chad Berginnis)

Recommended utility standards include the following:

- Prohibit exemption from flood protection standards for municipally owned utilities.
- Locate utility easements outside flood hazard areas where possible.
- Adopt a definition of critical facilities that includes major utility equipment (e.g., power substations, water/wastewater pumping stations) and require that critical facilities that are utilities be located outside the 500-year floodplain.
- Require that public utility facilities that cannot be located outside the floodplain be redundant to provide service to the affected area in the event of a flood.
- Require that utility transmission lines containing toxic or flammable materials be buried to a depth at least below the calculated maximum depth of scour for a 100-year flood, especially in velocity floodplain areas (floodways and coastal V-zones).

Owners Association Management of Infrastructure and Open Spaces

According to the Community Associations Institute, 20.7 percent of the US population, or 66.7 million Americans, live in 333,600 common-interest communities. Approximately 55 percent of these common-interest communities are homeowners associations (CAI 2015).

Subdivision standards across the country generally allow for the creation of owners associations (OAs)—usually either condo associations or homeowners associations. These OAs may manage any of the following: roads, parklands or other open space, stormwater, or flood control infrastructure. If an OA is managing these facilities, the facilities are usually considered to be privately owned. The increasing use of the OA may be seen as beneficial by tax-starved local governments that see them as a way to promote development and raise new tax dollars while avoiding liability for these new facilities. In these newer developments, "public" works are made the responsibility of private OAs (Berding and Weil 2012).

In theory, OAs absolve local governments of maintenance responsibilities for these privately owned facilities. But typically during and after floods local governments are looked to by all citizens to provide assistance, potentially increasing public pressure—and cost—to do something. However, there are many responsibilities that OAs should be undertaking to manage flood risk, depending on the facilities they are charged with maintaining:

- Flood response, especially if ponds within the subdivisions have emergency spillways or the pond/lake dam is threatened with imminent collapse. This could include warnings, evacuations, and road closures.
- Stormwater retention and detention facilities maintenance, which typically includes erosion control, sediment control (dredging), maintenance of inlets and outlets, dam/weir /retaining wall repairs, drainage improvements, inspections, and maintenance of vegetation.
- Bridge maintenance, repair, and replacement.
- Open space inspections and maintenance to ensure that trash, debris, or personal property does not accumulate in such areas, especially if they serve to store flood waters (Figure 5.6)

The reality is that, as it relates to flood risk management, OAs are typically not equipped to handle the immediate emergency or the aftermath of a flood, usually focusing only on flood insurance for buildings. The anecdotal evidence is not encouraging. Consider the Hopewell Heights development in Licking County, Ohio, where a small creek drains 200 acres upstream of a stormwater detention pond (Figure 5.7). The pond is partially owned by the homeowners' association; the other half of the pond is owned by the original developer. When originally constructed, the pond was 8 to 20 feet deep, but after 10 years sedimentation had reduced the depth to between 0 and 4 feet, nearly eliminating the pond's stormwater storage function. The homeowners association decided to dredge its half of the pond and perform needed improvements to the outlet, costing nearly $20,000, which will be assessed on approximately 40 homeowners in the development. Unfortunately, the other owner of the pond has refused to dredge the other half, imperiling the ongoing functionality of the pond for stormwater management.

Charlotte-Mecklenburg County in North Carolina, changed its development standards to require public dedication and maintenance of stormwater infrastructure after observing the inability of OAs to maintain their privately owned facilities. Often OAs have trouble keeping pace

Figure 5.7. Two views of the Hopewell Heights stormwater detention pond in Licking County, Ohio (Chad Berginnis)

with the cost of maintaining simple common area components. What will happen if much more sophisticated, highly engineered systems, such as levees or floodwalls, are dependent solely on homeowner assessments that must be willingly made?

To better plan for maintaining such facilities, planners may consider requiring OAs to conduct a reserve study, a budgeting tool intended to aid the directors of associations or other entities responsible for maintaining residential property, retail property, special districts, or any other physical plant or property for the future repair, replacement, and restoration of major components of the common areas during the economic life of a property (APRA 2012). Some states require the development and update of reserve studies every three to five years. According to the Standards of Practice for reserve studies of the Association of Professional Reserve Analysts, however, the physical analysis or site visit components of a reserve study will not consider events such as floods or incorporate flood risk (APRA 2012).

Still, a reserve study can be useful for projecting future maintenance costs of stormwater and flood protection infrastructure, provided the consultant conducting the study has the necessary expertise to determine the useful life and costs of stormwater or flood control facilities and the OA and residents understand that additional costs from flooding events are not included. A properly prepared reserve study can help minimize special assessments. While reserve studies are not typically performed until after an OA is formed, some communities like Raleigh, North Carolina, require completion of a reserve study prior to plat approval (see the recommended standard for the preparation of a stormwater maintenance manual and budget in the following discussion).

Recommended standards for OA management include the following:

- Require all stormwater and flood protection infrastructure to be turned over to the local government for maintenance.
- Require a reserve study from the developer to identify ongoing maintenance costs of all stormwater and flood protection infrastructure with reasonable maintenance and replacement life cycles as a condition of preliminary plan or final plat approval. In coastal areas, ensure that maintenance and replacement life cycles incorporate projected sea-level rise.
- Require the developer, especially in a phased subdivision, to identify annual maintenance costs of stormwater and flood protection infrastructure and fund the maintenance of such facilities until the OA is established.
- Include a mechanism provided for in final platting, such as a maintenance covenant, where the local government has the ability to take over maintenance of any stormwater facility that is not being maintained by the OA and assess subdivision property owners for the cost of any such maintenance.
- Require any pond, retention basin, or other waterbody to be included on one lot where possible, or at least to be entirely contained within a single subdivision.

PLATTING

While subdivision plats may not ever be viewed by subsequent buyers of lots, they nonetheless can serve an important function in providing information on flood risk. However, this information should be thoughtfully included as to not imply that a flood hazard never changes (such as putting a flood elevation on a plat unless it is also accompanied by an explanation that flood risk can change over time).

Property encumbrances such as restrictive covenants should also be indicated on subdivision plats. Restrictive covenants can be powerful tools. However, they must also be carefully written to ensure that areas that are meant to be set aside as reserve spaces due to flood risk have long-term protection.

Flood Hazard Information on Plats

While significant improvements in FIRMs have resulted in new flood maps being issued that are overlaid on an aerial mapping layer, effort is needed to transfer that information to subdivision plans and plats. Having such data on preliminary plans can help community staff and planning boards make informed decisions as the subdivision is being approved. Having information on final plats is very helpful in informing potential new residents and buyers of parcels of flood risk on the lots being developed.

Recommended standards for plats include the following:

- Show the 100-year (base flood) and 500-year elevation on all subdivision plans and plats.
- Require building pad and or proposed lowest floor elevations on final plats.
- Include a floodplain note on the plat or survey (for minor subdivisions) that could identify the parcel as being flood prone (with references to flood zones and FIRM panel information); state that improvements are subject to additional floodplain management regulations; or inform of the need to submit an elevation certificate or the need to

purchase flood insurance (Peoria County, Illinois; Bexar County, Texas).

Restrictive Covenants and Easements

Restrictive covenants, also called deed restrictions or easements, are tools that can be used to permanently protect floodplain or flood-prone areas. A conservation easement is a set of restrictions placed on a property to preserve its conservation values. The conservation values of the property and the restrictions created to preserve those values, along with the rights reserved by the landowner, are detailed in a legal document known as a conservation easement agreement.

This document is filed with the entity that accepts the easement, which may be the city, county, natural resources district, or a private conservation organization. A permanent conservation easement, to permanently protect the property, runs with the property and applies to the current owner as well as all future landowners. The donation of a conservation easement under certain circumstances may allow the landowner to claim a federal income tax deduction for the value of the easement, and insofar as a permanent conservation easement reduces the value of the land, it has the potential to result in reduced annual property taxes.

Communities may use conservation easements for the protection of floodplain areas in exchange for a density bonus (lot or dwelling unit). When subdivision regulations require open space dedication that is applied to floodplain areas, a conservation easement is preferable to a more open and generic "reserve area."

Recommended standards for restrictive covenants and easements include the following:

Figure 5.8. Subdivision floodplain boundary markers (Chad Berginnis)

- Incentivize conservation easements of floodplains by allowing for a density bonus on lots or dwelling units.
- Require a permanent conservation (preferred) or drainage easement for areas of lots in the floodplain that are not allowed to be developed (see "Use Restrictions," p. 74).

Lake County, Illinois, requires a stormwater/drainage restrictive covenant for each lot platted in areas that are designated as stormwater and drainage ways, floodplains, wetlands, and buffer areas. This permanent deed restriction limits uses, requires maintenance of the area by the lot owner or homeowners association, and, importantly, allows any property owner in the subdivision, property owners downstream or upstream adversely affected by any violation, or the municipality to have standing to bring an enforcement action.

Physical Monumentation of Floodplain Boundaries

As development is approved and future residents and business owners move in, the location of the flood hazard area may not be well known. This is especially true if the community requires mapping of conveyance areas that are not found on the community's FIRMs. Requiring a permanent physical monument of the floodplain boundary can act as a long-term reminder of the hazard area. Such markers should be appropriately spaced so each lot owner has access or visibility to the hazard area adjacent to the owner's lot.

Figure 5.9. Bioswales in a parking lot (above), along a pedestrian path (below), and in front of a building on the campus of Colorado State University (right) (Chad Berginnis)

For example, floodplain boundary markers are required in Licking County, Ohio. Figure 5.8 (p. 79) shows steel posts used as permanent markers, approximately four feet high with clear labels. In this subdivision, approximately 10 years old, a floodplain boundary marker is required for every other lot. The recommended standard is to require permanent monuments clearly showing the floodplain boundary with a density of not less than one monument every other lot.

WATERSHED MANAGEMENT

Perhaps nowhere have the science and techniques evolved more over the last 20 years than in the area of watershed management, especially for flooding. Powerful new models can now precisely show causation of flood events due to improper or undersized stormwater features. New techniques such as low-impact development and green infrastructure can result in more stormwater being held and infiltrated on site, and practices have now been widespread for some time. With even a few small changes, a community's subdivision standards can significantly promote these better practices.

Stormwater Management Approaches

Stormwater management over the past few decades has relied on highly engineered practices that channel stormwater quickly and efficiently away from the development site and into storm sewers, detention ponds, or nearby water bodies. This is also referred to as managing stormwater by "gray" infrastructure. It often involves clearing vegetation and dis-

turbing and compacting valuable topsoil at a site prior to regrading and paving.

These development practices can reduce soil permeability, increase stormwater volume, increase frequency and magnitude of flood events, increase pollution in water bodies (due to runoff and erosion), degrade stream channels, and decrease groundwater recharge. Also, in many older communities, stormwater and raw sewage from homes and businesses flow through the same pipes to wastewater treatment plants. This can result in combined sewer overflows, the discharge of untreated raw sewage and stormwater into streams and rivers after a wastewater treatment plant reaches capacity. Many communities struggle to maintain their aging stormwater infrastructure due to lack of funding. The result is frequent flooding and nonpoint source pollution degrading local watersheds.

Two concepts have emerged over the past 20 years that improve on the traditional notion of stormwater management by gray infrastructure alone. Low-impact development is a set of techniques with the goal to restore or maintain predevelopment hydrological conditions, usually focused on retaining more stormwater where it falls. It is generally focused on the site scale and uses natural and engineered systems. Similarly, green infrastructure is a set of techniques utilizing natural resources to manage stormwater and help preserve the ecological function of watersheds. As noted in Chapter 2, green infrastructure, when considered at the regional or watershed scale, typically refers to a network of open space and natural resources, but this term is also used to refer to green stormwater infrastructure at the site or neighborhood scale. For example, installing bioswales in a parking lot of a commercial subdivision is definitely a low-impact development technique and is also considered a green infrastructure technique at the site scale (Figure 5.9).

Green infrastructure and low-impact development are both decentralized stormwater management strategies that provide on-site water quantity and quality treatment. This is how they differ significantly from traditional gray infrastructure-based stormwater management. More recently, the terms have become interchangeable. Two particularly good resources for practicing planners and floodplain managers are the US Environmental Protection Agency's green infrastructure design and implementation webpage (www.epa.gov/green-infrastructure), which contains links to design manuals and design tools including those for arid regions and coastal areas, and the State of Rhode Island's *Low Impact Development Site Planning and Design Manual* (RDEM and CRC 2011), which has an extensive set of recommendations for low-impact development practices for roadways and parking lots. *Green Infrastructure: A Landscape Approach*, PAS Report 571, provides an in-depth exploration of the background, philosophy, approach, and application of green infrastructure (Rouse and Bunster-Ossa 2013). Similarly, the American Planning Association's *Low-Impact Development Essential Information Packet*, EIP-15, has case studies and sample ordinances (APA 2009).

To effectively reduce flood losses during low-frequency events (such as the 100-year flood), green infrastructure and low-impact development need to be deployed on significant portions of a watershed. Otherwise, benefits tend to be greatest at the high-frequency flood level. Unfortunately in many communities, legacy stormwater management standards—whether as part of the subdivision regulations or as a standalone ordinance—do not incorporate green infrastructure or low-impact development techniques and focus solely on high-frequency precipitation and flood events (i.e., 2-year, 10-year, 25-year), which have limited impact on flood risk reduction. This is probably due to how stormwater regulations initially made their way into local codes—as a result of the Clean Water Act—and their focus on eliminating water quality impacts due to the these high-frequency events and the resultant polluted runoff.

Today, communities can achieve both water quality enhancement and meaningful flood loss reduction. Many flood events are due to stormwater runoff. If flood risks were better managed in the areas outside designated Special Flood Hazard Areas, they could be maintained or reduced.

Recommended stormwater management standards include the following:

- Require green infrastructure and low-impact development techniques in both stormwater management and roadway design sections of subdivision regulations. Techniques most appropriate to these subdivision design elements might include bioswales, enhanced roadside infiltration ditches, and low-impact design roadway and parking design standards that generally reduce impervious area.
- Require post-development peak storm flows and runoff for the 100-year or less frequent storm be no higher than was the case prior to development.
- Require retention and detention facilities based on the 24-hour, 100-year storm.
- Prior to any site alterations in the subdivision, require the development and submittal of a stormwater control plan, stormwater operations maintenance manual, and budget.

A good example of using low-impact development comes from Rhode Island's *Low Impact Site Planning and Design Manual* (RIDEM and CRC 2011), which recommends, for parking lots of 10 or more spaces, requiring that 10 percent of the parking lot area be dedicated to landscaped areas that can include low-income development stormwater practices.

Habitat Protection

Salt and brackish waters and their adjacent floodplains host habitats that are vital to estuarine and marine animals, including fish, shellfish, waterfowl, and mammals. Freshwater floodplains support two major types of habitats: aquatic and riparian. These habitats are dependent on the quality and temperature of the water, availability of food, and, in the case of coastal areas, salinity. The federal government designates "critical habitat" as habitat important for threatened or endangered species. Human alterations and floodplain development activities—such as relocating channels; destroying pools and riffles; constructing dams, levees, and seawalls; clearing banks, or removing the tree canopy—can have significant impacts on habitat.

Most state-enabling statutes allow subdivision standards to protect aesthetic, cultural, and natural values. This authority, combined with other standards described previously in this document, can not only reduce flood risk but can also enhance the protection of critical habitat and rare, threatened, or endangered species. An integral element of the watershed is an intact riparian zone and the protection of habitat for aquatic and terrestrial species that occupy such areas.

From a habitat conservation perspective, most typical open space subdivisions provide limited value, especially those that simply fixed a percentage of land required to be set aside. However, conservation subdivisions, especially those with significant amounts of floodplain and wetland areas, can have significant co-benefits, not only protecting open space but preserving and enhancing riparian habitat.

In order to implement habitat protection standards, a local government should first compile an inventory of critical habitat in the community. The US Fish and Wildlife Service, state department of wildlife and fisheries, coastal conservation agencies, forestry or lands management departments, and even the community's own comprehensive plan may identify such areas.

Recommended standards for habitat protection include:

- Identify conservation land priorities such as protecting wetlands, undisturbed riparian areas, and rare or endangered species protection.
- Prepare a habitat assessment within a certain distance of a desired habitat protection area to demonstrate that any subdivision development activities will not adversely impact the habitat and species it supports, and describe any appropriate mitigation measures taken.
- Implement a riparian buffer zone based on habitat protection (see earlier discussions on buffer zones; those established for fish and wildlife habitat protection are generally larger than those for other purposes).
- Prohibit or minimize clearing, grading, and filling in floodplain or riparian buffer areas.

In Maine, Beginning with Habitat (www.beginningwithhabitat.org) is a collaborative program of federal, state, and local agencies and nongovernmental organizations working to take a habitat-based approach to conserving wildlife and plant habitat on a landscape scale. It compiles habitat information from multiple sources, integrates it into one package, and makes it widely accessible. Each Maine town is provided with a collection of maps and accompanying information depicting and describing various habitats of state and national significance found in the town.

CONCLUSION

This chapter was meant to provide several optional higher standards to consider for incorporation into a community's subdivision standards. Consideration of these standards will depend on a community's geography, development patterns, and political climate. Even the adoption of a few of these standards can result in a significant lowering of flood risk for current and future residents, businesses, and visitors in a community.

1 The Biggert-Waters National Flood Insurance Program Reform Act of 2012 authorized a National Flood Mapping Program. A required element to be mapped was residual risk areas, which include dam failure zones and levee overtopping areas. However, at the time of this publication, Federal Emergency Management Agency had not determined how it was going to include these datasets in its flood risk mapping products.

CHAPTER 6

THE ROAD AHEAD

As with so many other issues related to hazard planning, there is a need to look to the future in thinking about subdivision design and flood hazard areas. Change is a virtual certainty, and the big question is whether planners and floodplain managers will be prepared to help shape that future—in both best practice and policy terms. Simply waiting to see what the future holds has often been its own pathway to disaster.

The following discussion focuses on the identification of nine specific issues that became apparent from the research and content development of this report. It is not intended to be definitive but rather to spur discussion within our professions about the measures we need to undertake in order to better ensure public safety in the coming decades. The recommendations listed below are not in any order of importance; indeed, many are closely interrelated in actual practice, as the discussion will show.

Incorporate climate change considerations into planning standards for land use and development. Not so long ago, the inclusion of climate change considerations might have been deemed a difficult proposition. Climate science was a blunt instrument with rather general, regional implications that at best were challenging, if not impossible, to translate into actionable local planning solutions. But that is changing quickly as climate science advances. This is especially true in coastal areas, where the state of the science is much more advanced than in inland, riverine areas.

That is not to say that the advances do or will soon allow us to isolate climate change impacts specific to such small areas as subdivision plats. It does mean that the data at the regional level are beginning to allow scientists to assess impacts within certain ranges that at least can inform land-use policy, in areas like floodplains, in a manner that is not totally speculative. When planners consider the conditions that buildings and infrastructure must survive for the likely duration of their life cycle, which is almost always a matter of decades, it is possible to build in a margin of safety for likely ranges of precipitation within a metropolitan area. This is based on what is already known about the probable bifurcation of weather into greater extreme events involving either prolonged drought or more extreme storms.

In coastal areas subject to tropical storms and other coastal events such as nor'easters, these considerations likely will also influence estimates of the probable storm surge and wind impacts from such events. At the very least, this is likely to result in greater wisdom about more retreat from shorelines and river banks. What those estimates are in any given case will still depend heavily both on local values involving risk tolerance and on local climate profiles. In areas like the Great Lakes, however, it may also increasingly allow some differentiation of impacts both closer to and farther away from the lakes themselves.

What will be important for planners and local public officials is to understand where and how to access usable data with regard to climate change. At the 2015 National Planning Conference of the American Planning Association (APA), the very first session in the Climate Change and Planning track addressed this issue: Climate Change Projections and Community Planning. Attendees learned that the National Oceanic and Atmospheric Administration has funded regional centers, such as Great Lakes Integrated Science and Assessments at the University of Michigan, to provide such guidance and, most critically, to help translate scientific data into actionable state and local policy information regarding climate change. Other technical and academic resources abound today in federal agencies and universities. It is rapidly becoming the responsibility of the planning profession to learn how to use this information effectively.

Improve technology and visualization tools for subdivision design. In 2015, APA teamed up with partners from the University of California, San Diego; Placeways LLC, a consulting firm; and the National Charrette Institute on a project supported by the Federal Emergency Management Agency (FEMA) called "Innovations in Plan-

ning and Public Engagement for Community Resilience" (www.planning.org/nationalcenters/hazards/innovations) to help advance this technology objective. The result was web-based resources and hands-on training adapted to a variety of technological tools to assist with visualization of alternative-future designs for improved disaster resilience and scenario planning to better anticipate the disasters that future development must withstand. The effort to advance these tools included input from the technology and other sectors. One fact became clear during demonstrations in the Tech Zone at the 2016 National Planning Conference in Phoenix, Arizona: many communities want this sort of assistance.

Similar efforts have been underway for a number of years with various private technology firms and consultants. For example, McElvaney and Rouse (2015) describe the emergence of geodesign as an approach that combines geographic information systems with design capabilities—basically combining analysis of what is and what could be. The APA effort merely seeks to mainstream these approaches in the context of planning for resilience by making them better understood and more accessible on a platform planners are used to accessing, the APA website, linked with those of the partners and participants in the project.

In this particular arena, before new subdivisions are platted and built, communities and decision makers would be able to construct and act upon better visual and mental images of the outcomes of their decisions. Then future developments affected by flood hazards of any type are designed to be more responsive and resilient to those environmental hazards.

Expand the use of future-conditions analysis to include subdivision standards. Future-conditions analysis is not a technique of the future. Communities like Charlotte and Mecklenburg County, North Carolina, have shown that it is already entirely feasible, given adequate resources, to assess the impact of full buildout under existing land-use ordinances and policies on flood threats (Schwab 2010). It is no longer necessary to rely on relatively static data from National Flood Insurance Program Flood Insurance Rate Maps in order to improve policy with regard to future development. Much, though by no means all, of that new development in many communities involves building new subdivisions. Where that is the case, the community should reexamine what it allows—and what it requires—in its subdivision ordinance, in the same way that Charlotte and Mecklenburg County had to reassess allowable parameters of floodplain development as a result of its future-conditions analysis.

It should also be clear that there is or can be a dynamic relationship between the visualization and scenario planning tools noted in the previous section and the future-conditions analysis discussed here. Each technique can help inform the other.

Strengthen attention to local planning capacity for floodplain management and subdivision design. Based on the previously discussed issues, certain complaints are predictable, such as "We do not have the resources or the staff to do all this." Sadly, particularly in many rural counties lying in the path of expanding metropolitan area development, this may well be true. It sometimes seems to be in the nature of the US political system that such places lack the resources and expertise to control development effectively for the larger public interest until enough development has already occurred to generate the tax base to support an adequate planning staff. Even then, elected decision makers may be reluctant to confront the problem until flooding problems become manifest.

There is no getting around the fact that state technical assistance, including policy guidance, is crucial (see "Case Study: Montana Model Subdivision Regulations," p. 87). Regional planning commissions and metropolitan planning organizations, among other similar entities that are typically arms of state government, can also play a role closer to the ground by providing direct assistance. The case study of the Chicago area effort in this regard in Chapter 2 (p. 46) is one illustration; the Chicago Metropolitan Agency for Planning continues to offer regional planning assistance and direct technical support to local governments on issues like climate resilience and floodplain management.

Develop best practices and tools for local government to use green infrastructure and No Adverse Impact approaches to improve subdivision design in flood hazard areas. Another broadly emerging area of interest in recent years among local planners has been the use of green infrastructure, in part to mitigate the impacts of riverine and urban flooding, but also for coastal storm surge hazards. APA has dealt with this need in previous PAS Reports—*Planning the Urban Forest* (Schwab 2009) and *Green Infrastructure: A Landscape Approach* (Rouse and Bunster-Ossa 2013). Notably, the Hurricane Sandy Rebuilding Task Force (2013) put significant emphasis on the use of green infrastructure as a means of protecting against flood and storm surge damages.

In addition, the Natural Floodplain Functions Alliance, led by the Association of State Wetlands Managers, has furthered cross-disciplinary discussion of green infrastructure among floodplain management practitioners,

CASE STUDY: MONTANA MODEL SUBDIVISION REGULATIONS

Nicholas J. Walny, American Planning Association

The state of Montana is characterized by broad mountain ranges, low-lying valleys, lakes, rivers, and streams. With an estimated total population of 1,032,949 (US Census Bureau 2015) and a total land area of 147,040 square miles (USGS 2010), density is extremely low. The amount of impervious surfaces such as roads, parking lots, and roofs are well below the average of most areas in the country, with the exception of the city of Billings, due to the state's low population. However, major flood hazards can and do occur because of a multitude of naturally occurring and human-induced factors. The variety of ways a flood hazard may develop includes the following:

- flash flooding
- river flooding
- burn scars and debris flow
- ice and debris jams
- snowmelt
- dry wash
- dam breaks and levee failure

In 2011 Montana experienced a distinct blend of flooding over the course of a year. Flooding hit all corners of the state at some point during winter, spring, and summer. With both daytime high temperatures and overnight lows averaging below freezing for much of the previous December and the following January, river ice jamming became a major problem, particularly in west and central Montana. As the shift to spring brought warmer temperatures in April, snow rapidly melted. Smaller creeks and streams were quickly overwhelmed. In late May, a record-breaking rainstorm hit much of central, south central and southeast Montana. Several towns became inundated.

These storms, which brought rain to the plains, were bringing snow to the mountains late in the season. Cooler spring temperatures delayed snowmelt, and mountain snowpack, which typically starts coming out in April, persisted well into June and reached near record levels. Once the melt did begin, the runoff worked its way into streams already filled from plains snowmelt and water from recent rainstorms. Areas in southwest Montana and along the Rocky Mountain Front were hardest hit with this runoff (Figure 6.1 and Figure 6.2) (NOAA 2015). As a result, $60 million in damages occurred, and President Obama declared a major disaster in the state of Montana.

Due to the number of ways floods can occur (as they did in 1908, 1948, 1964, 1978, and 2011), the State of Montana advises local governments to adopt the Montana Model Subdivision Regulations

Figure 6.1. Flood waters from the Musselshell River inundate this home in the city of Roundup, Montana, during the record-setting 2011 flood event (Musselshell County, Montana)

Figure 6.2. The city of Roundup, Montana, saw record flood levels in May 2011, when the Musselshell River flooded, and floodwaters covered roads and highways (Musselshell County, Montana)

as an example and reference for preparing or revising their own regulations. This helps local communities take a positive step toward flood mitigation. Under the design and improvement standards section, all subdivisions approved by the governing body must comply with the provisions of the section, including floodway provisions (Joint Powers Insurance Authority of the Montana Association of Counties et al. 2006, VI-D, 54):

> Land located in the floodway of a 100-year flood event as defined by Title 76, Chapter 5, MCA, or other land determined by the governing body to be subject to flooding may not be subdivided for building or residential purposes or other uses that may increase or aggravate flood hazards to life, health, or welfare, or that may be prohibited by state or local floodplain or floodway regulations.

Also, the state provides measures for subdividers (developers), prohibiting them from building near a stream if no official floodway studies have been completed. The section reads as follows (Joint Powers Insurance Authority of the Montana Association of Counties et al. 2006, VI-D, 54):

> If any portion of a proposed subdivision is within 2,000 horizontal feet and 20 vertical feet of a live stream draining an area of 25 square miles or more, and no official floodway delineation or floodway studies of the stream have been made, the subdivider shall provide in detail to the Floodplain Management Section of the Water Resources Division of the Montana Department of Natural Resources and Conservation (DNRC), a flood hazard evaluation, including the calculated 100-year frequency water surface elevations and the 100-year floodplain boundaries. This detailed evaluation must be performed by a licensed professional engineer experienced in this field of work. The evaluation must follow the "guidelines for obtaining 100-year flood elevations in Approximate Zone A or unmapped areas."

Along with the Montana Model Subdivision Regulations, the Montana Department of Natural Resources and Conservation provides communities model floodplain hazard management regulations that include optional higher standards (Montana 2014). These regulations are for use by communities to update or establish local regulations. In relation to subdivision design in flood hazard areas, the following criteria should be met:

- The base flood elevations and boundary of the regulated flood hazard area must be determined and considered during lot layout and building location design.
- Locations for future structures and development must be reasonably safe from flooding.
- Adequate surface water drainage must be provided to reduce exposure to flood hazards.
- Public utilities and facilities such as sewer, gas, electrical, and water systems must be located and constructed to minimize or eliminate flood damage.
- Floodplain permits must be obtained according to these regulations before development occurs that is within the regulated flood hazard area.

By adopting and enforcing the state model subdivision regulations and model floodplain hazard management regulations regarding subdivision design, local communities gain protection from flood hazards and the external effects they create. A state-led approach influences local governments to take action in reducing the vulnerability of residents as well as the natural and built environments.

including members of the Association of State Floodplain Managers (ASFPM). Finally, in recent years, ASFPM has invested in No Adverse Impact tool development, providing new resources to both practitioners and decision makers. In 2016, ASFPM (2016) completed production of its No Adverse Impact how-to guides, each identifying up to five specific tools that local officials can use to achieve No Adverse Impact floodplain management.

This is likely to be an increasingly fertile area of investigation and innovation both for private companies offering services in this area and for academic specialists seeking to push the frontiers of what can be accomplished. Overall, the great benefit of this new surge of activity is that it should provide substantial guidance and training in coming years to local planners who, in the past, have often lacked a working knowledge of the benefits and opportunities that green infrastructure projects can bring to their communities.

Educate and inform stakeholders in the subdivision design approval process. The reasons for broader public engagement in the hazards planning process are so numerous and varied that FEMA in recent years has made "whole community" a cornerstone of its doctrine, particularly for Risk MAP (Mapping, Assessment, and Planning). Risk MAP has provided a means for FEMA to adjust its approach to floodplain mapping through a broader, more deliberate engagement with communities to focus more on risks than on maps alone. It shifts the emphasis to tools, planning, and outreach support.

Subdivision design is one specific element of that overall process that should not escape attention, in part because so much of it has probably seemed like a black box to most people outside the development community. Once public concern about growing flood impacts is combined with an understanding of the potential impacts of new residential development on flood risks, it seems logical that many stakeholders will be empowered to ask more intelligent questions about the entire process of subdivision approval.

One audience in particular that has not yet gained prominent attention from planners is owners associations (OAs). Our research has indicated that the capacity of most OAs may be inadequate to manage the increasingly complex infrastructure (e.g., levees) for which they have assumed responsibility. From plan review to ongoing outreach and educational activities, the trend toward OAs sharing such infrastructure responsibilities shows no sign of slowing down.

In PAS Report 560 (Schwab 2010), APA offered a Safe Growth Audit for use by communities in reviewing their policies and ordinances with regard to all hazards. While probably underutilized to date, there is no reason many communities, if they made the commitment, could not use this tool as part of their comprehensive planning process to help citizens ask the right questions related to flood hazards about needed reform of both zoning codes and subdivision ordinances. The tool, an abbreviated form of which also appeared in *Zoning Practice* (Godschalk 2009), serves well to direct both the public and policy makers to the right questions for reducing overall risk.

The proof is in the pudding. One community that has made limited use of the Safe Growth Audit—Charlotte, North Carolina—was also a pioneer in engaging the development community and others in examining the methodology of its stormwater services unit to achieve successful buy-in to the need to address persistent stormwater management problems in Mecklenburg County. Roseville, California, has also used extensive public education to advance its agenda on controlling flood risk, eventually achieving Class 1 status in the National Flood Insurance Program's Community Rating System. Both communities were the subject of case studies in PAS Report 560, and both have made further improvements over time. The logic for other communities to either follow or continue down this path is compelling.

Increase professional development of city staff on floodplain management and its relationship to good subdivision design and plan review. Although this is changing rapidly, a good deal of planning education still occurs without reference to the impact of hazards on a community, the most important of which typically is flooding. Planning schools still have some distance to go to incorporate adequate levels of training on the basics of floodplain management (Schwab 2015). Today floodplain management is beginning to establish itself as an academic concentration with recently developed bachelors and masters programs. Particularly with the heightened risks introduced with climate change in the form of more extreme weather events, it is critical that planning staff understand the impact of decisions about development connected with flood hazard areas.

Of course, planning education is only the first step, and most planners make numerous mid-course corrections in their careers to acquire additional training as they confront problems on the job. It is the role not only of APA and its chapters to make such training available but also that of numerous other entities, such as planning extension programs, nonprofits specializing in hazard-related issues, and state and regional technical assistance providers. Planners who also serve as community floodplain administrators may seek additional training or certification like the Certified Flood-

plain Manager designation. Floodplain management training is often offered through a state's floodplain management office, which also coordinates the state's involvement in the National Flood Insurance Program. All of these opportunities need to continue to be available and expanded in coming decades.

But there is one additional point that must be made here, which is not always underscored enough: It matters a great deal whether local government, as the employer of most planners, highlights and encourages these opportunities as an important source of professional growth. It is in the interest of these local governments to ensure that their own staff can adequately anticipate the impact of good subdivision design on overall flood risk in the community.

Increase the focus on hazard management to broaden the view of impacts from development. As we approach the conclusion of this report, one additional point is paramount: We have learned over time that good floodplain management is not just about how we manage the floodplain. It is, in many respects, about how we manage the entire landscape, or at least the entire watershed from which water travels into rivers, streams, and also urban areas and the built environment. Without a more holistic understanding of the topography of our communities and regions and how water moves, we are doomed to repeat many engineering mistakes of the past by creating unnecessary, and unnecessarily polluted, runoff. One byproduct of this is the challenge many communities face from what is often called urban flooding, which stems from the inability of the urban landscape to absorb excess flood water because too much of it is hardscape. We have learned that ratios of pervious and impervious surface matter greatly in reducing this problem.

The final section of Chapter 5 includes ample detail about why watershed management matters in the context of this report. The point here is not to repeat that detail but to plant the stake for this issue as one pointing to better future planning and development practices and to point the reader back to that very section for further information. Note that the discussion in Chapter 5 clearly ties the use of green infrastructure and low-impact development techniques to improvements in watershed management.

Incorporate the review of subdivision standards in local and regional hazards plans. There are many issues considered in most hazard mitigation plans, which accounts for at least some of their length. However, a prime motivation for APA in producing PAS Report 560 (Schwab 2010) was that too often planners provide little or no input into the plans; hence, the plans were not informed by solutions related to better land-use planning in relation to hazards. That shortcoming is less common than it was in the first wave of plans under the Disaster Mitigation Act of 2000, but it is still prevalent in many places and needs to be remedied where it exists—both through the deliberate inclusion of planners by whatever lead agency is preparing the plan and through the deliberate effort by local planners to carve out their own meaningful role by making land-use issues a central focus where that makes sense.

While land use may have little impact on some hazards like tornadoes, its role in reducing flood hazards is undeniable. A review of the role that subdivision standards and the subdivision approval process play within the hazard mitigation plan, especially where that is tied to any sort of hazards element in the local comprehensive plan, is long overdue in many cases. This is a high-priority area of concern for the APA Hazards Planning Center and will likely remain so for the foreseeable future because the stakes for the planning community, and the citizens it serves, are too high to do otherwise.

But this incorporation should not be limited to hazard mitigation plans. Although such plans have been uncommon until recently, the pre-disaster and post-disaster plans for recovery after major events that were outlined and discussed in detail in *Planning for Post-Disaster Recovery: Next Generation* (Schwab 2014) are another prime avenue for moving this issue forward.

The aftermath of a flood offers an opportunity to reflect on any new lessons learned and to incorporate them into the process of recovery. This may well in many cases include some review of the subdivision approval process and subdivision standards. The whole point of a recovery plan is to determine how best to create a more resilient community that will better withstand future disasters. But pre-disaster plans, which lack knowledge of the consequences of a specific event but can outline anticipated policy issues in order to expedite recovery, can potentially be a vehicle for identifying questions needing further examination.

Ultimately, all these plans must work together, along with the comprehensive plan, to help envision a stronger, safer, more resilient community. The precise issues that rise to the surface will be different in each community; the United States is a hugely diverse nation, particularly where climate and topography are concerned. What matters is the willingness to use the available tools as best they apply and to keep in mind an adage from that recent post-disaster recovery report: *We cannot know when a community will encounter its moment of truth, but procrastination is not an option.*

APPENDIX A: SAMPLE WORKSHOP FOR HOMEOWNERS ASSOCIATIONS

A Workshop for Homeowners Associations: Maintenance (Techniques or Practices) for Subdivision Drainage Systems

Monday, May 23, 2016
6:00 – 7:45 p.m. Vendor Exhibit
6:30 – 8:30 p.m. Workshop
College of Lake County, Wing C
19351 W. Washington, Grayslake
Due to construction, enter at B Wing, follow signs to C Wing lower level. Park in lots 4, 5 or 6. See map below.

Sponsored by College of Lake County | Lake County Stormwater Management Commission

Vendor Exhibit
Talk to consultants and contractors who design, install and maintain stormwater Best Management Practices (BMPs).

Workshop Topics
Why stormwater drainage systems are required.

Common subdivision BMPs and the need to maintain them.

Signs of failing stormwater structures.

HOA legal responsibilities & budget considerations.

Local HOA case study on shoreline erosion remediation projects.

Resources for sample maintenance plan, native vegetation, and more.

Ideal for HOA board members!

Featuring: John Bickley, III
Attorney-at-Law, Kovitz Shifrin & Nesbit

Kurt Woolford, Chief Engineer, LCSMC

HOA case study on solving a maintenance issue

Please RSVP: Darcy McNeill
dmcneill@lakecountyil.gov
847.377.7707

Stop by the vendor exhibits for expert advice on how to maintain your stormwater BMPs!

APPENDIX B: EXAMPLE ORDINANCE LANGUAGE

The excerpts below are taken from actual ordinances, codes, design/guidance manuals, and templates adopted by communities and carefully selected to only reflect those that can likely be incorporated into a community's subdivision regulations. Of course, this will depend on state-enabling authority, as well as the general structure of codes and regulations in a particular community.

NATURAL AND HUMAN-MADE GEOGRAPHIC FEATURES

Roswell, Georgia

Focus

Dams: Dam failure zones identified on plats

Language

Natural features within the proposed subdivision, including drainage channels, bodies of water, wetlands, wooded areas and other significant features. Of all water courses leaving the tract, the direction of flow shall be indicated, and for all water courses entering the tract, the direction and acreage of the drainage area above the point of entry shall be noted. Flood plains and dam failure flood zones shall be outlined. (NOTE: Disturbance of the 100-year flood plain is prohibited). (Subdivision Regulations, item #18 on Final Subdivision Plat Specifications document)

Borough of Raritan, New Jersey

Focus

Riparian Zones: Restoration of impaired riparian zones

Language

Any lands proposed for development which include all or a portion of a riparian zone shall, as a condition of any major subdivision or major site plan approval, provide for the vegetation or revegetation of any portions of the riparian zone which are not vegetated at the time of the application or which were disturbed by prior land uses, including agricultural use. Said vegetation plan shall utilize native and noninvasive tree and plant species to the maximum extent practicable in accordance with an approved riparian zone management plan. (Stormwater Management Regulations, § 315-46(B)(2))

Cumberland County, North Carolina

Focus

Levees: Identification of levee protection areas on plats and plans; establishment of maintenance easement

Language

The preliminary and final plats of a subdivision, group development, or mobile home park, or section thereof, in which it is proposed to alter the 100-year floodplain line by construction of a levee system, as such term is defined in Chapter 6.5, shall have the following additional lines drawn thereon:

1. A line or lines depicting the contour of the base or bases of the proposed levee system. Each such line will be designated as a "levee base contour line."
2. A line or lines, within the subdivision, twenty (20) feet outside the levee base contour line or lines, each such line to be designated as a "levee maintenance contour line."
3. A line delineating a revised boundary of the 100-year floodplain, which shall be placed on the final plat or amended final plat when a revised 100-year floodplain line pertinent to the subdivision, group development or mobile home park is redrawn on the official flood map(s), following approval by or Federal Emergency Management Agency (FEMA) of the levee system as constructed. Such line shall be designated as the "revised 100-year floodplain."
4. A line delineating the outermost boundary of an area twenty (20) feet from either side of the bank of every watercourse in the subdivision, group development or mobile home park, the flow of which will be restricted or stopped by closure of a levee. Such line shall be designated as the "watercourse maintenance line." (Subdivision Ordinance, § 3.16(b))

Licking County, Ohio

Focus

Waterbodies without Identified Floodplains: Mapping requirements for unidentified floodplains including intermittent streams based on future conditions

Language

Some floodplains in Licking County are identified on Federal Emergency Management Agency (FEMA) maps. The following shall apply to those floodplains identified on FEMA's Flood Insurance Rate Maps (FIRM) or to flood prone areas identified as follows:

> For any stream or body of water not identified by the FIRM, including intermittent streams, the developer shall determine the 100-year flood elevations and subsequent mapping, through a certified engineering analysis. These elevations shall be determined in accordance with FEMA's recognized state methods and based on "future conditions." (Subdivision Regulations, § 4.60)

City of Portland, Oregon

Focus

Waterbodies without Identified Floodplains: Mapping requirements for unidentified floodplains on streams draining one acre or more

Language

Unidentified Watercourse Flood Zones. These watercourses, generally draining one acre or more, are not identified in a Federal Insurance Study and may not be identified on the Water Features map. The flood protection elevation shall be the base flood elevation plus two feet of freeboard. The width of the floodway shall not be less than 15 feet. The floodway boundary, flood fringe boundary, and flood protection elevation data shall be based upon watercourse geometry, slope, channel roughness, effect of obstructions, backwater and other factors which affect flood flow. The requisite flood hazard data, maps, and sections shall be obtained and developed by procedures approved by the Sewage System Administrator. When appropriate and necessary data are available, the flood protection elevation and floodway and flooding fringe boundary data may be provided by the Sewage System Administrator.

If pertinent hydrologic data and topographic data are not available, inaccurate, or outdated, and where substantial alterations or relocations of a watercourse are involved, the Sewage System Administrator may require the permit applicant to secure a registered engineer and surveyor to develop and supply the requisite flood hazard data, maps, and sections. (Building Regulations—Flood Hazard Areas, § 24.50.050)

Fairfax County, Virginia

Focus

Dams: Identification of dam break inundation zones

Language

Proposed developments within the mapped dam break inundation zones of state regulated impoundments must be identified on all Preliminary Plan, Subdivision Plan, Site Plan, and Minor Site Plan submissions. The plan cover sheet has been modified to include a check box for submitting engineers to identify proposed developments in dam break inundation zones. Two additional copies of the plan are required for such developments. Maps depicting the impoundments and their associated inundation zones are available online. If the proposed development will change the spillway design flood standards of the impounding structure, the development cannot be approved unless it is modified so that it does not change the spillway design flood standards or the developer contributes a payment for the necessary upgrades to the impounding structure. In addition, when any part of the land proposed for subdivision lies in a mapped dam break inundation zone, such fact shall be set forth on the Final Subdivision Plat of the proposed development. Following completion of construction, the developer must provide the dam owner and the County with all information necessary for the dam owner to update the dam break inundation zone map to reflect any new development within the dam break inundation zone. (Letter #09-10—Development within Mapped Dam Break Inundation Zones of State Regulated Dams)

LAYOUT AND DESIGN

Maricopa County, Arizona

Focus

Use Restrictions: Restriction on reservation of land for future schools and fire stations

Language

The Board of Supervisors, upon recommendation of the Commission, may require that land areas within a subdivision be reserved for school sites and fire stations subject to the following conditions:

b. The required school reservations must be consistent with a specific request from the school district servicing the subdivision and/or the required fire station reservations may be consistent with a specific request from the fire district servicing the subdivision and must be in conformance with the following standards:

    1. Reservations may not be located within a floodplain. (Subdivision Regulations, § 308)

City of Nicholasville, Kentucky

Focus

Impact Analysis and Mitigation: Land unsuitable for development

Language

UNSUITABLE LAND CONDITIONS—If the Commission finds that land proposed to be subdivided is unsuitable for subdivision development due to flooding, poor drainage, topography or other such conditions which may endanger health, life or property; and if investigations conducted by the public agencies concerned determine that in the best interest of the public that the land should not be developed for the proposed purpose; the Commission shall not approve the land for subdivision unless adequate methods are proposed by the subdivider for solving those problems that will be created by the development of the land. (Subdivision Regulations, § 221.1)

Bighorn County, Montana

Focus

Impact Analysis and Mitigation: Erosion, debris flows, fill, water quality

Language

A Flood Hazard Evaluation is a professional assessment of all possible flooding hazards and a report of the risks associated with this potential flooding in the proposed subdivision. In addition to industry standard, one-dimensional, steady state water surface evaluation modeling, a flood hazard evaluation includes:

1. A discussion of overbank flow path uncertainty related to: rivers and stream channels that are topographically higher than surrounding floodplains, shallow flooding channels, alluvial fan flooding, debris jams, ice jams and/or diversions, and ditches.
2. A discussion of possible or predicted channel stability curing flood events, including the possibility of channel avulsion and/or thalweg migration that could affect the flooding dynamic in the project area.
3. A discussion of the risk of landslides and/or debris flows occurring and affecting flood behavior in the project area drainages.
4. An analysis of the stability and structural integrity of permitted and unpermitted floodplain fill in the vicinity of the project that contacts the regulatory 100-year floodplain, including rip rap, berms, levees, and other fill.
5. A statement attesting that all proposed sanitary sewer infrastructure meets 100-year flood design standards and/or will not otherwise contribute to water pollution during periods of flooding or high groundwater.
6. A discussion of irrigation ditches in the area and how they would affect the project should they fail, overtop or route surface runoff.
7. An identification of depressional areas (areas below the Base Flood Evaluation or design flood evaluation but unconnected to a separate and discrete flow path). (Subdivision Regulations, Appendix H)

Town of Winchester, New Hampshire

Focus

Ingress and Egress: Elevation of streets

Language

All streets shall be built a minimum of one foot above floodplain. (Subdivision Regulations, § 11(I))

City of Brevard, North Carolina

Focus

Impact Analysis: No Adverse Impact

Language

No Adverse Impact Determination.

a. After examination of the National Flood Insurance Program standards for floodplain development, the City Council of the City of Brevard has made the judgment that due to its geographic location, topography and the extensive riverine floodplain systems within its jurisdiction that the minimum standards of the National Flood Insurance Program are not wholly sufficient to protect its citizens and their properties from the effects of flooding, especially in situations where

flooding possibly could be exacerbated by development that would otherwise be allowable under the minimum standards of the National Flood Insurance Program, and that additional protections must be employed to protect the lives and property within the jurisdiction of the City of Brevard.

b. No structure or land shall be located, extended, converted, altered, or developed in any way within the special flood hazard area, nor shall any floodplain development permit be issued except as otherwise provided in this chapter, until the administrator makes a determination that the project would not increase danger to life or property and would have no adverse impact based upon the affirmative findings that:

    1. The granting of the floodplain development permit will not create a danger that fill, construction materials or other debris or construction spoils may be swept onto properties upstream from, downstream from, or adjacent to the project area, or increase erosion and sedimentation; and
    2. The granting of the floodplain development permit will result in no rise in the base flood elevation as defined by this chapter; and
    3. The granting of the floodplain development permit will not result in increased flood peaks, increased flood stages, or increased flood velocities during the base flood discharge; and
    4. The granting of the floodplain development permit will not increase or alter the width or extent of the floodway or special flood hazard area except within the property or properties upon which the floodplain development is located or the property of a consenting owner, where such property is protected from future development by means of a conservation easement or other, similar restriction that is acceptable to the administrator; and
    5. The granting of the floodplain development permit will not increase the susceptibility of any property to flooding during the base flood except the property or properties upon which the floodplain development is located or the property of a consenting owner, where such property is protected from future development by means of a conservation easement or other, similar restriction that is acceptable to the administrator; and
    6. The granting of the floodplain development permit will not increase the susceptibility of existing or proposed structure to flooding during the base flood; and
    7. The granting of the floodplain development permit will not detrimentally impact the functionality or level of service of any street, bridge or culvert, or public utility during the base flood; and
    8. The granting of the floodplain development permit will not reduce the effective base flood storage volume of the floodplain; [and]
    9. The granting of the floodplain development permit will not increase the susceptibility of any critical facility to flooding, nor detrimentally impact access thereto during the base flood; and
    10. The granting of the floodplain development permit will not otherwise increase the probability of flooding or property damage and thereby create a danger to life and property, or otherwise create conditions that are injurious to the public health, safety, and welfare, or detrimental to the value of adjoining property and associated uses; and
    11. The use, structure, or other activity that is the subject of the floodplain development permit will comply with all other requirements and specifications of Brevard City Code.

c. The burden of proof shall lie with the applicant, who shall be required to present evidence to substantiate any affirmative finding. The administrator shall maintain records containing specific evidence to substantiate any affirmative finding.

d. Property owners and any tenant or lessee thereof, who may be adversely impacted by the proposed floodplain development, shall be provided an opportunity to comment, in writing, upon such development or to provide information or evidence pertaining to a potential adverse impact. The administrator shall provide notification of the proposed floodplain development by means of first class mail to the owners of all properties lying within or adjacent to the special flood hazard area whose properties lie within the geographic scope of the hydraulic and hydrologic evaluation that is required by subsection (e)(5), below, or subsection 34-22(c)(2). The applicant shall be required to respond, in writing, to any claim of adverse impact by an affected property owner or tenant or lessee thereof.

e. In order to evaluate development proposals in the context of the required findings, the following, mini-

mum information is required for presentation to the administrator:

1. A narrative, written in non-technical language, which explains how no adverse impact is being accomplished with respect to the proposed project.
2. No rise certification documentation by a professional engineer is required to show that proposed encroachment into the special flood hazard area will cause no rise in the water surface elevation of the 100-year base flood as defined in this chapter.
3. No adverse impact certification documentation by a professional engineer is required to show that the proposed encroachment into the special flood hazard area will create no adverse impact upon any other property owner.
4. Other information as may be required by the administrator in order to evaluate the proposed floodplain development permit in the context of the required findings that are set forth in subsection 34-33(b), above.
5. All data and conclusions shall be demonstrated using the most current hydraulic and hydrological models employed by the Federal Emergency Management Agency (hereafter, FEMA) or North Carolina Emergency Management's Office of Geospatial and Technology Management (hereafter, NCEM GTMO) for the purposes of flood risk assessment and mapping. If there is no model available for the basin or watercourse affected by proposed development, a full hydraulic and hydrological model shall be developed by a professional engineer and approved by the administrator and/or FEMA/NCEM GTMO as appropriate.
6. Hydraulic and hydrologic conditions shall be evaluated within the project area, as well as upstream and downstream of the project area along the channel to the point where water surface profiles consistently meet the existing conditions as defined in the effective model. The administrator shall have the authority to determine the reach and scope of any hydraulic and hydrologic evaluation.
7. The developer or property owner of any development project that causes an increase in the base flood elevation or a change in the geographic extent of the special flood hazard area or floodway shall be responsible for revisions to the flood insurance rate maps, which shall be approved by FEMA, in accordance with 44 CFR 70. The developer or property owner shall be responsible for preparing and recording appropriate legal documents in which all property owners affected by the increased flood elevations or change to the geographic extent of the special flood hazard area or floodway have consented to the impacts upon their property, including development restrictions approved by the administrator. Prior to approval of any project, the developer shall conditional letter of map revision (CLOMR) first to the City of Brevard for review and approval and then to North Carolina Emergency Management for review. A letter of map revision (LOMR) must be obtained and new flood insurance rate maps produced and presented to the administrator within six months of completion of the proposed encroachment. The applicant shall enter into a written agreement with the city and provide financial security that is sufficient to cover all costs associated with completion of the LOMR and FIRMs. Such agreement and security shall be provided in accordance with the improvement guarantee requirements and procedures which are set forth in Chapter 16 of the City of Brevard Unified Development Ordinance. (Flood Damage Prevention Regulations, § 34-33)

City of Austin, Texas

Focus

Impact Analysis and Mitigation: No Adverse Impact

Language

(A) (5) requires that a final plat, subdivision construction plan, or site plan may not be approved unless the proposed development will not result in additional identifiable adverse flooding on other property and to the greatest extent feasible, preserves the natural and traditional character of the land and waterway. (Land Development Code—Drainage, 25-7-61)

(A) states that the owner or developer of property to be developed is responsible for the conveyance of all stormwater flowing through the property, including stormwater that is directed to the property by other developed property or that naturally flows through the property because of the topography.

- Development within the floodplain may cause adverse impact to others by obstructing the existing waterway or by placing fill in floodplain storage areas.

- Obstruction of the waterway reduces the cross sectional area of the channel and typically creates identifiable adverse impacts of increased erosion and scour at the obstruction and/or increased flood elevations upstream of the obstruction. A proposed site plan should not decrease the conveyance capacity of the channel and overbank areas. Hydraulic analysis is required to demonstrate that the proposed development will not create any additional identifiable adverse flooding on other property due to loss of conveyance.
- Placement of fill in the floodplain reduces the natural capacity of the floodplain to store floodwaters. Loss of floodplain storage typically causes higher peak flows and additional identifiable adverse flooding on downstream properties. A proposed site should not decrease the floodplain storage volume of the channel and overbank areas. Accurate plans and cut/fill calculations must be provided for any proposed development within the floodplain to demonstrate that any proposed fill is offset by at least an equal amount of excavation within the floodplain.
- Excavation and fill of the floodplain and modification of the channel are subject to requirements to preserve the natural and traditional character of the land and waterway.

The contours of the channel bottom change continually due to natural processes of deposition and scour. Temporary removal of sediments from depositional areas may have unforeseen impacts on channel erosion, and is not considered to affect calculations of cut and fill or conveyance. (Land Development Code—Drainage, 25-7-151)

INFRASTRUCTURE

City of Missoula, Montana

Focus

Utilities: Buried utility transmission lines in floodways

Language

Uses Requiring Permits - The following artificial obstructions and non-conforming uses may be permitted in the floodway subject to the issuance of a permit by the Floodplain Administrator:

1. Buried or suspended utility transmission lines, provided that:
   a. suspended utility transmission lines are designed such that the lowest point of the suspended line is at least six (6) feet higher than the elevation of the flood of 100-year frequency;
   b. towers and other appurtenant structures are designed and placed to withstand and offer minimal obstruction to flood flows; and
   c. utility transmission lines carrying toxic or flammable materials are buried to a depth of at least twice the calculated maximum depth of scour for a flood of 100-year frequency. The maximum depth of scour shall be determined from any of the accepted hydraulic engineering methods, but final calculated figures shall be subject to approval by the Floodplain Administrator. (Floodplain Regulations, § 5.01(B)(4))

Passaic County, New Jersey

Focus

Local Road Systems: Design standards for culverts and bridges

Language

For the purpose of sizing culverts and bridges on open streams a 100-year storm frequency will be used. For all other drainage facilities a 25-year storm frequency will be used unless otherwise directed by the County Engineer. (Subdivision Resolution—Design Standards, IV(E)(1))

Licking County, Ohio

Focus

Local Road Systems: Design standards for culverts and bridges

Language

Where natural or man-made drainage channels intersect any street right-of-way, it shall be the responsibility of the owner/developer to have bridges and/or culverts designed, approved, and constructed. Where culverts are required, minimum requirements shall be observed as follows: all roadway conveyances shall be approved by the LCE and designed to handle a minimum of a 100-year storm. For flood routing purposes, a variance may be granted allowing a road to be overtopped by the 100-year flood to an elevation not to exceed 2 inches (Subdivision Regulations, § 11.50)

State of Ohio

Focus

Utilities: Public water wells

Language

A public water system well shall have the casing, well cap, well vent, and pumphouse floor extending a minimum of three feet above the one hundred year floodplain elevation, or highest known flood elevation, whichever is higher. With prior acceptance of the director, in lieu of extending the casing a minimum of three feet above the one hundred year floodplain, a noncommunity public water system well may have both a watertight well cap and a well vent extending a minimum of three feet above the one hundred year floodplain elevation, or highest known flood elevation, whichever is higher. (Ohio Administrative Code 3745-9-05(Q)(1))

PLATTING

Lake County, Illinois

Focus

Restrictive Covenants: Sample stormwater/drainage restrictive covenant

Language

STORMWATER/DRAINAGE RESTRICTIVE COVENANT BY PLAT

_____, fee owner of the following described real property located in the _____, County of Lake, State of Illinois, such property being the real property now duly platted as _____, as such plat is now recorded as Document No. _____, in the office of the Recorder of Deeds of the County of Lake, State of Illinois, makes the following declarations as to limitations, restrictions and uses to which those areas designated as stormwater & drainage ways or floodplain wetland & buffer areas in said parcel/subdivision may be put, and specifies that such declarations shall constitute covenants to run with all the land, as provided by law, and shall be binding on all parties and their successors, and all persons claiming under them, and for the benefit of and limitations on all future owners in such parcel/subdivision and the surrounding and downstream and upstream areas, this declaration being in compliance with applicable stormwater and drainage rules, regulations, and ordinances, and suitable for such stormwater retention and drainage pathways and facilities, as specified herein:

1. Use Restriction. A restrictive covenant running with the land for the installation and maintenance of stormwater and drainage floodplain wetlands & buffer areas are reserved as shown on the recorded plat. Within these restricted areas, no structure, planting, or other material shall be placed or permitted to remain which may damage or interfere with the installation or performance of stormwater and drainage floodplain wetland & buffer areas, or which may change the direction of flow of stormwater or drainage channels in the restricted areas, or which may obstruct or retard the flow of water through stormwater and drainage channels in the restricted area. The restricted area of each lot shall be maintained continuously by the owner of the lot, except for those improvements for which a public authority or a homeowners association has formally accepted responsibility.
2. Term This covenant is to run with the land and shall be binding on all parties and their successors and all persons claiming under them, and all public agencies, for a perpetual period from the date these covenants are recorded.
3. Enforcement. Enforcement shall be by proceedings at law or in equity against any person violating or threatening to violate any covenant either to restrain violation or to recover damages. Enforcement may be undertaken by any grantor or grantee in the chain of title, any property owner in the subdivision, any property owner lying downstream or upstream adversely effected by any violation or threat to violate this covenant, or the host municipality or stormwater management commission.
4. Reference. This restrictive covenant shall be referenced on all deeds or other instruments of conveyance for all lots or parcels in said _____ subdivision.

(Template for establishing a stormwater/drainage restrictive covenant by plat of survey)

Howard County, Maryland

Focus

Restrictive Covenants/Easements

Language

For natural drainage systems, the 100-year floodplain shall be enclosed by a Public 100-Year Floodplain, Drainage & Utility Easement or, if the County so desires, conveyed to the County for its fee simple ownership. This area shall be defined by bearings, distances and coordinate values; be tied to property lines; and show the floodplain elevations at all bearing changes and at intervals not exceeding 200 feet between bearing changes. (Howard County Design Manual Vol 1—Storm Drainage, § 1.3)

Licking County, Ohio

Focus

Physical monumentation of floodplain boundary

Language

If areas subject to flooding are included on a lot these areas will need to be delineated by permanent markers on all lot lines, which will noted with their locations shown on the final plat. (Subdivision Regulations, § 4.60(1)(c))

WATERSHED MANAGEMENT

Birmingham, Alabama

Focus

Stormwater Management: Detention/retention facility spillway design

Language

Design Requirements:

a. The detention/retention facility including the principal spillway or outlet structure shall be designed based on runoff estimates for a rainfall event with a 25-year return period.
b. The emergency spillway shall be designed to accommodate the estimated runoff from a rainfall event with a 100-year return period without catastrophic damage to the facility or downstream areas. (Engineering Design Guidelines for Subdivisions or Commercial Developments, § 4.2, p. 6)

City of Brewer, Maine

Focus

Habitat Protection

Language

Any project involving significant wildlife or fisheries habitat or a unique natural area as identified by a government agency such as the Maine Department of Conservation or the Maine Department of Inland Fisheries and Wildlife, or in Brewer's 1995 Comprehensive Plan, shall include mitigation measures aimed at minimizing the adverse impacts of development on these resources. Such mitigation shall include as a minimum:

1. The clustering of the project to protect to the greatest extent the wildlife habitat pursuant to the Planned Unit Development standards of this Land Use Code (Section 425);
2. Setting back of any construction from the upland edge of any wetland area over 20,000 contiguous square feet to meet the most restrictive requirements of the district(s) in which it is located;
3. The setting back of any construction from any stream or waterway to meet the most restrictive requirements of any district(s) in which it is located;
4. Efforts to preserve the existing vegetation in such a manner that the only vegetation cut or removed shall be necessary for the actual construction involved. Specific vegetation to be retained and to be removed shall be indicated on the development plan;
5. Provisions to eliminate noise disturbance in the area. This shall include the construction of sound barrier fencing, and the planting of additional vegetation such as trees.

Mitigation measures shall be indicated clearly on the development plan prior to final approval. (Subdivision Performance Standards, § 435.1)

Bellingham, Massachusetts

Focus

Stormwater Management: Post-development peak flow and detention requirements

Language

Peak storm flows and run-off at the boundaries of the development in any storm of one-hundred-year frequency or less shall be no higher following development than prior to development, unless an increase is authorized by the Planning Board, following consultation with the Conservation Commission and consideration of the ability of receiving wetlands or waterbodies to absorb the increase and the consequences of providing detention capacity. In the Flood Plain District, adequate drainage systems shall be provided to reduce exposure to flood hazards. Drainage systems shall be designed based on a twenty-five-year frequency storm, except that detention facilities shall be based on a one- hundred-year storm, and in a one-hundred-year storm streets shall remain passable and drainage shall not enter buildings. (Subdivision regulations, § 4312)

Raleigh, North Carolina

Focus

Stormwater Management: Development of stormwater operations maintenance manual and budget

Language
Maintenance Manual and Budget

a. The stormwater control plan must be accompanied by a stormwater operations maintenance manual and budget.
b. Prior to either grading any portion of the development or submitting construction drawing plans of any applicable stormwater control facility to the City, whichever event first occurs, a stormwater operations maintenance and budget shall be submitted to the Stormwater Utility Division of the Public Works Department.
c. The maintenance manual shall contain a narrative describing each installed measure and device and its design specifications.
d. The maintenance manual shall describe which lots are served by each device.
e. The maintenance manual shall indicate for each installed measure and device what operation and maintenance actions are needed and what specific quantitative criteria will be used to determine when these actions will be taken.
f. The maintenance manual must indicate the steps that will be taken to restore a measure or device to the design specifications if a failure occurs.
g. The maintenance manual must contain a statement about the expected life of each stormwater control facility and a replacement schedule derived by dividing the initial construction cost of each stormwater control facility by the expected life of that stormwater control facility.
h. The budget shall include annual costs such as routine maintenance, repair, periodic sediment removal and replenishment of rip-rap, insurance premiums associated with the stormwater control facilities, taxes levied against the stormwater control facilities, mowing and reseeding, required inspections. (Unified Development Ordinance, § 9.2.2, p. 9–11)

GLOSSARY

ADCIRC A system of computer programs for solving time-dependent, free-surface circulation and transport problems in two and three dimensions. These programs utilize the finite element method in space allowing the use of highly flexible, unstructured grids. Typical ADCIRC applications have included: prediction of storm surge and flooding, modeling tides and wind-driven circulation, larval transport studies, near-shore marine operations, and dredging feasibility and material disposal studies.

alluvial fan Flooding occurring on the surface of an alluvial fan or similar landform which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flowpaths.

Community Rating System A voluntary incentive program of the National Flood Insurance Program that recognizes and encourages community floodplain management activities that exceed the minimum program requirements.

floodplain A generally flat area of land next to a river or stream. It stretches from the banks of the river to the outer edges of the valley and consists of two parts. The first is the main channel of the river itself, called the floodway. Beyond the floodway is the flood fringe. The flood fringe extends from the outer banks of the floodway to the bluff lines of a river valley.

floodway Part of a floodplain. Floodways can sometimes be seasonal, meaning the channel is dry for part of the year. A "regulatory floodway" refers to the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

freeboard A factor of safety, usually expressed in feet above a flood level, for purposes of floodplain management. It tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed.

green infrastructure A cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.

low-impact development Systems and practices that use or mimic natural processes, which result in the infiltration, evapotranspiration, or use of stormwater in order to protect water quality and associated aquatic habitat.

monumentation A monument is any object or collection of objects (physical, natural, artificial) that indicates the position on the ground. Primary monumentation and control are the base monuments used to control surveying, design, and construction of a project. Monumentation is also the relative course and distance between monuments.

natural and beneficial functions The functions associated with the natural or relatively undisturbed floodplains that moderate flooding, retain flood waters, reduce erosion and sedimentation, mitigate the effect of waves and storm surge from storms, and reduce flood-related damage. Ancillary beneficial functions include maintenance of water quality and recharge of ground water, which reduces flood-related damage.

No Adverse Impact An approach that ensures the action of any community or property owner, public or private, does not adversely impact the property and rights of others. An

adverse impact can be measured by an increase in flood stages, flood velocity, flows, the potential for erosion and sedimentation, degradation of water quality, or increased cost of public services.

Special Flood Hazard Area Land area covered by the floodwaters of the base flood is the Special Flood Hazard Area on National Flood Insurance Program maps. This area is where the program's floodplain management regulations must be enforced and where the mandatory purchase of flood insurance applies.

V-zone Areas along coasts subject to inundation by the 1-percent annual chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no base flood elevations or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Sources: ADCIRC, Association of State Floodplain Managers, Federal Emergency Management Agency, National Geographic Society, Texas Department of Transportation, US Environmental Protection Agency

REFERENCES

American Forests. 2003. *Urban Ecosystem Analysis: Mecklenburg County, North Carolina*. Available at http://charmeck.org/city/charlotte/epm/services/landdevelopment/trees/treecommission/documents/charlotte_final.pdf.

———. 2010. *Urban Ecosystem Analysis: Mecklenburg County and the City of Charlotte, North Carolina*. Available at http://charmeck.org/city/charlotte/epm/services/landdevelopment/documents/charlotte%20mecklenburg%20uea_lowres%20final2.pdf

American Lifelines Alliance. 2005. *Flood-Resistant Local Road Systems: A Report Based on Case Studies*. Available at www.floods.org/PDF/ALA_Flood-Roads_January%202005%20ASFPM%20final.pdf.

American Planning Association. 2009. *Low-Impact Development*, PAS Essential Info Packet 15.

———. 2013. *The Planners' Communication Guide 2.0*. Chicago: American Planning Association.

———. 2014. *Community Planning Assistance Teams: Living with the Saint Vrain*. Available at https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/communityassistance/teams/lyons/pdf/finallyonsreport.pdf. https://www.planning.org/communityassistance/teams/lyons/pdf/finallyonsreport.pdf.

APRA (Association of Professional Reserve Analysts). 2012. *Standard of Practice*. Available at www.apra-usa.com/.

ASCE (American Society of Civil Engineers). 2010. *So, You Live Behind a Levee!* Available at www.culvercity.org/home/showdocument?id=2076.

ASDSO (American Society of Dam Safety Officials). 2012. *Living with Dams: Know your Risk*. Available at www.damsafety.org/media/Documents/DownloadableDocuments/LivingWithDams_ASDSO2012.pdf.

Arendt, Randall G. 1996. *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks*. Washington, DC: Island Press.

———. 2015. *Rural by Design*, Second Edition. Chicago: Planners Press.

ASFPM (Association of State Floodplain Managers). 2004. *No Adverse Impact Floodplain Management: Community Case Studies*. Available at www.floods.org/PDF/NAI_Case_Studies.pdf.

———. 2007. *National Flood Programs and Policies in Review*. Available at www.floods.org/index.asp?menuid=%20443.

———. 2008a. *Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction*. Available at www.floods.org/PDF/WhitePaper/ASFPM_NBF%20White_Paper_%200908.pdf.

———. 2008b. *NAI—No Adverse Floodplain Management*. Available at www.floods.org/NoAdverseImpact/NAI_White_Paper.pdf.

———. 2010. *A Guide for Higher Standards in Floodplain Management*. Available at www.floods.org/ace-files/documentlibrary/committees/Insurance/ASFPM_Higher_Standards_Reference_Guide_1010.pdf.

———. 2013a. *Flood Mapping for the Nation: A Cost Analysis for the Nation's Flood Map Inventory*. Available at www.floods.org/ace-files/documentlibrary/2012_NFIP_Reform/Flood_Mapping_for_the_Nation_ASFPM_Report_3-1-2013.pdf .

———. 2013b. *Infrastructure: How-To Guide for No Adverse Impact*. Available at www.floods.org/NoAdverseImpact/NAI_How-to-Guide_Infrastructure.pdf.

———. 2014. "Columbia Venture, LLC v. Richland County Motion by the Association of State Floodplain Manager, Inc. for Leave to File Brief of Amicus Curiae in Support of Respondent." Available at www.floods.org/ace-files/documentlibrary/Legal_Papers/ColumbiaVenture_v_RichlandCounty_ASFPM_AmicusBrief_9-8-14.pdf.

———. 2016. "NAI Toolkit How-To Guides." Available at www.floods.org/index.asp?menuID=460.

Baltimore (Maryland), City of. 2013. *Disaster Preparedness and Planning Project: A Combined All Hazards Mitigation and Climate Adaptation Plan*. Available at www.baltimoresustainability.org/plans/disaster-preparedness-plan.

Benedict, Mark A., and Edward T. Mcmahon. 2006. *Green Infrastructure: Linking Landscapes and Communities*. Washington, DC: Island Press.

Berding, Tyler, and Stephen Weil. 2012. *No Reserves. No Insurance: What's Left If a Natural Disaster Destroys a Community Association?* Available at www.berding-weil.com/pdf/disaster.pdf.

Berginnis, Chad, and Bill Brown. 2016. [Demographic data on local floodplain managers in the United States.] Unpublished raw dataset.

Brody, Sam, Russell Blessing, Antonia Sebastian, and Philip Bedient. 2013. "Examining the Impact of Land Use/Land Cover Characteristics on Flood Losses." *Journal of Environmental Planning and Management* 57 (8): 1252–1265.

Cedar Falls, City of (Iowa). 2016. *Stormwater Management Program 2015*. Available at www.cedarfalls.com/DocumentCenter/Home/View/4151.

Center for Neighborhood Technology. 2009. "Green Values National Stormwater Management Calculator." Available at http://greenvalues.cnt.org/national/calculator.php.

Chapel Hill, Town of (North Carolina). 2015. *Future Conditions Floodplain Mapping Report*. Available at http://townhall.townofchapelhill.org/agendas/2015/01/26/materials.pdf.

Community Associations Institute. 2015. "Community Associations in the United States." Available at www.caionline.org/AboutCommunityAssociations/Pages/StatisticalInformation.aspx.

Crouch, Sherry, Manuel Perotin, and William Cesanek. 2014. *Planning Resilient Infrastructure*. Available at https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/research/postdisaster/briefingpapers/pdf/infrastructure.pdf.

Davidson, Debra J. 2010. "The Applicability of the Concept of Resilience to Social Systems: Some Sources to Optimism and Nagging Doubts." *Society & Natural Resources* 23 (12): 1135–1149.

Earth Economics. 2015. *Nature's Value in the Colorado River Basin*. Available at www.eartheconomics.org/FileLibrary/file/Reports/Earth%20Economics%20Colorado%20River%20Basin%20ESV%20FINAL.pdf.

Federal Interagency Floodplain Management Task Force. 1992. *Floodplain Management in the United States: An Assessment Report*, Volume 1, Summary Report. Available at www.fema.gov/media-library/assets/documents/432.

FEMA (Federal Emergency Management Agency). 1986. *A Unified National Program for Floodplain Management*. Available at www.fema.gov/media-library-data/20130726-1503-20490-9177/fema100.pdf.

———. 2001. *Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using Future-Conditions Hydrology for the National Flood Insurance Program*. Available at www.fema.gov/media-library-data/20130726-1545-20490-3997/frm_frpt.pdf.

———. 2005. "National Flood Insurance Program: Frequently Asked Questions, Repetitive Loss." Available at www.fema.gov/txt/rebuild/repetitive_loss_faqs.txt.

———. 2013a. *Mitigation Policy FP-108-024-01: Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs*. Available at www.fema.gov/media-library-data/20130726-1920-25045-4319/environmental_benefits_policy_june_18_2013_mitigation_policy_fp_108_024_01.pdf.

———. 2013b. *National Flood Insurance Program Community Rating System Coordinator's Manual*. Available at www.fema.gov/media-library-data/1406897194816-fc66ac50a3af94634751342cb35666cd/FIA-15_NFIP-Coordinators-Manual_2014.pdf.

———. 2014a. F*EMA Strategic Plan 2014–2018*. Available at www.fema.gov/media-library-data/1405716454795-3abe60aec989ecce518c4cdba67722b8/July18FEMAStratPlanDigital508HiResFINALh.pdf.

———. 2015. "National Flood Insurance Program Community Rating System." Available at www.fema.gov/national-flood-insurance-program-community-rating-system.

———. 2016. "Protecting Your Businesses." Available at www.fema.gov/protecting-your-businesses.

Godschalk, David R. 2006. "Buildout Analysis: A Valuable Planning and Hazard Mitigation Tool." *Zoning Practice*, March.

———. 2009. "Safe Growth Audits." Z*oning Practice*, October.

Godschalk, David R., and William R. Anderson. 2012. *Sustaining Places: The Role of the Comprehensive Plan*, PAS Report 567. Chicago: American Planning Association.

Godschalk, David R., and David C. Rouse. 2015. *Sustaining Places: Best Practices for Comprehensive Plans*, PAS Report 578. Chicago: American Planning Association.

Gresham, City of (Oregon) and Portland, City of (Oregon). 2004. *Pleasant Valley Natural Resources Protection Plan*. Available at www.portlandoregon.gov/bps/article/69463.

Highfield, Wesley E., and Samuel D. Brody. 2006. "Price of Permits: Measuring the Economic Impacts of Wetland Development on Flood Damages in Florida." *Natural Hazards Reivew* 7 (3): 123–130.

Holmes Jr., Robert R., and Karen Dinicola. 2010. *100-Year Flood–It's All About Chance*. Available at http://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210.pdf.

Hostetler, Mark E. 2012. *The Green Leap: A Primer for Conserving Biodiversity in Subdivision Development*. Berkeley: University of California Press.

Houston Parks Board. 2016. "Bayou Greenways 2020." Available at http://houstonparksboard.org/bayou-greenways-2020/2020.

Hurricane Sandy Rebuilding Task Force. 2013. *Hurricane Sandy Rebuilding Strategy*. Available at http://portal.hud.gov/hudportal/documents/huddoc?id=hsrebuildingstrategy.pdf.

IDNR (Illinois Department of Natural Resources) and NIPC (Northeastern Illinois Planning Commission). 1996. *Model Floodplain Ordinance: For Communities within Northeastern Illinois*. Available at https://datahub.cmap.illinois.gov/dataset/999f7f64-89ea-4429-9c20-3d8037854701/resource/68d43cb4-6ab6-4741-b05f-94373a45cefa/download/nipcjuly1996modelfloodplainordneil.pdf.

IPCC (International Panel on Climate Change). 2014. *Climate Change 2014 Impacts, Adaptation and Vulnerability*. New York: Cambridge University Press. Available at www.ipcc.ch/report/ar5/wg2.

Joint Powers Insurance Authority of the Montana Association of Counties, Montana League of Cities and Towns, Montana Board of Professional Engineers and Professional Land Surveyors, and the Department of Commerce. 2006. *Montana's Subdivision and Surveying Laws and Regulations*, 19th Edition. Available at www.mtcounties.org/sites/default/files/forms-downloads/model-policies-regulations-codes/mt-subdivision-surveying-laws-regulations.pdf.

Kusler, Jon A. 2011. *Assessing the Natural and Beneficial Functions of Floodplains: Issues and Approaches*. Available at www.aswm.org/pdf_lib/nbf.pdf .

Lewes, City of (Delaware). 2011. *The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan*. Available at www.ci.lewes.de.us/pdfs/Lewes_Hazard_Mitigation_and_CLimate_Adaptation_Action_Plan_FinalDraft_8-2011.pdf.

Lyons (Colorado), Town of. 2014. *Recovery Action Plan: Colorado Floods of 2013*.

McElvaney, Shannon, and David Rouse. 2015. "Geodesign and the Future of Planning." *PAS Memo*, March/April. Available at https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/pas/memo/geodesign/pdf/geodesignpasmemo.pdf.

Montana, State of. 2014. *2014 Model Regulations: Floodplain Hazard Management Regulations*. Available at http://dnrc.mt.gov/divisions/water/operations/docs/floodplain/permitting/model_regulations_2014_rev.pdf.

Montana Fish, Wildlife & Parks. 2012. *Fish and Wildlife Recommendations for Subdivision Development in Montana*. Available at http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/buildingWithWildlife/subdivisionRecommendations/documents.html.

Morris, Marya. 1997. *Subdivision Design in Flood Hazard Areas*, PAS Report 473. Chicago: American Planning Association.

Morris, Marya, ed. 2009. *Smart Codes: Model Land-Development Regulations*, PAS Report 556. Chicago: American Planning Association.

Musiol, Erin, and Marty Ryan. 2013. "Case Study: Cedar Falls, Iowa." Available at www.planning.org/research/postdisaster/casestudies/cedarfalls.htm.

National Research Council. 1996. *Alluvial Fan Flooding*. Washington DC: National Academic Press. Available at www.nap.edu/catalog/5364/alluvial-fan-flooding.

———. 2002. *Riparian Areas: Functions and Strategies for Management*. Washington, DC: National Academy Press. Available at www.nap.edu/catalog/10327/riparian-areas-functions-and-strategies-for-management.

National Resources Conservation Service. 2007. *Part 654 Stream Restoration Design, National Engineering Handbook*. Available at http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17770.wba.

New Jersey Future. 2015. *In Deep: Helping Sandy-Affected Communities Address Vulnerability and Confront Flood Risk*. Available at www.njfuture.org/wp-content/uploads/2015/10/NJFuture-In-Deep-10-15-WEB.pdf.

NIPC (Northeastern Illinois Planning Commission). 2003. *Conservation Design Resource Manual: Language and Guidelines for Updating Local Ordinances*. Available at www.ecologyactioncenter.org/mCLEANwater/wp-content/uploads/2012/03/Conservation_Design_Resource_Manual.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2015. "Flooding in Montana."Available at www.floodsafety.noaa.gov/states/mt-flood.shtml.

NOAA (National Oceanic and Atmospheric Administration) and ASFPM (Association of State Flood Plain Managers). 2007. *Coastal No Adverse Impact Handbook*. Available at www.floods.org/index.asp?menuid=340.

Norfolk, City of (Virginia). 2013. *City of Norfolk Coastal Flood Mitigation Program*. Available at www.norfolk.gov/DocumentCenter/View/3774.

Northampton County (Pennsylvania). 2005. *Two Rivers Area Greenway Plan*. Prepared by Urban Research & Development Corporation. Available at http://bushkill.org/Two_Rivers_Area_Greenway_Plan.pdf.

Ohm, Brian W. 2005. "Let the Courts Guide You: Planning and Zoning Consistency." *Zoning Practice*, November. Available at https://law.wustl.edu/landuselaw/Articles/Consistency,BrianOhm.pdf.

Opperman. Jeffery J. 2014. *A Flood of Benefits: Using Green Infrastructure to Reduce Community Flood Risks*. Available at www.conservationgateway.org/ConservationPractices/Freshwater/HabitatProtectionandRestoration/Documents/A%20Flood%20of%20Benefits%20-%20J.Opperman%20-%20May%202014.pdf.

Pennsylvania Land Trust Association and Brandywine Conservancy. 2014. *A Scientific Foundation for Shaping Riparian Buffer Protection Regulations*. Available at http://conservationtools.org/guides/132-a-scientific-foundation-for-shaping-riparian-buffer-protection-regulations.

Port Orange, City of (Florida). 2016. *Land Development Code of the City of Port Orange, Florida*. Available at www.municode.com/library/fl/port_orange/codes/land_development_code?nodeId=LADECO_CH8BUFICO.

Portland, City of (Oregon). 2015. *Pleasant Valley Natural Resources Overlay Zone*. Available at www.portlandoregon.gov/bps/article/82635.

Punchard, Darrin. 2015. "Living with the River in Lyons, Colorado." Association of State Floodplain Managers Annual National Conference, Atlanta, GA, May 31–June 5.

Rhode Island, State of. 2011. *Rhode Island Low Impact Development Site Planning and Design Guidance Manual*. Prepared by Horsley Witten Group, Inc. and Scott Millar, Rhode Island Department of Environmental Management. Available at www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/lidplan.pdf.

RIDEM (Rhode Island Department of Environmental Management) and CRC (Coastal Resources Council). 2011. *Rhode Island Low Impact Development Site Planning and Design Guidance Manual*. Available at www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/lidplan.pdf.

Roths, Richard. 2008. "Using Zoning to Reduce Flood Damages." *Zoning Practice*, March.

Rouse, David C., and Ignacio F. Bunster-Ossa. 2013. *Green Infrastructure: A Landscape Approach*, PAS Report 571. Chicago: American Planning Association.

Schwab, James C., ed. 2009. *Planning the Urban Forest: Ecology, Economy, and Community Development*, PAS Report 555. Chicago: American Planning Association.

———. 2010. *Hazard Mitigation: Integrating Best Practices into Planning*, PAS Report 560. Chicago: American Planning Association.

Schwab, James C. 2015. "A Rising Tide of Engagement." *Planning*, August/September, 14–19.

Smith, Adam B., and Richard W. Katz. 2013. "US Billion-Dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy, and Biases." *Natural Hazards*, 67 (2): 387–410.

SCDNR (South Carolina Department of Natural Resources). 2015. "South Carolina Flooding 2015." Available at http://scdnr.maps.arcgis.com/apps/MapJournal/index.html?appid=bc1ea6edf5eb495189be4968e0cd0edb.

South Carolina, State of. 2015. *The State of South Carolina in the Supreme Court: Columbia Venture, LLC, Appellant v. Richland County, Respondent*. Available at www.floods.org/ace-files/documentlibrary/Legal_Papers/ColumbiaVenture_v_RichlandCounty_SC_SupremeCourtOpinion_8-12-15.pdf.

Thomas, Edward, and Terri Turner. 2011. "Climate Change and Emergency Management: Adaptation Planning." Section Meeting, Providence, RI, Fall. Available at www.americanbar.org/content/dam/aba/publications/state_and_local_law_news/sl_34_3_thomas_turner.authcheckdam.pdf.

Turner, Terri L. 2012. "Promoting Flood Resiliency through the Regulatory Process." *Zoning Practice*, April.

UNISDR (United Nations Office for Disaster Risk Reduction). 2015. *The Human Cost of Weather Related Disaster: 1995–2015*. Available at www.preventionweb.net/files/46796_cop21weatherdisastersreport2015.pdf.

US Census Bureau. 1995. "Table 2. 1990 and 1980 Census Counts for Cities with 1990 Population Greater than 100,000." Available at www.census.gov/population/www/censusdata/files/c1008090pc.txt.

———. 2010a. "CPH-T-5. Population Change for Metropolitan and Micropolitan Statistical Areas in the United States and Puerto Rico (February 2013 Delineations): 2000 to 2010." Available at www.census.gov/population/www/cen2010/cph-t/CPH-T-5.pdf.

———. 2010b. "Lyons Town, Colorado: Profile of General Population and Housing Characteristics 2010." DP-1, American FactFinder.

———. 2010c. "QuickFacts: Plano City, Texas." Available at www.census.gov/quickfacts/table/PST045215/4858016.

———.2015."QuickFacts:Montana."Availableatwww.census.gov/quickfacts/table/PST045215/00,30.

US Department of Education. 2009. *Implementing Data-Informed Decision Making in Schools: Teacher Access, Supports, and Use*. Prepared by Barbara Means, Christine Padilla, Angela DeBarger, and Marinne Bakia, SRI International. Available at http://files.eric.ed.gov/fulltext/ED504191.pdf.

US Department of Housing and Urban Development. 2002. *The Natural and Beneficial Functions of the Floodplain: Reducing Flood Losses by Protecting and Restoring the Floodplain Environment*. Available at http://portal.hud.gov/hudportal/documents/huddoc?id=DOC_14217.pdf.

———. 2014. *Sample Restrictive Covenant for Floodplains and Wetlands*. Available at http://portal.hud.gov/hudportal/documents/huddoc?id=RestrictvCovFldplWtld.doc .

———. 2015a. "HUD Selects Finalists for National Disaster Resilience Competition." Available at http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2015/HUDNo_15-079.

———. 2015b. *National Disaster Resilience Competition: Phase 2 Fact Sheet*. Available at http://portal.hud.gov/hudportal/documents/huddoc?id=NDRCFactSheetFINAL.pdf.

US Environmental Protection Agency. 2016. "What Is Green Infrastructure?" Available at www.epa.gov/green-infrastructure/what-green-infrastructure.

US Geological Survey. 2010. "How Much of Your State Is Wet?" Available at http://water.usgs.gov/edu/wetstates.html.

Vogel, Richard, Chad Yaindl, and Meghan Walter. 2011. "Nonstationarity: Flood Magnification and Recurrence Reduction Factors in the United States." *Journal of the American Water Resources Association* 47 (3): 464–474.

Winters, Brad. 2015. R*eport for the Urban Flooding Awareness Act*. Available at www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Report.pdf.

Wright, James M. 2007. *Floodplain Management: Principles and Current Practices*. Available at https://training.fema.gov/hiedu/aemrc/courses/coursetreat/fm.aspx.

ACKNOWLEDGMENTS

Subdivision Design and Flood Hazard Areas is the result of a contract between the American Planning Association (APA) and the Federal Emergency Management Agency (FEMA). The work that provided the basis for this publication was supported by funding under Department of Homeland Security–Federal Emergency Management Agency cooperative agreement #EMW-2014-CA-00258-S01 with APA. The substance and findings of that work are dedicated to the public.

The report was developed under the auspices of the Hazards Planning Center, one of APA's National Centers for Planning. The center engages in research, policy, outreach, and education that advances hazard mitigation and disaster recovery through planning. For more information, visit www.planning.org/nationalcenters/hazards/. APA's National Centers for Planning conduct policy-relevant research and education involving community health, natural and human-made hazards, and green communities. For more details, visit https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/nationalcenters/pdf/nationalcentersbrochure.pdf.

Nicholas Walny served as an APA intern during this project, contributed three of the case studies, and contributed to Chapter 2. **Anna Read, AICP**, APA senior program development & research associate, led the writing of Chapter 2 and participated in other aspects of the project, including a February 2014 symposium to help define the dimensions of the project. **Joseph DeAngelis**, APA research associate, prepared the executive summary.

Several members of the staff of the Association of State Floodplain Managers also contributed to the project and the symposium: **Chad Berginnis**, executive director, who made major contributions to the report itself in Chapters 1, 4, and 5 and who was vital in helping define the overall project and its purpose; **Jeffrey Stone**, program manager; and **Bridget Faust**, project research specialist.

We would like to thank the following individuals at APA who contributed to or supported this project, including through participation in the symposium: **David Rouse, FAICP**, managing director of research and advisory services, who reviewed the manuscript and contributed project oversight; **Nick Ammerman**, library and taxonomy manager, who oversaw development of the annotated online bibliography; and library intern **Danielle Moore**, who contributed to the bibliography.

In addition, the following individuals served as invited experts at the symposium and contributed in other ways throughout the project: **Eric W. Kuklewski**, risk analysis branch chief, FEMA Region 5; **Fred Kaehler**, floodplain management and insurance branch chief, FEMA Region 5; **Julia McCarthy**, floodplain management specialist, FEMA Region 5; **Terri L. Turner**, development administrator/floodplain manager/hazard mitigation specialist for Augusta, Georgia, who also contributed to Chapters 1 and 4; **Samuel D. Brody**, professor, Texas A&M University, who contributed the Evia case study; **Jerry Brem**s, retired planning director, Licking County, Ohio, who contributed the Licking County case study; **J. William Brown**, formerly stormwater executive manager, City of Arlington, Texas, who more recently became program manager at the Association of State Floodplain Managers; **Tiffany Lyden**, floodplain outreach specialist, Montana Department of Natural Resources and Conservation; and **Deborah Mills**, hazard mitigation client manager, Dewberry.

We want to thank **Camille Fink**, APA Senior Editor, for her assistance with shepherding and copyediting the manuscript and participating in the symposium. We also want to thank **Kathleen W. Smith, AICP**, chief, Planning & Safety Branch, FEMA Federal Insurance and Mitigation Administration, who served as the agency project officer, participated in the symposium, coordinated peer review within FEMA.

Finally, the following individuals from FEMA all contributed subject matter expertise in advance of the symposium and participated in reviewing the draft manuscript: **Jonathan "Ed" Smith**, coordinator, National Flood Insurance Program, FEMA Office of Environmental Planning and Historic Preservation (OEHP); **Kimberly Pettit**, environmental protection specialist, FEMA OEHP; **Kathryn Bissell**, environmental protection specialist, FEMA OEHP; **Lois Forster**, senior floodplain management program specialist, FEMA; and **Jennifer Burmester**, national mitigation planning program manager, FEMA.

POWER TOOL

PAS SUBSCRIBERS GET EVERY NEW PAS REPORT, PLUS THESE RESOURCES FOR EVERYONE IN THE OFFICE TO SHARE

PAS Reports Archive
Free online access for subscribers

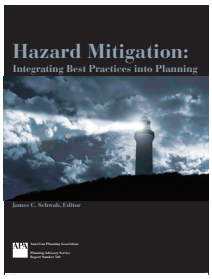
Inquiry Answer Service
A crack research team on call

PAS Memo
Bimonthly shoptalk on hot planning issues

PAS QuickNotes
Bite-size backgrounders on planning basics

PAS Essential Info Packets
Resource roundup on a single topic

Learn more about PAS subscriptions at **planning.org/pas**



PAS 560
2010
146 pp.
$60

Hazard Mitigation
James C. Schwab, FAICP, ed.

A gap often exists between hazard mitigation planning and other local planning and regulatory land-use processes. This report introduces hazard mitigation as a vital area of practice for planners and provides guidance on how to integrate hazard mitigation strategies into planning.

PAS 571
2013
144 pp.
$60

Green Infrastructure: A Landscape Approach
David C. Rouse, FAICP, and Ignacio F. Bunster-Ossa

Explore the benefits of green infrastructure. This well-grounded report outlines six principles for successful green infrastructure projects that can help clean the air and water, replenish aquifers, reduce flooding, and moderate the climate.

PAS 576
2014
200 pp.
$64

Planning for Post-Disaster Recovery: Next Generation
James C. Schwab, FAICP, ed.

This updated manual offers a no-nonsense explanation of the benefits—and limitations—of planning for unpredictable events. Case studies from big cities and smaller towns show what it takes to come back stronger from a natural disaster.

PAS 581
2016
84 pp.
$48

Coastal Zone Management
Elizabeth Felter and Marya Morris, FAICP

More than half the US population lives in coastal watershed counties. How can they break the cycle of damage-rebuild-damage? This report helps them find answers—and find the sweet spot between environmental protection, economic rewards, and social equity.

Order back issues of these and other PAS Reports at planning.org/books.

American Planning Association
205 N. Michigan Ave., Suite 1200
Chicago, IL 60601-5927

planning.org