THE 6TH GILBERT F. WHITE NATIONAL FLOOD POLICY FORUM

Increasing Our Resiliency to Urban Flooding

George Washington University – Marvin Center, 3rd Floor
800 21st Street NW, Washington, DC 20052
March 12-13, 2019

Thought Papers submitted by invited participants for background reading to help frame discussion prior to the event

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Using Natural Infrastructure Solutions to Increase Resilience
Gary Belan, Sr. Director Clean Water Supply, American Rivers

Communities in the United States are being threatened by sewage overflows, flooding, polluted stormwater, leaky pipes, and at-risk water supplies. These threats are a result of our nation's outdated water infrastructure and water management strategies, and their impacts fall disproportionately on low-wealth neighborhoods and communities of color that are already suffering from a lack of investment and opportunity. To solve this problem, we do not just need more investment in water infrastructure. We need a new kind of water infrastructure and management, and we need it in the right places. The solution is the equitable investment in and implementation of natural infrastructure. If natural infrastructure is used in a more integrated water system, we can transform and restore our environment, invigorate the economy, and confront some of our country's most persistent inequities.

Natural water infrastructure protects, restores, or mimics natural water systems, working with traditional infrastructure, like pipes and treatment plants, and reducing the strain on those systems. Examples include protecting source water streams that provide drinking water to our communities, reducing water treatment costs; protecting natural floodplain areas to reduce flood damage; and restoring or increasing urban trees and green space to soak up and clean polluted stormwater, which reduces the surges in stormwater pipes and prevents flooding. These natural solutions add flexibility and resiliency to our water infrastructure due to their ability to complement and supplement existing infrastructure efficiently and the ease with which they can be adapted to changing community needs.

It is easy to overlook the extent to which we depend on natural infrastructure until catastrophe strikes. We take for granted that water will continue to flow from the tap, reliable and safe, that our homes are protected, and that our local waterways are healthy. We have been steadily losing the natural systems that provide communities with these benefits, and as we have lost this natural infrastructure, we have failed to adequately replace the lost services they provide. The result is decaying or outdated infrastructure that cannot keep pace with changing demand for water and wastewater treatment, growing populations, and increasingly severe storms. While these challenges affect all communities, the most severe impacts often fall on low-wealth communities and communities of color due to historic underinvestment and disinvestment in these communities.

Equitable investment in water infrastructure explicitly engages community voice, policy, planning, investment, hiring, contracting, and operations to ensure that historically underserved communities receive the water infrastructure investment they need, in a manner that improves public health, improves livability, and supports community cohesion. Since, historically, infrastructure investments have closely followed the geography of opportunity – higher income areas have high-quality infrastructure investments, and low income areas have suffered decades of underinvestment and disinvestment, and crumbling systems of transportation, schools, and, in particular, drinking water and waste water. These disadvantaged communities often lack adequate infrastructure, lack affordable water rates, and lack access to clean, safe water. Disadvantaged communities are often located in floodplains, in drained wetlands, or adjacent to sewage outfalls, as a result of historic discrimination.

Water infrastructure and equity challenges can be effectively overcome together through a more holistic approach, particularly when natural infrastructure, with its flexibility, is included as part of the solution. This “integrated” or One Water approach to water management centers on breaking down ‘silos’ to create holistic, coordinated water systems that maximize economic, social, and environmental benefits in an equitable and sustainable manner. This integrated approach is achieved by bringing together city agencies, nonprofits, and other diverse stakeholders for collective problem-solving and decision-making that benefits all members of the community.

Natural infrastructure provides substantial economic and social benefits to the nation and to neighborhoods. The U.S. Water Alliance states in their Value of Water report that the U.S. needs to invest an additional $82 billion per year in water infrastructure – both natural and traditional – to meet projected needs. The same report states that by closing this gap over $220 billion in total annual economic activity would be added to the economy every year and would sustain approximately 1.3 million jobs over the next 10 years. In addition, investment in natural infrastructure creates local jobs.

According to a report by the Environmental Finance Center at the University of Maryland, natural infrastructure often increases local jobs, since these practices rely more heavily on local workers for installation and continued maintenance, in contrast to traditional infrastructure, which often relies on larger firms that outsource the work. As the number and scope of natural infrastructure initiatives increase, opportunities for developing more jobs will increase as well. According to the Brookings Institute, green job growth outpaced traditional job growth at a rate of nearly 2-to-1 in the nation’s 100 largest metropolitan centers from 2008 to 2010, providing diverse, career-starting opportunities in growth industries for communities that need them most.

To address the significant water infrastructure needs of the nation, greater investments in both natural and traditional water infrastructure are needed. From major metropolitan areas to unincorporated rural communities – particularly those home to low-wealth communities and communities of color – investments are needed to address the consequences of long deferred maintenance, underinvestment, and disinvestment. We will need to use existing water infrastructure funding mechanisms to implement natural infrastructure at the scale and scope needed to address our nation’s water infrastructure inequities. Funding mechanisms for natural infrastructure are diverse and include traditional mechanisms such as bonds, general funds, and state revolving funds as well as innovative approaches like public/private partnerships or incorporating water management in all types of infrastructure projects.

We must engage with multiple, crosscutting stakeholders. Where planning and decision-making tables are too small or exclusive, we must make them bigger and add more chairs for communities and partners that have not always had a seat at the table. The water management sector must break out of the silos that constrain diverse and innovative solutions. The challenge before us is clear. The solutions are tangible. The moment to create a better future for clean water and communities is now.

Urban Flooding: The Flood Hazard That Has Been "Left Behind"

Tom Leatherbee, MCP, AINS, CFM, Insurance & Regulatory Affairs Committee Chair, Oklahoma Floodplain Managers Association and **Jeff Bigby,** P.E., CFM, Chair, Oklahoma Floodplain Managers Association

Historically flood risk has been classified as being either coastal or riverine. This classification, rooted in insurance ratings and National Flood Insurance Program regulatory framework, is exclusionary in nature and has resulted in a deprioritization of urban flood risk. Despite efforts to shift risk communication messaging, achieving broad acceptance for non-floodplain risk has been difficult. Even after several significant flooding disasters have primarily impacted properties outside of mapped "high risk" areas, factors leading to urban flood risk being deemphasized remain.

<u>The Third Flood Hazard</u>

Until a more holistic view of urban flood risk becomes commonplace, it may be necessary to view urban flooding as a "Third Flood Hazard", on a level of hazard equal to riverine and coastal flooding. Other than after a flood or before a municipal stormwater improvements funding vote, flood risk rises to the consciousness of most individuals when they encounter the regulatory environment such as land use regulations or mandatory purchase requirements. Communicating about the "Third Flood Hazard" on multiple levels will help build the consciousness and support for more comprehensive hazard mitigation. This effort will be challenging without having the benefit of the "touch points" offered within the context of NFIP requirements.

<u>Reexamining Limiting Assumptions</u>

Urban flood risk cannot be adequately addressed unless current assumptions underlying flood damage protection and hazard mitigation are reexamined.

- The impacts of climate change on storm intensity and rainfall amounts must be considered since hydrology and hydraulic calculations requiring accurate data are needed for planning to inform risk reduction strategies.

- Certain NFIP practices that play a role in limiting hazard mitigation opportunities must not be ignored. Even though urban flood losses are increasing, much of it is occurring outside of the SFHA. Those losses are less likely to be insured, and thus the losses are not reflected in NFIP paid claims data and are not being classified as repetitive loss properties. Various factors contribute to urban flood risk being significantly more difficult to remediate using existing grant funding mechanisms.

<u>Stormwater Infrastructure</u>

Unlike riverine or coastal flood mitigation involving development restriction and restoring natural and beneficial functions and allowing floodplains to function as nature intended, urban flood remediation requires a careful balance of both infrastructure and regulation, due to the nature, density, and history of the built environment.

- Increased funding is important to address urban flooding, since much of the hazard is caused by undersized or poorly maintained conveyances. Anecdotally, communities with established stormwater utilities seem to be more advanced in their efforts to mitigate urban flooding. Consistent stormwater utility fee calculation methods, exemptions, user discounts, etc. are critically important to avoid political turmoil and litigation, thereby discouraging other communities from enacting necessary stormwater utilities. An interesting, albeit controversial idea, would be to require a dedicated funding mechanism for flood hazard mitigation as a prerequisite for NFIP participation. If all participating communities had a stormwater utility fee based on impervious surface area, mitigation would be more prominent.

- It is impossible to plan or implement flood hazard mitigation efforts in an effective and efficient manner without master drainage planning. A master drainage plan covering the affected subwatershed, detailing current to fully urbanized conditions should be a prerequisite to obtaining mitigation project funding. Without modeling fully urbanized conditions, it is not only impossible to plan and implement public projects, but also to adequately review and approve private development. Since master drainage planning reduces risk while maximizing public funds, plan creation must be seen as an eligible HM project or an additional set aside of hazard mitigation planning funds must be made available to communities.

- Effects of watershed increased impervious areas can be modeled using fully urbanized conditions, but even the best modeling often cannot account for decreased floodplain storage, lost hydrologic and water quality benefits of removed wetlands, water quality degradation, and adverse habitat impacts. Promotion and utilization of low impact development or green infrastructure for both new and infill development is necessary for overall health of watersheds.

<u>Regulation</u>

The minimum standards in 44 CFR §60.3 were never intended as a comprehensive solution to resolve flood risk. Acknowledging the political reality has made enacting more appropriate regulations impossible, alternative ways forward toward higher standards are necessary. The term “higher standards” is problematic from a political perspective, as is the current patchwork of varying standards between neighboring communities.

- National regulatory standards for land use and building construction that are sufficient to significantly decrease flood risk are needed. Critical standards are building elevation freeboard, development drainage design, and development peak flow reduction. Applying freeboard to structures above an adjacent street or overflow path can be just as important to urban flood mitigation as freeboard is above a riverine setting. Many habitable structures are flood damaged simply from poor development grading, inattention to overland flow paths, and inadequately sized stormwater conveyance systems. Peak flow reduction through stormwater detention facilities is a common national development practice, but is often badly executed due to poor design\construction\maintenance.

- Uniform national standards can be implemented through structured incentives and disincentives, but the structure must be simple and straightforward. The Community Rating System recognizes communities that go above minimum floodplain management standards, but it is far too complicated and actually may serve to increase the "patchwork" problem of conflicting regulations. A different approach may be the NFIP's Emergency Program vs. Regular Program. Communities choosing to forego adopting national standards could remain in the NFIP, but coverage amounts could be limited, deductibles increased, or a surcharge applied. Perhaps more palatably, communities choosing to adopt the few but meaningful new standards could have access to higher limits, lower deductibles, or actuarial based discounts.

- Current definitions of substantial improvement\substantial damage allow flood prone areas to become blighted with little incentive to mitigate. Adopting cumulative substantial improvement would allow the actual level of risk to determine the time period for required mitigation, all while providing a way forward to decrease risk to life and property and address the blighted conditions caused by repetitive flooding. Extending cumulative substantial improvement to flood losses occurring outside of the SFHA would serve similar goals.

<u>Mutual Aid</u>

Urban flooding produces a higher percentage of uninsured losses, due to lower levels of flood insurance penetration. Lack of insurance coverage amplifies the post-disaster sentiment that the most important goal is to get people "back where they belong" as quickly as possible. In Oklahoma, the OFMA Disaster Response Team (DRT) has taken a leadership role in educating community leaders about post-disaster response, particularly that putting families back in high-risk situations is not an act of compassion, but an act of desperation. The DRT has been particularly effective in conveying this message as an outside actor immune from local politics, it is seen as an expert, and it communicates while helping perform important post-disaster response work in the affected community. The OFMA DRT consists of trained and equipped volunteers with infrastructure allowing rapid deployment and effective response. The OFMA DRT has been requested by local communities, state coordinating offices and by FEMA to assist with substantial damage evaluation or similar post-disaster activities. Out of state deployment has not been possible due to current conflicts of regulations and program requirements.

- States should be encouraged to create volunteer flood Disaster Response Teams in the model of the OFMA DRT and the newly activated DRT team in Louisiana.

- A framework for interstate mutual aid should be created and should include a modest funding mechanism for deployment expenses.

<u>Embracing Opportunity</u>

Urban flooding brings not only risk to life and property but ongoing blighted conditions. Too often, flood risk mitigation and economic development are seen as opposing forces. This is especially true in urban areas, due to strict open space restrictions associated with acquisition projects that utilize hazard mitigation grant funding. While open space is often the highest and best use of flood prone land in traditional riverine or coastal environments, land costs and the nature of the flood risk in dense urban areas mean that responsible redevelopment would be the best alternative for the community. Additionally, existing community economic development tools such as Tax Increment Financing could be used alone or could be paired with other fundings to achieve flood risk reduction that otherwise would not be possible.

- Strict rules for post-mitigation land use associated with HM grant funding should be reexamined to allow mitigation projects in urban areas that achieve overall risk reduction but also contribute to the community's overall redevelopment objectives.

- The regulatory and mitigation framework for urban flood risk reduction must be cognizant of the adverse social justice impacts to floodprone areas. Many floodprone urban areas have been "left behind", with blight increasing from the impacts of routine "minor" flooding and being overlooked during infrastructure improvement or mitigation planning.

Conclusion

Urban flooding must be addressed from many different approaches just as riverine and coastal flooding are. A combination of building and development standards, incentives, funding, planning, structural improvements, education, and community directed activities are all required to address the "Third Flood Hazard".

This paper draws heavily on concepts discussed at the 2017 Oklahoma Flood Risk Symposium, sponsored by the ASFPM Foundation and the Oklahoma Floodplain Managers Association, Inc.

Policy-based Approaches to Increasing Resilience to Urban Coastal Flooding

By Derek Brockbank, Executive Director, American Shore and Beach Preservation Association (ASBPA)
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For more than 90 years American Shore & Beach Preservation Association (ASBPA) has been the leading advocate for maintaining and restoring beaches and shorelines. We recognize beach and shoreline restoration is just one tool for improving coastal resilience along developed coastlines, so we are increasingly broadening our perspective to support other science and policy "tools" – natural infrastructure, living shorelines, development setbacks and better building standards, pre-disaster mitigation, regional planning, etc. – that help coastal communities be better prepared for the next coastal catastrophe. However "shore and beach" is in our name and in our blood, and in addition to its value for coastal resilience, shore and beach restoration has strong economic, recreation and ecological benefits for which we also advocate.

ASBPA is broadly supportive of many policy efforts that increase resilience for coastal communities, but the following are our four policy priorities:

Funding.

Building resilience requires funding. As the United States grapples with the unavoidable coastal impacts of climate change coupled with decades of intense coastal development, major improvements in coastal resilience will take major funding. While some resilience measures can be achieved through private investment or public-private partnerships, much more will need to come from public investment at the local, state and federal level. ASBPA has focused its efforts in increasing federal funding for:

a) Coastal restoration – projects that rebuild eroded or degraded coastal and beach systems;
b) Coastal resilience – projects and planning that improves a coastal community's ability to withstand disasters; and
c) Coastal research – data acquisition and analysis in support of coastal studies that inform and improve the efficacy and efficiency of restoration and resilience.

Expediting projects

Coastal projects that seek to improve community resilience and restore habitat are too often delayed and made more expensive with lengthy regulatory review. The federal government should build on the strides taken recently to expedite permitting of coastal projects. Although speed and efficiency in regulatory review are necessary to deliver vital coastal projects in a timely manner, ASBPA recognizes that proper care must be taken to avoid developing policies or procedures that may undermine environmental protections. ASBPA is working to ensure regulatory processes across state and federal agencies can be implemented concurrently, and that regulatory agencies are able to make decisions in the legally required timeframes. ASBPA is also working to involve the private sector and coastal stakeholders in implementing projects, in the belief that the private sector can often operate quicker than federal agency implementation, and that engaging stakeholders through the implementation process will result in better projects that are less prone to lengthy legal battles.

Regional Resilience Planning

Coastal vulnerability doesn't end with political boundaries. Improving regional resilience will take science and policy working together across state lines and collaboration across jurisdictions. ASBPA is working to ensure the US Army Corps of Engineers (USACE) regional coastal resilience plans are being done collaboratively with coastal states and stakeholders. ASBPA is also working to ensure USACE has the authorization and funding to undertake resilience plans across the entire developed U.S. coastline.

Regional Sediment Management

The United States is facing a sediment crisis. Rivers have been channelized, dammed and hardened, preventing sediment that should be reaching the coast from ever getting there. Flood control projects prevent the natural deposition of sediment vital to coastal health. And sediment in the coastal system that's dredged to support navigation is disposed of as cheaply as possible, which often means removing it completely from the littoral system. As our coasts facing rising seas and increasing storm intensity, they are not being provided with the necessary sediment to counteract erosion and subsidence.

Improving coastal resilience means improving the nation's sediment management. This is part of ASBPA's efforts on its three other priorities – funding, expediting projects and regional resilience planning – but also a distinct goal on its own. ASBPA is working to ensure 100% of uncontaminated sediment is used beneficially along our nation's coasts, which will take a new understanding of the "federal standard," sediment budgets for every coastal region in the country and collaborative approaches to sediment management between federal and state governments, industry and stakeholders.

In conclusion, ASBPA's policy priorities advance coastal resilience in part through better management and restoration of beach and shoreline systems, but should also support many other aspects of coastal resilience. ASBPA will continue to focus its efforts on policies that advance the geophysical solutions to improving coastal resilience on developed coastlines and in urban environments, but we look forward to partnering with others who focus on other vital areas of coastal resilience to work in unison for the protection and betterment of our coasts.

Discussion Topic Area: Economics/Adaptation

TITLE: Adaptation planning in light of uncertainty.

Lynette Cardoch, PhD. Director or Resilience and Adaptation, Moffatt & Nichol

Climatic uncertainty is one of the largest hurdles we face in adaptation planning. Recent emphasis on scenario-based planning and trade-off identification has not always yielded sufficient information for a risk tolerance level to move forward. Alternatively, do-nothing scenarios are not cost-free, particularly in coastal areas with large populations centers and concentrations of assets.

The intent for this discussion is to identify the hurdles facing adaption planners and methods to allow for a proactive protection of people and assets. Topics can include:

- Time scales of decisions versus investments: The larger decisions of how to change a city and the accompanying complex infrastructure takes both a longer time and a larger economic investment. Yet, they are under pinned by the more immediate and less costly short-term decisions that need to be made. Without a clear path towards the longer-term vision, how do we conduct short-term investments that can feed into the larger picture? How can we move towards “no-regrets” investments while adaptively incorporating information as it comes available?

- Cascading failures: this concept is not new to adaptation planning. What is new is the more inter-related nature of the systems and the scales. While decades ago, severe events might have affected a town or series of towns, the interrelated nature of our economy now places a larger region and economic supply chains at risk. The failures can be deeper. How do we incorporate the right scale of time and place with solutions?

- Chronic stressors and stakeholder communications: much focus is placed on readiness for large events. However, there are many chronic stressors, such as under investment in public infrastructure, that erode the ability for an appropriate response when a large event occurs. How can be better communicate with our stakeholders such that there is support for investment to solve chronic stressors and, also, manage expectations?

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Science-based Approaches to Increasing Resilience to Urban Coastal Flooding

Nicole Elko, Science Director, American Shore and Beach Preservation Association (ASBPA)

The American Shore and Beach Preservation (ASBPA) was founded in 1926 to help coastal communities manage beach erosion in close partnership with research organizations like the National Research Council. Today, we continue to use science to inform coastal policy decisions.

For ASBPA's coastal community members, reducing coastal flood risk to their natural and built environments is one of the most important elements in building resilience. Coastal communities are exposed to increasing coastal hazards and risk due rising water levels, increasing storm intensity, coastal erosion, ill-advised coastal development, and other reasons. Many coastal communities rely on state, regional, or National products (e.g., FEMA flood maps) to understand their exposure to risk.

Some communities are taking matters into their own, local hands, by implementing planning efforts to identify critical infrastructure at risk to nuisance flooding, coastal storms, and on-going erosion, all of which are exacerbated by climate change. Others are looking at modifying development regulations to increase freeboard, setbacks, and buffers and reduce impermeable surfaces. Others are restoring and rebuilding coastal natural infrastructure, such as beaches, dunes and wetlands, to help keep floodwaters away from developments. No matter the approach communities take, planning guidelines to help coastal communities reduce flood risk need to be communicated in easy-to-understand messaging to coastal managers, who will then need to explain efforts to politicians and the public.

The role of ASBPA: A recent study by the National Academies of Sciences, Engineering and Medicine[1] recommended facilitating trusting relationships between scientists and coastal stakeholders using boundary organizations. Boundary organizations create and sustain meaningful links between knowledge producers and users, and are accountable to both. These organizations generally focus on user-driven science, seek to provide a neutral ground for discussion, and help deliver the resulting science to audiences that can use it.

The ASBPA is a trusted boundary organization with a good reputation for translating coastal science to decision makers for many years. ASBPA works with both academics and coastal managers in the following ways to achieve our science priorities that relate to increasing resilience to flood risks.

ASBPA has been distributing a magazine-style journal, Shore and Beach, to our members - coastal practitioners, since 1933. This journal includes articles that communicate fairly complex coastal management challenges to stakeholders at an appropriate level. Coastal community resilience, beach preservation, and long-term adaptation are common themes.

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[1] National Academies of Sciences, Engineering, and Medicine. 2018. *Understanding the Long-Term Evolution of the Coupled Natural-Human Coastal System: The Future of the U.S. Gulf Coast*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25108.

The ASBPA Science & Technology (S&T) Committee is in the process of identifying the nation's top five coastal management challenges for 2019. The goal of this effort is to socialize these challenges to inform applied coastal research investments and to publish white papers and easy-to-understand products describing each by 2022. Nuisance flooding, reducing coastal flood risk, and building resilience are bubbling to the surface as some of our biggest challenges.

The ASBPA S&T Committee has published at least one White Paper per year for the past 5 years. The papers' intended audience is non-technical coastal professionals and stakeholders. For example, a 2016 white paper entitled Resilient Coastal Systems and Community Planning (http://asbpa.org/wpv2/wp-content/uploads/2016/04/Reslience_White_Paper_Spring2014_82_2-4.pdf) intended to help coastal managers understand resilience in the aftermath of Hurricane Sandy.

Finally, ASBPA is collaborating with the U.S. Coastal Research Program (USCRP), a partnership of the coastal research community to coordinate Federal activities, strengthen academic programs, and build a strong workforce. In 2019, the USCRP is providing approximately $5M in competitive awards for academic proposals (https://uscoastalresearch.org/2019-awards-info) to address topics such as *Developing Community Resilience Guidance for Recovery & Mitigation and Adaptation*. These studies will examine how coastal communities can utilize best practices for recovery, long-term adaptive management and risk mitigation to recover faster from coastal impacts and adapt more readily to future events.

In conclusion, ASBPA's science priorities related to increasing coastal resilience work hand-in-hand with our policy priorities, described in a separate paper. We look forward to partnering with others who focus on other vital areas of coastal resilience to work in unison for the protection and betterment of our coasts.

National Association of Flood & Stormwater Management Agencies

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2019 Gilbert F. White Flood Policy Forum – March 12-13, 2019

Increasing Our Resiliency to Urban Flooding

The National Association of Flood and Stormwater Management Agencies (NAFSMA) appreciates the opportunity to participate in the 2019 Gilbert F. White Policy Forum. Having been created in 1978 as the National Association of Urban Flood Management Agencies or NAUFMA, this topic has long been a critical focus of the association's history and mission. As NAFSMA works to develop a formal position paper on urban flooding, the association's participants in this urban flooding forum have identified the issues outlined below as considerations in the association's discussions.

Most of NAFSMA's members are public agencies responsible for managing both the impacts of water quantity and water quality at the local and regional levels. Many are partners with the U.S. Army Corps of Engineers on flood damage reduction or ecosystem restoration projects; are Cooperating Technical Partners, participate in the National Flood Insurance Program and work with the Community Rating System and undertake hazard mitigation projects through FEMA; and hold National Pollution Discharge Elimination System (NPDES) permits with EPA or their respective states to manage the impacts of stormwater in their communities.

Some NAFSMA members assumed responsibility for the NPDES stormwater management program in the late 1980's by taking on permits even before the final NPDES rule was issued for large municipalities with populations of 100,000 or more in November 1990. Referred to as municipal separate sewer systems or MS4s, both the Phase One and smaller Phase Two communities (under 100,000 in population) have invested, and continue to invest in required approaches to address the impacts of stormwater runoff. It is important to keep in mind that the NPDES stormwater management program, especially for larger urban areas, is an important and complex regulatory program, with the cost of meeting these federal requirements falling completely on local governments.

Although loans in recent years have become available for stormwater management through EPA's state clean water revolving loan programs, the NPDES stormwater management program has been referred to as an unfunded mandate since it was launched about 30 years ago and was designed to be a federal water quality program under Section 402(p) of Clean Water Act.

While water quality issues have traditionally been managed under a federal regulatory umbrella (unless a state has assumed delegation for a particular program), it is important to note that drainage issues are primarily a local responsibility and as a result much of the expertise on these issues is appropriately found at the local and regional levels.

One of the key issues that needs to be addressed when discussing urban flooding is the definition of urban flooding itself. The definition of urban flooding in the Illinois Urban Flooding Awareness Act (PA98-0858) provided below seems to include local drainage and stormwater management issues as well as responsibilities that could fall on individual homeowners. "The inundation of property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. 'Urban flooding' does not include flooding in undeveloped or agricultural areas. 'Urban flooding' includes (i) situations in which stormwater enters buildings through windows, doors, or other openings, (ii) water backup through sewer pipes, showers, toilets, sinks, and floor drains, (iii) seepage through walls and floors, and (iv) the accumulation of water on property or public rights-of-way."

NAFSMA looks forward to this upcoming discussion on the definition of urban flooding, as well as the roles and responsibilities of each level of government. NAFSMA also cautions participants to keep in mind that the flood risk in urban areas is unique to each region and locality and changes drastically due to topography, geology, precipitation, age and size of drainage systems, types of sewer management (separate storm or combined sewer systems) and in most communities, drainage ordinances have been adopted to address stormwater runoff issues. Urban stormwater management agencies and utilities that have been established to address these issues already direct significant personnel and financial resources to meet current federal permit requirements and renew those permits every five years.

NAFSMA is concerned with language in this Gilbert White Forum prospectus suggesting that a uniform policy on urban flooding may need to be set for the nation. This approach would be inconsistent with an integrated water resources approach which helps to provide flexibility to municipalities in meeting their water quality needs. This approach outlined in The Water Infrastructure Improvement Act (H.R. 7279), which allows for an integrated plan (including meeting requirements for combined sewer overflow; a capacity, management, operation and maintenance program for sanitary sewer collections systems; a municipal stormwater discharge and more), was approved by Congress in December 2018 and signed into law in January 2019 (Public Law 115-436).

While NAFSMA looks forward to discussions of federal programs that could be expanded to provide additional financial and technical resources to address localized flooding issues such as FEMA's mitigation assistance programs or expanded insurance coverage for basement flooding, the association is concerned about top down federal policy approaches to address this issue. It is important to note that even the study commissioned on urban flooding by the State of Illinois states that "there is no single solution for reducing the damages experienced due to urban flooding." (Section 3 – Strategies for Reducing Urban Flood Damages - page 55) The report further notes that the long-term strategy for truly reducing flood damages is to mitigate flooding for individual structures and for communities to take actions by adopting policies and programs that alleviate the source of flooding.

NAFSMA welcomes the opportunity to be part of this important discussion and appreciates participating in the 2019 Gilbert White Forum. Although this paper presents some of the background issues relating to resiliency from urban flooding, it does not represent a formal NAFSMA position on these issues. The association will be working to develop a formal position on these issues in the upcoming months.

The Role of Catastrophe Models in the Evolution of the Flood Insurance Market

Roger Grenier, Ph.D., Senior Vice President, AIR Worldwide
Global Resilience Practice Leader

The evolution of catastrophe risk models is among the most significant developments in the insurance industry over the last 30 years. From the period before Hurricane Andrew until today, catastrophe models for hurricane, earthquake and other perils have become standard tools used by insurers and reinsurers develop rates, manage exposures and develop risk transfer strategies for extreme event risk.

In recent years, modeling technology has advanced to add flood risk estimation to the insurer's toolkit. Aided by increased computational power and high quality digital datasets, models now allow probabilistic simulation of flood risk at continental scale. By coupling climate models and physically-based hydrologic and hydraulic models with sophisticated simulation techniques, the models provide loss estimates for thousands of events in individual areas, providing a robust estimate of the full risk potential. An event-based framework allows insurers to understand and quantify the correlations within their portfolios, and the simulation approach can produce not only expected losses but also large loss scenarios at a wide range of annual probabilities.

Multiple cat models are currently being used to inform FEMA's Risk Rating 2.0 project, as a complement to other data inputs to the process. The models offer several advantages, including wider coverage, greater differentiation of risk within flood zones, and consistency in the quality and vintage of the underlying datasets. The models also allow explicit estimation of off-floodplain (pluvial) risk, a critical factor in areas prone to urban flooding. The models can also be updated more frequently and at lower cost than traditional flood hazard maps.

Because of these advancements, private insurers are increasingly turning to catastrophe flood models to develop flood products. With complete geographic coverage and options to include building-specific details such as basements or flood protection measures, the models facilitate integration with existing underwriting and pricing workflows. Over time, this will drive greater participation in the flood insurance market and progress towards the moonshot goals.

As the models and technology continue to evolve, we will see additional improvements in geographic resolution and techniques to capture flood risk at finer scales, which will be an important element to quantifying urban flood risk. Historically, the availability and continuous improvement of catastrophe models have driven efforts to collect more accurate and detailed data. For example, with hurricane modeling it is now common for insurers to capture and enter the roof material information for the locations they insure, since research has shown (and the models reflect) that roof details are an important element in structure vulnerability. Similarly, as it relates to urban flooding, more consistent and centralized collection of local drainage information and flood protection measures will be required to effectively model and quantify flood risk in urban areas, which will, in turn, contribute to a more robust insurance market in these areas.

Looking ahead, the large scale, data driven simulation methodologies employed by catastrophe models are well suited to evaluating the evolution in land use and building codes, as well as changes in rainfall/runoff patterns which may evolve under a future climate condition. As we move towards that future, we can expect the catastrophe flood models will play an increasingly larger role in evaluating risk and informing the insurance market.

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Shifting the Emphasis from Flood Control to Aging Infrastructure

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Charlotte-Mecklenburg Storm Water Services is a partnership which began in 1993 between the City of Charlotte and Mecklenburg County, NC, to form a single stormwater utility. The utility was initiated in response to the requirements of the Clean Water Act (Phase 1 MS4) and the growth of urban flooding problems that emerged after rapid urbanization in the late 20th century.

There are about 3,800 miles of drainageways in Charlotte and about 400 miles of mapped, federally-regulated floodplains in Mecklenburg County. The City of Charlotte's role is focused on drainageways serving less than one square mile including those in city streets. The County's role is focused on federally-regulated floodplains (drainageways serving more than one square mile). Additionally, both the City and County comply with Federal Clean Water Act requirements.

Since the utility's inception, $685M in investments have been made. About half was invested in flood reduction with the remaining invested in minor repairs/rehabilitation, surface water quality, and collaborative projects. While flooding still exists today, it occurs less frequently at fewer locations because the investments addressed the most frequent flooding problems.

Rapid urbanization continues and the mileage of drainage system has doubled since 1993, tracking closely with population growth. Sprawling suburban development has resulted in many pipes, curbs, and inlets that the utility has inherited from private developments, some being designed and constructed with less regulatory oversight than desired. The onset of inexpensive metal pipe was a natural attraction to private developers, but with its short lifespan of about 35 years, many of these pipes have now reached their expected lifespans and must be replaced. These and all the other drainage needs have resulted in a surge of end-of-life replacement needs.

Failing infrastructure most often appears as a collapsed pipe, either under a street or on private property (parking lot, near a home, a driveway). While failing infrastructure can cause flooding, the immediacy and public perceptions of a building, car, or pedestrian falling victim to a collapsed drain is a prevailing concern.

An earlier focus on end-of-life replacement would have been beneficial. Utility revenue has risen substantially but is inadequate, and currently the annual capital replacement need is four times higher than funding received (about $70M annually). As most revenue goes toward rapidly failing infrastructure, not enough remains for other program needs such as flood reduction, preventive maintenance or addressing impaired streams that fail to meet Clean Water Act criteria, an area of increasing importance to citizens.

Recently, the utility has shifted focus toward asset management techniques to identify age related problems earlier. Rehabilitation efforts are more often used to keep existing infrastructure in service for as long as possible so it reaches its full lifespan when capacity improvements can then be made. Flood reduction does not play as primary a role as it once did. Adoption of ordinances in the last 10 years that utilize improved stormwater control measures to mitigate the effects of impervious surfaces do help minimize the creation of new flooding and surface water quality problems, as do stronger regulatory oversight and better construction materials.

The effects of aging infrastructure are very tangible to citizens and elected officials as the utility deals with a growing buildup of capital needs. For an urbanized Charlotte, flood control, changes in rainfall, and additional impervious areas are less pressing issues than fiscal pressures, public safety risk, and reputational risk associated with failing infrastructure. As southern cities like Charlotte grow rapidly, and sprawling suburban development often continues, it is important for municipal leaders to fully understand the long-term consequences of growth on infrastructure and the environment that in turn affect the economy and quality of life of citizens. Careful consideration is required of the obligations incurred through annexations, limited construction oversight, and lacking design standards related to development. Adequate funding is instrumental for a comprehensive stormwater program that invests in long-term maintenance, rehabilitation, replacement and surface water quality. Local, state, or federal funding mechanisms are needed to overcome the wave of infrastructure replacement that is needed and accelerating over time.

Complete Risk Identification is Resilience Step One

Christopher A. Johnson, PE, CFM, Stormwater Program Manager, City of Fort Worth, Texas

Local community leaders must have clear, reliable risk information before they can make wise resilience decisions. We have too long allowed an incomplete representation of risk serve as the basis for decision making. Should we be surprised when our leaders make unwise policy decisions when we haven't communicated a complete risk picture? The following provides a few practical examples I've seen, and am dealing with in Fort Worth, Texas, with suggestions for improvement.

Examples of Incomplete Risk Identification

The National Flood Insurance Program (NFIP) has too much influence in on the general understanding of floodplains. Our local officials were stunned to learn that NFIP floodplains only reflect a small minority of actual flood risks in our community. Local design standards for new development that focus on limiting peak discharge, and assuming unsaturated soil conditions, do not protect from the devastating impacts of unaccounted for runoff volume. Further, the life safety implications of actively failing infrastructure are obscured in by a characterization of the infrastructure as simply "old". Risks that are somewhat intuitive for local floodplain and stormwater program managers, have in too many cases been poorly defined and quantified for use by community officials. Facts about all true floodplains, land use impacts, saturated soil conditions, and failing infrastructure (for a few examples) must be prepared and presented completely, consistently, and clearly. Better facts will produce better decisions.

Define Comprehensive Floodplains

Resilient local communities are those that identify their complete scope of risks. NFIP floodplains are a woefully incomplete representation of actual floodplains in many locations. A useful representation begins with identifying and communicating all floodplains. This includes those defined by the NFIP, plus all other floodplain areas regardless of the type of flooding or size of upstream watershed. In many local communities, there are enormous areas (cumulatively) served by undersized storm drains that make up most of the true flood risk to people and property. As we have observed in Fort Worth, this communication step alone requires an extensive education process, but many are beginning to learn that there are flood risks that are just as likely, and damaging, in our City outside NFIP floodplains.

Provide Reasonable Representation of Volume Impacts

Resilient local communities understand that large, intense rainfall events often come after extended periods of wet weather when soils have limited infiltration capacity. They also understand that development standards that rely on post-project peak discharge as a measure of an adequate "no adverse impact" design to be woefully lacking. The volume of storm event runoff accumulates with increasing watershed size, and flood risks are greatly underestimated. Unaccounted for soil saturation and/or land use changes (impervious cover), too often results in "unprecedented flooding". Yet this volume can be estimated empirically. Let's be sure to appropriately account for soil saturation and the impacts of anticipated land use changes (including those in watersheds beyond our jurisdiction). This approach allows us to properly identify the true magnitude of risk.

Assign Proper Risk to Failing Infrastructure

Resilient local communities identify and communicate those parts of their infrastructure which are failing. Much has been said about the challenge of aging infrastructure across the United States. When it comes to drainage related infrastructure, however, decision makers with limited resources first need a clear understanding of the quantity, location, and consequences of infrastructure that is actively failing. Focusing on a more robust replacement plan is more appropriate as a second step. In most communities, the ability to assemble the resources needed to deal with aging (alone) infrastructure is overwhelming. But when we identify and focus resources on infrastructure that is known to be actively failing, we manage the risk, protect the public, and assemble the facts (costs!) needed to support a more robust asset management approach to infrastructure in the future. Let's manage current risks now, and future risks as soon as practical.

Add in Anticipated Future Changes When Available

Resilient communities know how to optimize use of limited resources. That means we must make a clear distinction between "now" and "next" when we communicate with decision makers. Local officials are skilled at sniffing out anything that can be deferred. The recommendations above are intended to focus near term decision making on true risks we are able to define today (scope of all floodplains, saturated soils, and failing infrastructure). We must make it plain that an "unknown risk" is in no way a "non-risk". Once that initial foundation is firmly in place, we can add in the predictive elements (land use changes, regulatory implications, climate change, sea level rise, etc.). We can start with our best estimate of the current situation, refine it over time, and add in predictions of what is anticipated to change the current risk when such information is available. Currently, for many local communities, even the current risks are not fully known. So we must be clear to communicate what we know, and do not know, about our current risk situation. In other words, our message must include a clear distinction between the risk that "is now", is "currently unknown", and is "on the way".

Conclusion

Wise (resilient) local community decisions are based on consistent, reliable, and simple message of risk. The message must first be comprehensive, correct in magnitude, and current. Only then should it be predictive. Organizing our thoughts and strategies across the country, and at the local level, will help us overcome some of the incomplete, misleading, or confusing risk communication of the past. Complete, but simple, risk communication is step one. The rest will follow.

Reducing Future Flood Risk Through Targeted Protection of Floodplain Open Space.

Kris Johnson, PhD and Sarah Murdock, The Nature Conservancy

As Benjamin Franklin astutely noted in 1735, "*an ounce of prevention is worth a pound of cure*". Although Mr. Franklin was advocating for better fire preparedness, this axiom still holds true today in the context of mitigating flood risk in cities and towns across the United States. Investments to protect open space in floodplains today can avoid more costly flood damages in the future, and also provide a range of valuable benefits for people and for nature.

One of the most significant drivers of the steadily increasing flood damages experienced in recent years is unabated new development in areas prone to flooding. Although flood risk to existing assets and structures can be mitigated by a variety of structural and non-structural approaches, one of the most cost-effective ways to reduce risk in the long run is to avoid development and land use that puts people and property in harm's way. A new study by The Nature Conservancy, the University of Bristol and Fathom, a flood analytics company, concludes that the benefit of avoiding future flood damages greatly exceed the costs of floodplain protection in many parts of the country. To conduct this analysis, we applied a new large-scale hydrodynamic model that provides mapping of riverine and pluvial flood risk across the conterminous US. This new "big data" approach to delineating floodplains doesn't replace well-validated local flood models but instead offers another tool to evaluate urban flood risk, especially in regions where mapping is unavailable or out-of-date. In this study, we integrated this comprehensive floodplain mapping with land cover and public lands data to identify currently unprotected open space across the country where potential future development could occur. We then incorporated new spatial data from the Environmental Protection Agency about potential population growth and projected development to identify areas where construction of new residential and commercial structures could dramatically increase the number of people and the value of assets exposed to flooding. Using US Army Corps of Engineers depth-damage functions and data from the FEMA National Structure Inventory we estimated the cumulative damages to new construction from future floods and compared the projected flood damages with the cost of open space protection. Through this first-of-its-kind analysis using these new comprehensive floodplain maps, we identified counties across the US where floodplain conservation is likely a cost-effective strategy to mitigate future urban flood damages.

This new research demonstrates that as a country we could get a greater return on investment by allocating more resources to prevention of flood damages through floodplain conservation. Several important Federal Emergency Management Agency (FEMA) programs could be expanded to help spur investment in proactive and nature-based approaches to flood risk reduction. For example, the Pre-Disaster Grant Mitigation Program is the only FEMA program that provides funding for projects *before* a flood disaster has occurred. This program enables communities to seek funding for hazard mitigation planning and a variety of risk reduction activities, including acquisitions of repetitive loss properties and restoration of open space in floodplains. The Flood Mitigation Assistance Grant program, designed to fund projects that reduce claims to the National Flood Insurance Program, provides another opportunity to support floodplain projects. Last year an amendment passed empowering the President to set aside six percent of Disaster Relief Funds to be applied to pre-disaster funding; allocation of the full six percent of these funds which would greatly increase the annual funding available for investment in pre-disaster mitigation activities. Congress should also ensure that the maximum amount of funding possible is apportioned to Flood Mitigation Assistance from the National Flood Insurance Program. This grant program provides essential funding for homeowners covered by flood insurance to invest in flood mitigation measures such as home elevations and buyouts of the most flood prone properties. Investing in cost-effective flood risk reduction will lower the financial burden on the National Flood Insurance Program and lower our nation's cost of disasters.

Protecting open space is a key strategy for mitigating urban flood impacts and can prevent more people, property and infrastructure from being exposed to risk from future floods. New development will, and should, happen because it is essential for economic growth and to ensure the ongoing vitality of cities and towns across the country. Yet our analysis suggests that protecting open space in floodplains would curtail only a small portion of projected future development, leaving ample remaining land where development could occur in areas that would not increase exposure to floods. Protecting natural lands in flood-prone areas would provide other benefits to communities as well, by creating open space and recreation opportunities for residents, supporting habitat for wildlife, reducing water quality impacts from nutrient and sediment runoff and potentially providing flood mitigation for areas upstream and downstream as well. Conservation of open space in floodplains is not a viable option everywhere, but in many parts of the country it would be highly cost-effective and would also provide multiple valuable co-benefits. As such floodplain conservation is a critical tool for mitigating future flood risk and must become a more significant focus of policy and investment in the United States.

The Importance of Integrated Planning in Addressing Urban Flood Hazards

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Introduction

The field of floodplain management is fraught with challenges, but perhaps none as difficult as those facing urban communities. Unlike many rural and suburban communities, urban floodplain management presents additional obstacles resulting from historical development patterns and demographics. Due to the historical evolution of cities in the US, many urban areas throughout the country are located adjacent to oceans, bays and other waterways, which exacerbate flood hazards and risk. And for urban communities in coastal areas, hazards associated with storm surge and wave action significantly increase this vulnerability and risk. In addition, flood hazards in these coastal areas are increasing even more due to the effects of accelerated sea level rise, resulting in more "high tide flooding" events, aka "nuisance flooding." According to a report issued by NOAA in 2018 (NOAA, 2018, **2017 State of U.S. High Tide Flooding with a 2018 Outlook)**, yearly records include 22 days of high tide flooding in Boston, MA and Atlantic City, NJ, 23 days in Sabine Pass, TX and 18 days in Galveston, TX. The frequency of these events is likely to increase in the future, compounding the adverse impacts of urban flooding in coastal communities.

Urban Floodplain Management Challenges

Characterizing urban floodplain management challenges reveals a number of common factors: urban communities have high development density and impervious cover; urban stormwater infrastructure is often aged and undersized to accommodate today's runoff rates and volumes; residential development includes a high percentage of multi-unit housing that limits mitigation options; contaminated sites in urban communities can preclude green infrastructure designed to promote infiltration of stormwater; maintaining and upgrading infrastructure is complicated by the presence of multiple conveyance systems located beneath city streets and the different authorities charged with management of these systems; some urban communities have combined sewer systems that overflow during high rainfall events, discharging raw sewage into streets and threatening public health; and urban communities have greater ethnic diversity, which complicates communication regarding flood risk and emergency evacuation. These factors represent a combination of conditions that significantly challenge our ability to manage flood hazards in urban communities.

The Planning Challenge

In terms of flood hazard management planning, agencies tend to operate in silos, often without cross-cutting planning to look at multiple problems and combined solutions. This typically results from the planning agency structure - state, county, local - and associated mandates and jurisdictional constraints. Unfortunately, missed opportunities to collaborate on floodplain management planning will only perpetuate inefficiencies and impede our collective ability to address current and future urban flood hazards. Therefore, the promotion of integrate planning can be an effective tool to facilitate collaboration to better address these disconnects.

The Role of Integrated Planning

Given the constraints of some planning structures, finding opportunities to collaborate between multiple individuals and agencies - governmental, business, community, labor, nonprofit and academic - can align agencies and diverse perspectives to advance shared goals and accomplish much more than any individual organization. As we continue to develop and redevelop our urban communities, understanding the interconnection between sectors becomes critical to mitigating flood hazards, protecting people and property, enhancing the beneficial functions of natural resources, and maintaining water systems and infrastructure in the most efficient, cost-effective manner. Based on this understanding, integrated multi-objective planning becomes one of the most critical components of urban flood hazard mitigation, by identifying common ground between sectors and overlapping needs and solutions to address urban flood hazards.

These planning actions are also valuable in promoting statutory and regulatory changes, and guiding funding decisions related to floodplain management. The combination of strong regulatory actions and financial incentives, based on integrated planning, is most likely to result in positive outcomes that promote adaptation and flood mitigation. To that end, planning agencies need to work collaboratively with regulatory and funding agencies to provide the synergy that will define creative strategies necessary to manage flooding and to protect people and property in urban communities.

Potential Strategic Options

Integrated planning can identify a range strategies and solutions to address urban flood hazards in a comprehensive and efficient manner. Some potential options include:

- Regional stormwater utilities can be established to assume direct responsibility for managing stormwater and the costs for doing so, which often lie hidden in property taxes. Without a utility structure, there is often no entity or institution to fund or implement those obligations effectively.
- Incentives such as density bonuses and tax abatements for private developers to promote flood resiliency and adaptation through redevelopment planning, design and construction are effective strategies to mitigate flood hazards as part of urban redevelopment.
- The full exercise of zoning and regulatory authority must be exercised to address development density, impervious cover, open space, low-impact design, and stormwater management, especially in the context of urban redevelopment.
- Creative financing through, for example, Public Private Partnerships, credit trading, stormwater banks and the EPA State Revolving Fund program can finance infrastructure upgrades to mitigate flooding and promote enhanced water quality.
- Asset management planning can enable utilities and authorities to plan for and budget funds to support required maintenance and upgrades to ensure optimum flood mitigation performance of stormwater management systems.

Conclusions

Integrated planning can provide an honest evaluation of urban flood problems and the costs to address these problems. A comprehensive planning framework can also facilitate multi-community collaboration to define best practices for specific areas, identify a range of financing options, identify systematic obstacles and develop priority solutions. As daunting as these solutions and associated implementation costs may be, the cost of inaction will invariably be greater.

Gilbert White Forum on Increasing Our Resiliency to Urban Flooding, March 12-13, 2019

Technical Considerations for Addressing Urban Flooding Issues

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The Illinois *Report for the Urban Flooding Awareness Act* published in 2015 provides a comprehensive study of the issues surrounding urban flooding in Illinois and recommendations directed to the state legislature, agencies, communities, and individuals. The observations and recommendations from this report are widely applicable. The formulation of strategies used to reduce urban flood damages should come from the understanding that "The root causes of urban flooding are different and require different solution approaches. There is no single solution for reducing the damages experienced due to urban flooding. However, there are multiple strategies that can be adopted to deal with root causes, enhance public awareness and understanding of insurance options, and encourage communities and individuals to take action to reduce losses and avoid increasing flood damages in the future" (IDNR, 2015). This paper highlights a few points pertaining to technical issues that resonate in a national discussion.

Identifying the areas where urban flooding occurs is a logical point of inquiry to frame possible solutions in the discussion of building resiliency to urban flooding. In the working definitions of urban flooding used in the Illinois study (IDNR, 2015) and in a recent national study (University of Maryland et al., 2018), the cause of urban flooding is identified as rainfall "overwhelming the capacity of drainage systems" and the consequences include "…situations in which stormwater enters buildings through a) windows, doors, or other openings; b) water backup through pipes and drains; c) seepage through walls and floors." The root cause of water entering a basement can be very structure specific, such as sump pump failure, high groundwater seeping through aging basement walls, and gutters discharging near openings, and is not necessarily attributable to storm sewer system capacity or performance. Similarly, debris-blocked storm drains, which is a maintenance issue, can cause ponding and structure damage. Available sources of information, such as insurance claims, do not provide documentation on the root cause. In fact, owners may not know the cause. There is insufficient information to *consistently* identify or map areas of urban flooding resulting from rainfall exceeding the capacity of storm sewer systems. Rapidly changing landscapes add a further complication in maintaining data on current conditions. Furthermore, a survey of communities in Illinois (IDNR, 2015) indicated that most communities know where flooding occurs; the issue is finding the resources to formulate and pay for solutions.

Urban storm sewer systems have been constructed over decades under varying local standards that to some extent reflect community values. Contemporary urban stormwater systems are commonly designed to have the capacity to convey rainwater from events that occur on average once in five years (20% annual chance of occurrence) or once in ten years (10% annual chance of occurrence). Excess runoff, which can result in flooding, is expected during larger events that would happen less frequently, e.g., 25-year (4% annual chance), 50-year (2% annual chance), or 100-year (1% annual chance) events. Streets and grass swales are often part of the system intended to convey runoff in excess of the storm sewer design capacity. Detention and retention basins are used to mitigate increased runoff due to increased impervious surfaces; design criteria vary, but an example specification is the 1% annual chance rainfall over a 24-hour period. There are other standards to consider that can have a significant impact on flooding, such as the allowable release rate from detention systems (Flegel et al., 2019). Climate change is shifting the frequency of significant rainfall events; e.g., what was once the 10-year rainfall is now the 6-year event. In general, storm sewers were not designed to convey large, low-frequency events. Safety, cost, and community tolerance of subsequent surface flooding when system capacity is exceeded, are all considerations when a community sets design standards. These standards are to a large degree a reflection of local decisions, underscoring the community-based nature of the issues and providing insight into the difficulty of standardization or comparisons between urban areas.

Hydrologic and hydraulic computer models can simulate the movement of water from precipitation to transport through the conveyance system, albeit with some uncertainties from data and modeling assumptions. One great challenge of modeling urban storm sewer conveyance systems is their lack of visibility and accessibility. Many communities do not have complete records of the locations or sizes of storm sewers; thus efforts to model systems must start with the costly exercise of documenting the infrastructure. The calibration and verification of models requires flow measurements, which can be challenging to obtain in closed systems. Compiling the information on existing sewer systems is a critical step in understanding system weaknesses and prioritizing capital investments. Given the changing climate, a system model is needed to assess the impacts of future precipitation and adaptively manage infrastructure rehabilitation and improvements. Again, funding is the hurdle to overcome. Mechanisms that provide funding, such as revolving funds and legislation that enables communities to establish dedicated funding sources, should be considered as part of the national and state policy discussion.

In summary, urban flooding is uniquely a community issue and therefore must be addressed at the local level. Communities need resources to develop decision-support models, prepare long-term plans, and upgrade infrastructure.

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Urban Flood Risk Mitigation: Leveraging Private Flood Risk Tools & Capacities

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Urban flooding has become a chronic and costly problem across the US, stressing communities, ecosystems, and property owners. The lack of reliable spatial planning information can make it difficult for communities to make informed decisions about where and how to build and redevelop urban areas that are often the economic engines for local and regional commerce. The economic consequences of urban flooding can be high, with direct loss through damage and disruption, and indirect loss of economic development opportunities, foregone revenues, and credit rating erosion. Often, chronic urban flooding does not trigger federal disaster assistance programs and communities must manage these impacts as part of already oversubscribed local budgets.

Compounded with ongoing debates about the National Flood Insurance Program, disaster appropriations, and climate policy more broadly, the issue of urban flooding requires significant attention from both the private and public sectors. Opportunities are increasingly available to leverage private insurance and finance tools and capabilities to better understand and mitigate urban flooding. The Gilbert F. White Flood Policy Forum can catalyse leadership and collaboration across sectors to leverage risk analytics and innovative finance approaches to bridge the gaps that currently exist in the flood risk management framework. Insurance data and analyses are strongly positioned to complement and even strengthen public program design, benefit-cost analyses, and funding priorities.

1. Understanding Risk

In recent years, insurers have become the pre-eminent "gearbox" for translating science and engineering information on flood and climate risks into tractable information that can inform policy making, land use planning, mitigation project design, and financial decisions. With robust scientific, engineering, and mapping technologies, the industry can help communities understand urban flood risk and evaluate the full range of costs and potential benefits of projects early in the planning cycle. This includes an analysis of hazards, exposures and human behaviors, in order to get the economic, environmental, and social costs of the urban flood risk. And even if a claim is never filed, decisions to act – or not to act - are better informed and communities can evaluate the business case for resilience investment with greater precision.

2. Managing Risk

Historically, insurance has been the platform for standards and norms across the range of risks, driving the establishment of the world's first building codes, zoning laws, automotive safety standards and fire risk management, creating conditions for access to the shared pool of community capital. Risk analytics can inform risk management strategies and provide actionable data to help decision makers chose among the array of mitigation options in a tailored risk management strategy based on particular community objectives, risk appetites, budgets for premium. As these analyses incorporate the quantifiable ecosystem services that can help mitigate urban flooding, including wetlands, open space, and green infrastructure features, the performance metrics of those ecosystem services can be integrated to address water quality, erosion, and habitat loss challenges that often accompany urban flooding problems.

3. Risk Pricing, Sharing and Transfer

After risk-informed mitigation and risk reduction strategies have been implemented, insurance communicates the level of residual risk through the price system and also conveys when a risk may remain so high (at an individual or societal level) that it is uninsurable. Risk is shared between the individual or entity concerned and wider society through a range of mechanisms. The key is that this sharing of risk enables individuals, institutions and communities to achieve sufficient resilience to liberate resources to be put to effective use rather than being diverted to the costs of self-security.

The vast majority of insurance risk is shared via traditional policies for individuals or companies, but in recent years catastrophe risk financing facilities operating at a multi-sovereign level, often within developing markets, have received widespread attention. Leading and high profile examples, including the Caribbean Catastrophe Risk & Insurance Facility (CCRIF) and the Africa Risk Capacity (ARC) programs, support sovereign level risk via pooled multi-state facilities against defined levels of natural hazard events, using modern parametric and index-based coverage. Similar strategies are under consideration in Asia, the Pacific and elsewhere.

4. Parametric Insurance for Urban Flooding

Parametric insurance solutions offer quick, verifiable, and predictable payouts in the event of a flood, removing the need for lengthy loss-adjustment after an event. These solutions use index triggers in which the amount of a claim payout is dictated by a pre-defined objective trigger such as rainfall, erosive velocity, or even tidal or sunny-day inundation frequency, eliminating the costs and delays of investigating and adjusting loss following an event. Parametric solutions can also help cities smooth budget volatility and uncertainty, and can pay for extra costs a community may incur due to urban flooding, such as flood-fighting, overtime for staff and first responders, and even make capital available through grants or loans to affected homeowners and businesses in the community.

Specific to managing and transferring urban flood risk, it is clear that the NFIP can no longer be the only insurance solution that communities can turn to in order to address economic risks associated with floods of all sorts. Public programs and funds alone are not keeping pace with local drainage and infrastructure needs as extreme precipitation, tidal, and sunny-day flooding become more frequent and damaging. And municipal credit rating agencies are increasingly factoring in community resilience planning, insurance, and availability of liquidity to reduce dependency on federal aid into ratings, with implications for the cost of capital to communities.

The private industry has advanced dramatically since the creation of the NFIP and today has the scientific capabilities, coupled with advanced computing capabilities to understand and map urban flood risk at granular levels. The data processing and analytical abilities within the industry can more accurately price flood risk and attract private investment in infrastructure and ecosystem restoration and protection. Private insurance and finance can play a significant role in comprehensive flood risk management for those communities that seek to take greater responsibility and control of urban flood risk.

Using a Behavioral Risk Audit to Guide Contact with Officials to Address Urban Flooding[1]

John A. Miller, P.E., CFM, CSM, Mitigation Liaison, FEMA Region II

There are great physical and monetary challenges in addressing flood risk in urbanized areas. So too there are obstacles in getting local officials to recognize the need to address worsening urban flooding. This brief paper touches on this political problem using a Behavioral Risk Audit to address officials' inherent biases that lead to unsuitable action or inaction. Suggestions on how to overcome the biases are made and tallied in the below table.[2]

There are six biases that Meyer and Kunreuther (2017) examine in their book The Ostrich Paradox – Why we Underprepare for Disasters. Relating to local decisionmakers, these are:

- Myopia - making choices that are weighted on short time scales; "After we build back, and restore our tax base, we can worry about future storms. I've got an upcoming election"
- Amnesia – making decisions on recent occurrences experienced by the community; "We've had a streak of quiet years and it's hard to recall the trauma of the hurricane."
- Optimism – discounting the flood risk to the community; "We'll never experience Superstorm Sandy again. It was a once in a lifetime storm"
- Inertia – continuing historical practices or inaction as a default; "It's been flooding in that section of town for as long as I can remember. There's nothing we can do about it."
- Simplification – recognizing limited information; "FEMA maps don't show flooding there."
- Herding – following the practices of peer communities. "Riverdale's not doing anything about the flooding either."

Myopia is especially troubling to flood risk experts as this bias leads to a reset of pre-event conditions. It is exceedingly common for officials to drive a return to normalcy, even if that means a copy of the community's pre-storm vulnerability. A chance to realize adaptation practices when the community is focused on recovery must be championed to prepare for worsening urban flood risk. Show how long-term resiliency can produce short term gains, such as attracting businesses and private investment.

Community leaders tend to have a fading memory of the past and base decisions on the here and now – this is labeled the Amnesia Bias. It is likely that officials, and the community as a whole, will forget the consequences of historical flood events. This inattentiveness leads to a failure to invest in urban flood resilience as elected officials see more pressing budget needs. A physical reminder may help counter the bias, with the installation of high-water mark signage. In addition, anniversary memorials and documentary video can conjure memories of the flood event and resulting damages that are desired not to be repeated.

Optimism is a bane to proactive urban flood mitigation as it discounts the perception of community risk. Use of terms "100-year flood" and "Superstorm "enable leaders to interpret the occurrence as rare and will not happen again in the community's near future, therefore there is no need to prioritize resiliency improvements. To counter the Optimism Bias, reframe the time horizon, such as presenting the number of times a low area will flood in a 20-year period and populate this recurrence with the losses of property, such as the number of cars inundated, and homes and businesses with foul water first floor inundation and that cleanup cost.

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[1] This paper relies on the work by Robert Meyer and Howard Kunreuther of the Risk Management and Decision Processes Center at the Wharton School of the University of Pennsylvania (https://riskcenter.wharton.upenn.edu/), and specifically their book: The Ostrich Paradox – Why we Underprepare for Disasters. The reader is encouraged to consult this book (https://wdp.wharton.upenn.edu/book/ostrich-paradox/) for further understanding of biases and the details of a Behavioral Risk Audit only highlighted in this paper.

[2] The reader likely will have additional ideas on how to overcome officials' biases that will be appropriate to a region or community, and to the individuals and population; those in this paper are examples for discussion.

Communities are subject to the Inertia Bias: "if it ain't broke, don't fix it." With respect to urban flooding, many communities are doing what they always have done, and in many cases, that is nothing, including not funding stormwater infrastructure. To address this, show what recurrent flooding does to property values and revenues and how this jeopardizes a community credit rating.

It is not uncommon for communities to rely on limited information to make decisions – this is the Simplification Bias. Flood Insurance Rate Maps may not show flood risk due to undersize conveyance in urban areas. Community officials may interpret this as there being no flood risk. To counter the bias, it would be wise to prepare mapping of the urban flooding and compliment the aerial extents with street view representations of impacted areas.

The herd instinct, also known as the Herding Bias, is a powerful motivator at the local government level. Communities will look to peers in deciding direction and are reluctant to blaze a new path. It is essential to connect with community leaders to share examples of what like communities are doing to address risk and the multitude of benefits secured by those actions.

Behavioral Risk Audit to Address Urban Flooding Matrix[3]

Bias	Impact on Beliefs	Manifestation in Preparedness	Remedy
Myopia - making choices that are weighted on short time scales	Attention on recovery to pre-existing conditions after disaster	Inaction on long-term adaptation to worsening conditions	Show how long term resiliency can produce short term gains, such as attracting business
Amnesia – making decisions on recent occurrences experienced by the community	Forgetting the consequences of past floods	Failure to invest in urban flood resilience and direct funding to other budget demands	Reminders of event and damages; produce documentary; physical reminders such as high water marks
Optimism – discounting the flood risk to the community	Convincing oneself that the flood was a rare event and will never happen again in lifetime	There's no need to make resource intensive resiliency improvements	Demonstrate the number of times a low area will flood in a 20 year period; Total the losses of property (cars inundated, homes and businesses with dirty first floor inundation)
Inertia – continuing historical practices or inaction as a default	Nothing has ever been done to address the community flooding	No funding has ever been dedicated to correct the flood risk	Show what recurrent flooding does to property values and revenue
Simplification – recognizing limited information	The Flood Insurance Rate Map doesn't show flood risk in this area	The FEMA products doesn't depict risk so there's no need to adapt	Prepare mapping of urban flooding and show street view graphics of impacts to familiar spaces
Herding – following the practices of peer communities	Peer communities seem unmotivated and our community doesn't want to blaze the path	Our neighboring communities are not being proactive with urban flooding so the same with this community	Connect with community leaders and share examples of what "best practice" communities are doing to address risk and the multitude of benefits

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[3] Derived from Meyer and Kunreuther (2017) table 8.1.

Gilbert White Forum Increasing Our Resiliency to Urban Flooding
March 12 – 13, 2019

Urban Flooding – Affinities and Perspective

Molly J. O'Toole, P.E., D.WRE, CFM

We all can agree that urban flooding and damage from urban flooding has been around since urbanization. We can all agree that urban flooding occurs where rainfall falls. Full agreement may stop there. Definitions of urban flooding vary, as well as perceptions of acceptable urban flood impacts. This is due to the diversity of our Nation's land and landscape, and differences in urban development and building practices, but also due to our affinity to address the problem as seen today or the problem visualized for tomorrow. I submit that (1) the definition of urban flooding is key to moving forward with urban flood damage resiliency, (2) we cannot fall into the pitfalls that we have in the past in addressing riverine and coastal flooding by mapping land "in or out," and (3) we need to ensure that we're addressing watershed development and the urban flood problem on the horizon from redevelopment and continued urbanization. Our efforts have the potential to address water quality, groundwater recharge, habitat protection and economic considerations, along with reduced human-caused flood damage.

Definition and Perspective are Key: "The Growing Treat of Urban Flooding: A National Challenge" (Report) presents the FEMA definition of urban flooding and it includes "…caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems." We should be cautious to understand pluvial flooding, the chaos of heavy rainstorms and the direct flow into buildings before the drainage system is even detected by the runoff. Urban flooding is much more than overwhelmed capacities (and we should not lead folks to 'feel' that a larger capacity is all that's needed). Our definition of urban flooding should capture both current and potential urban flood problems. Important, too, is what we infer as a problem. Some feel water standing in their backyard in an urban flood problem. Are all temporary road closures a true problem, or elements of transportation planning in the future? Both redevelopment of existing urban areas and continuing urban sprawl need to be considered as we look at urban flooding. As we all know, most of Nation's large urban centers are "downhill" along rivers or large bodies of water - and the urban sprawl is uphill.

Let's Not Map the Ins and Outs: The National Flood Insurance Program created flood maps and the unintended language that a building is either "in or out" of a flood risk area. We have all seen that impact of this binary attitude. We are challenged to explain flood risk and mapping urban flood areas would exacerbate "in or out" mind-set. Urban flooding can be created wherever the rainstorm chooses to go (or stay). As an example: Lombard, Illinois, in DuPage County. DuPage County is quite flat, and the highest part of the County is Lombard. Lombard sits at the drainage divide of two of the County's major watersheds. If an engineer were to map an area of urban flooding, I doubt that they would consider the land at the watershed divide. Yet, in April 2013, Lombard made the news on The Weather Channel for urban flooding. Basement flooding occurred throughout the town. Schools, businesses and streets were closed. Any urban area can be subject to flooding due to excessive rainstorms and rain not being able to find a sewer, or able to make its way to a sewer due to fallen limbs or blockages. We are all "in." Mapping should be done for project purposes, but not for defining who is (and who is not) at risk.

Let's Be Cautious in Increasing Capacities: Also, we should not lean to heavily on increasing drainage system capacities. Storage of runoff in important. Capture water where its lands should be at the top of all recommendation lists. Capture has extended benefits of maintaining water budgets, including groundwater recharge. Separately, urban runoff taxes our streams and rivers with over-use, that the impact on those portions of our infrastructure is already heavy. We frequently see degradation of over-used streams and destabilized stream banks.

It's the Watershed: Our future climate is uncertain. Whether data shows much of our Nation having strings of wet years followed by strings of dry years or more severe storms, all developers, builders, property owners need to understand impacts and be responsible for impacts. And equally understand the impacts of increased downstream runoff (or sewer burden) and of rainwater not being allowed to feed our landscape, habitat and groundwater. All land development should be considered for regulation.

We All Need to Change: In so many parts of the country, folks make full use of basement areas living and for enjoyment. Basement floors have changed over recent decades from 4 to 6 feet below ground level to 12 to 15 feet to afford indoor basketball. And groundwater around these foundations are pumped on wet and dry day. Basements, and the allowance of basements needs to be reconsidered. In other parts of the county, slab foundations inches above the street level abound. This needs to be reconsidered; we need to make room for the rain.

Summary: Being careful and comprehensive in the definition of urban flooding - and urban flood problems - will pay dividends towards co-opting decision makers and people. Avoiding past pitfalls is also key. In large areas of the country, we are all "in" and at risk. Addressing the causes of potential future urban flood problems is every bit as important as alleviating the current urban flood impacts. Finally, the Nation needs to improve and adjust our ideas of good watershed management to ensure that we're considering all land development, water management, building design and infrastructure systems.

Gilbert White Forum Increasing Our Resiliency to Urban Flooding
March 12 – 13, 2019

The Evolving Concern of Urban Flooding in Illinois.

Paul Osman, CFM
Illinois Department of Natural Resources/Office of Water Resources.

The State of Illinois has a long-standing reputation as a national leader in Floodplain management. Strong state and local floodplain development regulations, strict compliance, state administered mapping and risk identification programs, and proactive mitigation efforts have resulted in impressive accomplishments. Despite these efforts, flood damages continue to rise in Illinois.

Much of this is due to evolving flood risks in Illinois. Urban flood damages are increasing. In August 2014, the Illinois General Assembly tasked the Illinois Department of Natural Resources/Office of Water Resources (IDNR/OWR) to prepare a report on the extent, cost, prevalence, and policies related to urban flooding. In addition, IDNR was tasked to identify resources and technology that may reduce the impacts of urban flooding.

Background Data:

- Urban Flooding occurs statewide; not just in the Chicago metropolitan area.
- $2.3 billion in urban flood damages occurred between 2007 and 2014.
- $1.2 billion was paid for sewer backup damage in basements.
- Over 90% of urban flooding damage claims occur <u>outside</u> of mapped floodplains.

Findings:

- Causes are unique to the specific location. Urban flooding is most common where: storm sewers are not designed to current standards and urbanization has increased runoff.
- Climate change is trending to more frequent and intense storm events.
- Countywide stormwater authority is only allowed in 16 counties, the majority of counties in the state are not allowed to pass any stormwater regulations.
- Communities have the authority to impose design standards and ordinances but, often do not have the legal authority to establish a dedicated funding stream which makes sustainability difficult.
- Urban flooding is expected to increase with annual rainfall trending upward over the last 100 years and more heavy rain events predicted in the future.
- There are many options to mitigate urban flood damages, such as adopting stormwater regulations, updating aging and undersized storm sewers, green infrastructure, and increasing open areas in areas of redevelopment.
- Changes to infrastructure and the urban landscape will take years; however, communities and individuals can act now to reduce risk and damages. Education and training for communities, insurance agents, and property owners is critical to understanding risks and how to mitigate and correctly insure those at risk.
- Urban flooding cannot be solved by Federal programs or Federal level mapping. The problems of localized flooding are small scale, rapidly evolving, and constantly changing. It requires locally based efficiency. The problem cannot be addressed by an unwieldy Federal bureaucracy.
- The state can provide leadership for communities. The state can develop tools, provide technical and financial assistance, and raise awareness.

- The Federal Government can provide assistance and incentives to encourage local actions.

The responsibility for urban flooding lies at all levels.
From state government to community regulation to individual property owners, a tiered approach is required for all aspects of stormwater management to be successful.

The recommendations listed in the Illinois report address the need for authorities, education and awareness, local regulations, collaboration between government agencies and communities, and funding for programs and data collection efforts to reduce future flood damage costs.

Urban Flooding Awareness Act –Summary Recommendations.

Illinois General Assembly

1. Give counties and communities the authority to generate stormwater fees.

2. Give all counties authority to adopt countywide stormwater ordinances.

3. Mandate flood insurance continuing education for insurance agents.

4. Fund an update of the existing rainfall frequency distribution study.

5. Fund rainfall, stream and other physical data collection for project studies and operation.

6. Create an annual program to buy-out flood prone houses in and out of the floodplain.

7. Continue leveraging federal funds through flood hazard mitigation programs.

8. Require NFIP participation for all flood related state funding or grants.

State Government

1. Start an IDNR / IEPA collaboration for using state revolving funds for stormwater.

2. Coordinate between state agencies to promote efficiency and resiliency in projects.

3. Educate the public on flood insurance and sewer backup coverage.

4. Incorporate green infrastructure options in state funded capital improvements.

5. Develop and promote a State model stormwater ordinance.

Local Government

1. Create or update stormwater ordinances using the new state model ordinance.

2. Complete pre-disaster planning for access to FEMA disaster money.

3. Regulate and maintain overland stormwater conveyance areas.

4. Use cost share programs for investigating individual house flooding.

Summary:
Urban flooding is a rapidly evolving localized problem. It cannot be solved at the state or federal level.

Rather, local communities must develop efficient and proactive program with support and incentives from state and federal partners.

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Appendix**:** https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Appendices.pdf

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Towards Integrated Flood Risk Management: Washington, DC Approach

Phetmano Phannavong, P.E., CFM, DC Department of Energy and Environment (DOEE)

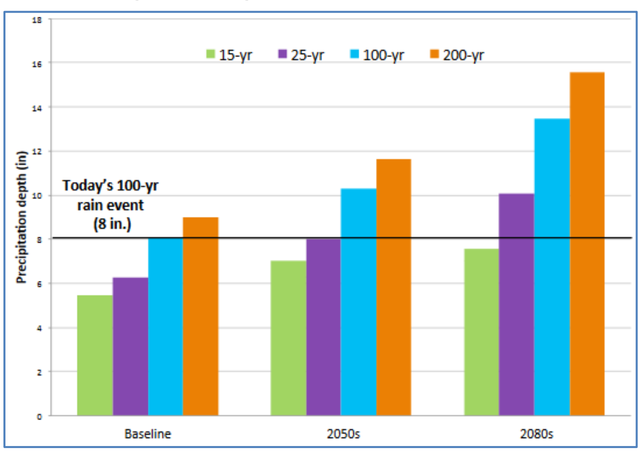
Summary

Washington, DC is extremely flood-prone. Its most costly flood event, the Federal Triangle flood of June 2006, caused the General Services Administration and the Internal Revenue Service $54 million in repairs in additional to $4 million associated with employee time lost (Source: National Capital Planning Commission). Jurisdictional issues complicate DC's flood risk management, where there is no single federal or DC agency that has authority to comprehensively address DC flood risks. Mitigating flood risks and responding to flood events requires strong coordination across multiple layers of government. Existing programs, such as the US Army Corps of Engineers' (USACE) Silver Jackets program, could be enhanced to leverage resources from federal, State, regional, and local agencies to tackle urban flood risk management. Increasing resilience to urban flooding needs an integrated flood model that combines all types of flooding source. Integrated flood modeling should be the backbone for urban flood resilience, serving as a decision-making tool for multiple purposes, including land-use planning, infrastructure upgrades, supporting flood insurance ratings, and responding to any flood emergency events at a neighborhood level.

Problem

Washington, D.C. is situated at the bottom of the Potomac River Basin. DC's location at the confluence of the Potomac and Anacostia Rivers, combined with buried waterways, broad floodplains, and relatively flat elevations at sea level, renders it highly susceptible to periodic flooding. DC is one of the most densely populated cities and contains vital historical and cultural resources, which make DC is at a high risk due to the consequences when a flood occurs.

Addressing flooding, which is the most costly natural disaster in the United States, will be even more challenging due to sea level rise, hurricane storm surge, and extreme storm events. Due to climate change, storm events are expected to carry more moisture and result in increasingly heavy rain or snow events. Most storm sewer and drainage infrastructure in DC is designed to carry the amount of rain associated with a 15-year storm event, which was historically about 5.5 inches of rain over a 2-hour period. By the 2050s, the 15-year storm event is projected to result in nearly 7 inches of rain. According DC's climate adaptation plan (Climate Ready DC, 2016), flooding associated with heavy rain events can be expected to be more frequent and more severe.



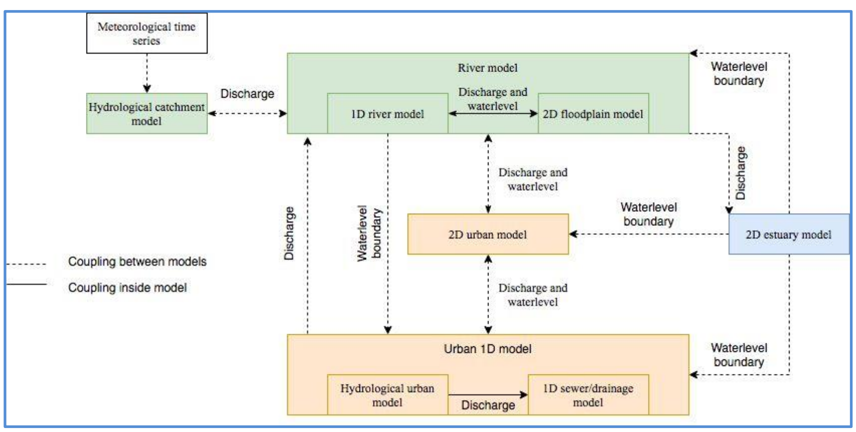
2-Hour Precipitation Projections in the DC Climate Adaptation Plan, Climate Ready DC (DOEE, 2016)

Despite these risk factors, no single agency has the authority needed to comprehensively coordinate, manage, and reduce flood risks in DC. Instead, each federal and DC agency has long-established missions, goals, and approaches where many agency authorities stop short in addressing flood risks holistically. Many programs have conflicting mission making comprehensive flood risk management is even more difficult to achieve.

Washington, DC Approach

Centralized Flood Risk Management Coordination through the DC Silver Jackets. Managing flood risks falls not only under floodplain management, but also stormwater management, land-use planning, emergency management, and many other programs within various local and federal agencies. Successfully managing complex DC flood risks requires an establishment of formal coordination among federal and DC agencies. Fortunately, Hurricane Sandy in 2012 spared DC. Afterward, DOEE, the National Park Service, and USACE chartered an interagency team, the DC Silver Jackets, to provide a platform for regional, federal, and DC government agency representatives as well as academia to advance joint initiatives to better prepare for floods in DC. The mission of the DC Silver Jackets is to address all types and all phases of flooding. Together, the team defines problems and leverages resources from member agencies to solve them through interagency flood risk management projects. The team maintains a cross-agency flood response plan, conducts annual flood awareness and insurance campaigns, and continues supporting flood policy changes in each agency. The DC Silver Jackets is looking for collaborations with private entities and non-profit organizations in upcoming years to ensure its ambitious goals are met.

Integrated Flood Modeling as the Backbone of Comprehensive Flood Risk Management. DC is at risk from three types of flooding sources because of its geographic location: (1) riverine from upstream the Potomac watershed, (2) coastal from the Chesapeake Bay, and (3) interior or inland flooding from heaving rainfall events. Climate change will exacerbate DC flooding risks where sea level is rising exponentially, and weather conditions are becoming extreme. Understanding the interconnection among these three flooding sources is essential in planning for infrastructure resilience and building resilient communities. In late 2018, DC developed a roadmap to create an integrated flood model that consolidates modeling of these flooding sources. In collaboration with the Rockefeller Foundation under the 100 Resilient Cities initiative, DC worked with Dutch water experts and engaged with federal, regional, and DC agencies in assessing existing flood modeling data and models, and creating a framework to collect, develop and maintain them. Currently, DC is exploring local and federal funding opportunities and other partnerships to develop the integrated flood model.



DC Preliminary Framework for Integrated Flood Modeling that Combines Fluvial, Pluvial, and Coastal Flooding (DOEE, 2018)

Thoughts on Increasing Resilience to Urban Flooding. Increasing resiliency to urban flooding is a daunting task that requires a strong partnership that leverages resources from all levels of government and private sector. While many flood experts are discussing new authority and funding to address urban flooding, there are existing programs, such as the USACE Silver Jackets program that could be utilized as a framework to leverage existing expertise, programs, and funding from both federal and non-federal partners. Urban flooding risks could be addressed through enhancing existing FEMA flood mapping program that incorporate modeling of all flooding sources in an integrated decision-making tool that serves multiple purposes and benefits of partner agencies in accordance with their mission and authority.

A Water District's Actions to Tackle Urban Flooding Problems

Afshin Rouhani, P.E., Water Resources Policy & Planning Unit Manager, Santa Clara Valley Water District and Vincent Gin, P.E., Deputy Operating Officer, Watershed Stewardship & Planning, Santa Clara Valley Water District

The Santa Clara Valley Water District, now known as "Valley Water" is a special district responsible for providing drinking water, flood protection, and environmental stewardship to all of Santa Clara County in California. Its service area includes farms and open space lands as well as the urban landscape of San Jose, Palo Alto, and the rest of Silicon Valley. Valley Water operates ten dams, three water treatment plants, and manages approximately 275 miles of valley streams and channels for flood protection and stream habitat stewardship, with an annual budget of $500 million.

As the urbanized area of Santa Clara Valley is a relatively flat landscape shaped by the action of dozens of seasonal creeks large and small, winter flooding has been a significant risk from the beginning. Flood waters often rise quickly in creeks which are fed by a combination of upstream watersheds and miles of city storm drains, which efficiently convey water to the creeks. Over the past few decades, Valley Water has invested approximately $1 billion dollars in capital projects to reduce flood risk to approximately 100,000 parcels of land; though tens of thousands of parcels remain at risk of frequent flooding. This paper briefly describes three somewhat unique ways Valley Water addresses its urban flooding risks.

<u>*FEMA Continuing Technical Partners Program*</u>

A key component of Valley Water's work to address urban flooding is developing a better understanding of how storm drains may increase or reduce flood risks. Specifically, Valley Water has partnered with FEMA through the Continuing Technical Partners (CTP) grant program to conduct detailed studies which model the storm drain network. The software used (ICM) directly routes rainfall over both natural and urban watersheds, into the storm drains, creeks, and pump stations. Software such as this has two main advantages: (1) it directly couples flow in the creeks with flow in the storm drain network; and (2) it explicitly models the storm drain pipes, significantly improving the accuracy of the beneficial storage provided by the storm drain network. This type of approach can also make it easier to identify deficiencies in storm drain networks.

Valley Water has conducted three such studies since 2014. The information gained has been shared with the relevant cities, who use it to inform planning of new proposed developments as well as informing existing residents who may be pondering their flood risk and the wisdom of buying insurance. The results of these studies have provided some interesting insights. In some areas, the old (but still commonly used) methodology for parameterizing the effects of storm drains may dramatically underestimate their storage capacity. In two of the three studies completed, the updated methodology showed that the 1% floodplain was considerably smaller than previously calculated. More accurate modeling of actual flood risk is vital to proper prioritization of capital projects under constrained finances, especially as more and more funds are needed for operation and maintenance of existing infrastructure.

CRS Fictitious Community

For areas that still remain at risk of frequent flooding, Valley Water works actively to help residents understand their risk, know what to do if a flood occurs, and how to mitigate their risk. Valley Water conducts outreach campaigns providing important information, advertises and stocks sand bag distribution centers, and collects and disseminates emergency information during events.

Though it is not itself a land use agency nor a NFIP community, as of 1998 Valley Water has been an active participant in FEMA's CRS program, which provides participating communities with discounts on flood insurance based on qualifying flood mitigation activities the communities perform. This is through formation of a "Fictitious Community," whereby Valley Water coordinates and collaborates with the local cities and county in its jurisdiction on CRS activities. Valley Water has developed and maintains an online database of its own and community qualifying CRS activities, assists in coordinating FEMA audits, all to make it easier for the communities to receive credits for qualifying mutual work. Of the 14 cities and the county within Valley Water jurisdiction, ten participate in the program, receiving up to a 25% discount on flood insurance. As full 1% flood protection to all flood prone areas is not a short-term solution, coordinating beneficial flood mitigation activities and reducing flood insurance costs is an important part of Valley Water's service to its urban community.

Stormwater Pollution Prevention

Stormwater pollution is a significant part of the urban flooding problem. In June 1990, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) received the first municipal stormwater permit in the nation from the San Francisco Bay Regional Water Quality Control Board. Valley Water originally organized and managed SCVURPPP, which is an association of the fourteen cities and towns, the County, and Valley Water, who all share a common permit to discharge stormwater to creeks and South San Francisco Bay.

The total population within the Program area is approximately 1.7 million. The Program incorporates regulatory, monitoring and outreach measures aimed at reducing pollution in urban runoff to improve the water quality of South San Francisco Bay and the streams of Santa Clara Valley. The goal of the stormwater permit is to reduce pollution in stormwater to the "maximum extent practicable" and to avoid discharges (with some exceptions) of water that is not stormwater – only rain down the storm drain. Over the years, the Water Board has amended the permit to include expanded requirements for controlling pollutants from new and redevelopment activities (Provision C.3) and in various other ways. Since Valley Water's mission includes environmental water quality and stewardship, its participation in this work has become an important part of its mission.

Gilbert F. White National Flood Policy Forum
INCREASING OUR RESILIENCY TO URBAN FLOODING
March 12-13, 2019

The Moving Targets of Infrastructure, Development and Climate in United States Cities

The existing stormwater infrastructure in our cities is comprised of connected systems to transport and/or store water planned and built over decades, and in some cases over hundreds of years. Our built environment changes with each new development or redevelopment, making it likely that the existing stormwater infrastructure connecting to it becomes outdated and inadequate over time, especially as we see an increase in rainfall over time, and in coastal areas increases in tidal inundation. How can we collect and use the data on our existing infrastructure capacity so we can estimate more accurately the flooding risk in our cities? What we are trying to be resilient for - flood levels, frequencies and duration – changes as climate increases the water we have to manage in our urban environments. How do we address this moving target, which needs reliable projections into future decades, in planning and building public infrastructure and private properties that need to last to sustain local and regional economies?

The many engineering projects over time that add up to our existing systems were built with plans that can be compiled and evaluated by the drainage sub-basins that they serve, and show how the connected systems and sub-basins match up at their interfaces. Big data storage and very robust computing is needed to bring an accurate picture of existing infrastructure into focus and allow new development and redevelopment to benefit from improved data on expected impacts, including projections of increased rainfall for the expected life of the public and private infrastructure systems, that form the capacity needed for new and connecting systems. We also need this base floor of information to begin planning the improvements to aging existing systems.

Funding for local governments to collect and evaluate this data and segregate it by sub-basins is not readily available. Slow progress can perhaps be made under current budgets if staff can be dedicated to develop it in one sub-basin at a time. But planning and development of new projects could help by requiring the connecting systems in the sub-basin be identified, and to put the capacity of the out flowing connected system in the design review for compliance with the stormwater permit for the project. Additionally, the projected rainfall during the useful life of the development could be required, identifying a source of this data for uniformity across the jurisdiction. Maintaining a database and map of the system could include these additions as development and redevelopment occur, and over time the larger picture could be pieced together and the critical spots identified could be the focus of the limited local government resources to fill in missing portions of the sub-basins.

The ability to more accurately identify flood risk, including the projected conditions for the life of a development (public or private), may help mitigate a growing unintended effect of projected increases in flooding and storm impacts. One major financial issue for the private landowner is the map that shows the flood risk for their property. The coastal sea level rise viewer, specific studies of areas for increased storm flooding and other efforts to project flooding can have a chilling effect on property values in those areas shown to be at increasing risk. The aging infrastructure evaluation suggested above will likely bring other properties into the risk maps. The investment in real property and development typically has a useful life or return on investment period. When the projected increase in flooding risk includes an area where the investment was not matched to the ‘new’ risk, devaluation is likely. How do we identify flood risk without causing financial harm to those who will need robust financial resources to respond to, or to become more resilient in preparation for storm and flooding events? There is no program in place that would allow a transfer of the financial risk and protect that investment, whether public or private. Can we develop financial tools in concert with the effort to better identify our infrastructure capacity with new climatic conditions as well as plan for more resilient development and redevelopment in areas that are projected to see increased risk? Or do we just pick a point at which we abandon the private investment in properties in some parts of our cities as part of resiliency? There is a real need for a mechanism to transfer development investment value from properties in an area that will succumb to flood damage to areas that are projected to maintain property values over time. The infrastructure investments and tax base economic balance for local governments is a consideration in any long term plans to respond to flooding risks and increasing our urban resiliency. Public and private investments are at risk as we face changing climatic conditions incrementally affecting our built environment and challenging our local governments.

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Nelson Mullins Riley & Scarborough LLP
Charleston, SC

Gilbert F. White Forum

February 25, 2019

Urban flooding and climate change: policy implications and needs

Shana Udvardy, Climate Resilience Analyst, Union of Concerned Scientists

The latest reports on climate change, the Fourth National Climate Assessment (NCA4) and the United Nations Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5 Degrees C, provide daunting findings including that climate change is affecting us here and now and that without urgent action we'll see greater risks and impacts for society. The IPCC findings clearly indicate that we are nowhere near on track to meet the goals of the Paris Agreement. In fact, the current commitments by countries would have us reach a level of global warming that is closer to 3 degrees C – far above the 1.5 Degree C goal and 2 Degree C target of the Paris Agreement.[1] That trajectory of warming would have devasting impacts to ecosystems and biodiversity among many other negative consequences. The IPCC report calls for an urgent and rapid ramping up of emissions reductions now.

Humans have increased the global average temperature by 1 Degree C or 1.8 Degrees Fahrenheit above pre-industrial levels primarily due to the burning of fossil fuels. What does this warming world mean for urban flooding along our rivers and coasts? The NCA4 indicates that since the beginning of the last century annual precipitation has increased across most of the eastern and northern United States and decreased across the southern and western United States.[2] Projections for annual precipitation this coming century show significant increases during the winter and spring months over the Northern Great

[1] *See* https://www.ucsusa.org/our-work/ucs-publications/IPCC and https://www.ipcc.ch/sr15/

[2] Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose, and M. Wehner, 2018: Our Changing Climate. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 72–144. doi: 10.7930/NCA4.2018.CH2

Plains, the Upper Midwest, and the Northeast.[3] Global average sea level has risen by about 7–8 inches (about 16–21 cm) since 1900, due to warmer oceans and melting land ice.[4] Relative to the year 2000, global sea level is very likely to rise 1 to 4 feet (0.3 to 1.3 m) by the end of the century.[5] In short, we'll see more frequent and heavy rainfall events that could lead to more flooding in some regions[6] and chronic flooding along our coasts due to rising seas.[7]

Climate change will make some extreme weather events more extreme.[8] The future portends an increase in eastern North Pacific hurricane rainfall and intensity as well as an increase in the frequency and severity of landfalling "atmospheric rivers" on the West Coast.[9] Scientists found that human caused climate change made the rainfall from Hurricane Harvey that hit the Houston, Texas region in 2017 roughly three times more likely, and about 15% more intense.[10] The 52 inches that fell in one location was so unprecedented that the National Weather Service needed to adjust its color chart and add two new colors, given the off-the-charts record rainfall.

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[3] *Ibid*

[4] Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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[6] Union of Concerned Scientists. 2018. Climate Change, Extreme Precipitation and Flooding: The Latest Science. https://www.ucsusa.org/global-warming/global-warming-impacts/floods

[7] Union of Concerned Scientists. 2018. Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate. https://www.ucsusa.org/global-warming/global-warming-impacts/sea-level-rise-chronic-floods-and-us-coastal-real-estate-implications

[8] Union of Concerned Scientists. 2018. Attribution fact sheet: The Science Connecting Extreme Weather to Climate Change. https://www.ucsusa.org/our-work/global-warming/science-and-impacts/climate-attribution-science

[9] Ibid, see footnote 2.

[10] van Oldenborgh, G.J., K. van der Wiel, A. Sebastian, R. Singh, J. Arrighi, F. Otto5, K. Haustein, S. Li, G. Vecchi, and H. Cullen. 2017. Attribution of extreme rainfall from Hurricane Harvey. Environmental Research Letters, Volume 12, Number 12. https://iopscience.iop.org/article/10.1088/1748-9326/aa9ef2#acknowledgements

Urban flooding solutions need to be ramped up at all levels of government

The majority of American people (85%) live in metropolitan areas and account for 91% of the 2015 Gross Domestic Product (GDP).[11] Many of these urban areas across the United States have been hammered by heavier and more frequent rainfall events. For example, Pittsburgh, PA experienced 11 flash flood events between 2007 and 2013.[12] Port cities along our coasts will see the compounding impacts of both extreme precipitation and rising seas. In Charleston, SC for example, extreme rainfall and high tide flooding in 2015 caused a cascade of impacts including dam failures, interruptions in transportation and electric power, flooded homes and businesses and broadscale impacts on the local economy.[13] Urban areas will need policies and resources from all levels of government to reduce risks to and costs of flood events.[14] Included here is a sample of policies the federal and metropolitan governments could implement.

The Administration and Congress must provide leadership on urban flooding

- The Administration and Congress should:
    - Ensure vertical and horizontal integration and coordination among local, state, and federal governments on urban flooding. Science and policy experts agree that an easy first step for this Administration (in coordination with Congress) would be to establish a federal task force of state and local governments, Indian tribes, and nongovernmental organizations, to help develop actions and solutions around urban flooding.[15] Successful models include the

[11] Maxwell, K., S. Julius, A. Grambsch, A. Kosmal, L. Larson, and N. Sonti, 2018: Built Environment, Urban Systems, and Cities. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 438–478. doi: 10.7930/NCA4. 2018. CH11
[12] *Ibid*
[13] *Ibid,* at footnote 11
[14] Galloway, G.E. et al. 2018. The growing threat of urban flooding: A national challenge. University of Maryland, Center for Disaster Resilience, and Texas A&M University, Galveston Campus, Center for Texas Beaches and Shores. College Park: A. James Clark School of Engineering.
[15] *Ibid*

State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience[16] and the Hurricane Sandy Rebuilding Task Force which cities support.[17]

- Establish new funding sources for cities and states to help reduce flood risk to urban areas. Examples of financial mechanisms include: a 'Build America Bonds' program, challenge and competition programs at the Department of Housing and Urban Development (HUD), popular state-revolving loan programs, green bonds, and innovation funds and trust funds.
- Provide robust resources for more science and analysis on urban flooding, including:
  - ramping up resources for the U.S. Geological Survey (USGS) to increase the number and coverage of riverine and stream gauges;
  - robust funding for FEMA's flood mapping program;
  - appropriate funds to USGS, the National Aeronautics and Space Administration (NASA), and the Federal Emergency Management Agency (FEMA) to track, map and assess extreme precipitation events including the flood footprint both in extent and depth; and
  - reactivate the stalled Technical Mapping Advisory Committee (TMAC) and charge it with conducting additional research and analysis on a climate informed science approach (CISA) for implementing the federal flood risk management standard (FFRMS) for riverine areas.[18]

- Pass legislation and sign into law a new program under HUD, in coordination with FEMA, to track and provide analysis on funding and policies on buyouts and retreat from riverine and coastal areas. The same program or a separate program should address how to identify and target resources

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[16] *See* https://obamawhitehouse.archives.gov/administration/eop/ceq/initiatives/resilience/taskforce

[17] 100 Resilient Cities. 2018. Safer and stronger cities strategies for advocating for federal resilience policy. http://100resilientcities.org/wp-content/uploads/2018/03/100-Resilient-Cities-Safer-and-Stronger-Cities-Final-PDF.pdf

[18] ASFPM Foundation. 2015. Meeting the challenge of change: Implementing the Federal Flood Risk Management Standard and Climate-Informed Science Approach. A Summary Report based on the 5th Assembly of the Gilbert F. White National Flood Policy Forum, Washington, D.C.

towards low-income, elderly and minority populations that can be affected by flooding to a greater degree because they have fewer resources (for example flood insurance, access to transportation and cash) to relocate.[19]

Cities must improve risk disclosure and reduce flood risk

- Cities should:
    - Develop non-regulatory flood maps that account for climate change and sea level rise based on the best available science. For example, in 2016 New York City and FEMA released news on their coordinated effort to use climate change informed maps to develop long term planning and not for insurance purpose, to help protect affordability of flood insurance.[20]
    - Adopt a climate informed science approach to a flood-ready standard to ensure the development of buildings and infrastructure can withstand future flooding. The Association of State Floodplain Managers (ASFPM) Foundation released a report with recommendations on how the federal government can help provide guidance and leadership on this front.[21] While roughly 600 communities already require structures to be built from 1 to 3 feet above the 100-year flood level[22], many ought to revise these requirements based on future projections. Building above future flood levels, especially for infrastructure, can have a high return on investments (ROI): for roads and railroads it's 11 to 1; for water and wastewater facilities it's as high as 31 to 1; and for electric and telecommunications it's as high as 9 to 1.[23]

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[19] *Ibid*, see footnote 2.
[20] *Ibid*, see footnote 14.
[21] *Ibid*, see footnote 18.
[22] *See* the Association of State Floodplain Managers report at: *https://www.floods.org/ace-files/documentlibrary/FloodRiskMngmtStandard/States_with_freeboard_and_CRS_Communities_with_Freeboard_in_Other_states_2-27-15.pdf*
[23] The National Institute of Building Sciences (NIBS). 2018. Natural Hazard Mitigation Saves Study. See https://www.nibs.org/page/mitigationsaves and https://cdn.ymaws.com/www.nibs.org/resource/resmgr/docs/MSv2_Utilities_and_Transport.pdf

- Establish and fund a robust buyout and relocation program for repetitively flooded structures.

Urban Flooding: Not Always a "Hidden" Challenge

Anna Weber and Meleah Geertsma, Natural Resources Defense Council

Different types of urban flooding require different solutions

There is no single, standardized definition of "urban flooding," and the phrase can be used to refer to a range of flood events. The Background section of the Forum Overview describes two distinct types of flooding:

(1) Large-scale but relatively low-frequency flooding that occurs in an urban area, due to a storm surge or catastrophic rain event.
(2) Chronic flooding not associated with proximity to coasts or rivers, due to urban landscapes that cannot absorb or otherwise manage rainfall.

Climate change is undoubtedly affecting vulnerability to both types of flooding, and solutions are needed for each. However, they are separate phenomena with different contributing factors, and addressing them will require different solutions. For example, mitigation funding tied to flood insurance is unlikely to be appropriate for infrastructure-related urban flooding that occurs outside of mapped floodplains. The forum's outputs should clearly define the type(s) of urban flooding that are considered and the recommendations should be tailored to the type of flooding they are meant to address.

We must recognize the longstanding challenge of chronic urban flooding

Chronic urban flooding—wherein even minimal rains can overwhelm local drainage capacity, leading to wet basements and sewer backups—is not a new problem, but it has received less attention from researchers and policymakers compared to other types of flooding. As described in a recent paper:

> Practitioners and scholars have largely overlooked recurrent inland urban flooding as a threat to public health. The experiences of those that are particularly vulnerable are often underacknowledged, and these populations are often untapped sources of knowledge vital to informing effective prevention and response strategies.[1]

This type of urban flooding is deeply rooted in the social factors shaping our physical landscape. It disproportionately affects low-income and minority residents, and it is directly related to the deteriorated or inadequate infrastructure found in impoverished, neglected, and/or socioeconomically isolated urban communities. The forum's discussion of urban flooding should recognize the past and ongoing hazards faced by these communities and ensure that they have a seat at the table, with their input given primary consideration in forming recommendations. Urban flooding may be referred to as a "hidden challenge,"[2] but it is not hidden to those who have lived with its effects for years or—in too

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[1] Natalie Sampson et al., "'We're Just Sitting Ducks': Recurrent Household Flooding as An Underreported Environmental Health Threat in Detroit's Changing Climate," International Journal of Environmental Research and Public Health 16, no. 1 (December 20, 2018): 6, https://doi.org/10.3390/ijerph16010006.

[2] University of Maryland, College Park and Texas A&M University, Galveston Campus, "The Growing Threat of Urban Flooding: A National Challenge," November 2018, https://cdr.umd.edu/urban-flooding-report.

many cases—decades. In addition, action to address this type of flooding should not wait until urban flooding as a whole is fully defined or characterized.

The forum should consider urban flooding's unique policy challenges

Recent research into urban flooding illustrates a number of policy gaps that make it difficult to compel action. The recent University of Maryland/Texas A&M University report points out that there is generally no clear jurisdiction or responsibility for urban flooding, across all levels of government. This complicates data collection, funding availability, and priority setting. For example, the National Flood Insurance Program (NFIP) is not designed with urban flooding risk in mind, so it does not provide communities with the right tools to address this issue. Outside of the NFIP, state and local stormwater policies largely derive from the federal Clean Water Act and, as such, they primarily focus on water quality considerations rather than flooding. Finally, incidents of urban flooding are often too localized to trigger disaster declarations and the accompanying government assistance.

At the local level, urban flooding can lead to challenging investment decisions. How should utilities allocate resources when faced with the costs of bringing the worst-off customers up to a minimal standard of infrastructure and flood protection service, versus costs associated with increasing the level of service for larger numbers of customers who already meet a minimum standard? For example, one participant in the University of Maryland/Texas A&M University urban flooding survey stated:

> The Village of [redacted] is a prime example of a community that faces urban flood issues. [Redacted] is not adjacent to a major tributary receiving water, but has several isolated neighborhoods that face significant urban flooding during even moderate events. While these locations are few, the impact felt by these residents is massive. Although these are small areas within the community, the Village continues to struggle with the concept of allocating major capital funding to help only a small contingent of the community. Due to this struggle, these areas continue to go unmitigated.[3]

The forum should consider these and other questions that are specifically related to chronic urban flooding in underserved areas.

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[3] University of Maryland, College Park and Texas A&M University, Galveston Campus, "The Growing Threat of Urban Flooding: A National Challenge. Volume 2: Survey Report and Comments," November 2018, https://cdr.umd.edu/urban-flooding-report.

THE GROWING THREAT OF URBAN FLOODING: A NATIONAL CHALLENGE

2018

University of Maryland,
College Park

A. James Clark School of Engineering
Center for Disaster Resilience

Texas A&M University,
Galveston Campus

Center for Texas Beaches and Shores

THE GROWING THREAT OF URBAN FLOODING:

A NATIONAL CHALLENGE

2018

BISMARK, NORTH DAKOTA, PHOTO BY DAVID VALDEZ/FEMA

CONTENT

BALTIMORE, MARYLAND, PHOTO BY STANLEY ANDERSON

BLOOMINGDALE NEIGHBORHOOD, WASHINGTON, DC

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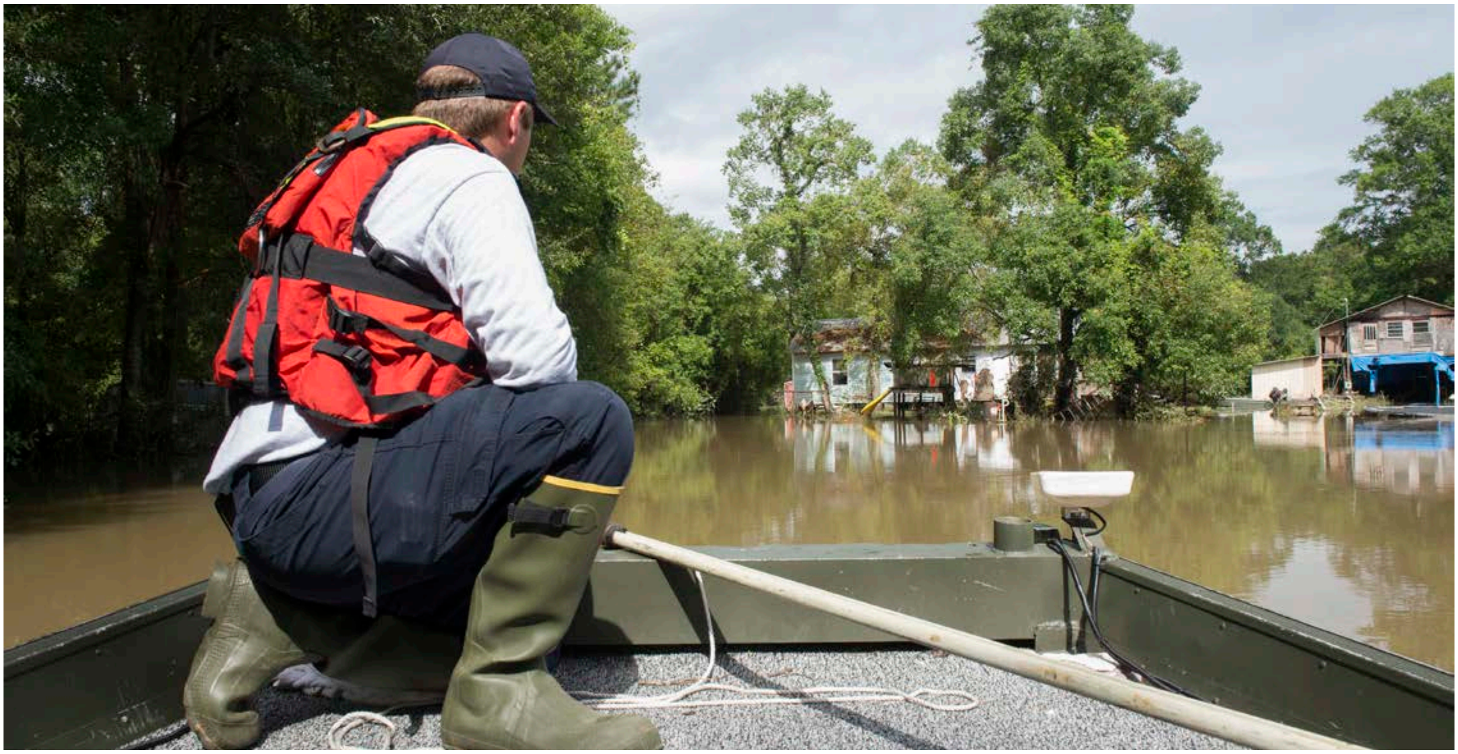
The team offers special thanks to the Association of State Floodplain Managers and the National Association of Flood & Stormwater Management Agencies and their constituent committees, and to the Center for Neighborhood Technology for their efforts in supporting the study. The team also acknowledges the ongoing efforts of the American Society of Civil Engineers, the American Water Works Association, the National Academies Committee on Urban Flooding, and the National Low Income Housing Coalition to deal with urban flooding issues. This study could not have been conducted without the assistance of the dedicated individuals who work within federal, state, and local governments.

CITATION: University of Maryland, Center for Disaster Resilience, and Texas A&M University, Galveston Campus, Center for Texas Beaches and Shores. The Growing Threat of Urban Flooding: A National Challenge. 2018. College Park: A. James Clark School of Engineering.

COVER: Heavy rains produce neighborhood flooding. Kenilworth, Illinois, 2013. Source: Village of Kenilworth.

THE GROWING THREAT OF URBAN FLOODING



GONZALES, LOUISIANA, PHOTO BY J.T. BLATTY/FEMA

Over the past decade, major hurricanes and extreme storm events have wreaked havoc on many urban areas throughout the United States. While the major storms of 2017 and 2018 (Florence, Harvey, Maria, and Irma) will be remembered as hurricanes, in many cases it was the intense rainfall that brought urban areas to a standstill, overwhelming homes and transportation arteries with flood water.

Aging and inadequate infrastructure, coupled with rapid land development, increased the amount of storm runoff to already stressed drainage systems, creating pockets of flooding in ill-equipped and vulnerable neighborhoods. In many communities, a lack of resources, a division of responsibilities among various departments, and a reluctance to deal with the impacts of increasingly intense precipitation and climate change has slowed progress in meeting the challenges of urban flooding.

In 2016, the Center for Texas Beaches and Shores at Texas A&M University, Galveston Campus and the Center for Disaster Resilience at the University of Maryland initiated a joint study to determine the extent and consequences of urban flooding in the United States and explore what actions might be taken to mitigate this flooding in the future. Center researchers analyzed available data concerning urban flooding, surveyed municipal flood and stormwater managers, and met with professionals whose disciplines intersect with urban flooding at the local, state, and national level. This report presents the results of that study, addressing issues that affect urban flood risk reduction, examining critical challenges, and offering recommendations for action.

THE STUDY TEAM REACHED THE FOLLOWING CONCLUSIONS:

1. **In much of the United States, urban flooding is occurring and is a growing source of significant economic loss, social disruption, and housing inequality.** Extensive suburban development that creates higher flood flows into urban areas, aging and frequently undersized infrastructure in older sections of communities, an inability to maintain existing drainage systems, increases in intense rainfall events, and uncoordinated watershed management all contribute to these increases in urban flooding.

2. **The growing number of extreme rainfall events that produce intense precipitation are resulting in—and will continue to result in—increased urban flooding unless steps are taken to mitigate their impacts.** The 2017 National Climate Assessment concluded that "heavy downpours are increasing nationally, especially over the last three to five decades...[and that]... increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions."

3. **Communities across the nation are facing similar challenges with urban flooding.** However, the unique hydrological, physical, and social characteristics of these communities mean solutions are best developed locally. While the magnitude of urban flooding challenges merit federal guidance and support when needed, responsibilities must rest primarily at the local level.

4. **While primary responsibility for mitigation of urban flooding rests with local governments, the division of responsibilities among federal, state, regional, local, and tribal governments for urban flood and stormwater management are not clearly defined.** Responsibilities are diffused and lack the collaboration and coordination necessary to address the technical and political challenges that must be faced.

5. **Many of the urban wastewater and stormwater systems that provide the backbone of urban flood mitigation are in poor condition and—in some locations—are inadequate and in need of strong support.** The human and fiscal resources necessary to address urban flooding are not generally available at the levels required.

6. **At the federal level, there is no agency charged with oversight of federal support of urban flood mitigation-related activities.** While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding.

7. **The economic and social impacts of urban flooding are generally not well known and understood by many public officials and the unaffected public.** Social vulnerabilities and inequities in disaster recovery for low-income populations are not being fully addressed.

8. **Governments, at all levels, have not provided effective means to communicate risks to those in urban flood-prone areas.** A significant number of these areas are not identified by maps produced under the Federal Emergency Management Agency National Flood Insurance Program, and actions by those responsible for urban flood mitigation are needed to delineate these areas. Communication of flood risk is often seen by public officials and developers as a negative.

9. **Many homeowners and renters living and working in areas affected by urban flooding do not understand that they can take steps to significantly reduce their property's vulnerability, and many lack the resources and support necessary to carry out such actions.** Information on how a resident can reduce their property's flood risk is not accessible or well-articulated.

10. **Data—covering insurance claims, assistance, and loans for flood mitigation—are not easily available or shared with local decision makers, researchers, and the residents themselves.** More accessibility and availability of data is critical to effective response, recovery, and long-term mitigation of flood events. This data must be provided in an easily interpreted and spatially identifiable format.

THE STUDY TEAM RECOMMENDS THAT:

1. **Governors, tribal leaders, and regional and municipal officials should review the current responsibilities for oversight of urban flooding mitigation, as well as flood, water, wastewater, and stormwater management in their jurisdictions; provisions, as appropriate, should be made to ensure efficient and effective multi-jurisdictional planning and operation of these activities and services on a geographic scale that matches the problems being addressed.**

2. **The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.**

3. **The administration, in coordination with Congress, should assign one federal agency to provide interim oversight of federal support of urban flood mitigation activities, the development of the national forum, and the preparation of a post-forum report for the administration, Congress, the states, municipalities, and tribes.**

4. **Attention should be given at all levels of government to ensure that efforts to mitigate urban flooding reach areas that have the highest risk of flooding and cross all economic and social levels and that locally supported steps must be taken to incentivize individual homeowner mitigation efforts.**

CHAMPAIGN, ILLINOIS, PHOTO BY C. ELIANA BROWN

LOW IMPACT DEVELOPMENT, PHOTO BY VIRGINIA SOIL AND WATER CONSERVATION DISTRICT

5. **In coordination with ongoing efforts to ensure that those at risk of flooding are aware of their vulnerabilities, FEMA, USACE, NOAA, USGS, EPA, and HUD, in collaboration with urban flood communities, should integrate urban flood risk communication outreach into their ongoing programs for riverine and coastal flooding and ensure that analysis of future conditions should include the impacts of climate and weather and future development.**

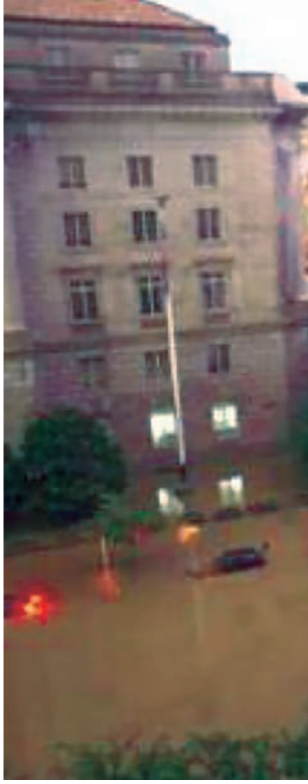
6. **States should consider integrating urban flood risk communication, mapping, and risk disclosure measures into real estate transactions in urban flood areas.**

7. **The Congress and the administration, in coordination with state governors, regional, local, and tribal officials, should develop appropriate mechanisms at the federal, state, and local level to fund necessary repairs, operations, and upgrades of current stormwater and urban flood-related infrastructure.**

8. **Congress should direct the administration to establish a risk identification grant program that enables communities to develop effective means of identifying the risks they face from urban flooding.**

NEW HARTFORD, IOWA, PHOTO BY GREG HENSHALL/FEMA

9. **The administration should support continued research into urban flooding to ensure that the full extent of the threat is identified and that steps are taken to formulate solutions to policy and technical issues.**



I. URBAN FLOODS: THE NATION'S HIDDEN CHALLENGE

THE INCREASING THREAT TO OUR COMMUNITIES

While riverine and coastal floods continue to pose a major threat to communities across the United States, causing billions of dollars of losses every year, urban flooding, which is often neglected in community planning and preparedness, is also having significant impacts. Increasing rainfall, combined with rapid land use change and development in flood-prone areas, has amplified the adverse economic and human impacts in recent years. Never have the repercussions of storm events driven by both coastal surge and rainfall been so damaging to local communities. Losses from acute and chronic floods have become especially problematic in low-lying urban areas, where stormwater infrastructure deterioration, population growth, and development have accelerated over the last several decades. Unfortunately, limited information is available about the extent and consequences of urban flooding. In much of the country, little is being done to address these consequences and develop plans to address problems before they get worse. This report seeks to provide information that will help governments and the public better understand the challenge of urban flooding and act on it.

MICHIGAN UNDERWATER

On August 11, 2014, heavy rains moved into Southeast Michigan and the metropolitan Detroit area, including the city of Flint and the Saginaw Valley. Four to six inches of rain fell in a four-hour period, and over 75,000 homes and businesses suffered damage. The intensity of the rainfall overwhelmed the area's drainage systems, which were in poor condition.[1] The estimated total damages exceeded $1.8 billion, making it the costliest U.S. flood event in 2014 and accounting for 60% of flood damage nationwide, according to the National Weather Service. Seventeen percent of the impacted residences were owned by low-income households and 13% by elderly households.

FIGURE 1. FLOODED HOMES RESULTING FROM AN INTENSE RAINFALL EVENT, AUGUST 2014. SOURCE: MICHIGAN STATE POLICE.

Between 2007 and 2011, urban flooding in Cook County, Illinois resulted in over 176,000 claims or flood losses, at a cost of $660 million dollars. Seventy percent of 115 respondents to a survey conducted by the Chicago-based Center for Neighborhood Technology (CNT) indicated that they had flooded three or more times during this five-year period; 20% had flooded 10 or more times.[2] In 2016, the city of Baton Rouge was inundated by an estimated 1,000-year rainfall event that flooded 48,000 structures and created over $1 billion in property damage. City officials pointed to the need to expand the community stormwater capacity.[3]

Urban flooding occurs not just in major cities but in the majority of U.S. communities, large and small. For smaller communities, the impact is more severe because they frequently lack the resources to deal with significant rainfall events and, because of their size, do not rise to the level of losses associated with federally-supported disaster assistance. In May 2018, Ellicott City, Maryland was hit by a second estimated 1,000-year rainfall event in two years and was once again subject to more than a billion dollars in damages. In June 2018, eight inches of rain fell in four hours on Ankeny, Iowa, flooding over 2,000 homes. The assessment of losses has not been completed.[4]

Urban flooding not only causes major property damage, it is also responsible for fatalities and injuries. Each year, people die while trying to move cars through deep or fast-moving water in streets. In July 2018, the tenant of a basement apartment in Englewood, Colorado was trapped in her apartment by waters from a major downpour and drowned. Stories of similar incidents or near misses are frequent.[6]

OUR NATION'S CAPITAL

In June 2006, heavy rainfall over downtown Washington, D.C. caused major flooding in the Federal Triangle, the area between Pennsylvania and Constitution Avenues and the home of many major government agencies. As a result, the headquarters building of the Internal Revenue Service was shut down for six months; areas in the National Archives Building, the Departments of Justice and Commerce, and the Environmental Protection Agency were also damaged. Total damages to the government buildings and adjacent commercial properties were estimated in the tens of millions of dollars. No judgment was made as to the potential damages to the iconic structures and their contents. Again, inadequate drainage was given as the cause of the flooding.[5]

FIGURE 2. FLOODING AT CONSTITUTION AVENUE AND 10TH STREET NW, WASHINGTON, D.C., JUNE 2006. THE INTERNAL REVENUE SERVICE IS ON THE LEFT; THE DEPARTMENT OF JUSTICE ON THE RIGHT. SOURCE: U.S. GENERAL SERVICES ADMINISTRATION.

FROM THE COMMUNITY

(Comments from respondents of this study's national survey of flood and stormwater professionals.)

"The Village of [redacted] is a prime example of a community that faces urban flood issues. [Redacted] is not adjacent to a major tributary receiving water but has several isolated neighborhoods that face significant urban flooding during even moderate events. While these locations are few, the impact felt by these residents is massive. Although these are small areas within the community, the Village continues to struggle with the concept of allocating major capital funding to help only a small contingent of the community. Due to this struggle, these areas continue to go unmitigated."

Flood issues are traditionally associated with riverine and coastal areas, but increasing attention is being given to urban flooding, where flood risk is more a function of the human-built environment. Population growth and associated development in metropolitan areas along the coast, combined with aging stormwater infrastructure and changing weather patterns, have given rise to an urban-specific flood problem of national importance. In this new category of flooding, risk and impacts are no longer tied to the Federal Emergency Management Agency (FEMA)-defined floodplains. Instead, significant flood losses can occur miles from a delineated floodplain where these urban losses are embedded in a highly developed landscape. Riverine and coastal floods occur when the river rises out of its banks, or coastal tides and surges rise above the shoreline. Flood flows can stretch to the highest ground in the vicinity, yet the FEMA-identified regulatory floodplains only include limited areas of the total floodplain. Low spots in the floodplain create areas for rainwaters to accumulate. Heavy rainfalls can exceed a stormwater system's ability to move the rainfall from inland areas to the river for eventual flow to larger rivers or coasts (Figure 3). Given that the urban footprint in the United States is predicted to increase from 3.1% to 8.1% from 2000 to 2050[7], especially in coastal regions, urban flood losses will continue to mount and present an important national policy problem for years to come.

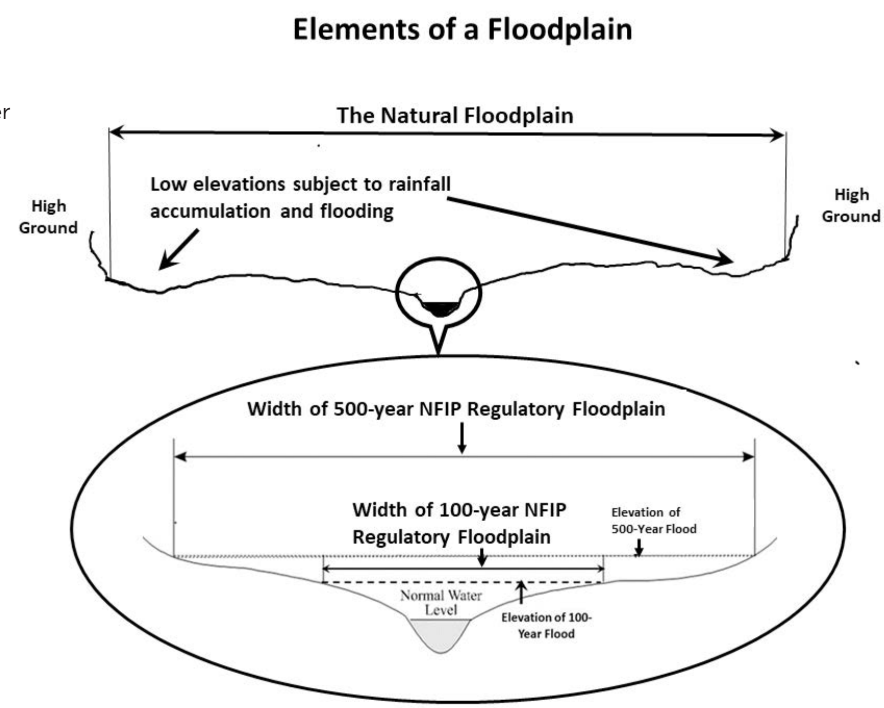


FIGURE 3. THE 100-YEAR FLOODPLAIN REPRESENTS AN AREA WHERE THERE IS A 1% ANNUAL CHANCE THAT A FLOOD WILL OCCUR, AND A 500-YEAR FLOOD IS WHERE THERE IS A 0.2% CHANCE EACH YEAR OF SUCH AN EVENT. SOURCE: CENTER FOR DISASTER RESILIENCE, UMD.

THE EFFECTS OF FLOODS ACROSS THE UNITED STATES

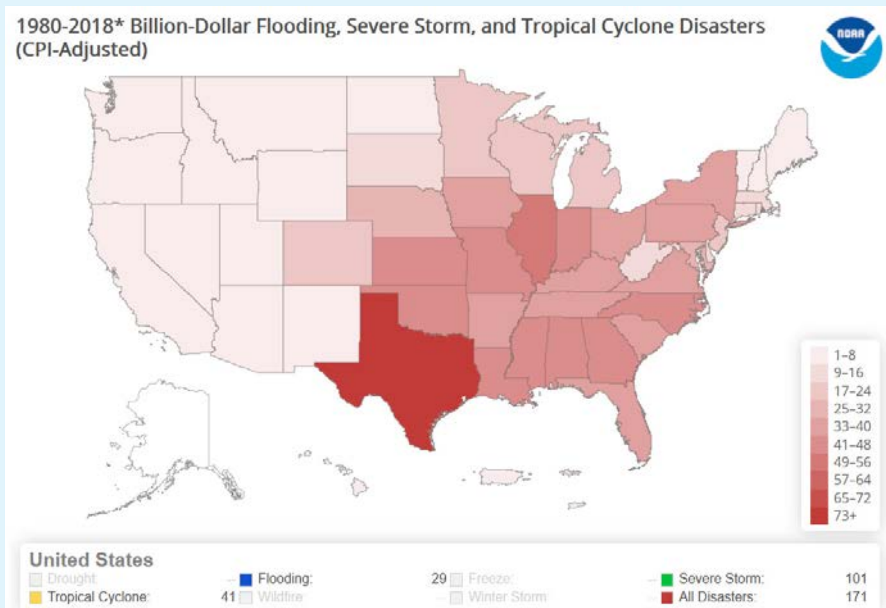
FROM THE COMMUNITY

"It's important to raise the awareness of "localized" floodplain management. Too often developers, builders, and engineers only consider the FEMA designated floodplains."

In 2017, New York University's Fuhrman Center reported that "an average of 15 million people nationwide lived in the 100-year floodplain in 2011-2015, representing nearly 5% of the nation's population. More than 30 million people—nearly 10% of the nation's population—lived in the combined 100- and 500-year floodplain during this period. Two-thirds of the population living in the nation's combined floodplain lived in Texas or New York." Figure 4 illustrates billion-dollar flood, severe storm, and cyclone disasters from 1980-2018. The National Weather Service (NWS) reports that between 1984 and 2013, flood losses in the United States from freshwater sources were estimated to be $238 billion (7.95 billion/year adjusted to 2014 inflation).[8] The estimate does not include damages from coastal storm surge events (e.g., Sandy and Katrina). Most of the statistics on flood losses in the United States are developed from information gathered in response to significant flood events or as a result of claims submitted against the National Flood Insurance Program (NFIP) (Figure 5).

There is very little data identifying where urban area flooding (not connected to rivers or coastal areas) is taking place in the United States, the consequences associated with this flooding, or the profile of those who have been affected. Data from commercial insurance policies are not normally publicly available, so claims made against those policies rather than the NFIP are not spatially defined for use by the public or by public officials.

FIGURE 4: 1980-2018* BILLION-DOLLAR FLOODING, SEVERE STORM, AND TROPICAL CYCLONE DISASTERS (CPI-ADJUSTED). SOURCE: NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION (NCEI) U.S. BILLION-DOLLAR WEATHER AND CLIMATE DISASTERS (2018), NCDC.NOAA.GOV/BILLIONS/MAPPING.



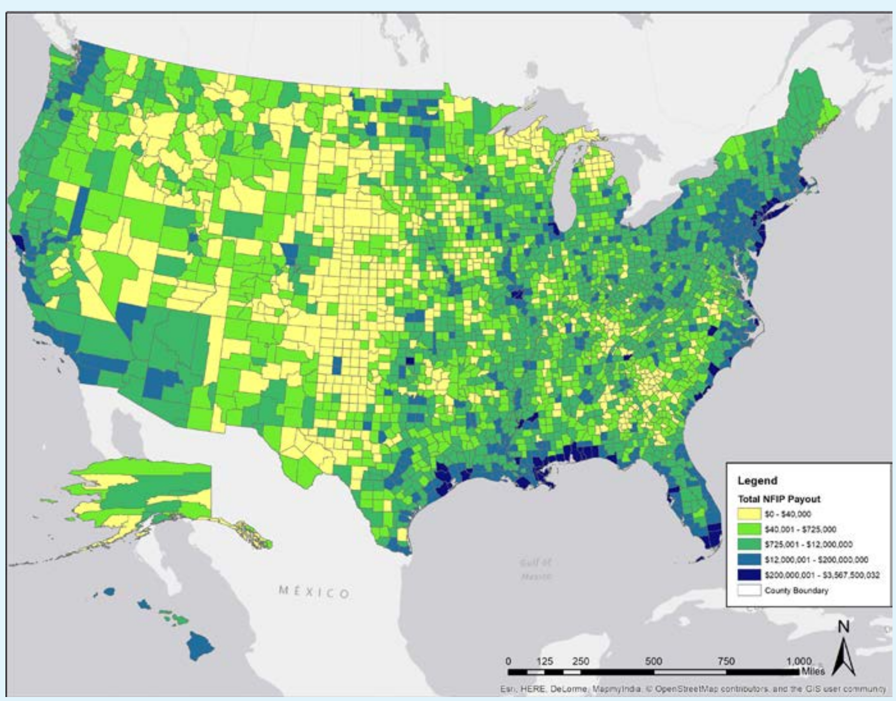


FIGURE 5. NFIP CLAIMS PAYOUTS BY COUNTY, 1974-2014. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

WHAT IS URBAN FLOODING?

FIGURE 6. NEIGHBORHOOD FLOODING FOLLOWING INTENSE RAINFALL, SAN JOSE CALIFORNIA, FEBRUARY 2107. SOURCE: SAN JOSE FIRE DEPARTMENT.

While infrequent major storm events and floods have created historic riverine and coastal disasters, urban flooding, which occurs frequently and ubiquitously, is constantly gnawing at the fabric of communities. The total cost of urban flooding has not been accurately recorded for several reasons: such floods occur frequently; they are scattered in neighborhoods throughout communities; they do not rise in total economic costs to the level of major events; and they are often not reported. Yet these events inflict significant economic and social damage on groups that have the least ability to deal with them. Cars and household items, in the absence of liquid assets, are frequently their most valuable possessions.

FEMA defines urban flooding as "the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. It excludes flooding in undeveloped or agricultural areas. It includes situations in which stormwater enters buildings through a) windows, doors, or other openings; b) water backup through pipes and drains; c) seepage through walls and floors." The definition has been expanded to include specific issues, such as sewer water backing up into homes, water seeping through foundation walls, clogged street drains, and overflow from sound walls, roads, or other barriers that restrict stormwater runoff. In 2015, at the direction of the state legislature, the Illinois Department of Natural Resources conducted a study of urban flooding within the state, characterizing such flooding "...by its repetitive, costly, and systemic impacts on communities, regardless of whether or not these communities are located within formally designated floodplains or near any body of water. These impacts include damage to buildings and infrastructure, economic disruption, and negative effects on health and safety."[9]

FROM THE COMMUNITY

"The areas being impacted by urban flooding are those that were built prior to our agency's existence. The system was taken over from the cities and standards were changed to reduce impacts due to urban flooding and continue to change to mitigate the climate impacts. While a Corps system protects the community from stream flows up to the 200-year event, urban flooding continues due to the magnitude of storms that exceed the capacity of the urban storm drainage system. Very few in the community recognize this reality."

FIGURE 7. BRIDGEVILLE, PENNSYLVANIA RESIDENTS MUCK OUT THEIR BASEMENT AFTER A FLASH FLOOD. SOURCE: FEMA NEWS/PHOTO BOB MCMILLIAN.

II. ANALYZING URBAN FLOODING

The analysis in this report is based on a national survey of municipal flood and stormwater managers and professionals working in these fields; the examination of available data from federal agency programs, commercial organizations, and nongovernmental organizations; and nationwide outreach efforts to determine the nature and extent of urban flooding.

83%

of respondents indicated they had experienced urban flooding in their communities (n=388).

46%

indicated that urban flooding occurred in numerous areas or most areas in these communities (n=325).

85%

had experienced urban flooding outside the Special Food Hazard Area. 15% had not (n=296).

51%

of the communities had been affected by moderate or larger urban floods (n=325).

65%

of respondents reported that less than 10% of moderate urban flood damages in their communities were covered by insurance under the the National Flood Insurance Program (n=242).

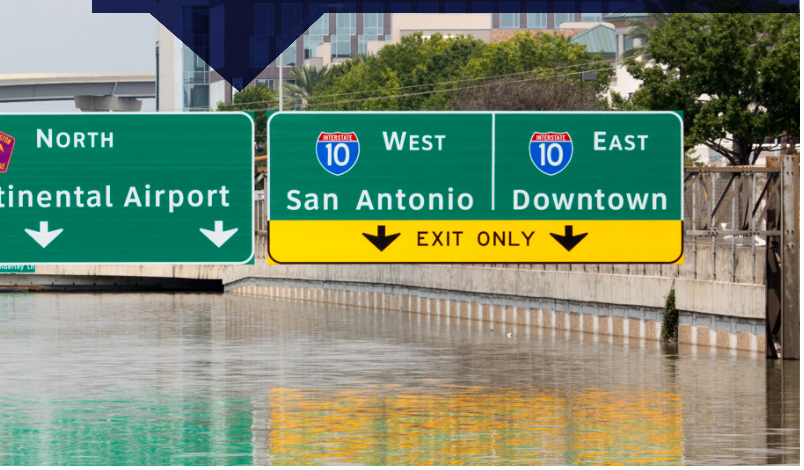
HOUSTON, TEXAS AFTER HURRICANE HARVEY

NATIONAL SURVEY

To gather information about the nature and extent of urban flooding, the study team identified and sent e-mail requests to over 1,000 stormwater and floodplain management practitioners in both municipalities and organizations that work with municipalities. Over 700 individuals responded to the survey, representing or having knowledge of over 350 municipalities. Respondents represented 48 states (exceptions were professionals in Wyoming and Montana, who were contacted by telephone). The respondents represented large, moderately-sized, and small communities. In addition, respondents provided 103 general comments on the topic as well as 883 comments or explanations to supplement answers to specific questions. The average number of responses to non-demographic questions was 306; however, the same individuals did not answer every question. In listing survey results, the percentage of respondents providing a given answer are shown against the number of respondents who provided answers to that question (e.g. n=X). A copy of the survey, including extracts from survey comments, can be found in Volume 2 of this report, available at cdr.umd.edu/urban-flooding-report.

FROM THE COMMUNITY

"Our county is becoming more & more developed, and we have a well-developed stormwater program to address much of this. However, we lack the urgency to do anything about our current stormwater management issues for a number of reasons: 1) political will is not supportive; 2) Most of the flooding occurs in low-income areas; 3) Flooding is not widespread when it does occur (like the 2010 [redacted] flood that affected all income levels and thus prompted an aggressive, progressive policy shift that requires low impact development); and 4) the general population does not understand stormwater infrastructure and/or are unwilling to maintain the part of the system that is on their property (easements, swales, storm drains, etc.), which cuts the streams off from their floodplains and exacerbates flooding conditions, now even in times of moderate rain events. Whew!"



DATA ANALYSIS

In determining where urban flooding has occurred across the country and its impacts, multiple data sets were used with a focus on available geospatial data, which more accurately identified the location and consequences of urban flood events.

One of the significant limitations in analyzing floods losses or government expenditures is that individuals and communities are only eligible for some programs when a federal disaster declaration has been made by the president. The result of this restriction is that smaller, chronic flood events or flooding in neighborhoods with less expensive homes may not be represented in the data.

PRINCIPAL DATA SOURCES

- The National Flood Insurance Program, 1972-2017. Insurance claims and policies: residential building damage (up to $250,000) and insured contents damage (up to $100,000).
- Small Business Administration loans (2004-2016) to individuals and businesses located in a county where a federal disaster has been declared.
- FEMA's Individual Assistance grants, 2004-2016, for disasters classified as floods; provides grants up to $33,000 (adjusted each year) to homeowners and renters when a federal disaster has been declared.
- FEMA/HUD Hazard Mitigation Grant Program property buy outs, 1998-2013.
- FEMA Public Assistance grants, 1992-2017; costs to remove debris, fund emergency protective measures, and repair/replacement of disaster-damaged facilities that are publicly owned. Provided to local government and some non-profits where a federal disaster has been declared.
- U.S. Census, 2010.
- NOAA Hydrologic Information Center—flood loss data.
- U.S. Census Bureau American Community Surveys.

OUTREACH

Over two years, the study team traveled extensively throughout the United States, connecting with professionals in the stormwater and flood management fields, public officials with responsibility for infrastructure management, and officers and committee members of professional associations. The team made presentations at meetings of government agencies and professional organizations and conducted focus groups. They met with senior officials of the Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), FEMA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Housing and Urban Development (HUD), as well as staff of members of Congress. The team was also able to meet with academics and practitioners from abroad to discuss the challenges they faced in their countries.

OBTAINING THE DATA

As indicated earlier in the report, neither the federal or state governments track urban flooding as it occurs or over time. Some communities maintain records of flooding, but they are generally inconsistent in both time and content. There is no national data repository that is collecting such information. The bits of data that are collected are not collected in a standard format, vary in geospatial specificity, and exist across the records of multiple organizations. Information collected by commercial organizations, such as insurance companies, is not publicly available and is generally protected by privacy restrictions that limit their use by even government and academic researchers. NOAA, as indicated earlier, maintains a record of significant weather events and their location; it includes supplemental information on impacts of weather events, as well as information on damages, fatalities, and injuries that occur as a result. To find out where urban flooding is taking place, the study team used the survey to garner information from those representing urban areas, participated in meetings and focus groups, met with selected municipalities, and reviewed flood-related literature and the media to identify where urban flooding has been reported or discussed. The team also analyzed datasets relevant to national and urban flooding, which identified conditions that reflected a probability that urban flooding is occurring in specific areas.

III. WHERE DOES URBAN FLOODING OCCUR?

Eighty-three percent of survey respondents (n=320) indicated that urban flooding was occurring in their associated communities. Since the respondents represented 48 states, it is clear that such events are occurring nationally (representatives of the two states that did not respond to the survey indicated telephonically the presence of urban flooding in those states). Discussion with participants at major stormwater and flood conferences, contact with non-governmental organizations, and participation in focus groups confirmed the widespread nature of urban flooding and that urban flooding was affecting both large and small communities. A review of news alerts from online sources using the search term "urban flooding" found that reports of multiple urban flood events occurred almost daily and were geographically distributed across the country.

Since 1993, the NOAA flood loss database has included descriptive information on flood events from regional field office reports of the National Weather Service (NWS). Flood loss submissions provide state and county location of the event as well as dollar losses and fatalities connected with the event. Using the terms "urban flooding" and "street flooding" to screen descriptive entries in the database, the study team found 3,663 entries either meeting the criteria or relating to what likely were urban flood events. These events were distributed across the entire United States (Figure 8). These basic searches helped confirm the information garnered from the survey, outreach activities, and media reports. States differed in both the distribution of storm events and how individual NWS regions reported events.

FIGURE 8. NUMBER OF URBAN FLOODING OBSERVATIONS BY STATE (1993-2017). SOURCE: NOAA; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

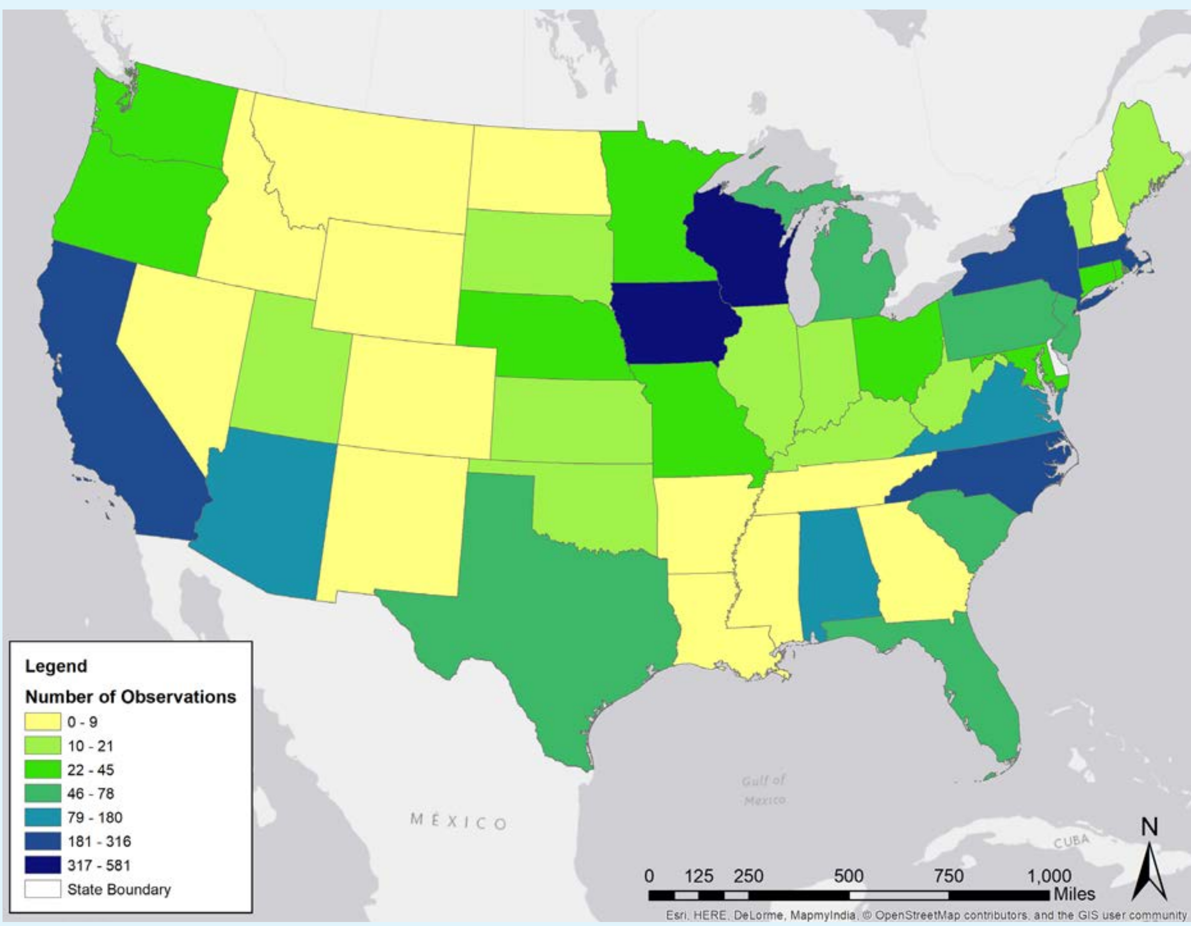
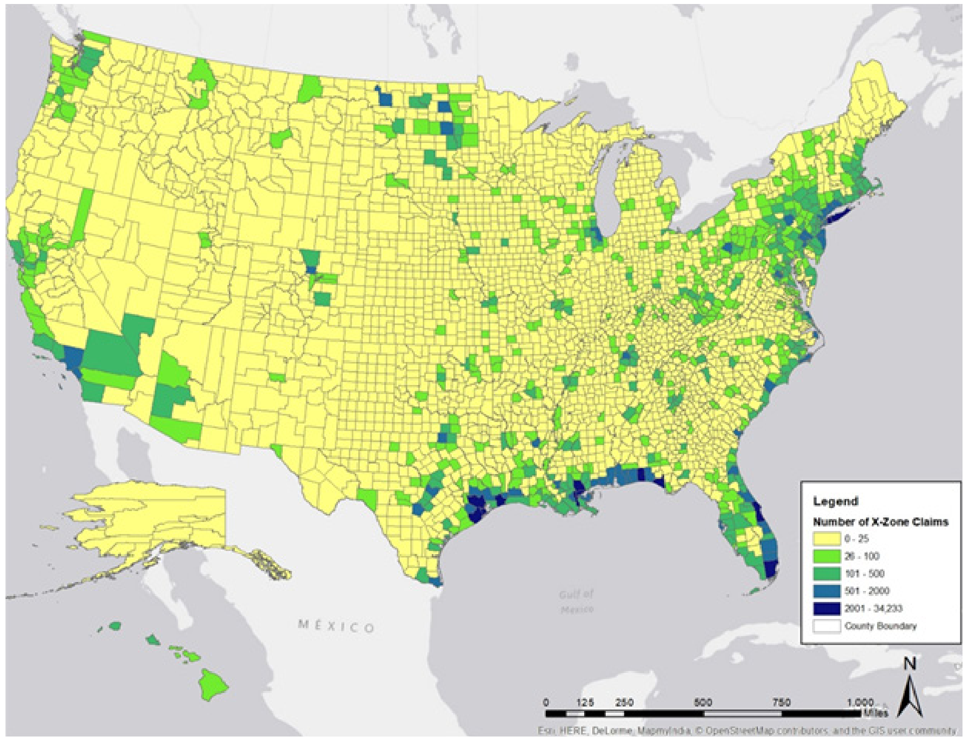


FIGURE 9. NFIP CLAIMS PAYOUTS BY COUNTY, 1974-2014 FOR PROPERTIES OUTSIDE THE SFHA (100-YEAR FLOODPLAIN). SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.



Nationwide, approximately 25% of all NFIP claims are submitted by policyholders whose property is outside of the FEMA-defined 100-year flood zone. The percentage of these claims that are attributable to riverine and coastal flooding versus urban flooding is difficult to determine accurately. When claims are attributed in the FEMA data to a specific flood event, it is likely that claims in and outside the 100-year zone can be attributed to a riverine or coastal flood. Where flood claims are isolated in areas outside of the 100-year zone, it can be assumed that they are urban rainfall events rather than coastal or riverine. In both cases, determination requires careful analyses of the data at property level. Overall, trends in urban flooding are identified with the entire dataset; further analysis focuses on inferring flood damage outside the 100-year floodplain as well as storm surge zones to focus on urban flooding that is considered lower probability. Data used in this section include damages from 1972-2014.

Figure 9 indicates the number and location of claims against the NFIP from property located outside of the 100-year floodplain. While coastal areas are well known for their vulnerability to hurricanes and riverine flooding, and the threat of these events increases participation in the NFIP, the high participation outside of the 100-year floodplain in inland areas may reflect increasing attention to rainfall events versus riverine floods.

FLOOD INSURANCE

The NFIP was established by Congress under the National Flood Insurance Program Act of 1968 to enable homeowners in floodplains to obtain insurance at a time when commercial insurers were not willing to underwrite flood risks. Under the NFIP, insurance is made available to all homeowners and small businesses in and outside the Special Flood Hazard Area (SFHA) and located in communities that have agreed to be part of the NFIP. Lending institutions that offer federally-backed mortgages must require those owning structures located within the SFHA to purchase flood insurance (the requirement is on the lending institutions and not on the home/business owner). Premiums on properties located in the SFHA are considerably higher than those outside the SFHA. The existence of the mandatory purchase requirement leads home and business owners located outside the SFHA to the erroneous conclusion that if they are not required to purchase insurance, they do not have a risk.

This pattern is especially true in urban zones with a history of flooding related to significant rainfall events and not coastal or riverine floods. In 65% of the 242 responses concerning moderate or larger urban floods, 10% or less of residences damaged responded as being covered by insurance under the NFIP; in only 13% of the responses was the coverage greater than 50%. Since property owners may also purchase commercial flood insurance or add homeowner policies that cover basement or other flooding, survey respondents were asked to estimate extended coverage. In 80% of the 198 responses covering those affected by a moderate or larger urban flood, 10% or less of properties were estimated to have commercial coverage. In only 19% of the communities was the coverage greater than 50% (since data on personal insurance coverage is not public, it is difficult to obtain an accurate picture). In areas immediately adjacent to SFHAs where there has been flooding, data indicates that there is some adoption of NFIP insurance because the potential of a flood crossing the 100-year line is more obvious; however, the farther property is from a major river or stream, the less likely will there be the purchase of insurance.

Commercial insurance is also available in many areas and is frequently used to supplement NFIP insurance when a property's value exceeds the NFIP limit of $250,000 for residential structures.

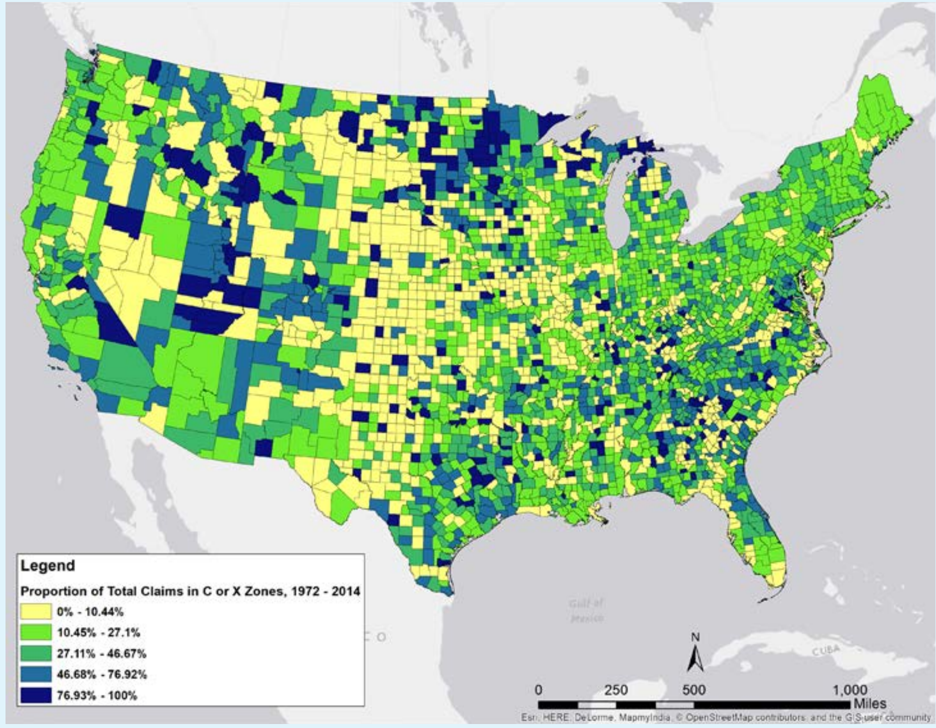


FIGURE 10. PERCENTAGE OF TOTAL NFIP CLAIMS BY COUNTY (1972-2014) ATTRIBUTABLE TO PROPERTIES OUTSIDE THE SFHA. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

Figure 10 indicates the percentage of NFIP flood claims outside of the SFHA by county as a percentage of the total claims in and out of the SFHA. Where the percentages are higher than 25%, it is more likely that urban flooding is also higher. It is apparent that when this figure is compared to Figure 9, the distribution of high claims areas is much different. In Figure 9, areas of high claims were clustered around traditional centers of hurricane and riverine flooding activity.

Insights can also be gained by mapping the property locations of FEMA Individual Assistance (IA) grants (Figure 11) to identify regions where individual assistance plays an important part in addressing post-disaster mitigation needs of communities; it can also indicate areas where the population may not have participated in or have access to the NFIP. Again, because of privacy act restrictions, geospatial accuracy is limited by zip code data.

At the local level, NFIP claims or other requests for assistance can be plotted against the 100- and 500-year flood zones to determine if the damages were occurring in areas where there were also NFIP claims (which include information on the cause of the flooding) or in areas where riverine flooding was not noted as a cause, leading one to assume urban flooding. Unfortunately, much of this information is covered by the privacy act, which limits its availability for analysis at the property level and pushes the analysis to broader areas such as the zip code or census tract, thereby reducing its accuracy.

Similar analyses could be used to examine data on buyouts, hazard mitigation grant program activities, public assistance grants, and commercial insurance payments.

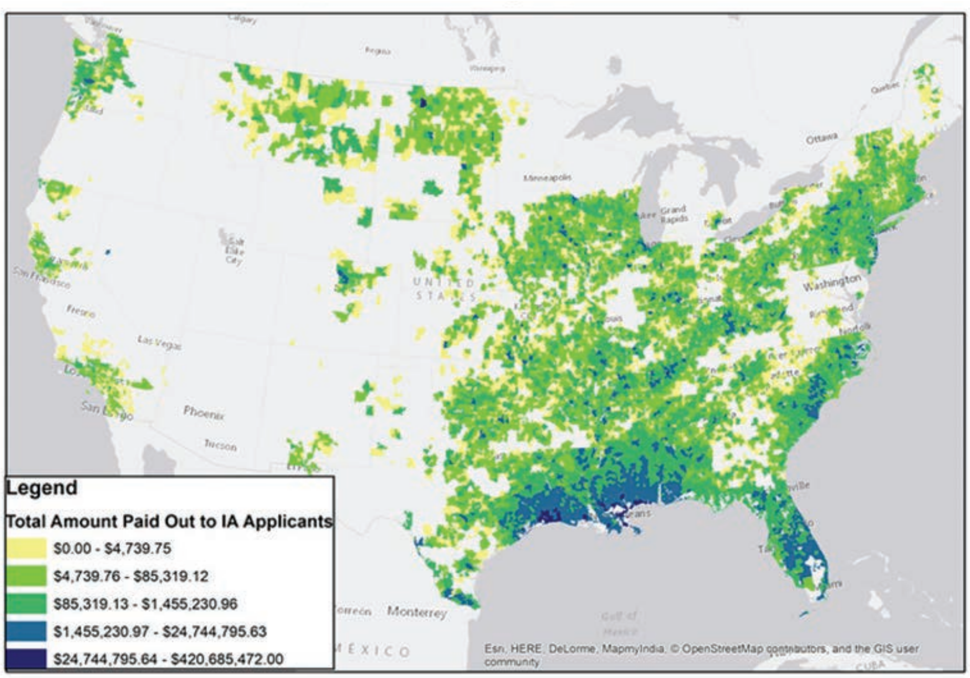


FIGURE 11. FEMA IA GRANTS BY ZIP CODE, 2004-2016. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

ANALYSIS AT THE LOCAL LEVEL

Figure 12 indicates NFIP and commercial flood claims in Rock Island County, Illinois by census tract between 2007 and 2014. During that time, there were 1,972 urban flood damage claims. Seventy-one percent of these occurred outside the 100-year floodplain. Differentiating between riverine and urban flooding would require property-level analysis.[10]

Additional insight can be gained by plotting and then visually comparing different claims data sets to identify areas where NFIP claims are low and individual assistance requests are high, possibly indicating urban flooding as opposed to coastal flooding. In the case of Figures 13 and 14, by examining the New York, New Jersey, and Connecticut data at the zip code level, it is possible to identify specific neighborhoods where anomalies exist. Note the areas in New York City identified by the red oval.

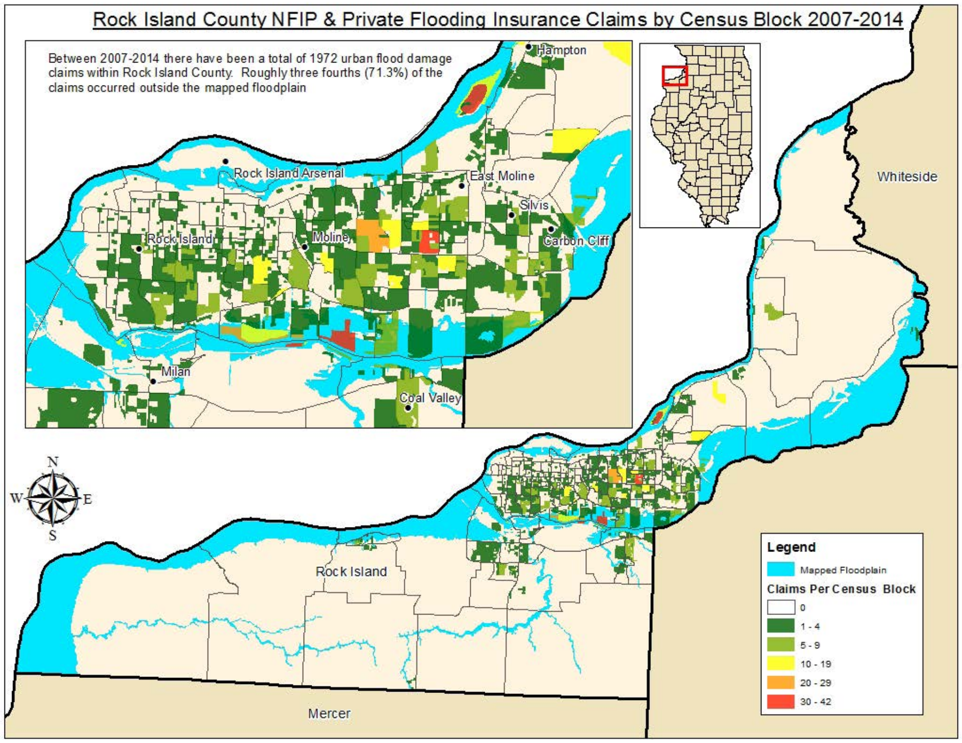


FIGURE 12. ROCK ISLAND COUNTY NFIP AND PRIVATE INSURANCE CLAIMS BY CENSUS BLOCK, 2007-2014. SOURCE: ILLINOIS STATE WATER SURVEY.

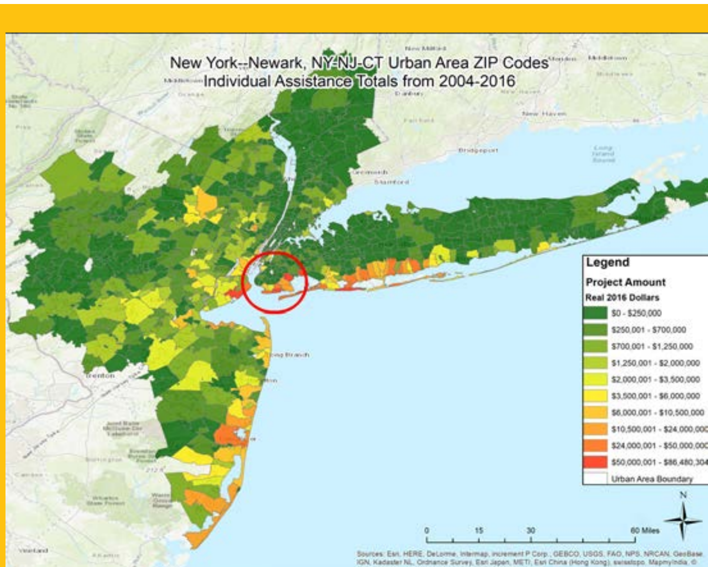


FIGURE 13. IA PROGRAM TOTALS BY ZIP CODE 2004-2016. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

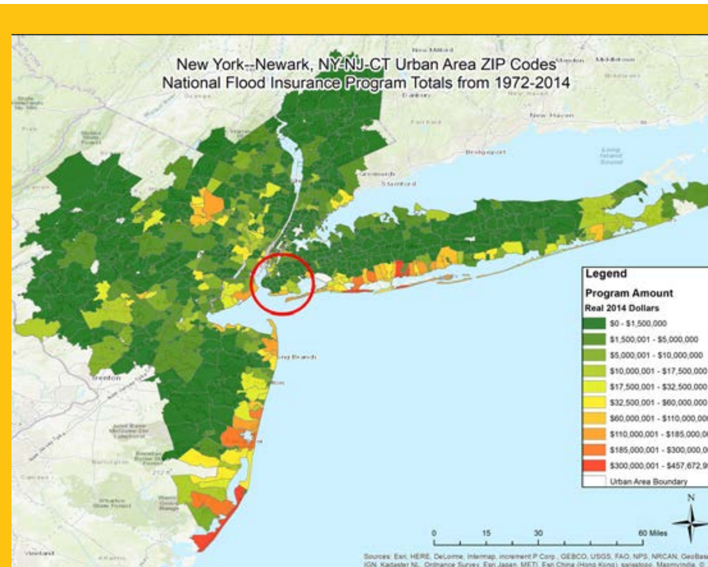


FIGURE 14. NFIP TOTALS BY ZIP CODE 1972-2014. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

OTHER DATA SOURCES

Some communities, as resources permit, attempt to map and gather information on events as they occur. Such analyses generally represent points in time as opposed to collections that represent the true history of flood activity. Nevertheless, they do provide indicators of where flooding is occurring in a given community and offer initial notice to those in the community of where such risks exist.

Figure 15 was prepared by the District of Columbia government and regional agencies to identify areas prone to flooding. Except for flooding directly adjacent to the Potomac and Anacostia Rivers and Rock Creek, the majority of inundation within the District is caused by intense rainfall events coupled with poor drainage.

Figure 16a indicates the location of significant rainfall events reported by NOAA in the Baltimore, Maryland area that have produced urban flooding. Note the scatter within the region. The city of Baltimore developed a similar map to identify areas subject to frequent flooding (Figure 16b). Some of these areas are isolated and clearly represent urban flooding. Flooding in other areas adjacent to major streams or the harbor is caused by riverine and coastal events.

Following Hurricane Harvey, The Harris County Flood Control District in Houston identified houses within the country that flooded. Figure 17 plots the location of flooded homes and indicates that 68% of them were outside of the 100-year riverine floodplain. While some of this flooding is the result of stream and bayou flooding, much was related to heavy rainfall.

In conducting an engineering analysis of flooding in several neighborhoods in the Borough of Queens, New York City officials used contemporary engineering models to identify the impacts of major storm events. Figure 18 illustrates the result of a 100-year rainfall event on a neighborhood and identifies the urban flooding that occurs from poor stormwater drainage.

Nationally, 85% of study survey respondents (n=296) reported that some or all of the urban flooding was occurring outside the 100-year floodplain. They also indicated that urban flooding was typically scattered throughout their community as opposed to being focused in one area.

The state of Illinois study found that 90% of the claims for flood damage in urban areas that were filed between 2007 and 2014 were for properties located outside of the 100-year floodplain and most likely represented urban flooding.[11]

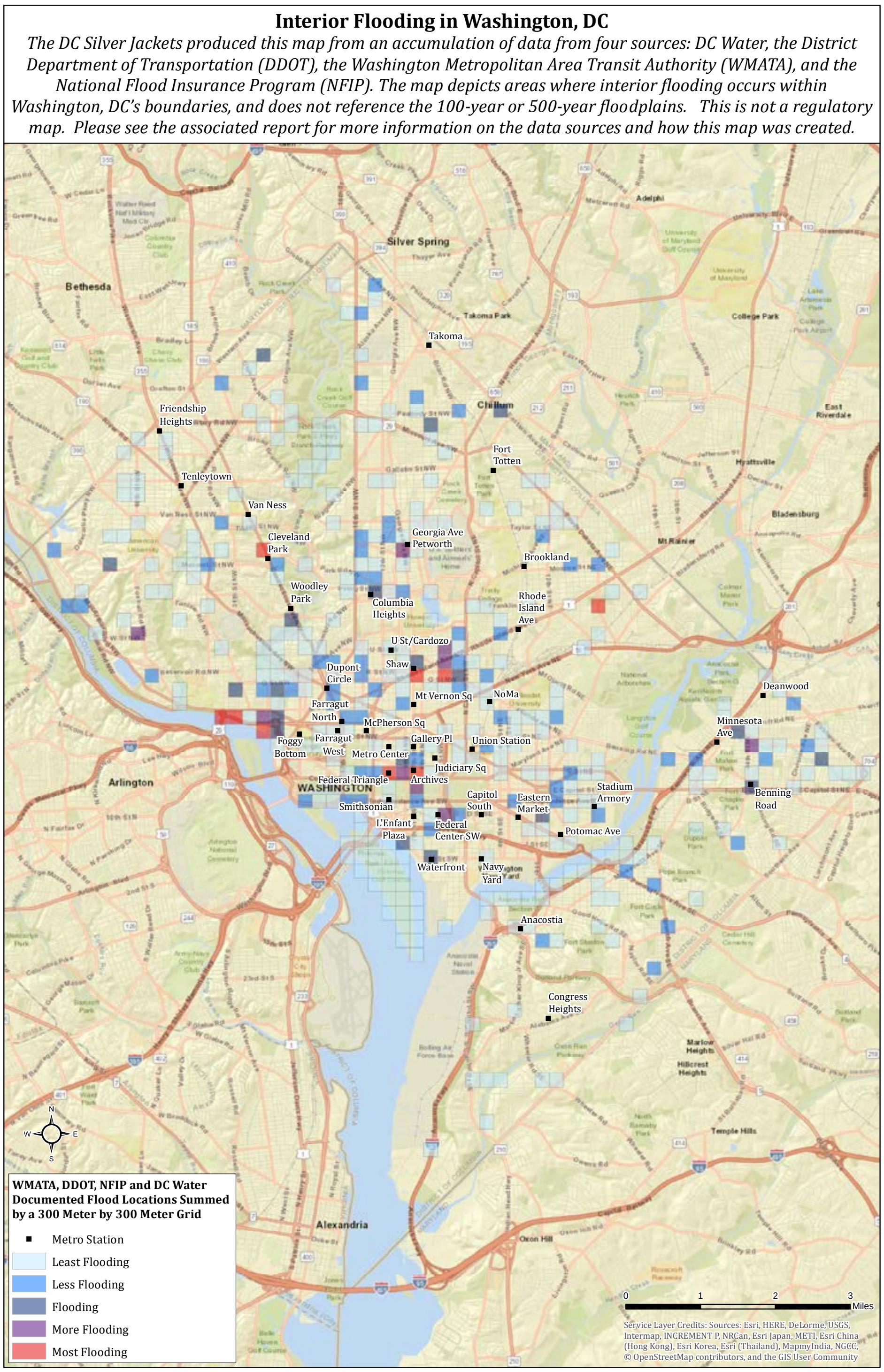
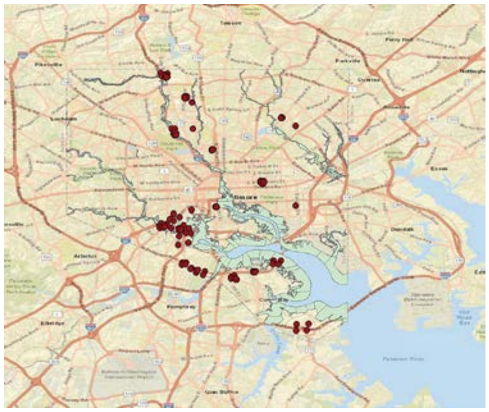


FIGURE 15. FLOOD-PRONE AREAS IN WASHINGTON, D.C. SOURCE: DC SILVER JACKETS, SILVERJACKETS.NFRMP.US/STATE-TEAMS/WASHINGTON-DC.

FIGURE 16A AND B. FLOOD-PRONE AREAS IN BALTIMORE, MARYLAND. LEFT MAP (A) SHOWS HEAVY RAINFALL EVENTS REPORTED BY NOAA. RIGHT MAP (B) INDICATES, IN PURPLE, FLOOD-PRONE AREAS. SOURCES: NOAA; MAP BY CENTER FOR DISASTER RESILIENCE; NOAA; MAP BY CITY OF BALTIMORE, 2017.



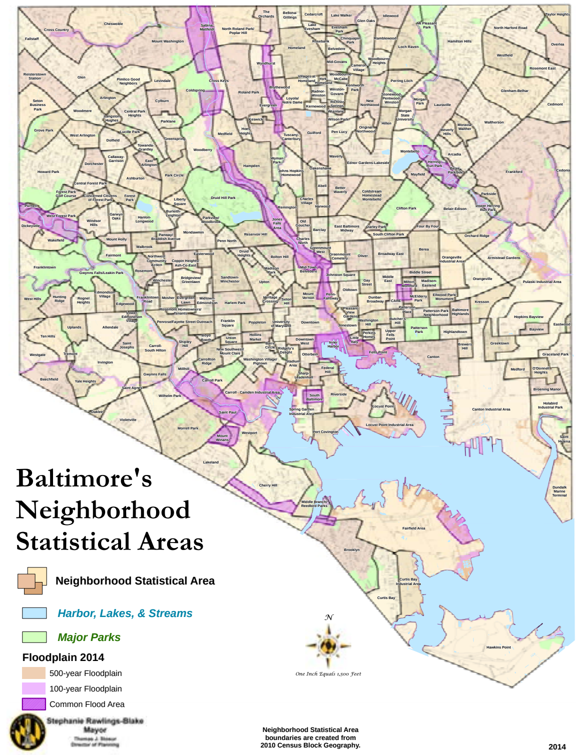
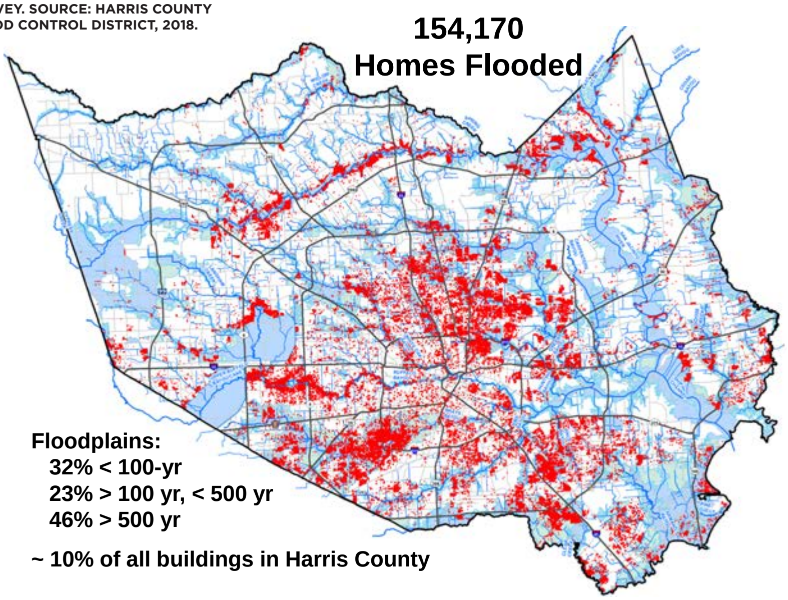


FIGURE 17. HOMES FLOODED IN HOUSTON, TEXAS DURING HURRICANE HARVEY. SOURCE: HARRIS COUNTY FLOOD CONTROL DISTRICT, 2018.



Observation:

Urban flooding is occurring in all regions of the United States. The exact locations of this flooding are difficult to determine accurately but is known to those in the communities responsible for flood and stormwater management.

FROM THE COMMUNITY

"The problem in most communities is lack of enforcement. Communities need a comprehensive plan to address development, infrastructure needs, stormwater runoff, and building codes. When a community doesn't address these issues it only exacerbates other problems and continued urban sprawl eats up rural areas causing flooding, erosion, and infrastructure malfunction. Only 1/3 of the state has building codes which enforcement is not uniform and the other 2/3 do not enforce floodplain regulations or even bother to look at stormwater."

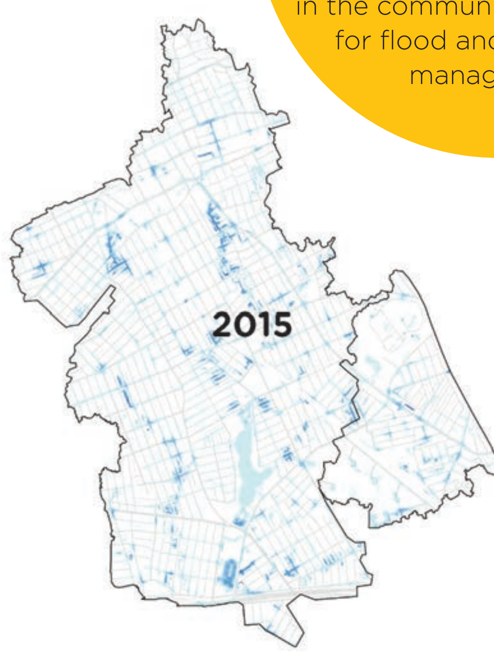


FIGURE 18. NEW YORK CITY: URBAN AREAS IDENTIFIED (LIGHT BLUE SHADING) AS SUBJECT TO FLOODING IN A 100-YEAR STORM. SOURCE: NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION, JANUARY, 2017. CLOUDBURST RESILIENCY PLANNING STUDY. PREPARED BY RAMBOLL A/S.

IV. WHY DOES URBAN FLOODING HAPPEN?

While urban flooding is caused by a variety of factors, it essentially represents an inability on the part of a community to manage runoff from large rainfall events and to move the water off affected areas in a timely and efficient manner. Tackling this challenge requires a comprehensive approach to stormwater management that can identify the nature of the risk and that can build and maintain infrastructure that can deal with runoff.

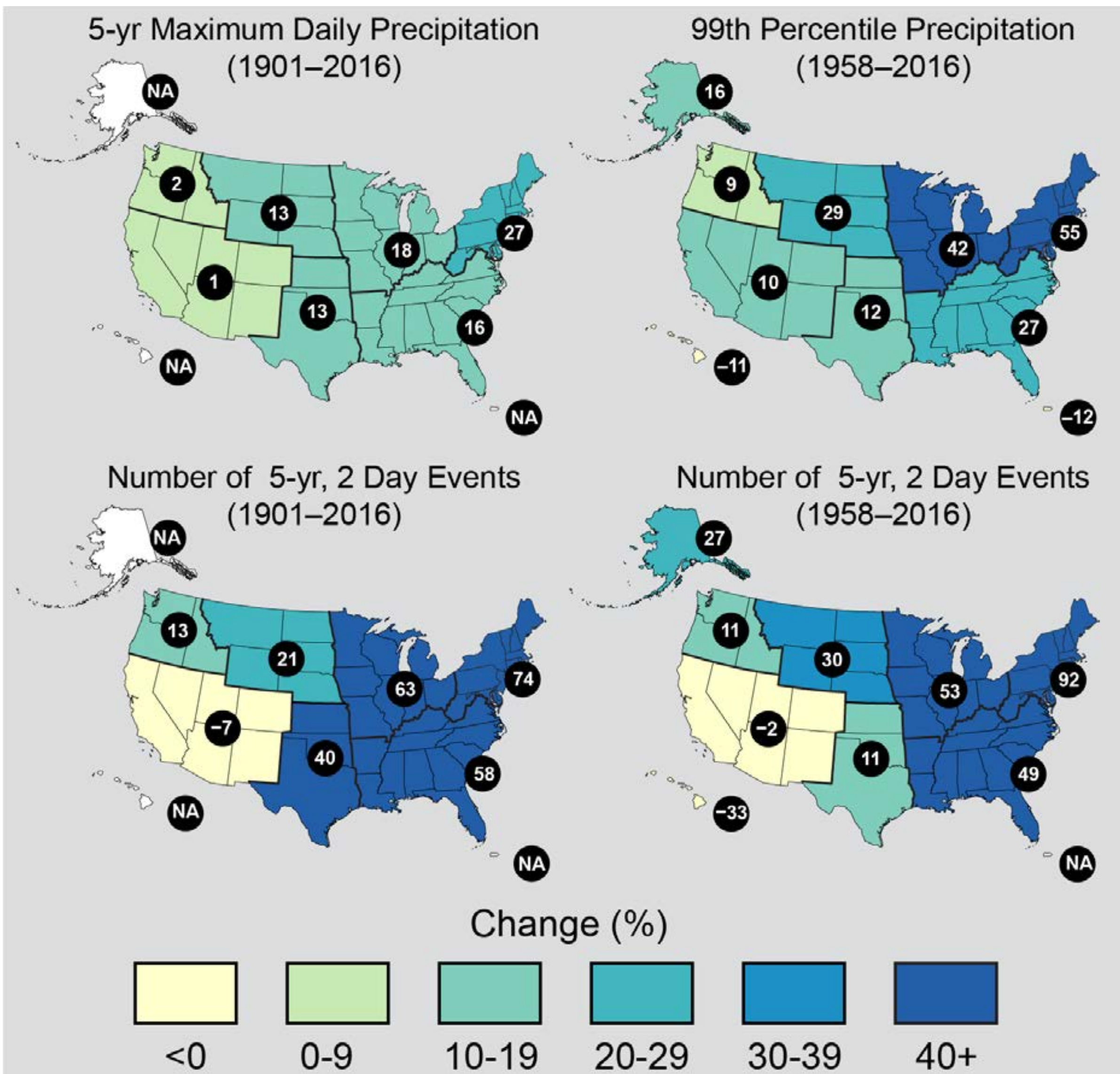


FIGURE 19. INCREASE IN EXTREME PRECIPITATION ACROSS THE UNITED STATES. "THESE MAPS...[INDICATE] THE PERCENTAGE CHANGE... (UPPER LEFT) THE MAXIMUM DAILY PRECIPITATION IN CONSECUTIVE 5-YEAR PERIODS; (UPPER RIGHT) THE AMOUNT OF PRECIPITATION FALLING IN DAILY EVENTS THAT EXCEED THE 99TH PERCENTILE OF ALL NON-ZERO PRECIPITATION DAYS...; (LOWER LEFT) THE NUMBER OF 2-DAY EVENTS WITH A PRECIPITATION TOTAL EXCEEDING THE LARGEST 2-DAY AMOUNT THAT IS EXPECTED TO OCCUR, ON AVERAGE, ONLY ONCE EVERY 5 YEARS...; AND (LOWER RIGHT) THE NUMBER OF 2-DAY EVENTS WITH A PRECIPITATION TOTAL EXCEEDING THE LARGEST 2-DAY AMOUNT THAT IS EXPECTED TO OCCUR, ON AVERAGE, ONLY ONCE EVERY 5 YEARS, AS CALCULATED OVER 1958–2016.... THE NUMBER IN EACH BLACK CIRCLE IS THE PERCENT CHANGE OVER THE ENTIRE PERIOD, EITHER 1901–2016 OR 1958–2016." SOURCE: CLIMATE SCIENCE SPECIAL REPORT, FROM EASTERLING ET AL. (2017).

FIGURE 20. LARGE HOMES REPLACE SMALLER HOMES, INCREASING RUNOFF FROM ROOFS AND DRIVEWAYS (HOUSTON). SOURCE: GOOGLE EARTH.

AGING AND INADEQUATE DRAINAGE SYSTEMS

Many older communities still rely on stormwater, water supply, and wastewater systems that were designed for conditions that existed decades ago and comprise infrastructure that has significantly deteriorated or is undersized for contemporary standards. **In the study survey, 70% of respondents (n=243) reported that inadequate drainage systems were their community's principal problem.**

INCREASES IN LOCAL AND REGIONAL RUNOFF

Of the 243 survey respondents, 57% noted that the failure to make infrastructure improvements as changes occurred in hydrology (increased rainfall) and developments (paving land over), increased runoff within the communities. For example, Midwestern states have experienced a 31% increase in very heavy precipitation events between 1958 and 2007, and this trend is expected to continue.[12] The 2017 National Climate Assessment indicates that "heavy downpours are increasing nationally, especially over the last three to five decades. The largest increases are in the Midwest and Northeast. Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions" (Figure 19).

When large new developments are constructed, they often replace forests and fields that previously captured rainfall or slowed stormwater migration. New homes, streets, and driveways move rainfall quickly into natural and constructed drainage systems, frequently overwhelming their capacity and creating flood problems. This is also an issue when smaller houses are replaced by larger structures (aka, "McMansions"); natural absorption is lost and runoff is increased, frequently overwhelming the existing drainage systems (Figure 20). Large-scale, upstream development can significantly alter the flood risk to downstream communities that must accept the increased water flow.

FROM THE COMMUNITY

"The most significant and constant & unaddressed cause of flooding in Overland Flow caused by insufficient attention to lot design local drainage at the subdivision block and lot level slab-on-grade construction, especially when on-site drainage impacts more than 2 lots before it reaches public conveyance, such as public streets and storm sewers."

FIGURE 21. TYPICAL URBAN STREET FLOODING.
SOURCE: S.D. BRODY, TEXAS A&M.

FIGURE 22. A BLOCKED CATCH BASIN IN DETROIT, AS REPORTED BY A HOMEOWNER. SOURCE: EN.SEECLICKFIX.COM.

SEWAGE AND STORMWATER BACKUPS

In many cases, the absence of building standards or adequate design at the time of initial construction has led to systems that are unable to handle the impact of community growth, resulting in sewage backups on a large scale. In many communities, there is a need to separate stormwater and wastewater disposal to prevent pollution, but funds are not available to carry out such a retrofit activity. Modern technology has developed valves or similar systems that can prevent many, if not all, backups into homes, but their expense and installation requirements are outside the means of low-income residents in high-risk zones.

CHANGES IN LOCAL PHYSICAL CONDITIONS

In some cases, changes in groundwater conditions or a failure to even consider groundwater as a threat only increase the challenges for local officials. Highway and road construction often create obstructions that block historic drainage paths. Some communities' original drainage plans called for the use of streets as rainfall storage areas, but the increase in runoff and rainfall now frequently exceeds the street storage capacity and pushes water into homes and businesses. The use of streets for storage also creates severe transportation problems and interferes with commuting and school transportation. During excessive rainfall periods when street storage is frequently ineffective, the overflow creates new and unforeseen pathways for drainage flows with unexpected, negative consequences; in recent rainfall events, sound barriers along highways have created "dams," flooding properties behind them.

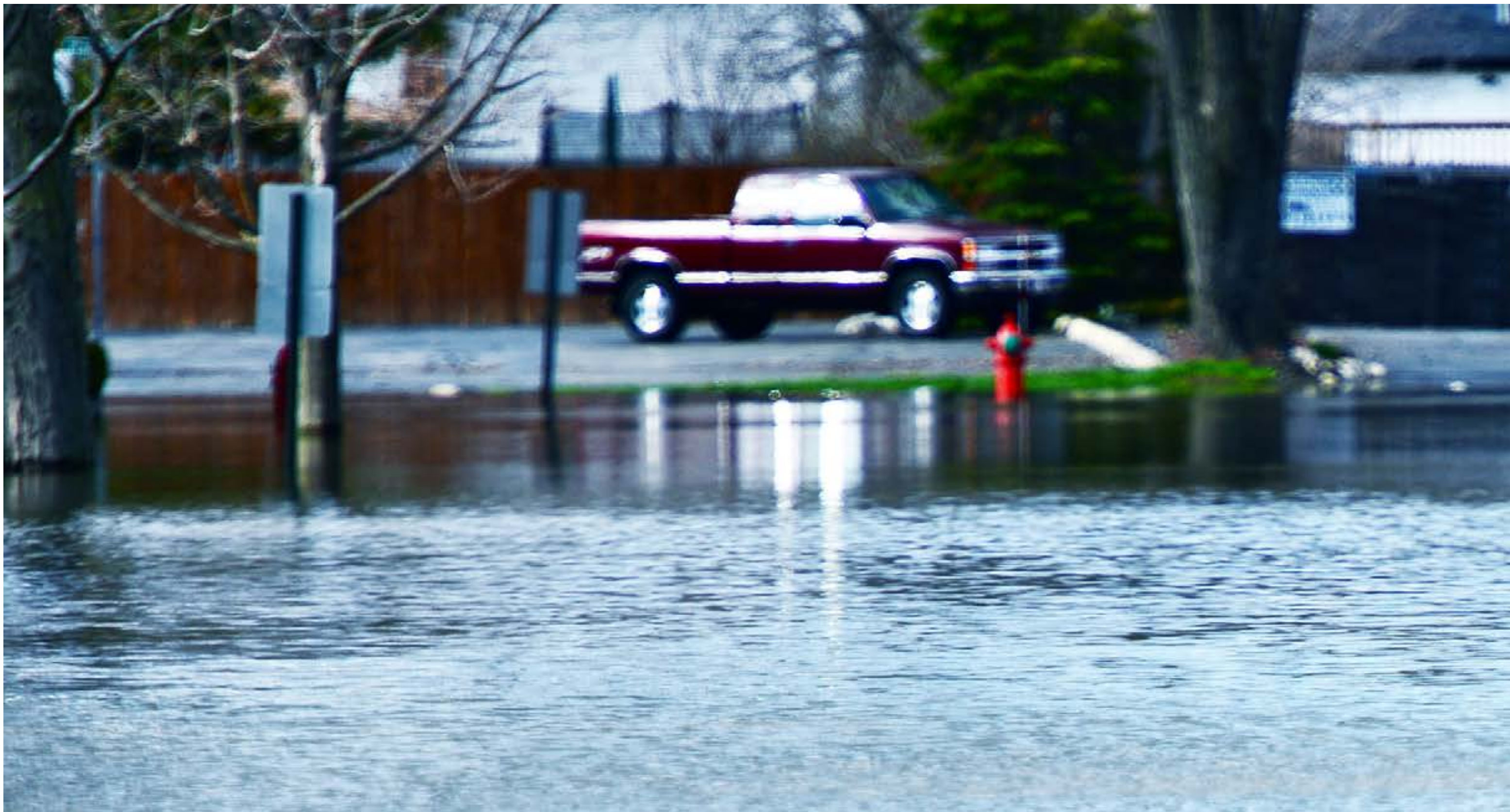
FIGURE 23. A BLOCKED STREET DRAIN
HOUSTON. SOURCE: S.D. BRODY, TEXAS A&M.

FAILURE TO MAINTAIN DRAINAGE SYSTEMS

All stormwater collection systems require continuous maintenance. Drain blockage, the collapse of pipes, or restrictions in channel capacity, retention, and detention storage can substantially reduce the function of a stormwater system and create flooding in the affected areas. For example, because of a lack of funding, the city of Detroit has been unable to routinely clean its 95,000 catch basins since 2010; where basins are blocked, streets flood. This year, with an infusion of resources, it will begin a three-year program to inspect and clear 30,000 of these catch basins.[13] The city reports that 75% of the drains citywide are covered by debris or have a blockage. While Detroit's problems are severe, they are mirrored on a lesser scale by similar problems in other communities (Figures 22, 23).

In many communities, areas prone to river, stream, or coastal flooding are protected in part by the construction of levees and floodwalls, which block the rising waters from entering low areas. However, when heavy rainfall events occur either in conjunction with external flooding or independently of it, the interior areas must address disposal of the rainwaters that are accumulating behind the structures. When the water elevation on the river side is higher than the elevation of rainwaters on the inside, and gravity evacuation cannot occur, pumps must be used. When they fail from lack of maintenance or power failures, the results can be disastrous. In August 2017, three years after completion of the $14 billion post-Katrina upgrade of the New Orleans levee system, pumps designed to evacuate water from inside the levees during heavy rainfall events failed. New Orleans also reported that the city had funds to clean only 68 of 13,000 miles of drainage canals in the city. Homes and businesses in several neighborhoods including the Bourbon Street District were flooded, causing damages in the millions of dollars.[14]

HOUSTON, TEXAS, PHOTO BY G. GALLOWAY



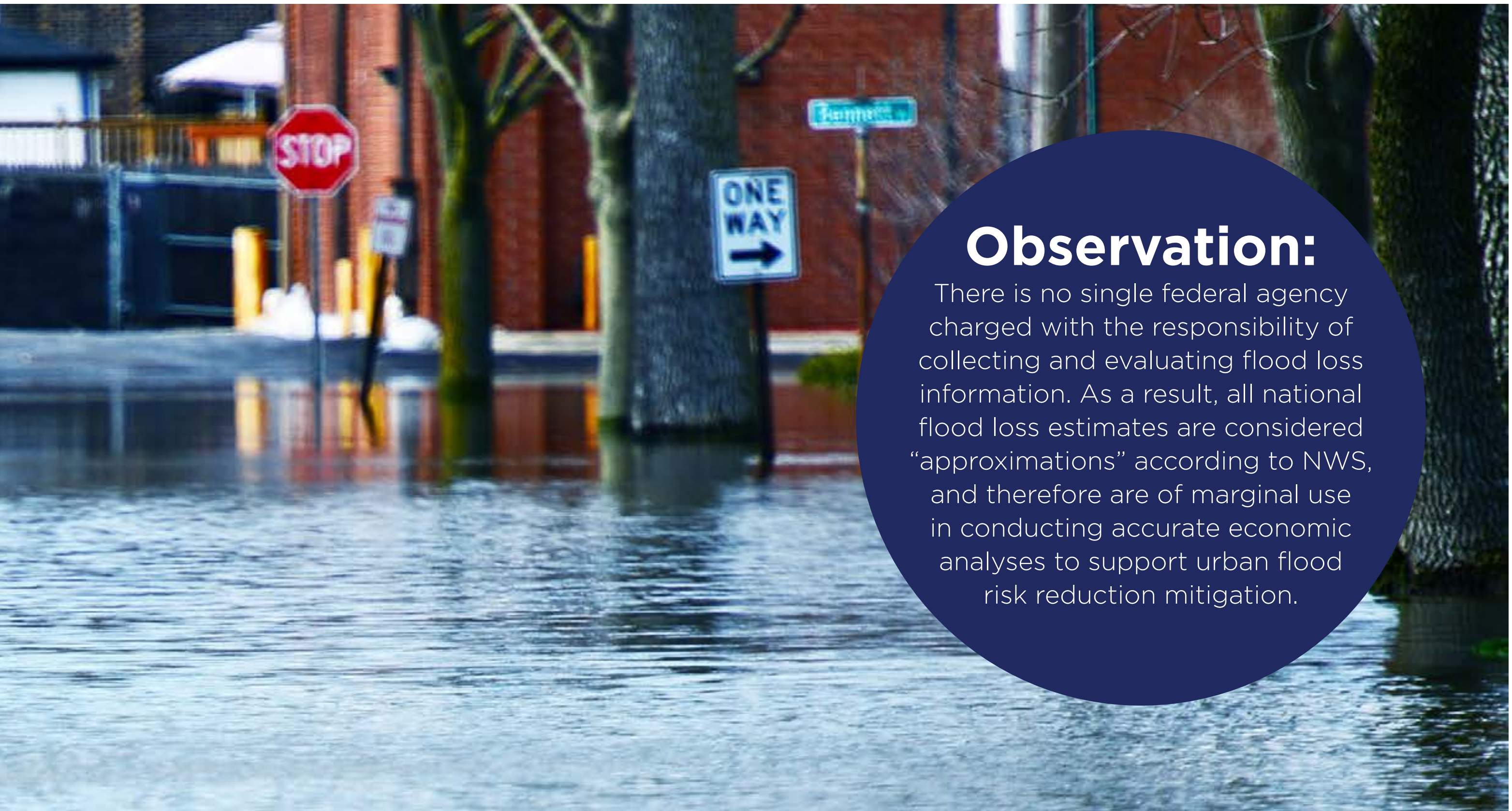
V. THE CONSEQUENCES OF

Of the 325 survey respondents reporting urban flooding impacts, 50% reported that the consequences of flooding were moderate or significant; 2% reported disastrous consequences. In Canada, severe rainfall has replaced fire as the leading cause of damage to homes. The cost of sewer backup and basement flooding exceeds $2 billion (CND) per year and has "been rising at an unsustainable rate for more than 25 years."[15] Information drawn from interviews conducted by the study team support this general impression. In the case of major rainfall events in large metropolitan areas such as Detroit, Washington, D.C., and Baton Rouge, the consequences are often disastrous; because of their magnitude, these events are chronicled by federal, state, and local agencies. In contrast, when a three-block area in a city is frequently flooded by heavy rainfall trapped in depressions, the flood event is noted, but the damage rarely becomes part of the permanent record. When heavy rains fill streets with water and damage cars parked in these locations, some owners make individual insurance claims; yet in many cases, owners lack coverage for flood-related damages to their automobiles. In general, the consequences of urban flooding fall into two categories: economic and social.

THE ECONOMIC COSTS OF URBAN FLOODING

At the national level, no one federal agency is charged with responsibility for identifying and accumulating data about flood losses. Any tally of urban flood losses, where it exists, is far less accurate than the riverine and coastal data.

Each agency manages its own programs and the expenditures that support them. FEMA manages the NFIP and maintains data on claims paid and grants supported. NFIP policy payments generally reflect losses, but individual assistance payments, which are capped, generally only report part of the loss; homeowners must deal with costs above the cap on their own. Public assistance payments reflect losses, but only to the level of funds available (not actual losses). HUD tracks its grants, as does the Small Business Administration (SBA), yet its loans represent federal support rather than the actual amount of damage incurred. Commercial insurers track loss data through their policies and release most of it to the public at the macro level. When seeking support for a Presidential Disaster Declaration, states are required to identify the losses that qualify them for federal aid. Typically, however, once the declaration has been made, concern over the completeness of loss of data disappears and further tabulations are left to academics and the media.



Observation:
There is no single federal agency charged with the responsibility of collecting and evaluating flood loss information. As a result, all national flood loss estimates are considered "approximations" according to NWS, and therefore are of marginal use in conducting accurate economic analyses to support urban flood risk reduction mitigation.

URBAN FLOODING

Over the years, NOAA has attempted to gather data on storm-related losses nationwide, but program modifications and a reduction in funding has resulted in a lack of data continuity. NOAA indicates that "the National Weather Service's primary mission is to provide weather information for the protection of life and property. Ancillary to this mission, NWS field offices provide loss estimates for significant flood events… Therefore, the resulting data are to be considered rough estimates, and may be unrepresentative of actual damages."[16]

Little effort has been made to separate losses resulting from riverine and coastal floods and losses from urban flooding. Since many losses from urban flooding are caused by storms with limited spatial extent, these losses seldom reach the level necessary to obtain a Presidential Disaster Declaration, and the incentive to track losses beyond that point is limited. As indicated in a previous section, however, NOAA has provided descriptive information about storm events since 1993, including damages reported by various sources in a storm area, so that estimates can be made of some of the losses attributed to urban flooding. Between 1993 and 2017, NOAA reported losses of over $17 million on 3,663 flood events, with 27 deaths attributed to those events. In some cases, although damages occurred, the NWS data collectors were unable to obtain them for the record.

Research conducted by Chicago's CNT in 2012 indicates that communities across the Great Lakes region are suffering from the impacts of urban flooding caused by moderate and heavy rain running off roofs, roads, and parking lots. The economic and social consequences can be considerable. Experts estimate that wet basements decrease property values by 10-25%, and that, according to FEMA, "almost 40% of small businesses never reopen their doors following a flooding disaster." Statistics from the SBA indicate that "over 90% of businesses fail within two years of being struck by a disaster." [19]

The costs of urban flooding are finally being recognized in both financial and social terms. Accurate records on urban flood losses are not well maintained or even captured. Little is done to capture secondary effects, such as loss of hourly wages for those unable to reach their workplaces; hours lost in traffic rerouting and traffic challenges; disruptions in local, regional, and national supply chains; or school closings with resultant impact on parents. Where all these costs come together, seemingly minor economic impacts of urban flooding would grow significantly.

THE SOCIAL IMPACTS OF URBAN FLOODING

Advocates for national fair and equitable housing have contended that low-income households are frequently—for economic and discriminatory reasons—forced to live in areas subject to higher flood risk. In the 291 reporting communities in the survey, 50% of those affected by urban flooding were residents with low and moderate-income status; an additional 20% were reported to be in the low-income group.[17]

In 2015, the NYU Furman Center reported that "while the nationwide poverty rate and the poverty rate of those living in the 100-year and combined 100- and 500-year floodplains are about the same, a higher share of the population lives in a moderate- or high-poverty census tract in the 100-year and combined floodplains than in a non-floodplain (Figure 24). [Study note: in many cases, those said to be living in a "non-floodplain" actually live in a natural floodplain or a topographic anomaly and are still subject to flooding.] While at the national level, the population in the floodplain largely mirrors the population more generally, the Furman Center notes that "disaggregating the data at the state level begins to reveal important variation and localities may see more variation as they explore neighborhoods within their jurisdiction."[18]

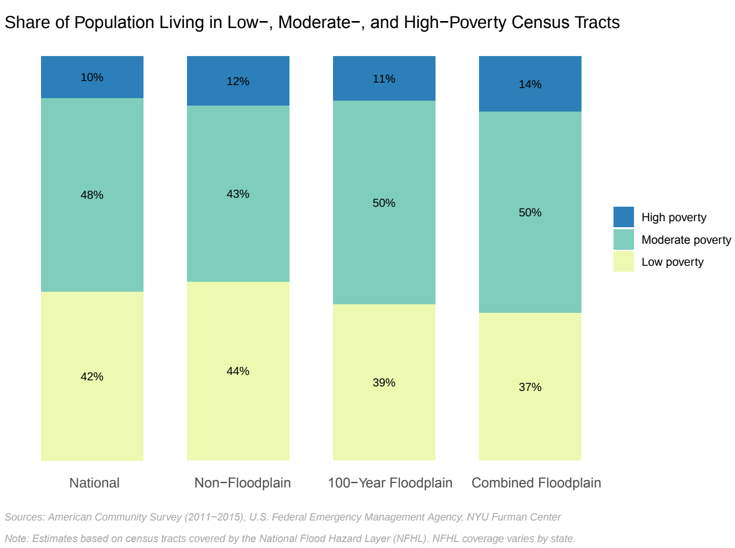


FIGURE 24. POPULATION IN U.S. FLOOD PLAINS. SOURCE: NYU FURMAN CENTER (DECEMBER 2017). DATA VIA AMERICAN COMMUNITY SURVEY (2011-2015) AND FEDERAL EMERGENCY MANAGEMENT AGENCY.

In April 2018, FEMA released a report on the affordability of flood insurance and provided data on the distribution by income of those purchasing insurance under the NFIP. The data indicated that low-income households are less likely to purchase flood insurance than higher-income households, even though low-income families are more likely to live in high-risk flood zones (low-income was defined as having less than 80% of the area median income). The data indicated that slightly more than 50% of households located in the 100-year floodplain (SFHA) that did not have insurance were low income. It also stated that of those households in the SFHA that had NFIP insurance, only 26% were low income. The Natural Resources Defense Council noted that median income of households without flood insurance was only $40,000, and, "with the average policy costing $1,098 per year, those that can least afford to pay for flood insurance are those who can least afford to be without, given a high level of risk." For example, in Louisiana, a high flood state, the median income of the 240,000 households lacking flood insurance and living in the SFHA was $33,000, while the median income of the 221,000 with flood insurance was $73,000 (Figure 25).

FROM THE COMMUNITY

"Urban flooding generally affects the poor at higher levels than more prosperous segments of our society. Additionally, the majority of public housing and poor neighborhoods developed 40 to 50 years ago, at a time when well-to-do urbanites traded townhomes for suburban life and that urban vacuum created low-cost opportunities for the bottom middle class to become first-time home owners. These traditionally high flood-prone areas evolved from middle class to low middle class to working poor neighborhoods and now they're in areas that are prime for commercial redevelopment as our urban centers continue to expand outward. It is time that we look at getting a do-over. An opportunity to re-imagine what public housing should look like, feel like, and be, instead of what we allowed it to become. We should find new areas that can be re-developed into mixed-use sporadic housing that doesn't create a conglomeration of the downtrodden but a comingling of our poor with middle class home owners that encourages opportunity and discourages blight."

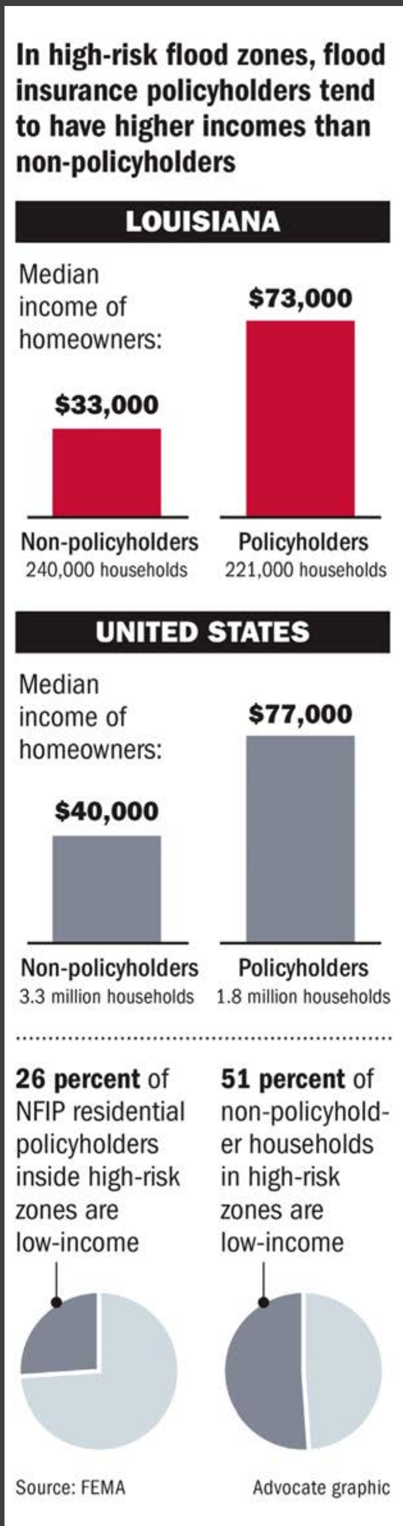


FIGURE 25. INCOMES OF FLOODPLAIN OCCUPANTS.
SOURCE: DAN SWENSON/THE ADVOCATE, THEADVOCATE.COM.

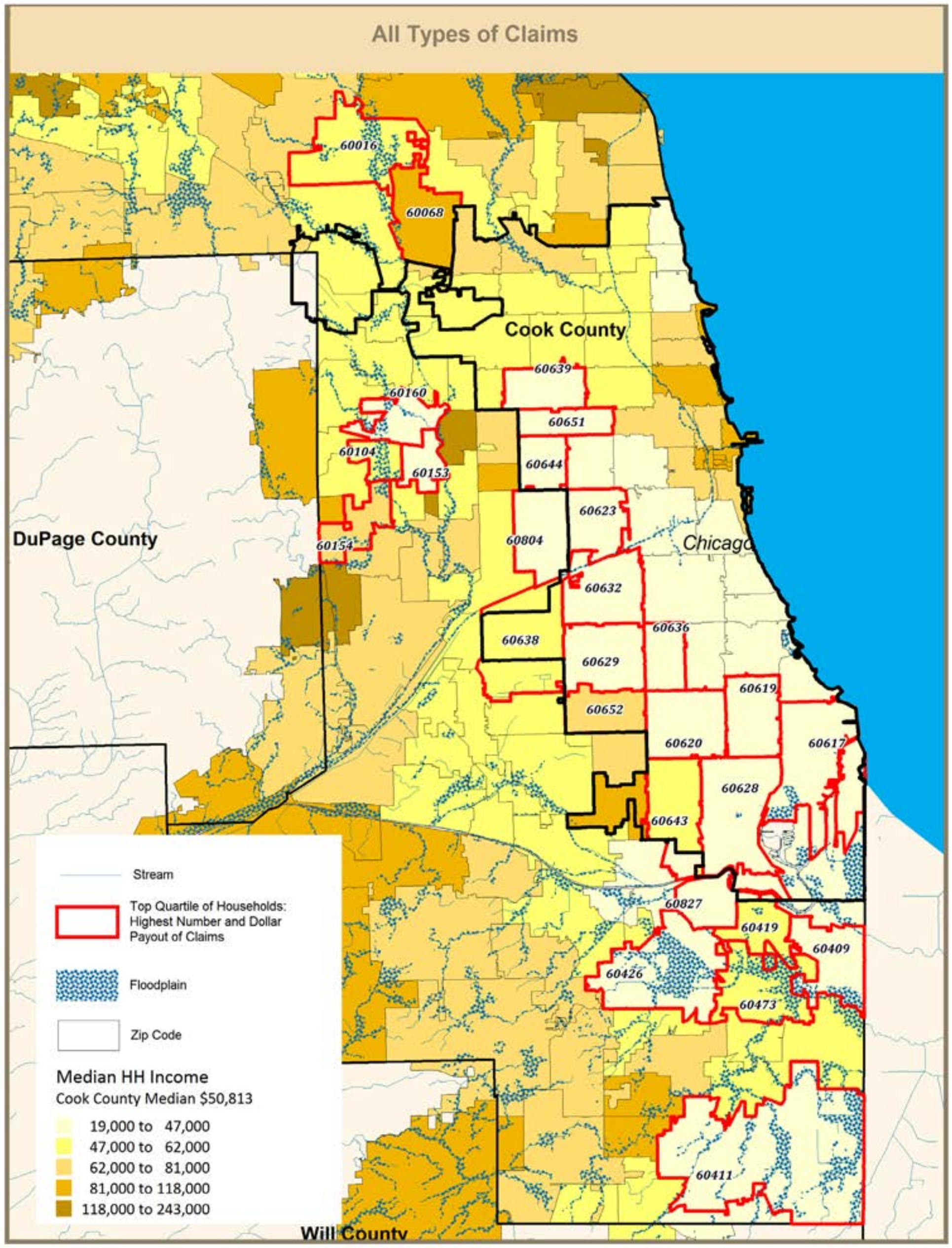
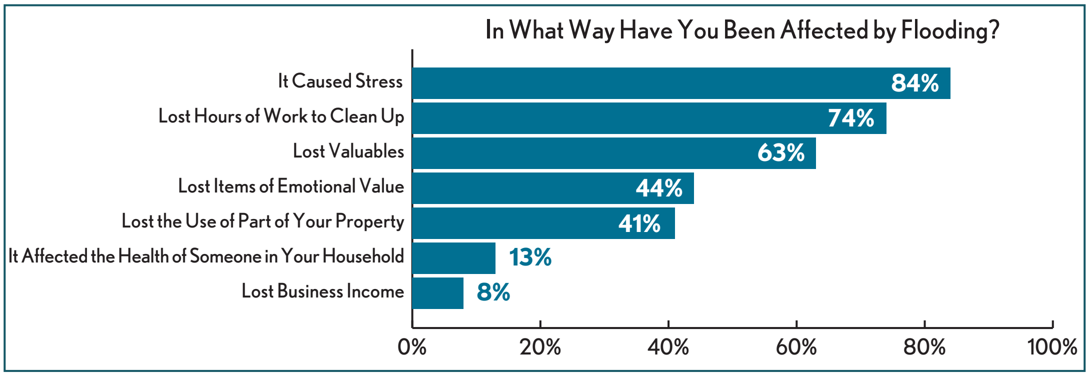
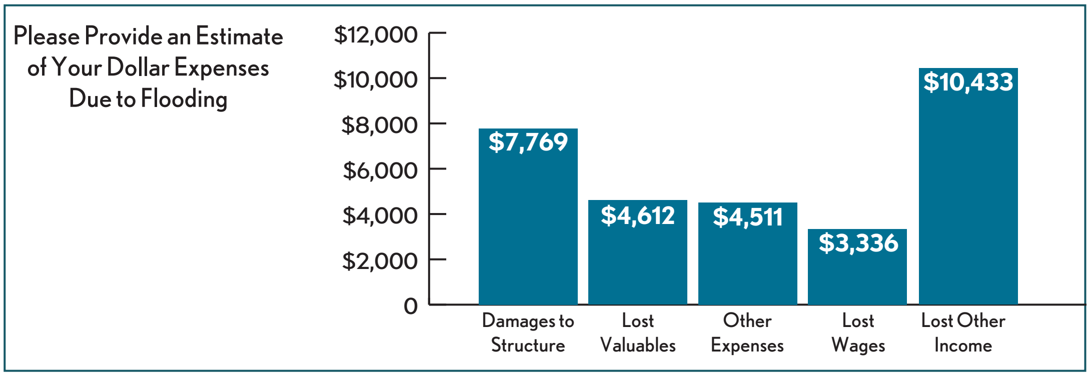


FIGURE 26. MEDIAN HOUSEHOLD INCOMES IN CHICAGO ZIP CODES WITH LARGEST TOTAL FLOOD CLAIM PAYOUTS AND NUMBERS, 2007-2011. SOURCE: CENTER FOR NEIGHBORHOOD TECHNOLOGY, THE PREVALENCE AND COST OF URBAN FLOODING, ©2014.

FIGURE 27. IMPACTS OF FLOODING IN CHICAGO ON FLOOD-AFFECTED POPULATION (N=115). SOURCE: CENTER FOR NEIGHBORHOOD TECHNOLOGY, THE PREVALENCE AND COST OF URBAN FLOODING, ©2014.





In Cook County, Illinois, analysis by CNT of flood claims over a five-year period indicated that the household incomes in 67% (18 of the 27) of zip codes with the highest concentration of flood damages were below the median for Cook County as a whole. Nine of the 22 zip codes in Cook County had no SFHA within the zip codes yet are in the zip codes with the highest concentration of damage claims, indicating damages were from urban flooding (Figure 26). [19]

Several flood studies have found that those with low or moderate income and those facing social challenges lack the resilience to deal with flooding of any kind, particularly repetitive urban flooding. For those lacking critical resources (savings, insurance, etc.), the flood losses gnaw away at their well-being. The CNT found that of those affected by urban flooding in a Chicago study, "84% suffered stress and 13% ill health. Forty-one percent lost the use of part of their property, 63% lost valuables, and 74% lost hours of work to clean up" (Figure 27). [20] Seventy percent of the respondents to this study's survey (n=227) indicated that rental properties represented 25% or less of properties moderately affected by urban flooding.

Problems created by living in a flood-prone area are compounded by the level of protection and mitigation provided to those that live in underserved communities. In 2014, the city of Houston, Texas commissioned a study on open ditch drainage, recognizing that this approach is generally not as effective as underground movement of stormwater. On completion of the study, an analysis by Texas Housers (the Texas Low Income Housing Information Service) found that 88% of Houston's open ditch drainage are in African American neighborhoods; according to the city's own report, nearly half of these ditches couldn't provide stormwater protection for the homes they serve in even modest storms (Figure 28).

GRAND RIDGE, FLORIDA, PHOTO BY ANDREA BOOHER/FEMA

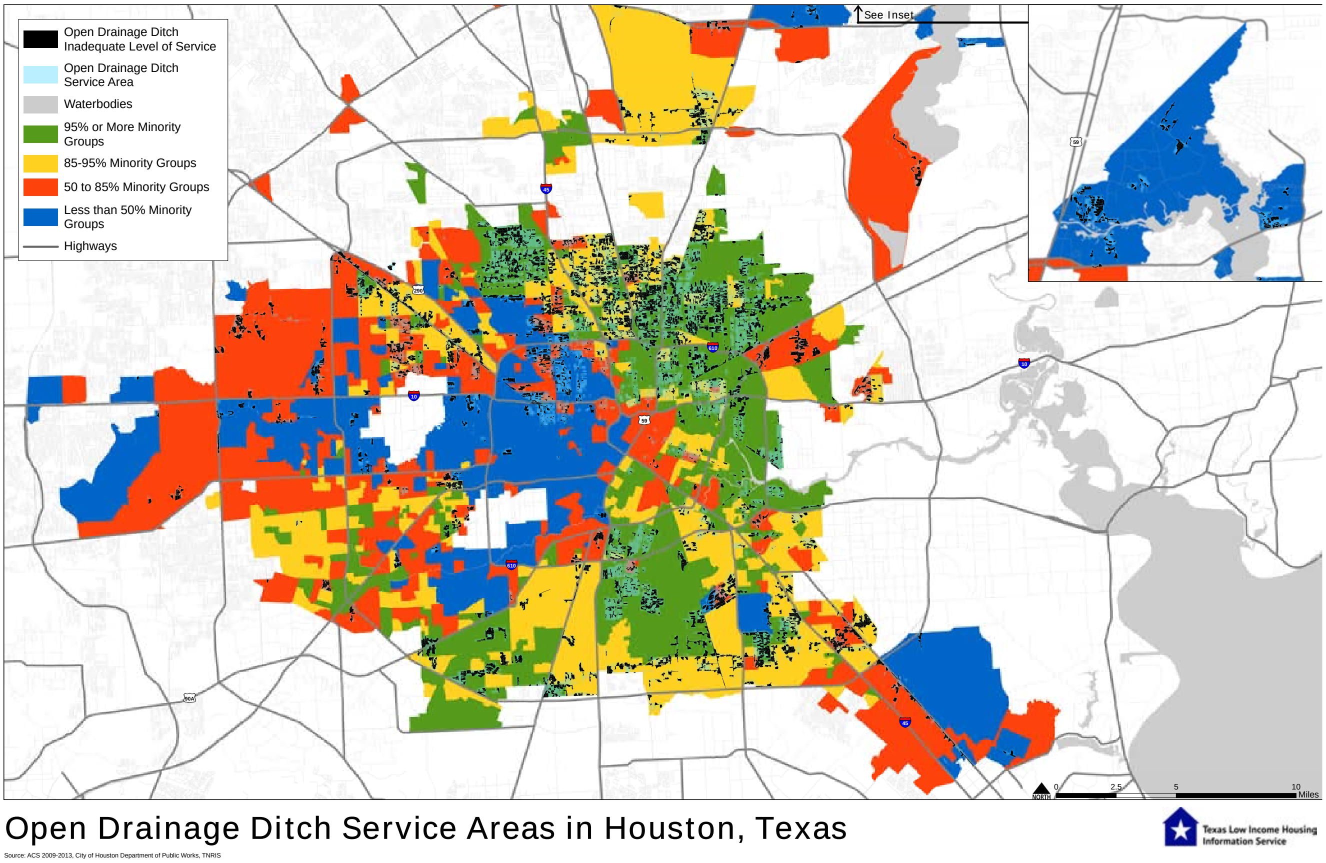
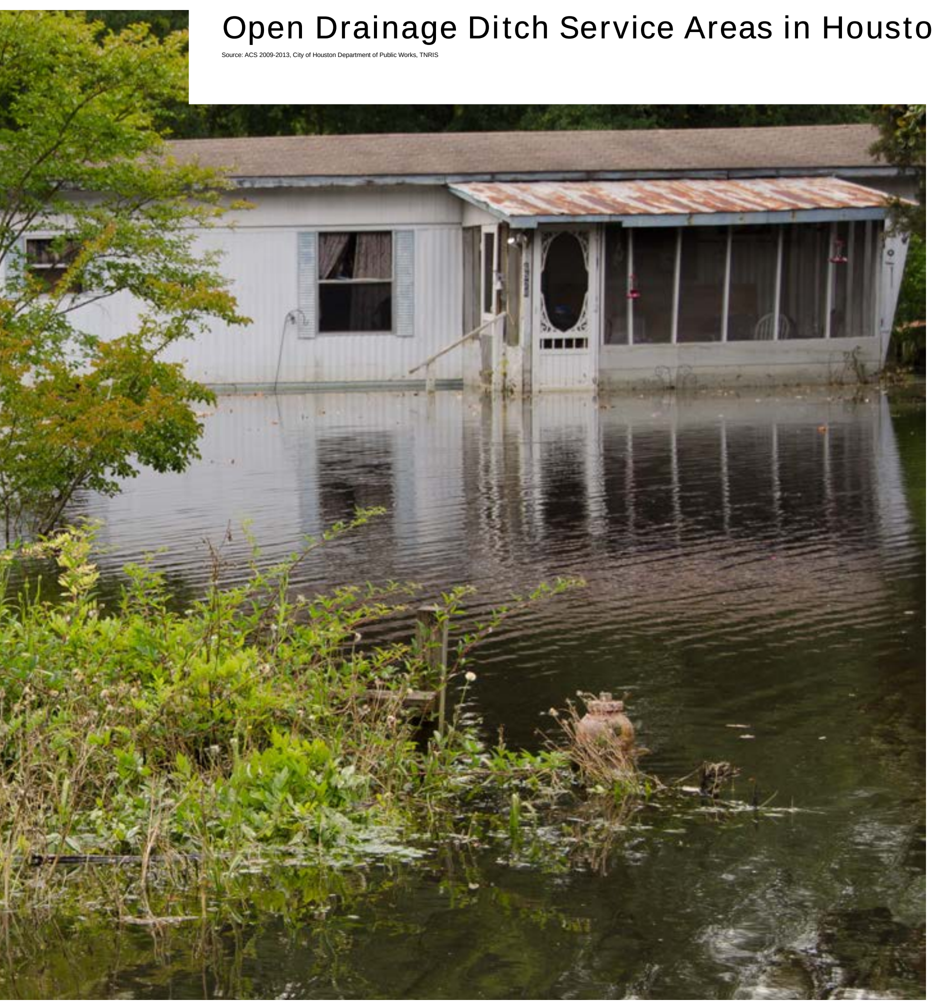


FIGURE 28. OPEN DRAINAGE DITCH SERVICE AREAS IN HOUSTON, TEXAS.
SOURCE: TEXAS LOW INCOME HOUSING INFORMATION SERVICE, 2017.



FROM THE COMMUNITY

“[Redacted] was developed and exists on [high ground]. The urban flooding that occurs in the heart of the central city is mainly attributed to existing drainage infrastructure that predates today’s design standards or insufficient pipe sizes for the now fully developed urban areas. The [redacted] and [redacted] parts of the city have many socio-economically depressed areas. These areas were developed when building codes allowed dense neighborhoods to be constructed without adequate buffers in close proximity to streams. There have been little improvements due to lack of funding, State permit approval, and in some cases, will.”

VI. WHAT CAN BE DONE ABOUT URBAN FLOODING?

After a natural disaster, the federal government supports recovery with a variety of programs designed to supplement state and local capabilities, particularly when the magnitude of disasters is so high that state and local governments cannot deal with them alone.

CLEARWATER, FLORIDA, PHOTO BY KATHY/CC BY 2.0

In 1936, the federal government, in collaboration with state and local governments, developed flood control works where such projects were justified. Through the construction of dams, levees, channels, and other works (primarily by USACE), major flood losses were reduced but not eliminated, and the growth in population continued to see people move to areas of flood risk. Between 1984 and 2009, USACE estimated that flood risk reduction projects prevented over $700 billion in damages.[21]

Through the 1968 NFIP, the federal government-initiated efforts to mitigate flood losses using a federally-backed framework that permits home and business owners to purchase insurance for properties susceptible to flooding when their communities agree to participate in the NFIP and limit future development in flood-prone areas. The magnitude of NFIP claims has served as a measure of the nation's flood vulnerability.

Between 1974 and 2014, the NFIP has paid out $51.6 billion dollars in claims (Figure 5). Claims paid out in 2015-2017 are estimated to be more than $13.4 billion, largely because of major hurricanes and storms along the Gulf Coast and in Puerto Rico. The majority of the claims payments are as a result of riverine, coastal, and major storm flooding.

As previously discussed, in addition to the NFIP, FEMA provides post-disaster assistance in the form of IA grants and grants to public entities (Public Assistance —PA) largely for infrastructure repair. The SBA is authorized to provide loans to individuals and businesses affected by flooding. The FEMA Hazard Mitigation Grant Program (HMGP) funds large hazard mitigation projects, including buyouts that occur in multiple counties or statewide. Unlike PA funds, which are intended to help communities quickly respond to and recover from disasters, HMGP funds are intended to support projects and measures that will help a community reduce its risk from future disasters.

Figure 29 represents the range of the extensive federal support for flood-related disasters in terms of total payout amounts from these programs to entities within each county across all the available years from each dataset, from 2004-2014. Greater amounts of damage along heavily populated coastal counties can be visualized. All states along the Gulf of Mexico reported higher amounts of loss due to their increased vulnerability from hurricanes, storm surge, and higher precipitation averages. Several Louisiana and Texas counties display higher than average losses, possibly due to their encounter with multiple tropical events, such as Hurricanes Allison, Katrina, and Ike. The second most noticeable location

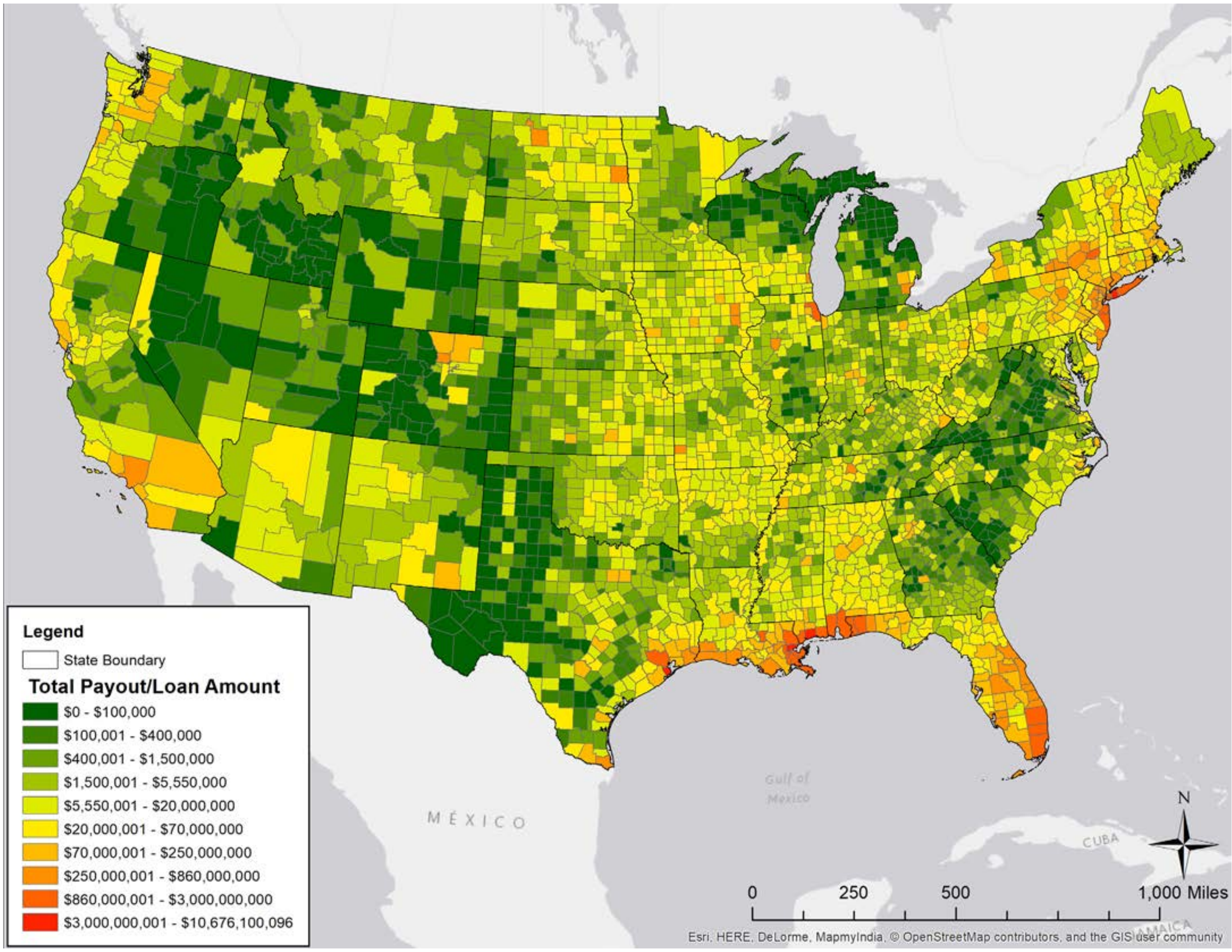


FIGURE 29. TOTAL FEDERAL PAYOUTS/LOAN AMOUNTS FROM NFIP, SBA, IA, PA, AND HMGP BY COUNTY 2004-2014 (ADJUSTED). SOURCE: FEMA NFIP, HUD, SBA; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

in the United States reporting higher amounts of loss is throughout the coastal and near-coastal areas of New York, New Jersey, and Connecticut.

Assessments at broad spatial scales are useful, but dealing with urban flooding requires attention to the differences that exist among local communities. Every community is different in its physical and social makeup and owns a unique history of development. Over the years, a community's physical attributes (topography, soil, flora, and fauna) have shaped its approach to dealing with stormwater and urban flooding. The economic strength of its population has determined how it addressed the problems it faced. Techniques used to mitigate urban flooding are many and are often seen in the quality of a community's infrastructure and its capability to deal with such challenges. Older communities, in part, must rely on stormwater systems that have been in place for decades or centuries. Standards initially established as reasonable are no longer seen as appropriate. Managing a 10-year storm, a high bar 50 years ago, may no longer be a viable standard for a growing community, but represents the capacity of many systems that are already in the ground.

Observation:

There are many strategies for tackling urban flooding, but in all cases, it is the combination of tool selection, funding, and a public's will to proceed that determine the level of success.

COMPREHENSIVE PLANNING

Serious efforts to reduce urban flooding require a forward-looking plan for the development, implementation, and enforcement of building codes through collaboration and coordination among neighboring governmental entities responsible for managing urban flooding and the development of comprehensive plans for the watershed.

Urbanization and the proliferation of impervious surfaces across watershed units are major contributors to adverse impacts associated with flood events. The conversion of natural landscapes to urban or suburban developments can diminish the functionality of hydrological systems, reducing soil infiltration and increasing surface runoff and peak discharge into nearby streams. Flood impacts are driven not solely by the amount of impervious surface, but by its pattern and intensity across a given landscape. The specific form of the built environment is the more important trigger for flood losses over time.

Large amounts of sparsely-developed areas consistent with "sprawl" actually exacerbate property damage from flooding. In this situation, outwardly expanding, low-density development patterns can fragment hydrological systems and amplify surface runoff by spreading out impervious surfaces over a larger area. Features of the built environment, such as sound walls, roadways, fences, etc. can exacerbate urban flooding by changing drainage patterns, blocking overland flow, and increasing local ponding.

FIGURE 30. AN ATHLETIC FIELD AT A FRIENDSWOOD, TEXAS JUNIOR HIGH SCHOOL BEING USED AS A DETENTION POND DURING HURRICANE HARVEY, 2017. SOURCE: W. HIGHFIELD, TEXAS A&M.

Population growth and development can fragment or remove natural ecosystem functions, such as naturally occurring wetlands that hold, store, and slowly release runoff. Loss of wetlands significantly increases flood losses within adjacent properties and beyond.

FROM THE COMMUNITY

"As communities move forward with their planning processes, planning for stormwater should not be ignored. Stormwater management must be part of the overall planning/zoning process. Stormwater management is not only about considering the flooding potential within FEMA-designated floodplains adjacent to creeks and rivers or designing a drainage system to convey the standard 10yr event, it is also about understanding the characteristics of each watershed and how new development can create its own microcosm of flooding potential, be it 640 acres or only 6.4 acres. As we reshape the land and install drainage systems that are typically designed to convey runoff well below the ever-increasing intensities that are becoming more the norm than not, we must always ask ourselves, how does the stormwater find relief? If overland relief is ignored, then that new roadway can become a dam for tomorrow's miniature urban reservoir of flooding. If flood-prone areas are not protected and allowed to be filled, be they FEMA or local, then what we thought was flood-prone is actually larger and the impacts and the costs become unmanageable."

CAPTURING RAIN WHERE IT FALLS

Many cities and towns across the United States are giving considerable attention to plans that support the capture of rain in areas where it falls. The use of building codes that eliminate increases in runoff from newly constructed properties, the assessment of stormwater fees based on the amount of infiltration that takes place on a given piece of property, and actions by individual home and business owners such as rain gardens, green roofs, rain barrels, etc. can significantly reduce the volume and timing of intense rainfall runoff. Carefully designed bioswales and detention (Figure 30) and retention ponds can make even larger contributions to runoff reduction. The EPA offers considerable information about such activities.[22]

FIGURE 31. SANDBAGS BLOCKING STORMWATER FLOW FROM WASHINGTON METRO SUBWAY AIR VENT. SOURCE: G. GALLOWAY, UMD.

FIGURE 32. PERMANENT PROTECTION FOR WASHINGTON METRO SUBWAY VENT. SOURCE: WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY.

ELIMINATING OR REDUCING THE RISK OF FLOODING

A challenge for older communities are areas where significant improvement in drainage is too costly to be considered. In these cases, elevation of the structures where such efforts are economically feasible or "buying out" properties at risk should be considered. Elevating a structure does not guarantee its safety, but when the height of elevation is carefully considered, it can significantly reduce the threat to the property (and reduce insurance costs). By removing a property from a flood-prone area, buyouts eliminate future losses, can create green space to support retention or detention areas, and offer space for community recreation.

ADEQUATE MAINTENANCE

Many of the problems associated with urban flooding can be addressed with techniques well known to those responsible for storm and floodwater management systems. Unfortunately, almost all of these techniques require resources to carry them out. Often, the manpower and the dollars to address these issues are absent from budgets or at the bottom of the priority list. As indicated in an earlier section, maintenance of stormwater systems is extremely important; a failure to carry out needed maintenance or replace aging systems creates repetitive challenges for the community. Some of the maintenance requirements can be reduced through local resident participation in maintenance activities, such as clearing drains of debris or reporting such problems as they occur, prior to storm events. Community outreach can alert citizens of their responsibilities and demonstrate how their actions can provide benefits for the entire community.

Actions can also be taken at the individual home or business level to reduce urban flooding. Egresses can be blocked either permanently or temporarily to prevent flood waters from entering and flooding basements and the upper floors. Losses to high-value items can be reduced by moving them to higher elevations within the structure. FEMA and USACE provide extensive literature on how to "flood proof" properties.[23] Innovative and simple solutions, such as sandbagging openings to below-ground utilities or other activities, can substantially reduce losses (Figure 31). More permanent solutions (Figure 32) reduce the labor costs involved in periodic use of interventions, like sandbags.

A significant problem in many communities is backup of sewage from sewer line connections into homes and businesses when combined or sewage-only systems are overtaxed. These problems can normally be addressed by use of backflow prevention valves (Figure 33).

Many homeowners and renters living and working in areas affected by urban flooding do not understand that they, individually, can take steps to significantly reduce their property's vulnerability. Many lack the resources and support necessary to carry out such actions. Information on how residents can reduce their property's flood risk frequently is not accessible or well-articulated.

UPGRADING OF CAPACITY STANDARDS

A failure to upgrade current storm and wastewater capacity standards places communities and their citizens at risk. Most older stormwater, wastewater, and combined systems that were designed with limited capacity have become overwhelmed by flow increases spurred by hydrologic change and urban growth. Systems designed to handle the five-year storm are inundated by current conditions; the potential for significant increases in the size and scope of future rainfall events put even seemingly high-capacity systems at risk. Individuals designing systems that deal with riverine and coastal flooding face the same challenges and are moving rapidly to address them. Again, because of the diverse nature of the urban flooding community, collaborative action is often not being taken to develop modern capacity standards.

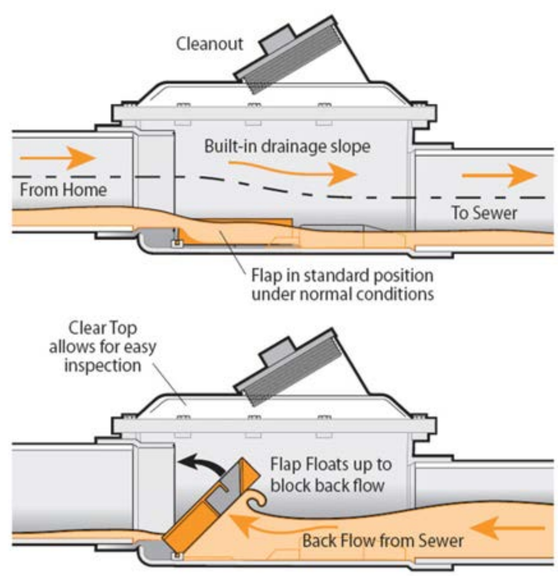


FIGURE 33. TYPICAL BACKFLOW PREVENTION VALVE DESIGNED TO PREVENT SEWAGE FROM BACKING FROM SEWAGE SYSTEM INTO PROPERTY. SOURCE: SQUARE ONE INSURANCE SERVICES, SQUAREONEINSURANCE.COM.

RISK COMMUNICATION: GAINING PUBLIC UNDERSTANDING

A majority of residents in urban flood-prone areas generally do not understand the actual risks (nature of hazard, consequences, and probabilities of occurrence) that they face from urban flooding. Also, in many cases, public officials are not doing an effective job of getting the word out. Of the 227 survey respondents, 58% reported this condition in the communities they represented. Numerous federal reports over the last decade have indicated that miscommunication is a significant challenge in all types of flooding. The most common response by those “caught off guard” by unexpected flooding was, “I just did not know that I was at risk; nobody told me.” For decades, people living in flood-prone areas have relied on NFIP maps to determine if they were at risk (i.e., in the SFHA and needed to buy insurance). However, since FEMA NFIP flood maps do not normally provide adequate information concerning flood risk in urban flood zones and most communities do not actively publicize the location of such areas, occupants are ill-informed about any risks.

There is no simple approach to identifying and assessing urban flood risk and communicating that risk to those who are affected. Since a significant amount of urban flooding may occur outside the bounds of the SFHA (that is delineated by the 100-year flood under the NFIP), there is currently no tool available to communities to assist in similarly delineating potential levels of urban flood risk.

FIGURE 34. HIGH WATER MARK SIGN IN CEDAR RAPIDS, IOWA. SOURCE: KCRG-TV.

Use of high-water mark signs (Figure 34) that identify the height of historical floods can also alert residents to their risks and lead them to possible mitigation methods. However, in many communities, public officials and current residents object to the use of such signs which are seen to devalue the nearby property.

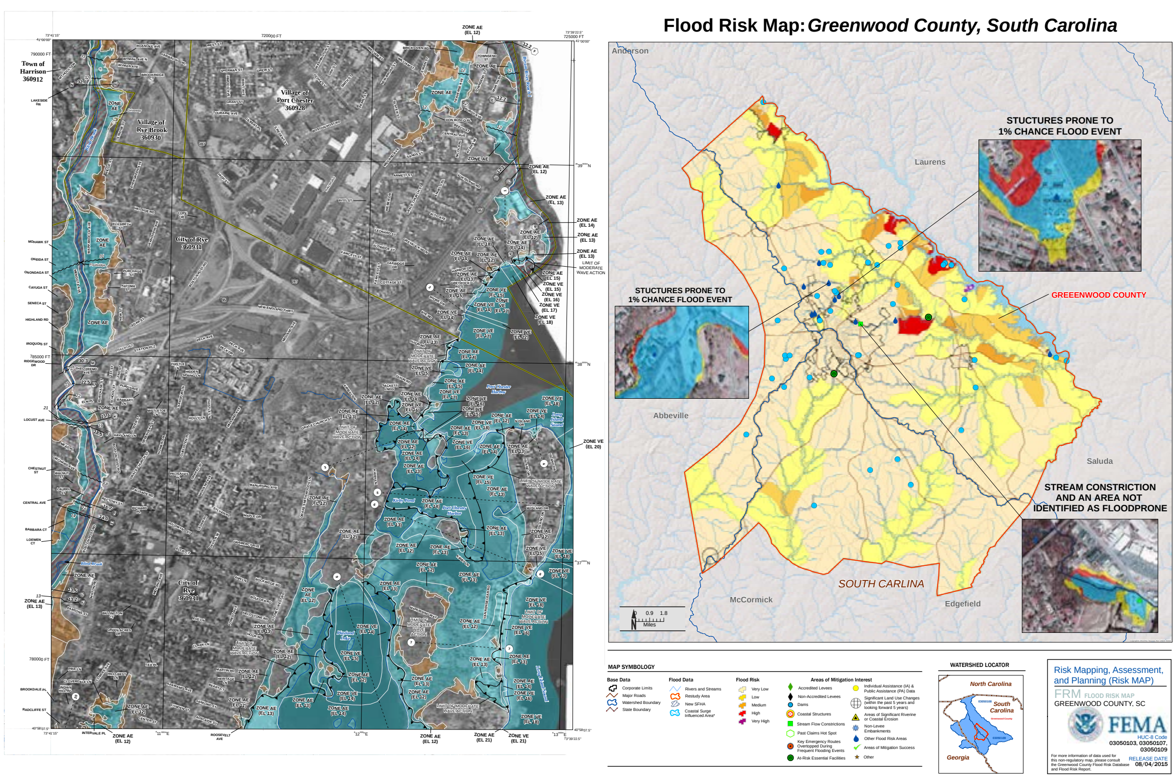


FIGURE 35. LEFT MAP: A FEMA FLOOD INSURANCE RATE MAP IDENTIFYING SFHA (ZONES AE AND VE) AND ZONE X (500-YEAR FLOODPLAIN IN ORANGE COLOR) AND AREAS BEYOND. RIGHT MAP: A FEMA FLOOD RISK MAP IDENTIFYING FIVE LEVELS OF RISK FROM “VERY HIGH” (PURPLE SHADING) TO “VERY LOW” (YELLOW SHADING). SOURCE: FEMA. THIS PRODUCT USES THE FEDERAL EMERGENCY MANAGEMENT AGENCY’S API, BUT IS NOT ENDORSED BY FEMA.

FIGURE 36. MAP ON LEFT IS A FIRM FOR A NEIGHBORHOOD IN A TEXAS COMMUNITY. THE GRAY SHADING INDICATES THE SFHA IN THAT AREA. THE RED BOX IDENTIFIES THE LOCATION OF THE AREA SHOWN IN THE RIGHT MAP WHERE, DUE TO PROBLEMS WITH THE LOCAL DRAINAGE, THE AREAS SHOWN IN BLUE ARE SUBJECT TO URBAN FLOODING BUT NOT REFLECTED ON THE FIRM. SOURCE: THE ASSOCIATION OF STATE FLOODPLAIN MANAGERS ANNUAL CONFERENCE, 2018.

FIGURE 37. SWISS SURFACE RUNOFF HAZARD MAP. THE DARKER THE SHADE OF PURPLE SHOWN, THE HIGHER THE WATER LEVEL IS PREDICTED TO RISE DURING A FLOOD. SOURCE: © DATA: SWISSTOPO, FOEN.

MAPPING URBAN FLOOD ZONES

Flood Insurance Rate Maps (FIRMs) identify SFHAs and guide the development of flood insurance rates under the NFIP. They have also been incorrectly seen as tools to communicate basic flood risk—property is subject to flooding (in the SFHA) or not (outside the SFHA).[24] To better communicate risk, FEMA, under the Risk MAP program, has developed a set of mapping products that better convey flood risk messages to the public, although none have been accepted as substitutes for FIRMs. These products, where SFHA may not even be mentioned, offer some ideas on how best to portray urban flood risk (Figure 35). Pilot programs, such as one being examined by a Texas community (Figure 36), can identify, through use of high-resolution models, areas of potential urban flooding.

Switzerland's government recently launched a website entitled "Hazard Map Surface Drainage Switzerland" that provides a map of areas in Switzerland that are potentially affected by major surface rainfall runoff. The objective of this mapping is not to offer high-resolution information about flooding depths, but instead focus on providing "stakeholders, such as builders, planning and architecture offices, building authorities, natural hazard departments, civil protection, insurance companies, and others with a basis to help them recognize the dangers at the early stage and to prevent damage with appropriate measures." The maps (Figure 37) that were developed through a partnership between the Swiss government and Swiss insurance associations are not legally binding documents but alert users to the challenges they face. Switzerland reports that "up to half of all floods in Switzerland are not caused by overflowing rivers and lakes, but by excess rainwater not being absorbed into the ground [emphasis added]."[25]

NASA is supporting a program called "Monitoring Urban Floods Using Remote Sensing," which uses space resources to identify flooded urban areas on a timely basis. Because satellites are continuously observing various locations, a time series of flood activity can easily be developed. Planners and managers can begin to identify areas of frequent inundation and long-term risk. Smaller communities that lack the resources to carry out their own image acquisition through commercial sources can take advantage of NASA's efforts.[25]

FROM THE COMMUNITY

"NFIP FIRM maps, although useful to some extent, have done somewhat of a disservice in communicating flood risk to the general public. There is a sense that if I'm in the SFHA, I'll be flooded and if I'm out of the SFHA, I won't ever be flooded. Further FIRM maps (at least in the Midwest) imply that flooding only occurs in riverine scenarios, and not in local areas."

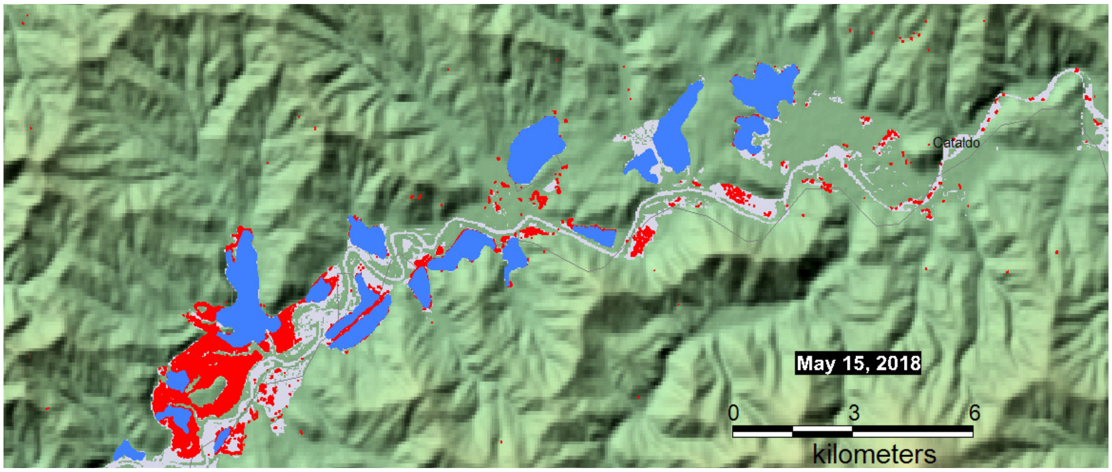


FIGURE 38. NASA HIGH ALTITUDE FLOOD MONITORING. "RED IS FLOOD MAPPED FROM COPERNICUS SENTINEL 1 SAR DATA PROVIDED BY THE EUROPEAN SPACE AGENCY. BLUE IS A REFERENCE NORMAL WATER EXTENT (SWBD). LIGHT GRAY IS ALL PREVIOUSLY MAPPED FLOODING. FOR THIS SAR-BASED MAPPING, A CHANGE DETECTION METHOD IS USED (GIS FILE NAMES SHOW COMPARISON IMAGE DATES). TOP: COEUR D'ALENE RIVER, FALSE COLOR COMPOSITE USING DATA FROM SEPTEMBER 27, 2017 (BEFORE) AND MAY 15, 2018 (DURING). THE 10 M. RESOLUTION OF THE SAR IMAGE HAS BEEN SOMEWHAT DEGRADED BY APPLICATION OF A 5X5 LOW PASS FILTER TO REDUCE SPECKLE. A BAND RATIO AND FLOOD IMAGE INTENSITY ALGORITHM ARE USED TO IDENTIFY NEW WATER, ALREADY VISIBLE IN THE SAR IMAGE ITSELF AS RED COLORS." SOURCE: DARTMOUTH FLOOD OBSERVATORY AT THE UNIVERSITY OF COLORADO, FROM SATELLITE DATA PROVIDED BY NASA AND COPERNICUS/EUROPEAN SPACE AGENCY.

Many flood and stormwater communities have suggested that mapping of urban flood zones be added to the mapping program of the NFIP, as FEMA is already involved in such activity. Others have argued that identification of urban flood zones should be the responsibility of local governments, which have intimate knowledge of the needs of the community and how best to convey the information. In addition, the latter group indicates that moving urban flood zone determination and mapping into an already complicated federal-state-local process would add significant burdens to communities and that the methodology for determining levels of risk are significantly different in urban versus riverine and coastal areas. Urban floods are generally tied to heavy rainfall events as opposed to river and coastal waters flood events, and movement of the rainfall runoff through stormwater structures, streets, natural drainage, and open channel infrastructure, all of which are subject to disruptions (e.g., culvert and pipe blockages, neighborhood back-ups, etc.), are not normally accounted for in riverine flood frequency determinations. As gleaned in recent urban floods across the country, it is extremely difficult to determine the recurrence interval of an urban flood event. A 100-year urban flood event that is in reality a 100-year rainfall event is difficult to compare to a 100-year event in the riverine and coastal context.

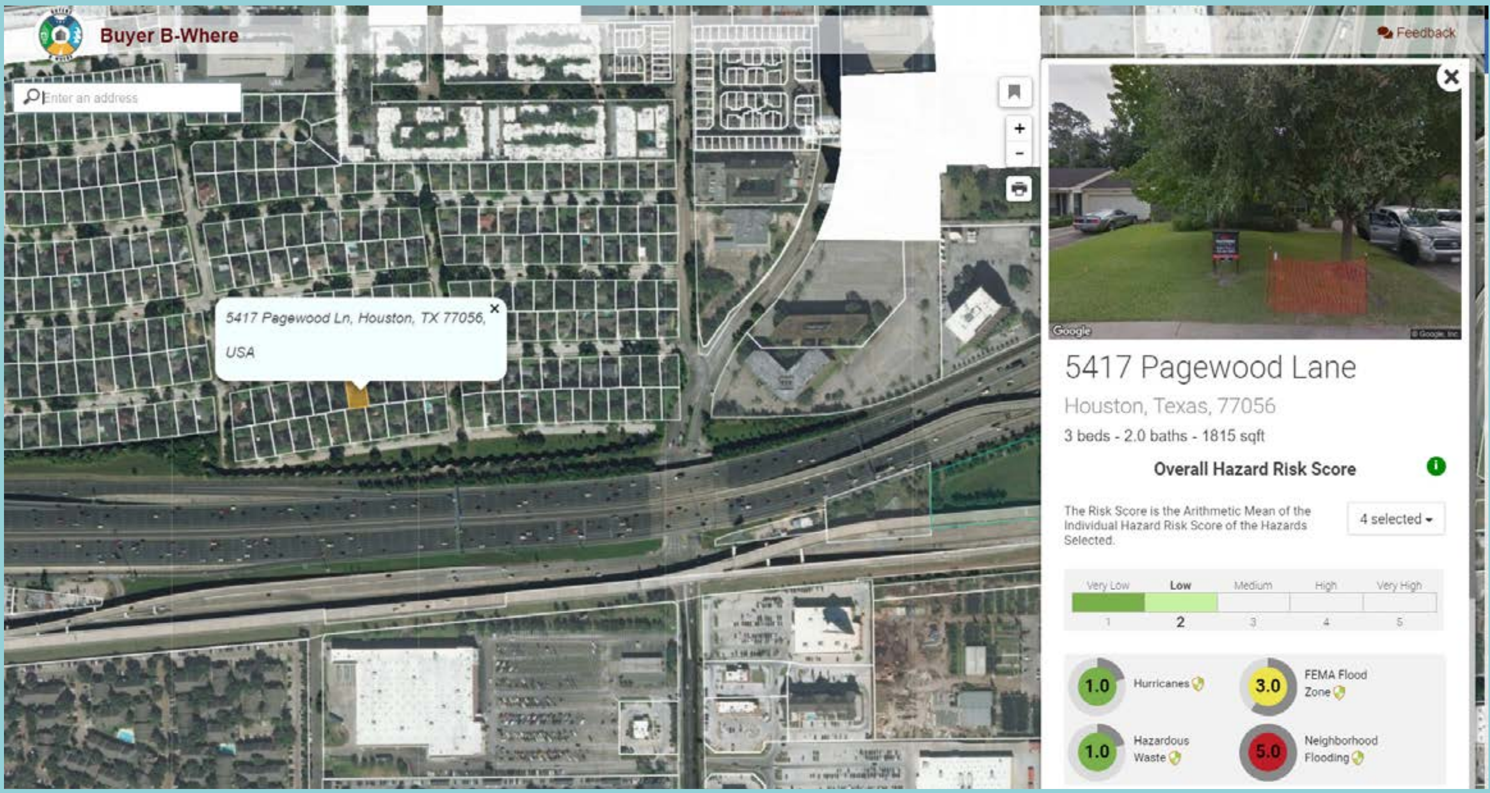


FIGURE 39. AN ILLUSTRATIVE PANEL FROM THE BUYERS BE-WHERE SOFTWARE FOR THE PROPERTY INDICATED. THE PANEL PROVIDES INFORMATION ON SEVERAL LOCAL HAZARDS. SOURCE: BUYERS-BEWHERE.COM.

DISCLOSING RISKS IN USER-FRIENDLY WAYS

Renters and buyers of property in an urban flood zone are faced with a lack of available information about flood risk or even previous flood history. Some states require that the seller or the agent formally disclose to the buyer or renter that the property is in the SFHA. Lenders can require that elevation certificates be provided to indicate that the property is not in the SFHA, but again, these provisions are applicable to property where the SFHA has been mapped. In the urban case, no such map exists, and the tools for identifying risk have not been developed.

Software programs, such as Texas A&M University's "Buyers Be-Where" (Figure 39), could be used to disseminate urban flood risk information (Buyers-bewhere.com). However, because such information is often seen as having negative consequences on the economic viability of community development, public officials are frequently reluctant to "push" the information to the public, preferring to make it available only to those who know of its existence and ask for it. As a result, potential home buyers or renters often move into an area and are blindsided when floods occur. Another available risk disclosure tool is FloodTools (floodtools.com) (Figure 40). Operated by National Flood Services, it provides risk information on properties in all states, including maps of previous flood events.

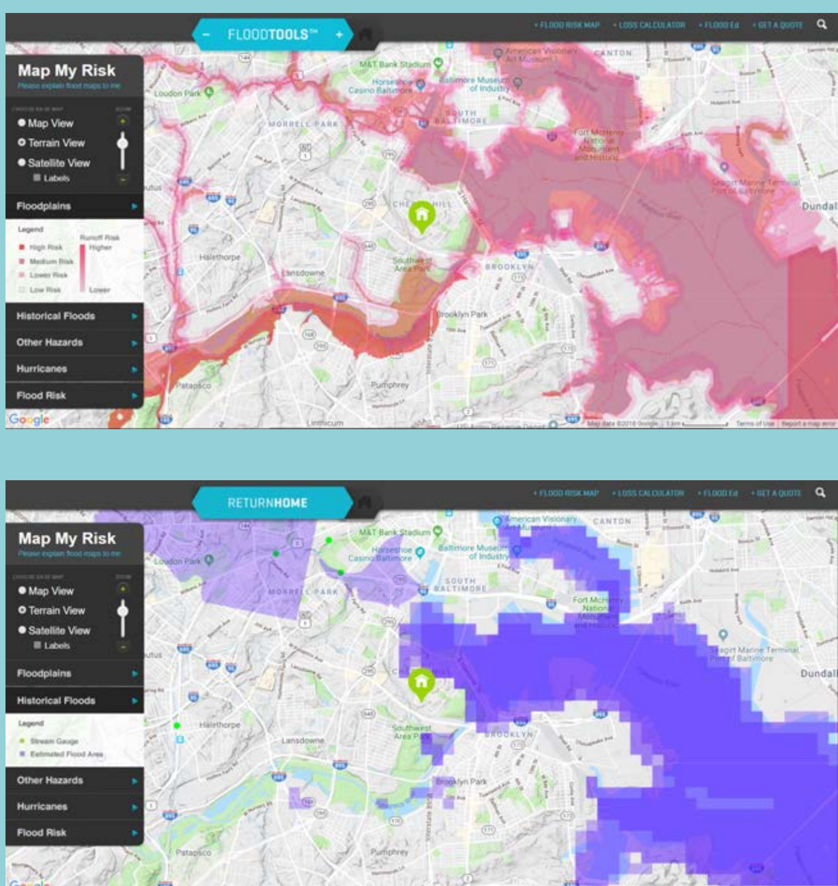


FIGURE 40. ILLUSTRATIVE PANELS FROM THE FLOODTOOLS SOFTWARE FOR THE PROPERTY INDICATED. THE TOP PANEL PROVIDES INFORMATION ON THE FLOOD RISK, AND THE LOWER PANEL PROVIDES A HISTORY OF FLOODING. SOURCE: FLOODTOOLS.COM.

INSURING AT-RISK PROPERTIES

Purchase of insurance is a significant means of reducing the flood risk of individuals and businesses, but many in urban flood-prone areas do not purchase it because it is seen as unaffordable. Most property owners or rental occupants at risk do not understand how insurance works or understand the risks they face.

A key consideration in bringing insurance to urban flood risk zones is the fact that when a community joins the NFIP and a FIRM is prepared, the entire community, in or out of the SFHA or marked zones, is eligible to purchase insurance. This means that occupants of scattered flood-prone 'islands' within the community can obtain insurance, generally at low rates. Community programs that encourage the purchase of flood insurance in areas outside the SFHA can be successful and reduce the risk to those that purchase insurance.

FROM THE COMMUNITY

"Lack of funding and lack of political will are the most significant issues. Much of the available funding requires a cost share and significant participation in the NFIP program. Most properties outside the mapped floodplain do not carry flood insurance. This then requires localities to fund these initiatives by themselves. Additionally, new development outside the floodplain generally has limited stormwater control requirements. Local CEOs are often reluctant to require stormwater controls as they fear this would dissuade development."

VII. MAJOR CHALLENGES

While there are many approaches to reducing the risk of urban flooding and every community must develop its own plan to deal with its unique risk, it is obvious that communities face common challenges that extend beyond better engineering and planning.

PENSACOLA, FLORIDA, PHOTO BY ANDREA BOOHER/FEMA

LACK OF RESOURCES

Communities across the country lack the resources to effectively operate, maintain, and upgrade their water, wastewater, and stormwater systems, and to manage the urban flooding that occurs as a result of the shortfall; there are limited federal programs to support such activities. The 2017 American Society of Civil Engineers infrastructure report card assigns a grade of D+ to wastewater/stormwater systems across the nation. Of the 305 reporting communities surveyed, 41% indicated that funding was the principal bar to moving forward with urban flood mitigation. At the individual level, most homeowners or renters lack the resources and/or the knowledge to address flooding issues that are primarily structure focused, such as sewage and stormwater backup. A recent Canadian report indicated that the risk of damage to homes from sewer backups alone "could be eliminated through the installation of a backwater valve...[and] the preventable damage to homes is greater in any recent year than the cost of purchasing a backwater valve for every home in Canada."[27]

While there are federal and state grant and loan programs to address water, wastewater, stormwater, and flood infrastructure, the amounts available fall far shy of the amounts needed. Recent attention to urban flooding indicates that addressing this flooding will significantly increase the demand for funds.

POPULATION AND URBAN GROWTH

Increasing population in urban areas is exacerbating urban flooding problems. Those at the lowest end of the economic spectrum face the challenge of finding the least expensive housing, often moving into basements or other areas subject to more frequent flooding. Even public housing faces these flooding challenges.

CLIMATE CHANGE

The 2017 National Climate Assessment indicates that major rainfall events are continuing to increase in many parts of the country and that these increases will result in more urban flooding.

The assessment finds that:

"Heavy downpours are increasing nationally, especially over the last three to five decades. The heaviest rainfall events have become heavier and more frequent, and the amount of rain falling on the heaviest rain days has also increased. Since 1991, the amount of rain falling in very heavy precipitation events has been significantly above average. This increase has been greatest in the Northeast, Midwest, and upper Great Plains – more than 30% above the 1901-1960 average...Flooding may intensify in many U.S. regions, even in areas where total precipitation is projected to decline.

Urban flooding can be caused by short-duration, very heavy precipitation. Urbanization creates large areas of impervious surfaces (such as roads, pavement, parking lots, and buildings) that increased immediate runoff, and heavy downpours can exceed the capacity of storm drains and cause urban flooding. Flash floods and urban flooding are directly linked to heavy precipitation and are expected to increase as a result of increases in heavy precipitation events."

FROM THE COMMUNITY

"Challenges of urban flooding include large public cost of numerous small projects to minimize or reduce flood risk to a few affected private properties. Because retrofit storm sewer upgrades are expensive and usually disruptive, they are not as highly prioritized as major stormwater projects such as arterial roadway bridge or culverts, regional detention ponds, etc. Often the repetitive flooding has been going on for so many years in older areas of towns, that it is just considered business as usual, even for the property in some cases."

Sea level rise is occurring around the globe, and while much attention is being paid to the impacts on major coastal cities of the world, sea level rise will also affect the thousands of smaller communities that exist along our shorelines. The increase in sea level in itself will flood many coastal areas. In addition, sea level rise will cause significant challenges to the drainage systems in coastal communities; infrastructure built to conditions of a century ago will no longer be able to operate.[28]

While professionals dealing with urban flooding at the local level are aware of the challenge of climate change, including sea level rise, those they work for and the public at large may not be as cognizant of the implications of climate change. More than 60% of the reporting communities indicated they were taking future conditions into account in planning required upgrades and new work; however, the lack of public understanding of the potential impacts of climate change are limiting public support for such climate change-related activity and any funding increases that would be required to address climate change.

PRIORITY SETTING

Because urban flooding may cover only selected areas in a community, it is frequently of less concern to those not effected. It gets less attention from public officials and the public in general until a major event creates a significant disruption. Many urban floods involve only a small percentage of a large community and affect segments of the community in lower-valued properties. Occurrences are not headlined in newspapers or the focus of major governmental actions. Seventy percent of survey respondents (n=345) indicated the urban flooding was a significant concern of those affected, but only 34% indicated that elected officials and the community, in general, saw it as a matter of importance. Twenty-eight percent of the respondents noted that the community saw urban flooding only as a nuisance.

CHICAGO, ILLINOIS, PHOTO COURTESY OF CNT/RAINREADY

GOVERNANCE

The management and oversight of activities related to urban flooding are scattered throughout governmental entities at all levels. The dispersal of responsibilities creates overlaps in actions and limits progress in resolving urban flooding issues.

It is clear that professionals involved in urban flood mitigation and in water, wastewater, and stormwater management believe that the principal responsibility for management of urban flooding and related aspects of flood and stormwater management should be at the local level. It is at this level where the problem is best understood; however, local efforts should be supported by state and federal agencies with regards to the fiscal challenges in the management and integration of other related state and federal programs. There are significant challenges in sorting out the responsibilities of the multiple agencies that act at the municipal level in the water, wastewater, and flood management arenas. In many places, municipal flood management is separated from municipal stormwater management and the programs are frequently in conflict. A report by the state of Illinois on urban flooding and the results of a symposium held by the Illinois Association for Flood and Stormwater Management clearly defined many of these challenges at the state and local level.[29]

> **Observation:**
> There is no federal agency charged with oversight of federal support of urban flood mitigation-related activities.

At the federal level, the responsibility for urban flooding is not clear. The USACE is seen to have principal responsibility for major flood risk reduction activities and focuses its activities on prevention of damage from riverine and coastal floods. When a major river or bayou flows through an urban area, as they do in the Houston metropolitan region, USACE may participate in urban flood reduction activities. However, under USACE regulations, the discharge of a stream or a waterway creating this urban flooding must be in excess of 800 cubic feet per second or the 10-year flood, which severely limits USACE participation in urban activities.

FEMA operates the NFIP and is responsible for federal actions in response to disasters, which normally require a Presidential Disaster Declaration of their severity and, as a result, dramatically limits federal fiscal support in limited-area flood events where statewide impact is low. FEMA requires control by local communities of floodplain management activities in coastal and riverine SFHAs and, to a considerably lesser degree, in the 500-year floodplain, where they pose little or no restrictions on development. Most people in an urban area, where the community participates in the NFIP, are eligible to purchase flood insurance, but since the NFIP is focused on riverine and coastal flooding, little attention is given to increasing participation by urban community members in the NFIP insurance program.

The EPA has principal responsibility for water quality and provides national oversight on activities related to the treatment and disposal of waters in urban areas. However, the EPA does not fully integrate floodwater and floodplain management into the activities they guide or support. Over the last decade, the EPA has put considerable attention into separating urban stormwater flows from urban wastewater flows to prevent the former from becoming carriers of pollution during major storm events. However, little attention has been given to integrating the stormwater system solutions with related floodplain risk reduction systems. In a 2009 National Research Council study on stormwater for the EPA, the primary focus was on water quality, seemingly portraying wastewater as distinct from stormwater in the management of urban water challenges. [30]

While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding and need coordination both at the federal level and with state and local governments. The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.

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ATTENTION TO ENGINEERING AND SCIENCE

Over the last five decades, considerable attention has been given to improving the science and engineering connected with the management of floods and the employment of the multiple tools available to reduce flood risk and to prevent significant flood events. Unfortunately, there have been no similar efforts in the area of urban flooding. Several areas in need of attention emerged during this study.

DATA AVAILABILITY AND SYNCHRONIZATION

Technical and demographic data concerning urban flooding is scattered among many agencies and is captured and stored in differing formats, thereby limiting analysis and development of high-quality solutions. Agencies are protective of data that they have collected and analyzed and are often reluctant to share with other entities. However, without complete watershed-level information, reliable solutions will not be developed. Privacy act restrictions frequently reduce the number of datasets available for analysis, when, after carefully planned scrubbing, data might be made available without jeopardizing privacy.

MODEL ORDINANCES

Model ordinances provide great assistance to communities that lack the capacity to develop their own. Because solutions to urban flooding are at the intersection of several sub-disciplines, each with its own constituency, it is difficult to find a single model ordinance that would satisfy all needs across the spectrum of challenges that must be faced; therefore, it may be necessary to develop a suite of such ordinances. Development will require a collective action by professional organizations that deal with floodplain management, stormwater management, and water and wastewater management, as well as other organizations that influence urban planning and design.

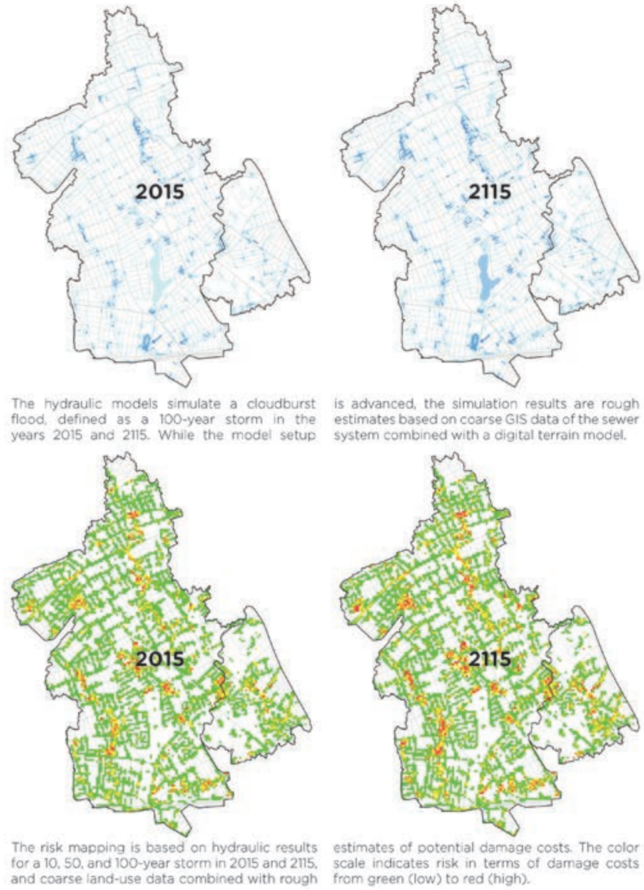

FIGURE 41. NEW YORK CITY URBAN FLOOD MODELING. SOURCE: NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION, JANUARY 2017. CLOUDBURST RESILIENCY PLANNING STUDY. PREPARED BY RAMBOLL A/S.

URBAN FLOOD MODELS

Efforts over the last decades have focused on improving the plethora of hydraulic and hydrologic models available in support of watershed management, systems analyses, engineering design, and standards development. Considerably less attention has been given to the development of models that examine the urban environment. To identify urban flood potential under intense rainfall events, New York City recently made use of models that offer new techniques and follow-on analysis illustrating spatial flood dynamics over time (Figure 41).

[16] NWS Hydrologic Information Center – Flood Loss Data. http://www.nws.noaa.gov/hic/. "The National Weather Service's primary mission is to provide weather information for the protection of life and property. Ancillary to this mission, NWS field offices provide loss estimates for significant flood events. No one governmental agency has specific responsibility for collecting and evaluating detailed flood loss information. Therefore, the resulting data are to be considered rough estimates, and may be unrepresentative of actual damages."

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VII. MOVING AHEAD: CONCLUSIONS AND RECOMMENDATIONS

THE STUDY TEAM CONCLUDED THAT:

1. In much of the United States, urban flooding is occurring and is a growing source of significant economic loss, social disruption, and housing inequality. Extensive suburban development that creates higher flood flows into urban areas, aging and frequently undersized infrastructure in older sections of communities, an inability to maintain existing drainage systems, increases in intense rainfall events, and uncoordinated watershed management all contribute to these increases in urban flooding.

2. The growing number of extreme rainfall events that produce intense precipitation are resulting in—and will continue to result in—increased urban flooding unless steps are taken to mitigate their impacts. The 2017 National Climate Assessment concluded that "heavy downpours are increasing nationally, especially over the last three to five decades…[and that]… increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions."

3. Communities across the nation are facing similar challenges with urban flooding. However, the unique hydrological, physical, and social characteristics of these communities mean solutions are best developed locally. While the magnitude of urban flooding challenges merit federal guidance and support when needed, responsibilities must rest primarily at the local level.

4. While primary responsibility for mitigation of urban flooding rests with local governments, the division of responsibilities among federal, state, regional, local, and tribal governments for urban flood and stormwater management are not clearly defined. Responsibilities are diffused and lack the collaboration and coordination necessary to address the technical and political challenges that must be faced.

5. Many of the urban wastewater and stormwater systems that provide the backbone of urban flood mitigation are in poor condition and—in some locations—are inadequate and in need of strong support. The human and fiscal resources necessary to address urban flooding are not generally available at the levels required.

6. At the federal level, there is no agency charged with oversight of federal support of urban flood mitigation-related activities. While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding.

7. The economic and social impacts of urban flooding are generally not well known and understood by many public officials and the unaffected public. Social vulnerabilities and inequities in disaster recovery for low-income populations are not being fully addressed.

8. Governments, at all levels, have not provided effective means to communicate risks to those in urban flood-prone areas. A significant number of these areas are not identified by maps produced under the Federal Emergency Management Agency National Flood Insurance Programs, and actions by those responsible for urban flood mitigation are needed to delineate these areas. Communication of flood risk is often seen by public officials and developers as a negative.

9. Many homeowners and renters living and working in areas affected by urban flooding do not understand that they can take steps to significantly reduce their property's vulnerability, and many lack the resources and support necessary to carry out such actions. Information on how a resident can reduce their property's flood risk is not accessible or well-articulated.

10. Data—covering insurance claims, assistance, and loans for flood mitigation—are not easily available or shared with local decision-makers, researchers, and the residents themselves. More accessibility and availability of data is critical to effective response, recovery, and long-term mitigation of flood events. This data must be provided in an easily interpreted and spatially identifiable format.

THE STUDY TEAM RECOMMENDS THAT:

1. **Governors, tribal leaders, and regional and municipal officials should review the current responsibilities for oversight of urban flooding mitigation, as well as flood, water, wastewater, and stormwater management in their jurisdictions; provisions, as appropriate, should be made to ensure efficient and effective multi-jurisdictional planning and operation of these activities and services on a geographic scale that matches the problems being addressed.**

2. **The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.**

3. **The administration, in coordination with Congress, should assign one federal agency to provide interim oversight of federal support of urban flood mitigation activities, the development of the national forum, and the preparation of a post-forum report for the administration, Congress, the states, municipalities, and tribes.**

4. **Attention should be given at all levels of government to ensure that efforts to mitigate urban flooding reach areas that have the highest risk of flooding and cross all economic and social levels and that locally supported steps are taken to incentivize individual homeowner mitigation efforts.**

5. **In coordination with ongoing efforts to ensure that those at risk of flooding are aware of their vulnerabilities, FEMA, USACE, NOAA, USGS, EPA, and HUD, in collaboration with urban flood communities, should integrate urban flood risk communication outreach into their ongoing programs for riverine and coastal flooding and ensure that analysis of future conditions should include the impacts of climate and weather and future development.**

6. **States should consider integrating urban flood risk communication, mapping, and risk disclosure measures into real estate transactions in urban flood areas.**

7. **The Congress and the administration, in coordination with state governors, regional, local, and tribal officials, should develop appropriate mechanisms at the federal, state, and local level to fund necessary repairs, operations, and upgrades of current stormwater and urban flood-related infrastructure.**

8. **Congress should direct the administration to establish a risk identification grant program that enables communities to develop effective means of identifying the risks they face from urban flooding.**

9. **The administration should support continued research into urban flooding to ensure that the full extent of the threat is identified and that steps are taken to formulate solutions to policy and technical issues.**

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State of Illinois
Illinois Department of Natural Resources

REPORT FOR THE Urban Flooding Awareness Act

JUNE 2015

Report for the Urban Flooding Awareness Act

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The executive steering committee included the Metropolitan Water Reclamation District of Greater Chicago, DuPage County Stormwater Management, the Madison County Stormwater Program, the City of Decatur, Federal Emergency Management Agency, Illinois Emergency Management Agency, Illinois Environmental Protection Agency, and Illinois Department of Natural Resources. Funding for the report provided by the State of Illinois and through the Federal Emergency Management Agency's Community Assistance Program – State Support Services Element. A full digital copy of the report is available on the Illinois Department of Natural Resources and Illinois State Water Survey webpages. Cover: Top right photo used with permission from The Center for Neighborhood Technology other photos by Illinois Department of Natural Resources

June 2015

Urban Flooding Awareness Act

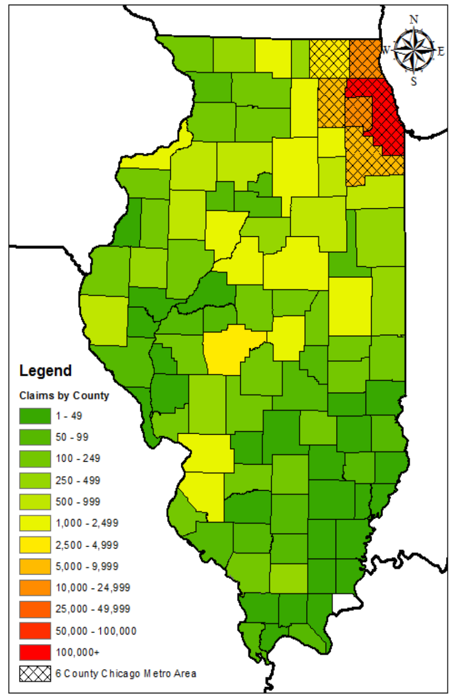
The Illinois General Assembly under the *Urban Flooding Awareness Act* (effective August 3, 2014) tasked the Illinois Department of Natural Resources (**IDNR**) to prepare a report on the extent, cost, prevalence, and policies related to urban flooding in Illinois and to identify resources and technology that may lead to mitigation of the impact of urban flooding. IDNR has prepared this report in collaboration with the Illinois Emergency Management Agency (**IEMA**), the Illinois Environmental Protection Agency (**IEPA**), the Illinois Housing Development Authority (**IHDA**), the Illinois Department of Commerce and Economic Opportunity (**DCEO**), the Illinois Department of Insurance (**IDOI**), the Federal Emergency Management Agency (**FEMA**), the Metropolitan Water Reclamation District of Greater Chicago, (**MWRDGC**), the Illinois State Water Survey (**ISWS**), and other concerned agencies.

The *Urban Flooding Awareness Act* specifically identifies nine topics to be addressed in the report as follows:

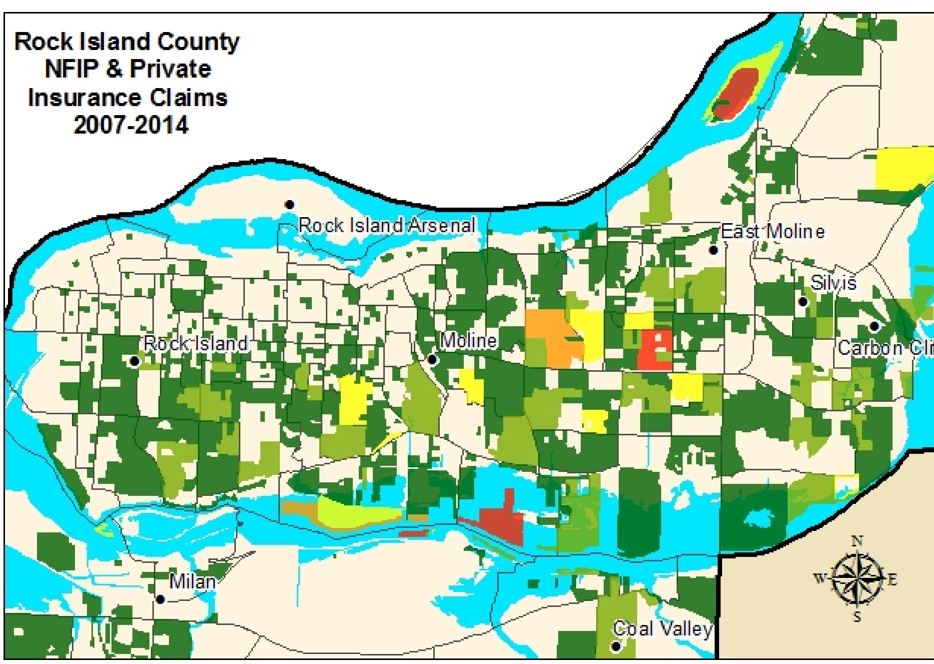
1. Prevalence and costs associated with urban flooding events across the state, and the trends in frequency and severity over the past two decades
2. Apparent impact of global climate change on urban flooding
3. The impact of county stormwater programs on urban flooding over the past two decades, including a list of projects and programs and the flood damages avoided
4. An evaluation of policies such as using the 100-year storm as the standard for designing urban stormwater detention infrastructure and the 10-year storm for the design of stormwater conveyance systems
5. Review of technology to evaluate the risk of property damage from urban flooding and whether a property is in or adjacent to a 1% (100-year) floodplain or not, including LiDAR and GIS
6. Strategies for minimizing damage to property from urban flooding, with a focus on rapid, low-cost approaches such as non-structural and natural infrastructure, and methods for financing them
7. The consistency of the criteria for state funding of flood control projects between IDNR, IEMA, and DCEO
8. Strategies for increasing participation in the National Flood Insurance Program (NFIP) and Community Rating System (CRS)
9. Strategies and practices to increase the availability, affordability and effectiveness of flood insurance and basement back-up insurance

Executive Summary

The Illinois General Assembly under the *Urban Flooding Awareness Act* (effective August 3, 2014) tasked the Illinois Department of Natural Resources (IDNR) to prepare 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. IDNR has prepared this report in collaboration with the other state agencies identified in the Act. The *Urban Flooding Awareness Act* specifically identifies nine topics to be addressed in the report. These topics fall under three themes: Past, Current and Future flooding; Effectiveness of Projects, Programs and Policies; and Strategies for Reducing Urban Flood Damages. Each of the topics is explored in the main body of the report, with more detailed analyses provided in the appendices.



Flooding in urban areas has received increasing attention in the last decade, with at least $2.319 billion in documented damages between 2007 and 2014, of which $1,240 billion were private claims that typically represent basement flooding and sewer backup. Although the largest percentage of insurance claims is from northeastern Illinois, urban flood damages and problems occur statewide in urban areas. Urban flooding as defined by the Act is "The inundation of property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. 'Urban flooding' does not include flooding in undeveloped or agricultural areas." **Over 90% of urban flooding damage claims from 2007 to 2014 were outside the mapped floodplain,** which is roughly proportional to the developed floodplains within Illinois urban areas.

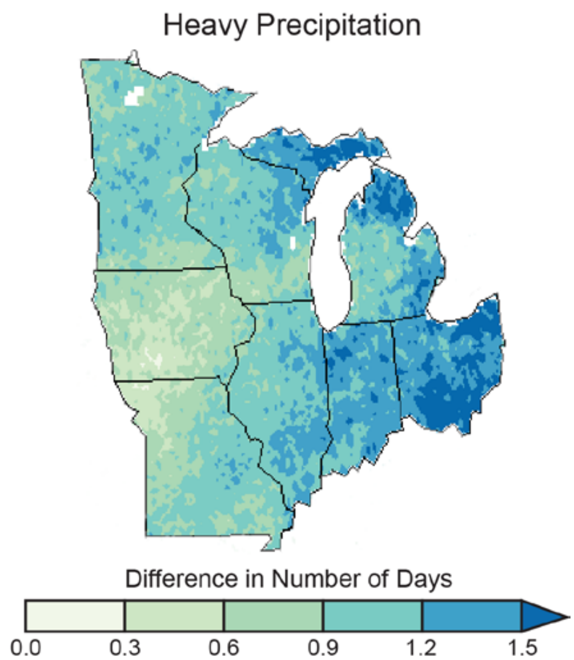


Between 2007 and 2014 there have been a total of 1972 urban flood damage claims within Rock Island County. Roughly three-fourths (71.3%) of the claims occurred outside the mapped floodplain.

Legend
Mapped Floodplain
Claims Per Census Block
0
1 - 4
5 - 9
10 - 19
20 - 29
30 - 42

There are numerous contributing factors to urban flooding, and in any location the causes may be unique. Urban flooding is most common in older sections of communities where original storm sewers were not designed to present-day standards; urbanization has increased runoff, and climate is trending to more frequent and intense storm events. In counties which have been granted countywide authority to establish funded stormwater management programs, progress is being made to reduce urban flooding, but much remains to be done. Most counties do not have authority to establish programs to manage the effects of urbanization. **Communities may have the authority to impose design standards and ordinances but often do not have the legal authority to establish a dedicated funding stream,** making it difficult to maintain and improve storm sewer systems when these repair projects must compete for general funding support.

Urban flooding is expected to increase unless action is taken. There are a number of factors contributing to increased precipitation and more heavy rain events in recent decades, and several lines of evidence suggest that the current patterns will continue in the future. Technology provides numerous tools to analyze data and develop strategies to deal with existing and future urban flooding. However, current basic data collection and analyses are inadequate, and efforts should be extended to ensure Illinois is collecting information needed to guide programs and policies to reduce flood damages. There are many options to mitigate urban flood damages, such as green and gray infrastructure, and increasing open areas in areas of redevelopment. **Storm sewer infrastructure is the underpinning of urban drainage, and action is needed to update aging, undersized systems.**



Possible increases in the heaviest 2-percent storms from the 1971-2000 base period to the period 2041-2070 based on the A2 high emission scenario. Source NCA (2014).

Changes to infrastructure and the urban landscape will take years; however, communities and individuals can take action now to reduce risk and damages. Programs such as the Community Rating System provide guidance for higher standards and community actions to reduce risk. Individuals can purchase sewer and basement insurance as riders to homeowners insurance and flood insurance through the National Flood Insurance Program. Education and training for communities, insurance agents and property owners is critical to understanding risks and how to mitigate and correctly insure those at risk. Sustained outreach is needed for better informed stakeholders.

The state can provide leadership for communities. The state can develop tools, provide technical assistance and raise awareness. The state can incentivize communities through a variety of mechanisms including access to grants and revolving funds for communities that take responsibility for addressing flooding issues. Most importantly, the state can assist communities by aligning the authorities for justification of state capital projects. These are currently inconsistent, making it more difficult to seek funding from one state agency versus another for similar flood damage reduction purposes.

The responsibility for urban flooding lies at all levels, from state government to individual property owners, and a tiered approach is required for all aspects of stormwater management. The research presented in this report has led to 33 recommendations that have been grouped by four levels of responsibility **(see Urban Flooding Awareness Act Report Recommendations, page 78)**, some of which require legislative action, executive authority, state agency engagement, community action, and action by an informed public.

As recommended in this report, the Illinois Department of Natural Resources is already working with other key state agencies to: develop a draft state model stormwater ordinance for local communities, determine how best to appropriate expenditures of state revolving funds for stormwater management measures; and coordinate federal and state mitigation grant programs and projects potentially addressing urban flood measures through the Illinois Mitigation Advisory Group. **The remaining recommendations in the report address the need for authorities, education and awareness, local regulations, collaboration between government agencies and communities, and funding for programs and data collection efforts to reduce future flood damage costs in the State of Illinois.**

Harlem & Irving Park, April 2013, (WGNTV)

Lake Zurich basement, June 2013 (Chicago Tribune, Dan Waters)

Table of Contents

Introduction

The State of Illinois has a long history of losses due to flooding. All of the 102 counties have experienced flooding sufficiently severe to warrant a Presidential Disaster Declaration. When the average citizen suffers property damages, transportation disruption or employment interruption because of excess water, regardless of the source or cause, they have experienced flooding. News reports and public comments about flooding often do not identify the source of the excess water causing the damage. However, in the myriad of government programs and regulations, there are very specific definitions of "flooding" as it pertains to a particular program. This report examines urban flooding as defined by the *Urban Flooding Awareness Act*. The intent is to better understand the characteristics of urban flooding and the factors contributing to urban flooding: where it occurs, why it occurs, how it is currently managed, how it could be managed, where responsibilities lie for management as well as looking to the implications of changes in the future climate.

Available information and data related to urban flooding have been collected statewide to address the topics identified in the Act. The common factors contributing to urban flooding were identified to develop a common understanding of the focus of the investigation. A working definition of "urban" was used to develop geographic distribution. A systematic review of data was conducted to determine the prevalence and costs associated with urban flooding, past to future. Current programs at the community, county, state and federal level were reviewed to explore the effectiveness of projects, programs and policies. Strategies and recommendations for minimizing the impacts of urban flooding were explored and evaluated.

The report begins with a working definition of urban flooding, an examination of the factors contributing to urban flooding and the geography and demographics of urban areas in Illinois. Each of the issues identified in the Act are organized under three themes: Past, Current and Future; Effectiveness of Projects, Programs and Policies; and Strategies for Reducing Urban Flood Damages. Each section provides a brief description of the issues, data, observations and recommendations where appropriate. Recommendations are summarized at the end of the report (see Urban Flooding Awareness Act Report Recommendations, page 78). Detailed analyses supporting and/or enhancing the information included in each chapter of the report are provided in the appendices.

Urban Flooding

Urban flooding as defined in PA98-0858, the *Urban Flooding Awareness Act*

"The inundation of property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. 'Urban flooding' does not include flooding in undeveloped or agricultural areas. 'Urban flooding' includes (i) situations in which stormwater enters buildings through windows, doors, or other openings, (ii) water backup through sewer pipes, showers, toilets, sinks, and floor drains, (iii) seepage through walls and floors, and (iv) the accumulation of water on property or public rights-of-way."

Characteristics

Urban flooding is characterized by its repetitive, costly and systemic impacts on communities, regardless of whether or not these communities are located within formally designated floodplains or near any body of water. These impacts include damage to buildings and infrastructure, economic disruption, and negative effects on health and safety.

Common Factors

In an urban environment, these common factors can independently or in combination lead to urban flooding and urban flood damage.

- **Environmental factors**
  - A flat or gently sloping landscape inhibits immediate flow of precipitation away from sites and increases the potential for flooding issues.
  - Precipitation that cannot be absorbed by saturated or poorly drained soils or that occurs in areas with high groundwater can accumulate in low-lying areas and enter buildings.
  - Increasing frequency and intensity of weather events are placing more pressure on urban drainage systems.
- **Development and impervious surfaces**
  - In an urban setting, overland water paths may not be provided or can be obstructed by development, causing localized flooding.
  - As more land is converted to urban and suburban areas, the amount of undeveloped land available for water infiltration into the soils decreases.
  - The natural process of overbank flooding from rivers, streams, and lakes can be exacerbated by development, leading to frequent and chronic flooding.
- **Aging and limited infrastructure**
  - *Combined sewer capacity exceeded*: Older areas of communities may have combined sanitary and storm sewers, which can be overwhelmed during precipitation events.
  - *Storm sewer capacity is exceeded*: Storm sewers are designed to convey specified precipitation events that, if exceeded, will result in water ponding in streets, yards and right-of-ways, adversely affecting quality of life, property values, and public safety.
  - *Storm sewers that cannot drain due to flooded open channel receptors*: During major precipitation events impacting a larger geographic area, receiving rivers and streams may rise to a depth that prevents the discharge from storm sewer outlets, even to the extent of backflow through the sewer system.

Urban Areas

Urban areas are defined by the U.S. Department of Commerce, U.S. Census Bureau (USCB) as densely developed residential, commercial and other nonresidential areas. For the purpose of data analyses, census block data were used to identify the geographic locations of urban areas. The USCB definitions were used as a basis but broadened to encompass high-density population areas where urban flooding may occur. See Appendix A for a detailed description of urban area census analyses.

In total, 291,988 census blocks are designated as urban in Illinois for the purposes of urban flooding, including at least a substantial part of 1,193 municipalities. See Appendix A for a complete list of urban municipalities. Total urban land area in Illinois shown in Figure 1 is 4,170 square miles out of 56,350 square miles (7.4 %). Fifty-two percent (52%) of Illinois urban area is located in the six-county Chicago Metropolitan Area of Cook, DuPage, Lake, McHenry, Kane, and Will Counties, and 7.8% of urban area is located in the St. Louis Metro East area (Madison, St. Clair, and Monroe Counties). The remaining 37.2% of urban area is located throughout Illinois, a significant portion of which includes Bloomington-Normal, Champaign-Urbana, Danville, Decatur, Peoria, Rockford, Springfield, the Quad Cities, Carbondale, and numerous county seats.

Census Block Data

In urban areas, a census block can be as small as one city block but is much larger in rural areas. Census blocks can range in population from zero to several hundred. Blocks are typically bounded by streets, roads or creeks.

Urban Demographics

A total of 12.8 million people live in Illinois, of which 11.7 million (90.5%) live in urban areas as delineated in Figure 1. Approximately 70% of the urban population lives in the six-county Chicago Metropolitan Area (Cook, DuPage, Kane, Lake, McHenry, and Will Counties), 4% live in the St. Louis Metro East area (Madison, Monroe, and St. Clair Counties), and the remaining 26% are located in the remaining Illinois urban areas (Figure 2). Cook County accounts for 5.1 million (63%) of the 8.2 million living in the Chicago Metro area, or over 44% of all urban dwellers in Illinois. The median household income in 2013 in urban Illinois was $55,439, compared to the median of $57,196 for all of Illinois (Figure 3). See Appendix A for additional demographic details.

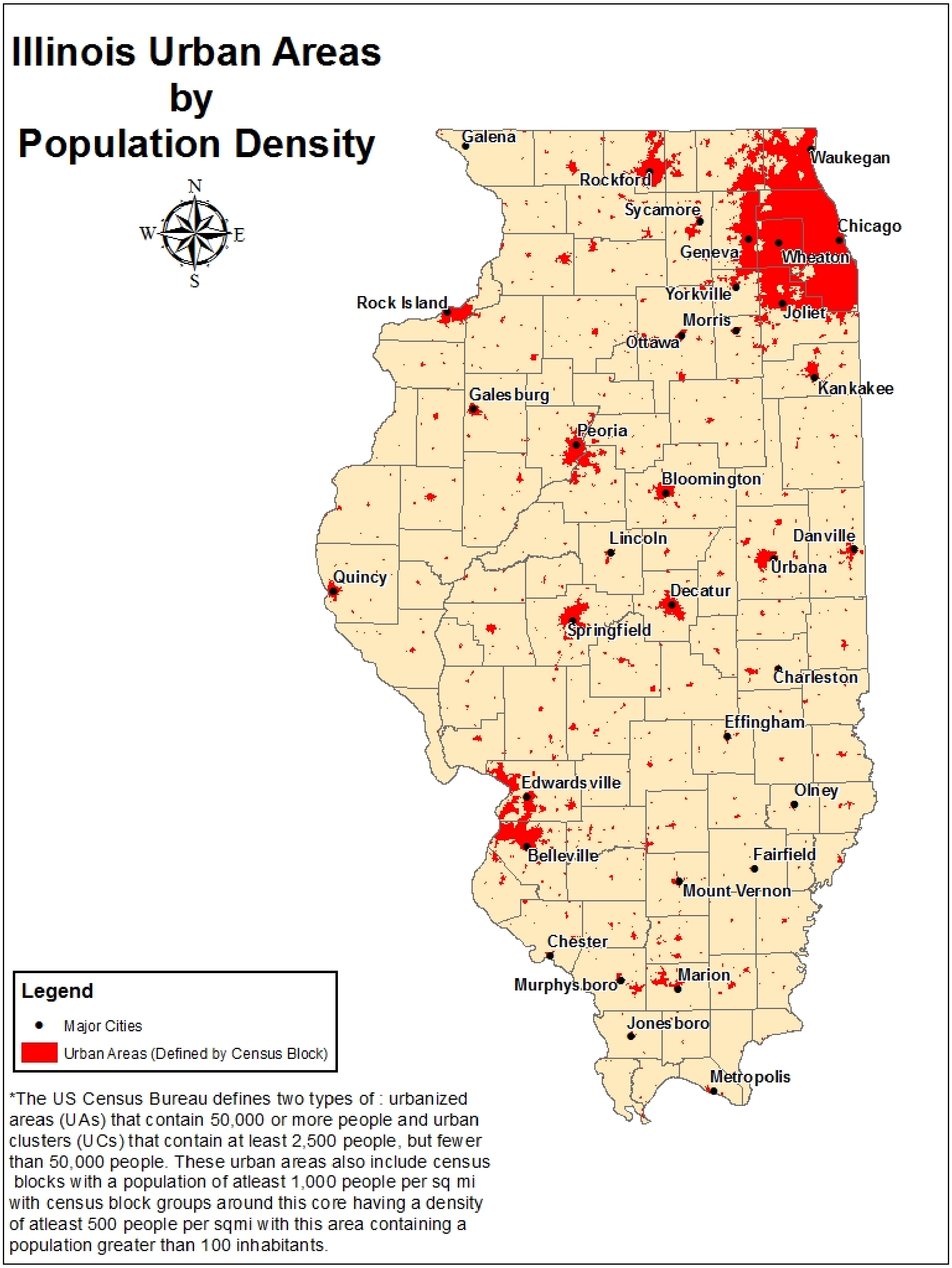


Figure 1: As of 2014, urban areas in Illinois account for 7.4% of total land area of the state. Land use within areas now identified as urban has changed from forest, agriculture, and wetlands to developed urban uses, which now cover about 80% more land area.

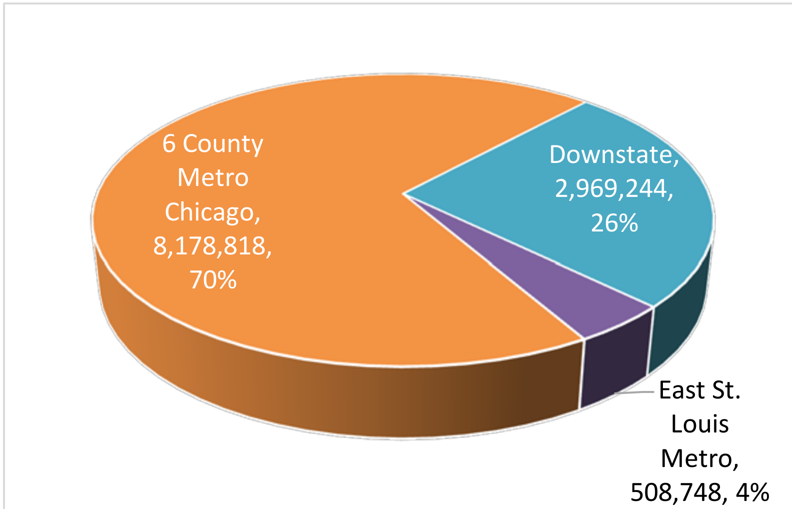


Figure 2: Illinois urban population by region

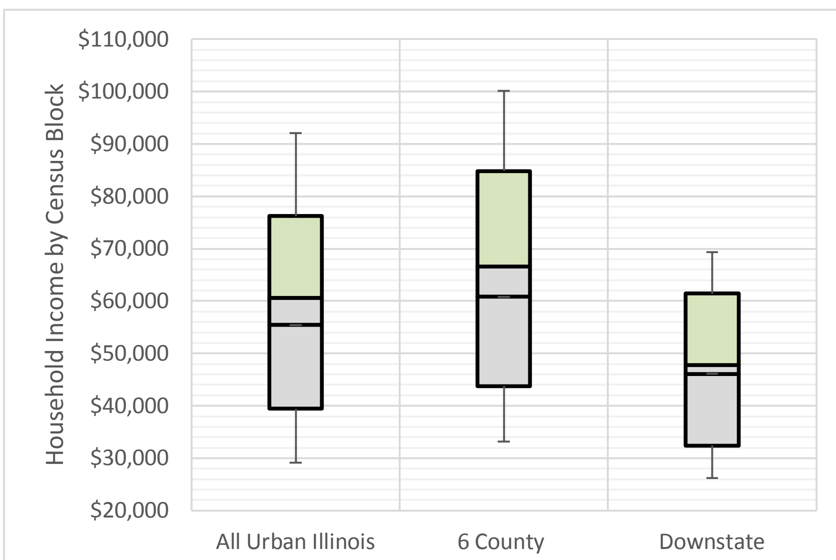


Figure 3: Household income in Illinois urban areas. Median household income in 2013 in urban Illinois was $55,439, compared to $57,196, the median of all Illinois. The median household income of the six-county area is $60,833 and $54,094 for Cook County alone. The remainder of Illinois had a median household income of $46,107.

Stakeholder Engagement and Data Gathering

Urban Flooding Survey

A survey was drafted by IDNR and hosted on the online site, Survey Monkey. Links to the survey were distributed in October 2014, which remained open until November 12, 2014. The survey was designed to collect uniform urban flooding data from communities including: amount, type, cause, management methods, project funding, and general design criteria. Invitations to the voluntary, online survey were sent to more than 300 individuals (16 federal representatives, 134 county representatives, 64 city representatives, and 107 other stakeholders), and 123 responses were received. Survey respondents represent 120 municipalities, townships, counties or other entities located within 21 Illinois counties. The survey findings are detailed in Appendix B.

Stakeholder Meetings

Three sets of meetings were held at different stages during the report writing process: information gathering, data analysis, and recommendation formulation. One meeting for each stage was held in the Springfield and northeastern Illinois areas and were attended by federal and state government partners, county agencies and engineers, municipalities, and other engineers, associations, and groups interested in flood management. The minutes and attendee lists from these meetings can be found in Appendix B.

In addition, an executive committee was formed to provide input during monthly conference call meetings held to discuss report content and progress. Members of the executive committee were chosen from a wide range of groups, which included the Metropolitan Water Reclamation District of Greater Chicago, DuPage County Stormwater Management, the Madison County Stormwater Program, the City of Decatur, FEMA, IEMA, IEPA, and IDNR.

Data Gathering

Information was requested and gathered from many different sources during the data collection phase of the report through numerous meetings and contacts (see Appendix B). Insurance information was gathered from IDOI and FEMA. Stormwater ordinance information was collected from communities and counties. Reports were requested from counties with stormwater authority to determine the benefits of those authorities. Information about combined sewer locations was supplied by the IEPA.

Illinois Flood Risk Symposium

The Illinois Association for Floodplain and Stormwater Management (IAFSM) in partnership with the Association of State Floodplain Managers (ASFPM) Foundation held a Flood Risk Symposium on February 10, 2015. IAFSM hosted the symposium to facilitate discussion of urban flooding as highlighted by the *Urban Flooding Awareness Act*. The 80 symposium attendees included a diverse representation of professionals that included local floodplain managers from Chicago and downstate Illinois, state and federal officials, urban planners, insurance and real estate representatives, hydrologists, hydraulic engineers and experts in key topics. The symposium was held to identify: urban flood risk, urban flood risk reduction methods, and sources of funding. The IAFSM Illinois Flood Risk Symposium report, provided in Appendix C, presents an overview of the discussions, captures the consensus of these professionals, and identifies recommended actions toward addressing urban flooding issues.

Section 1
Past, Current, and Future

This section examines the cost and prevalence of urban flooding, tools for identifying potential urban flooding areas, and the outlook for climate change impacts. The prevalence and cost of urban flooding is explored by examining past flood events and available information on cost. Understanding that there are multiple contributing factors, available tools and data that could indicate areas potentially at risk of urban flooding are reviewed. Current knowledge of climate trends and their implications are discussed.

Source: Center for Neighborhood Technology

Source: Center for Neighborhood Technology

Chapter 1: Prevalence and Cost

The cost of flooding spreads through many sectors, with direct damages to structures, damages to infrastructure, economic losses from business interruption, interruption of service, and more. This chapter focuses on damages experienced by individuals and communities using data available on insurance payouts and disaster relief. Data on economic losses due to interruption of services or productivity are not available. The data presented serve as an indicator of the geographic distribution and magnitude of the costs associated with flooding in urban areas.

Key Findings

- Flooding in urban areas has resulted in at least $2.319 billion in documented damage since 2007. 85.2% of all payouts (2007-2014) were located in the six-county Chicago Metropolitan Area of Cook, DuPage, Kane, Lake, McHenry, and Will Counties (Figure 1.1).

- The top five damaging storm events in Illinois occurring between 2007 and 2014 totaled $1.6 billion and 69% of all payments.

- The limited time frame (2007-2014) of data for private insurance claims and disaster assistance claims makes determining the presence (or lack) of a trend difficult. However, on the basis of the National Flood Insurance Program (NFIP) claims data that span a much longer time period (1979-2014), the following trends were observed:
  - NFIP claims and payouts have trended up steeply during the last 15 years, driven by the three largest events.
  - Over 90% of urban flooding damage claims from 2007 to 2014 were outside the mapped floodplain, which is roughly proportional to the developed floodplains within Illinois urban areas. The household income distribution of NFIP claimants is very similar to the household income distribution for all urban areas. The private insurance income distribution is shifted slightly towards higher annual income households. The income distributions of NFIP and private insurance claimants may be affected by the insurance options and individual choices.

- Individual Assistance payments from FEMA constitute a large portion of the costs of urban flooding, but this source of support is only available when there has been a Presidential Disaster Declaration.

- Data limitations are important to note when assessing the findings in this section. The various data available represent different time periods, different degrees of accuracy, and likely represent only a sample of claims and damages that actually occurred. The cost, timing, prevalence, and trends of urban flooding presented are qualitative indicators.

Three cost indicators have been examined (see Appendix D). These are:

- Private insurance claims
- National Flood Insurance Program (NFIP) claims (see Chapter 7 for more information about the NFIP)
- Federal disaster relief

Private claims data represent basement/foundation flooding, including sump pump failure and sewage backup not due to riverine flooding.

The NFIP claims data represent flooding due to overland flow (primarily riverine), which may or may not coincide with urban flooding as defined for this report.

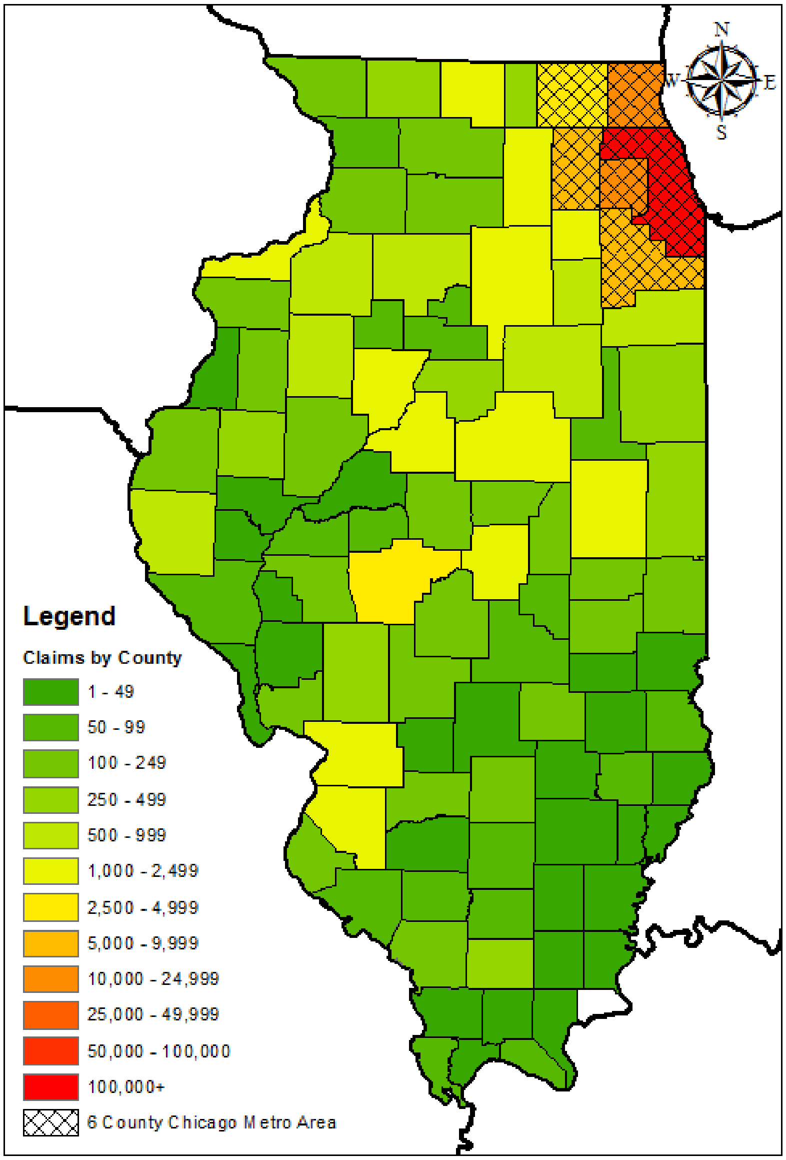


Figure 1.1: Urban Flooding Claims by County. Between 2007 and 2014, 175,775 out of 184,716 (95.16%) of private insurance claims and 12,950 out of 14,693 (88.13%) of NFIP claims were located in urban areas. A total of 94.63% of all claims were located within urban areas and were located in 101 out of 102 counties.

Federal Disaster Relief claims relating only to flooding and severe storm events were included in the urban flooding analysis. The Disaster Relief Fund provides Individual Assistance (IA) and Public Assistance (PA) programs. IA provides money and services to people in presidentially declared disaster areas and include both household and personal assistance. These payments are not dependent on property ownership or whether a dwelling is located in a designated floodplain. Small Business Assistance loans are also available but not included in these totals. The PA program offers assistance to state, local, and tribal governments after a declared major disaster or emergency for eligible disaster-related damage.

Urban flooding is not concentrated to small areas but is far-reaching and affects much of the urban landscape. Figure 1.2 displays the Rock Island urban area and the number of NFIP and private claims per census block between 2007 and 2014, within and outside of the mapped floodplain.

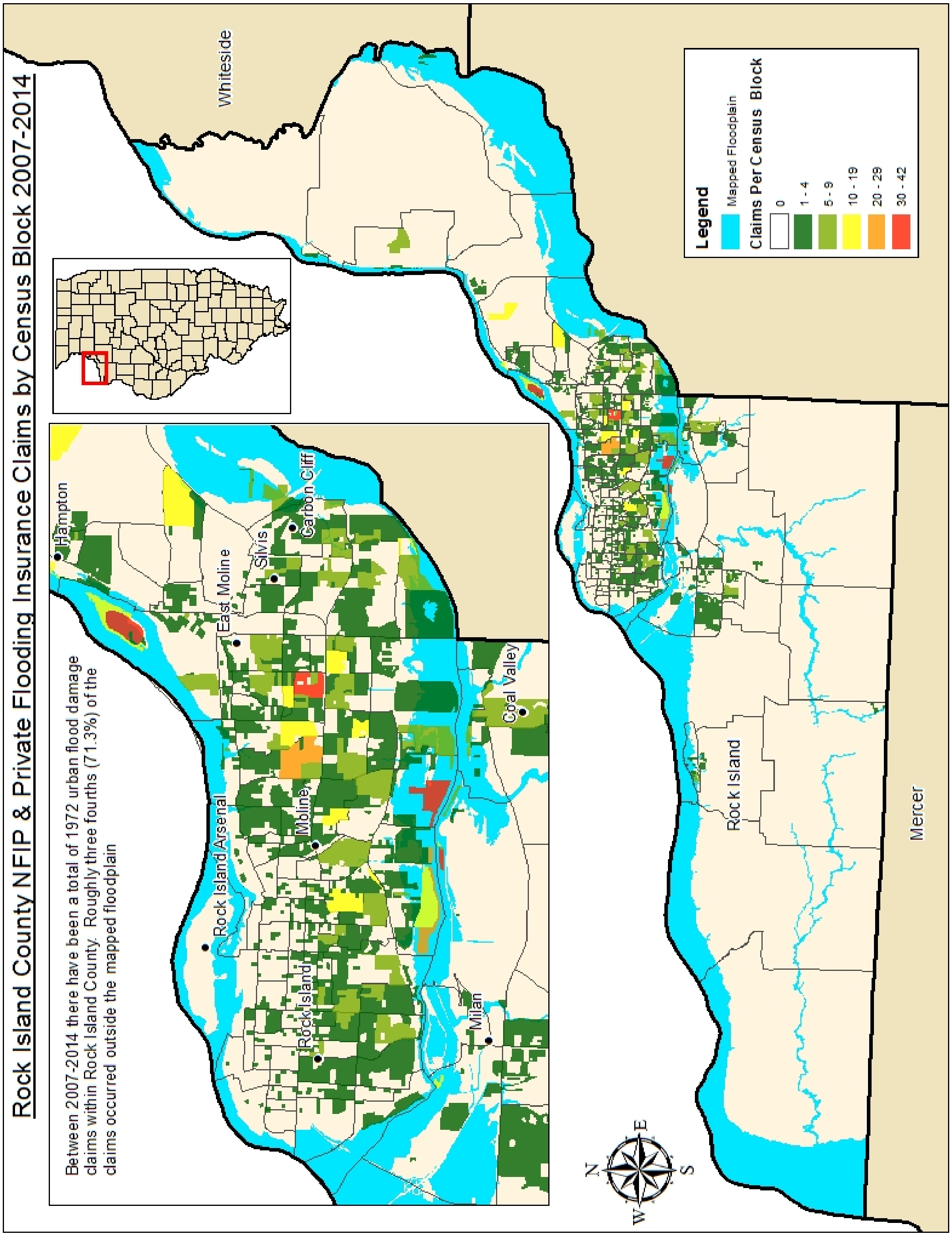


Figure 1.2: Between 2007-2014, there have been a total of 1972 urban flood damage claims within Rock Island County. Roughly three-fourths (71.3%) of the claims occurred outside the mapped floodplain."

Urban Flooding in the Floodplain

To determine the prevalence of urban flooding in relation to riverine floodplains, the NFIP and private claims data were compared with the most current 1% annual chance floodplain (100-year flood) dataset for Illinois. The disaster assistance data could not be used in the analyses as the data are aggregated by zip code and not by census block. Using the national land cover data set (see Chapter 3), urban areas were divided into "developed" and "undeveloped" areas. Undeveloped areas are composed of open water, forest preserve, and other types of open space. Comparing the classifications of the urban area within the floodplain, the approximate urban developed area within the floodplain was determined.

About 11.3 % of urban areas are within the mapped floodplain (471 square miles of mapped floodplain in 4,171 square miles of urban area). About half of the area of mapped floodplain (Special Flood Hazard Area) in urban areas has been developed.

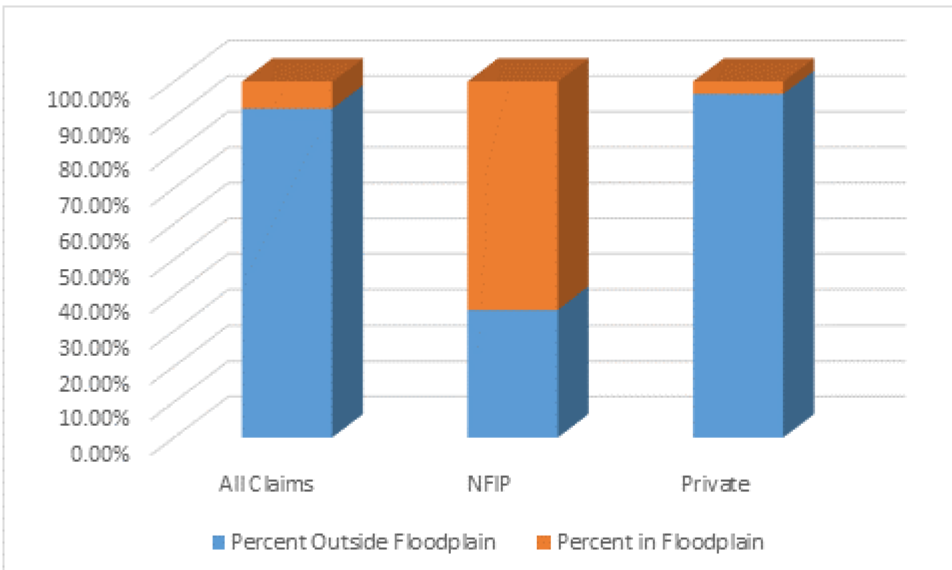


Figure 1.3: Between 2007 and 2014, most (96.5%) of private insurance claims are for structures outside the mapped floodplain; however, a significant number of NFIP claims (35.9%) are outside the mapped floodplain.

Table 1.1: Insurance Claims in and out of the mapped floodplain 2007-2014.

Claims Source	Percent Outside Floodplain	Percent in Floodplain
All Claims	92.3%	7.7%
NFIP	35.9%	64.17%
Private	96.57%	3.57%

Private, NFIP and Federal Disaster Relief claims data have limitations which must be considered when interpreting the data. Private insurance claims reflect the ability and willingness of individuals to pay increased insurance costs for riders to cover sump pump failure or sewer backup and may also be limited by the reluctance of individuals to file claims; NFIP policies are not in place for many structures located both within designated flood hazard areas and those structures located near, but outside the mapped floodplain; and federal disaster assistance becomes available only when certain thresholds are met.

Compilation of these data provides an indication of the cost of urban flooding as indicated in Table 1.2 and Figure 1.4. Private insurance claims data are available for the period 2007 to 2014, NFIP data are available from 1979 to 2014 but were calculated only for the period from 2007-2014, and Disaster Assistance in the form of PA and IA is available from 2007-2014. Statewide data on economic losses due to service interruptions and productivity are not available, but there is a potential for further study either through direct data collection or through modeling.

Table 1.2: Claims Payments 2007-2014

Claims Source	Total Payout ($)	Urban Claims	Urban Claims Paid	% No. Paid
Private	$1,239,984,361	175,775	136,687	77.76%
NFIP	$229,743,519	12,950	10,662	82.33%
IA	$691,868,175	308,540	206,126	66.81%
PA	$157,568,563	-	-	-
Total	$2,319,164,168	497,265	353,603	71.08%

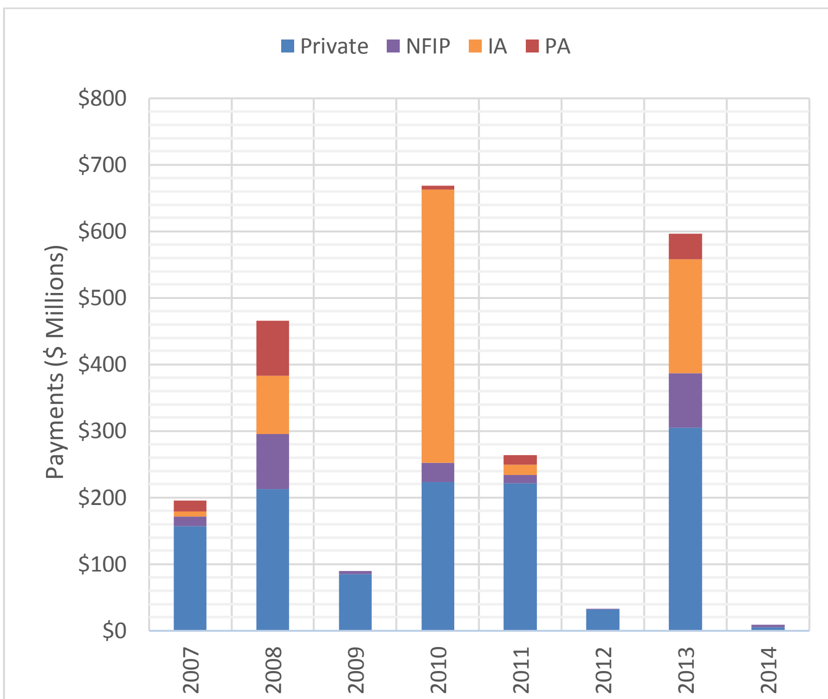


Figure 1.4: Total flooding insurance payouts per year, partitioned by claim type. Private insurance covers the majority of urban flooding claims on average; however, disaster relief assistance payouts can be significant in some years. Private claims current through September 2014 and NFIP current through October 2014.

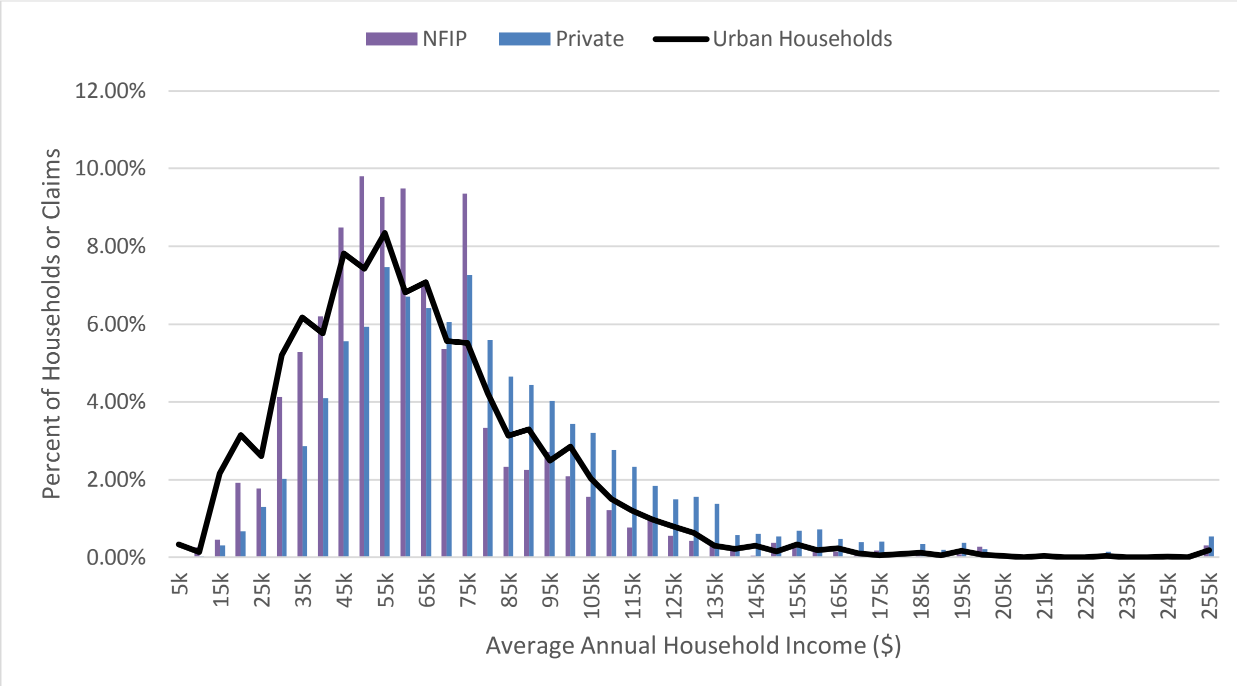


Figure 1.5: Distribution of annual household income for Illinois urban areas and the distributions of annual household income for the NFIP and private insurance claims. The NFIP distribution is very similar to the distribution for the urban area income. The private insurance distribution is shifted slightly towards higher annual income households.

Even though the NFIP claims do not represent the definition of urban flooding, this is the only claims data with a decades-long record, which assists in examining trends in flooding claims. Figure 1.6 shows the increase in NFIP claims payments in Illinois over the decades. Average annual NFIP urban payouts ranged from $6.1 million to $8.7 million during the 1970s, 1980s, and 1990s. During the 2000s, the average annual payout jumped to $12.5 million, and during the first five years (2010-2014) of the 2010s, the average annual payout increased to $25.5 million.

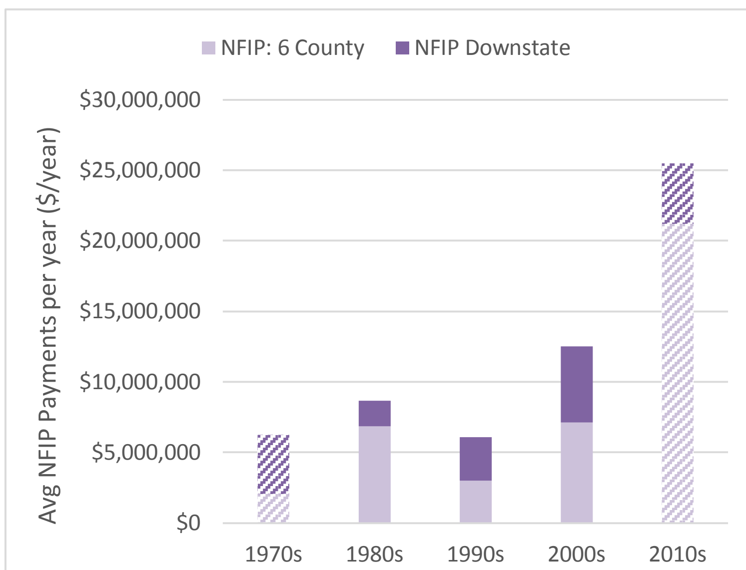


Figure 1.6: NFIP claims and payouts have trended up steeply during the last 15 years primarily due to three large storm events. It is too early to determine if the first half of the 2010s is the beginning of a trend, but this analysis can be readdressed in five years. Hatching denotes decades with partial data (1976-1979 and 2010-2014).

The timing, location, and magnitude of a single severe storm event greatly affect the corresponding urban flooding and insurance claims and payouts. The five storm events resulting in the highest total NFIP payouts (1976-2014), the highest total private payouts (2007-2014), and the highest total payouts (2007-2014) are shown in Table 1.3. The top three storm events were the same for both the NFIP and private claims. Four of the top five storm events in terms of total NFIP and private insurance payouts prompted disaster declarations and so IA and PA were also distributed.

Table 1.3: Storm Event Ranks by NFIP, Private, and Total Payments

Rank	NFIP (1976-2014)	Private (2007-2014)	NFIP + Private (2007-2014)
1st	4/17-18/2013	4/17-18/2013	4/17-18/2013
2nd	9/13-14/2008	9/13-14/2008	9/13-14/2008
3rd	7/23-24/2010	7/23-24/2010	7/23-24/2010
4th	7/17-18/1996	7/22-23/2011	7/22-23/2011
5th	8/14/1987	8/23-24/2007	8/23-24/2007

Recommendations

1. The Illinois General Assembly should allow the Illinois Department of Insurance to mandate continuing education specific to flood insurance for insurance agents.
2. Insurance companies only retain claims data for eight years. The General Assembly should fund a program at the Illinois Department of Insurance to archive basement flood damage claims data from private insurers to maintain a long-term census block database of flooding claims for future analysis.
3. The Illinois General Assembly should fund research to determine if lower income households have adequate private basement backup and flood insurance as they appear to have fewer private insurance claims than higher income households. If affordability is an issue with private basement coverage or flood insurance, incentive programs and insurance pools used by other states should be investigated.
4. The Illinois General Assembly should direct research on a state Urban Flood Mitigation Pool funded from a very minimal surcharge on all homeowner's policies in Illinois. This mitigation funding stream could be granted to local governments to identify, study, and mitigate the most egregious urban flood areas in the state.
5. The Illinois Department of Insurance should encourage outreach and education efforts at the local level to ensure that citizens understand the differences between flood insurance and sewer backup coverage.

Chapter 2: Climate Trends and Climate Change

Key Findings

- Illinois precipitation has increased by 10% in the last century. Much of this increase has been from the more intense storms of over an inch. This pattern of more intense storms is expected to continue.
- Although there is significant uncertainty in climate projections, particularly in precipitation and flood projections, increases in the frequency and intensity of extreme precipitation events and urban flooding are projected for all U.S. regions (NCA, 2014).

Precipitation Patterns in Illinois

Illinois receives between 36 and 48 inches of precipitation from north to south on average. Illinois is much wetter than states to the west because of its closer proximity to the Gulf of Mexico, our major source of moisture. About half of the precipitation in Illinois comes from thunderstorms during the warmer months of the year. By their nature, thunderstorms are usually short and intense rainfall events, which can be especially challenging in urban areas. The rest of the precipitation is produced by passing warm and cold fronts and slow-moving low-pressure systems. Some of that precipitation can fall as snow. In this report, precipitation refers to rain events and the water content of snowfall events.

While most daily precipitation amounts are 1 inch or less, the number of days with over 1 inch of precipitation ranges from 7 to 10 days across northern and central Illinois to 10 to 15 days across southern Illinois south of Interstate 70 (Figure 2.1). In fact, up to 40% of the total precipitation in any given year comes from the 10 days with the most rain. In the urban environment, wet months or even wet weeks can increase the risk of flooding from a subsequent storm by saturating the soils, filling retention ponds, and increasing levels of rivers, lakes, and streams. As a result, a 2 to 3 inch storm at the end of a wet week or month may do more damage than the same storm falling during a dry week or month.

Figure 2.1: Average number of days per year with at least an inch of precipitation.

On rare occasions, Illinois has received large amounts of rain from the remains of tropical systems as they move up from the Gulf of Mexico. Examples of this include the remains of Hurricanes Ike and Gustav in 2004 and Hurricane Isaac in 2012. While no longer at hurricane strength, these were capable of producing 3 to 6 inches of rain over very wide areas in 1 to 3 days.

Snowfall is common in Illinois. On average, winter snowfall totals can range from 12 inches in southern Illinois to 36 inches in northern Illinois. Amounts are typically a little higher in the Chicago area due to the additional impact of lake-effect snows. Snowfall can be a contributor to urban flooding if large amounts of it are melted in short order. This can be compounded by melting over still-frozen soils, blocking of storms drains by snow and ice, and rainfall falling on top of the snow pack.

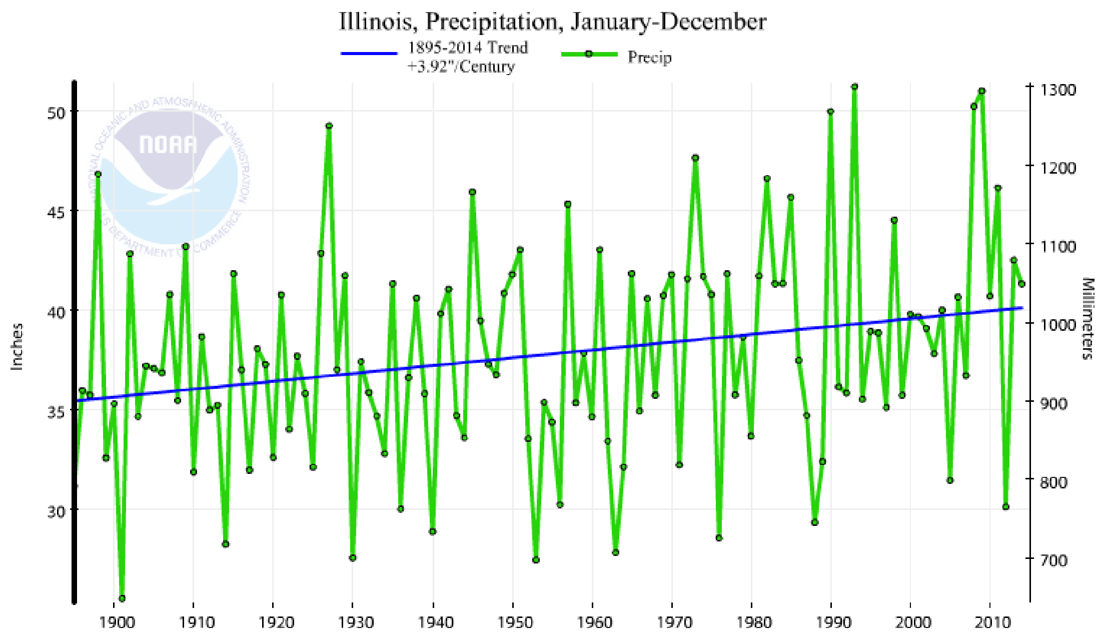


Figure 2.2: Statewide average annual precipitation for Illinois from 1895 to 2014. The green line represents the year to year variation. The blue line is the trend line. Source: National Center for Environmental Information (2015)

Trends in Total Precipitation in Illinois

Historical records since 1895 (Figure 2.2) illustrate the large year- to-year variability in precipitation in Illinois, a trademark of our climate. These data indicate that the statewide average precipitation has increased from 36 to 40 inches or 10% over the last century. Illinois has been more likely to experience exceptionally wet years in recent decades. The year 1993 was the wettest on record with 51.18 inches. The next two wettest years were 2009 with 50.96 inches and 2008 with 50.18 inches. All three years were noted for widespread flooding issues in Illinois.

Trends in Heavy Precipitation Events between Major Illinois Cities

A recent study of changes in heavy precipitation events (Groisman et al., 2012) over the central U.S., including Illinois, found little change in the number of storms between ½ to 1 inches. However, heavy storms (1 to 3 inches), very heavy storms (3 or more inches), and extreme precipitation (more than 6 inches) were becoming more frequent. In fact, the extreme precipitation events increased by as much as 40% during the second half of the study period (1979-2009) compared to the first half of the study period (1948-78).

For this report, daily precipitation records for the last 100 years were examined for several major cities in Illinois. These cities include Chicago, Rockford, Moline, Peoria, Springfield, Bloomington-Normal, Champaign-Urbana, Edwardsville, and Carbondale. Daily precipitation amounts were placed into three categories: 1 to 2 inch storms, 2 to 4 inch storms, and 4 or more inch storms. This slightly different list of categories was chosen to better reflect the kinds of storms found in Illinois. The results are summarized in Figure 2.3 for the entire state. The results for individual cities are provided in Appendix E.

The 1 to 2 inch storm events per city showed modest changes between decades and a small increase over time. The most recent decade, 2005-14, was the highest with an average of 81 events per city.

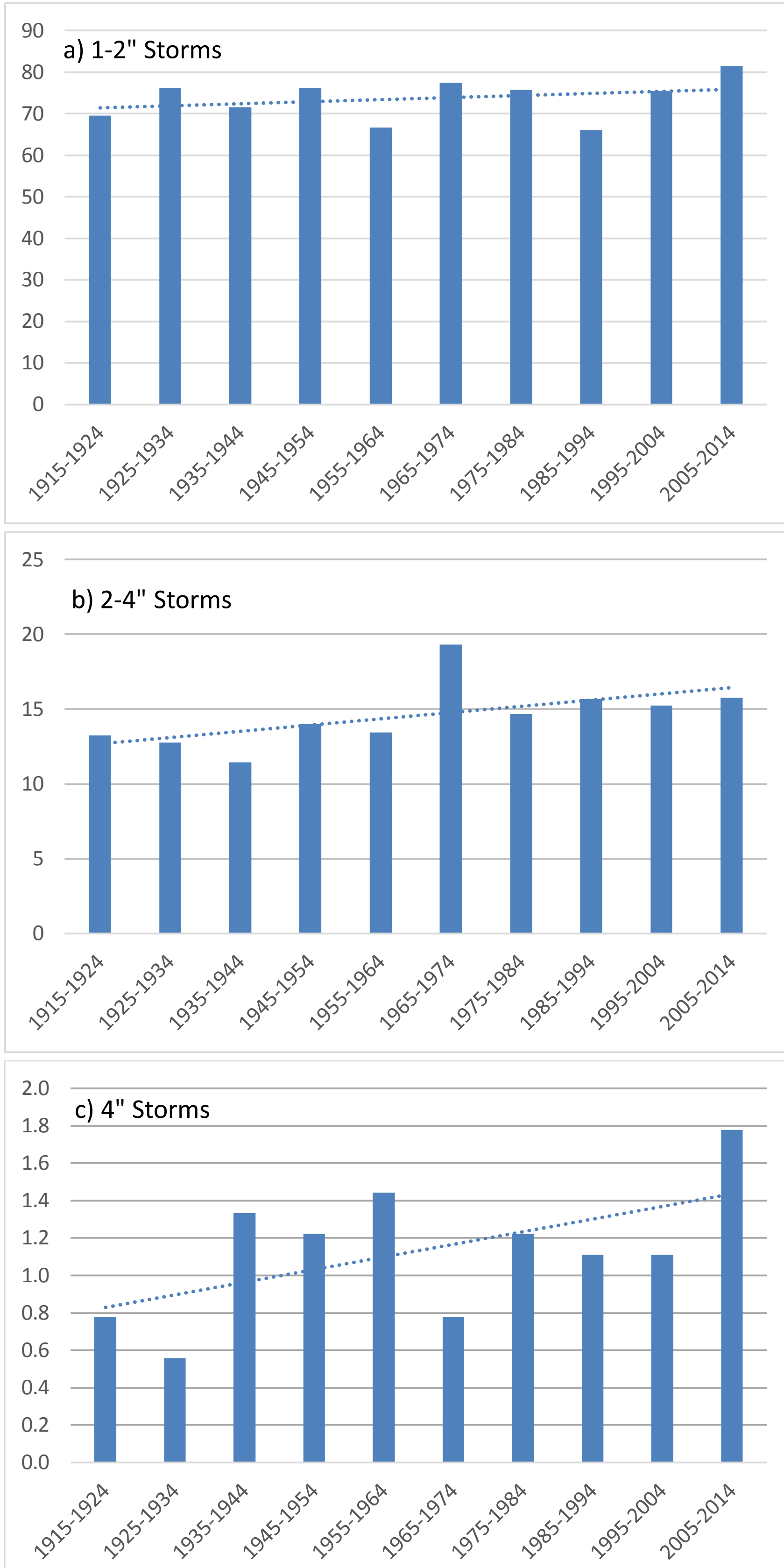


Figure 2.3: Statewide average changes in storm frequency by decade per city for a) 1-2 inch storms, b) 2-4 inch storms, and c) greater than 4 inch storms. The blue dotted line indicates the trend over time.

The statewide average number of 2 to 4 inch storm events per city showed more changes between decades and a moderate increase over time. The lowest decade was 1935-1944 and was likely associated with the number of severe droughts during that period. One of the busiest decades was 1965-1974, when the cities averaged 19 events per decade. The statewide average number of storm events exceeding 4 inches per city has increased steadily over the last century with 2005-2014 the busiest with an average of 1.8 events per city.

Discussion on Precipitation and Heavy Rain Events

There are a number of factors contributing to more precipitation and more heavy rain events in recent decades. First is that temperatures in the U.S. have warmed by about 1.5 to 1.9 degrees (depending on the calculation used) over the last century. Meanwhile, temperatures in Illinois have warmed by about 1.0 degree over the last century. Warmer air has the ability to hold more water vapor. This ability increases by almost 4% with each degree increase. This means that on average storms have slightly more water available for precipitation. It is also possible that the characteristics of storms are changing as the U.S. gets warmer. For example, a longer warm season increased the opportunity for thunderstorms. Additional work in Illinois suggests that the increasingly intense agricultural practices of the Midwest (more acreage and more plants per acre) have elevated summer humidity levels as well (Chagnon, Sandstrom, & Bentley, 2007).

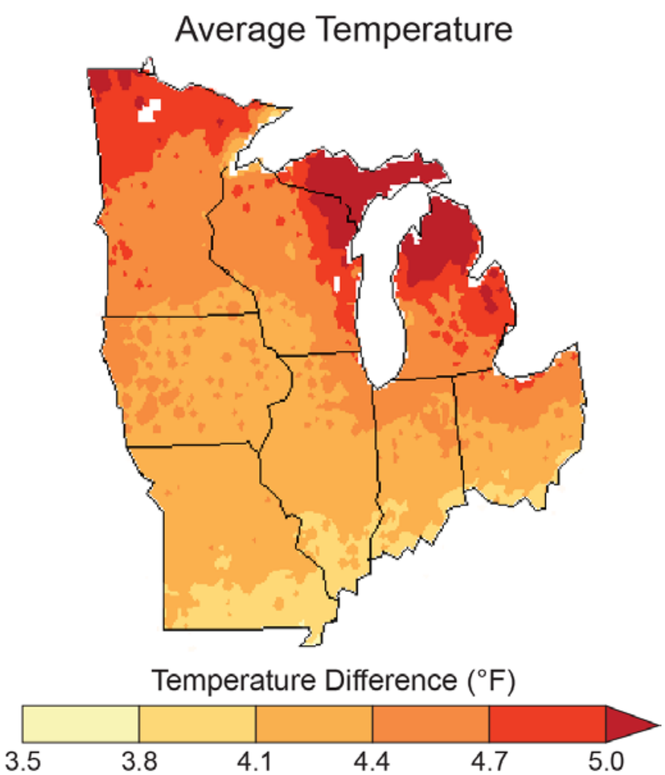


Figure 2.4: Possible increases in the temperature from the 1971-2000 base period to the period 2041-2070 based on the A2 high-emission scenario. Source: NCA (2014).

Another contributing factor is natural variability in precipitation, as is illustrated in analysis of heavy storms in Illinois cities (see Appendix E) – some areas of the state are just stormier than others.

There are several lines of evidence suggesting that the current patterns will continue in the future. The first line of evidence is that past studies in Illinois and elsewhere have suggested that the most recent 5 to 15 years are the best predictor of conditions for the next 1 to 5 years (Easterling, Angel, & Kirsch, 1990). So this suggests that the current wetter and more intense conditions will likely continue in the short term.

The U.S. Global Change Research Program (USGCRP), which was established by presidential Initiative in 1989 and mandated by congress in the Global Change Research Act of 1990 to "assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change," has prepared the National Climate Assessment indicating that temperatures in the U.S. and

Midwest will increase over the next century. The magnitude of this increase is closely tied to the amount of future emissions of heat-trapping gases. One of the higher emission scenarios results in mid-century temperature increases of 3.8 to 4.6 degrees across Illinois (see Figure 2.4). Over the years, a variety of models and scenarios have all resulted in some degree of warming over the next century. As mentioned earlier, warmer air is able to hold more water vapor at the rate of almost 4% per degree increase. This line of evidence suggests that future storms will produce more precipitation and more intense storms as the U.S. and Illinois warms.

The final line of evidence is based directly on the possible future changes in precipitation found in global and regional climate models. It is important to note that model projections of future precipitation patterns are less certain than temperature projections. As noted earlier, while the models have consistently shown warming over the next century, some models indicate that conditions will get wetter while others indicate conditions will get drier across the Midwest. The NCA report based on the most recent research indicates that the Midwest is expected to be wetter by the 2041-2070 timeframe (Figure 2.5). Overall, the Midwest is expected to be wetter in winter and spring and less so in fall while summers could be drier. The NCA report indicates that the Midwest is expected to experience more heavy rain events in the future (Figure 2.6).

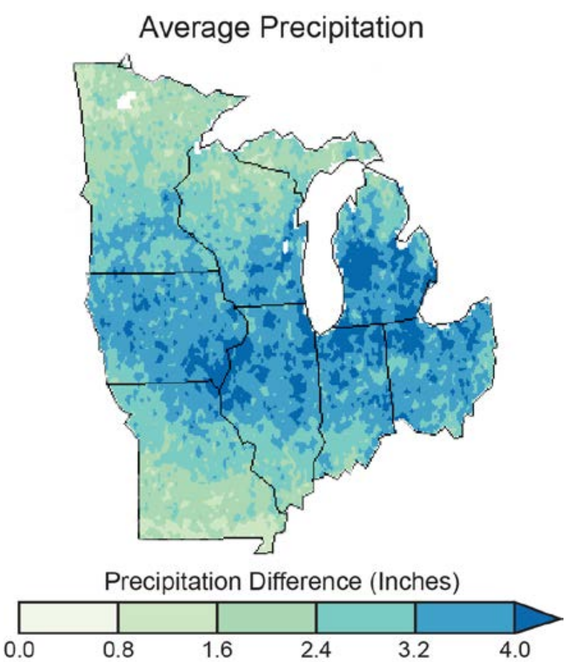


Figure 2.5: Possible increases in precipitation from the 1971-2000 base period to the period 2041-2070 based on the A2 high emission scenario. Source: NCA (2014).

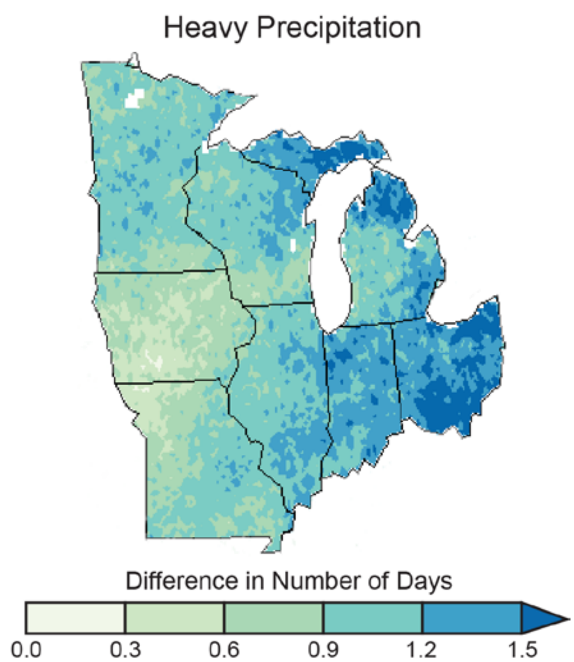


Figure 2.6: Possible increases in the heaviest 2 percent storms from the 1971-2000 base period to the period 2041-2070 based on the A2 high emission scenario. Source: NCA (2014)

Climate Change Considerations

The average Earth surface temperatures increased by 0.83 °C (1.5 °F) from 1880 to the present (IPCC, 2013). Many scientists attribute global warming to human-induced increase in concentrations of greenhouse gasses. According to the U.S. National Climate Assessment (NCA, 2014) "many lines of independent evidence demonstrate that the rapid warming of the past half-century is due primarily to human activities." The NCA Assessment also points to the accumulating evidence of human-induced climate change which further expands our understanding of the observed trends in climate variables.

Traditionally, infrastructure design concepts relied on the assumption that past events can be used to predict future events. Statistical analyses of precipitation and discharge data are used to estimate the magnitude of precipitation or streamflow likely to occur within a time period, such as once in ten years, or once in 100 years on average. No change in the frequency of extremes over time was considered in manuals used by engineers, climate scientists and hydrologists (Perica et al., 2013; USGS, 1982; Soong et al., 2004). However, numerous publications indicate that the frequency of extremes has been changing and is likely to continue changing in the future (Milly et al., 2008; IPCC, 2007). Due to the changing (nonstationary) nature of precipitation and flood extremes, we can no longer rely on analyses of past data to estimate future events. Thus, to estimate the magnitudes and frequencies of future events, it is necessary to account for the nonstationary nature of precipitation and flooding.

Climate models are a primary tool used in climate projections to study the effects of increasing concentrations of greenhouse gasses. Global climate models (GCMs) simulate interactions of the atmosphere, oceans, land surface and ice, and project future climates for various scenarios. Recent analyses (NCA, 2014) indicated that climate models have become more comprehensive and that the earlier predictions have been confirmed. Despite the continuous improvements of these models, the GCM output is averaged over large areas and is not suitable for flood studies. The typical GCM output grid-cell size is approximately 50×70 miles in Illinois. Given that coarse GCMs poorly represent local-scale precipitation, methods have been devised to translate the data to smaller areas. This is called spatial downscaling. There are different techniques that can be applied in spatial downscaling and also to downscale the time increments of the GCM climate data to smaller time increments, making them more usable in flood studies. However, the process and techniques for spatial and temporal downscaling are still evolving.

Decision-making under uncertainty can be particularly challenging. The projected climatic variables, such as temperature and precipitation, are very uncertain. Figure 2.7 shows the projected global temperature change based on two Intergovernmental Panel on Climate Change (IPCC) climate scenarios: A2 which assumes continued increases in emissions throughout this century, and B1, which assumes significant emissions reductions. Because of uncertainties in average temperature and precipitation, the projected changes in their extremes are even more uncertain, making it very difficult to predict future flooding.

Nonetheless, some studies (Mills, 2005) have offered evidence of the direct and significant effects of climate change on increased flooding. Seneviratne et al. (2012) suggest that flood characteristics have changed over time, but the causes and patterns of these changes are complex and regionally dependent. Thus, these changes should be studied separately for different regions. NCA (2014) states "Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions." Furthermore, the same source indicates that the large observed increases of heavy downpours in the Midwest are among the largest in the U.S. As a result of a direct link of urban flooding and heavy precipitation, it is expected that urban flooding will also increase (NCA, 2014), particularly in urban areas in the Midwest.

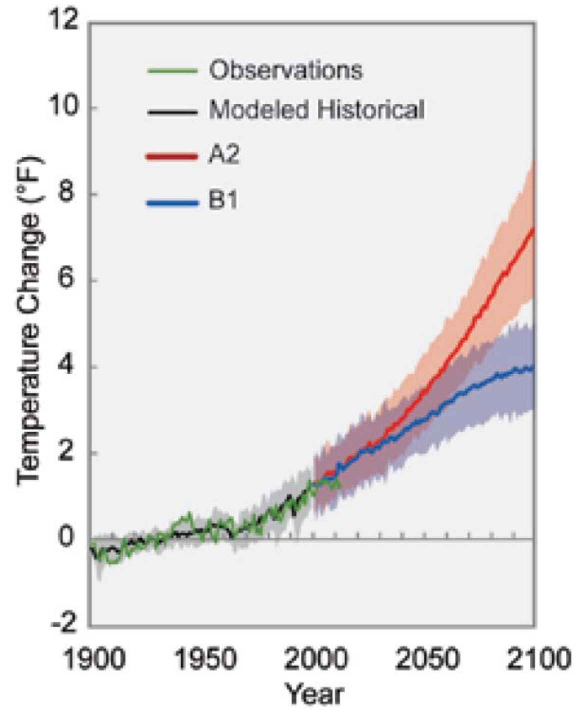


Figure 2.7: Projected global temperature change showing two scenarios: A2 which assumes continued increases in emissions throughout this century, and B1, which assumes significant emissions reductions. Shading indicates the range (5th to 95th percentile) of results (NCA, 2014).

While projections of flood frequency are uncertain, including data, sampling variability, modeling, and scenario uncertainties, there is an increasing need to incorporate uncertain scientific information of varying confidence levels into flood frequency estimates. Numerous attempts to quantify these sources of uncertainty have been published using multi-model (ensemble) analysis (Christiansen et al., 2010, Smith et al., 2014). These studies can be used not only for determining the expected magnitudes of projected precipitation and floods, but also they offer tools for determining the uncertainty in these projections, typically expressed through the confidence limits around the projected rainfall or flood magnitudes. The confidence limits are of critical importance for making decisions in uncertain environments.

Recommendations

1. The State should fund the Illinois State Water Survey to update the existing rainfall frequency distribution information using the additional rainfall gauge data that are available with routine updates every 15 years. Future precipitation projections and also future land use should be included where it is available. When planning stormwater infrastructure modifications and enhancements, local governments should take into consideration these future precipitation trends and land use information.

2. Data collection is vital to all flood studies, project design and project operation; therefore, the Illinois General Assembly should continue to provide cost share funding to allow for the following: a)maintenance and expansion of the USGS stream and rain gage network by the Illinois Department of Natural Resources; b)continued monitoring of climate and flood data by the Illinois State Water Survey to better validate and fine tune the present climate projections and their effects on urban flooding; and c)continued monitoring of progress in climate model developments and new scientific approaches to account for climate and other uncertainties.

Chapter 3: Technology and Data for Identification of Urban Flooding Potential

Geographic Information Systems (GIS) is a dynamic computerized data system designed to interpolate, analyze, manage, store, and present geographical and spatial information. GIS data that can be applied in the analyses of urban flooding include soils data, topography, land cover and density of urban development, topological wetness index, census data, historical rainfall data, existing infrastructure design, plans, and functionality, and documented flooding problems or flooding.

Hydrologic and hydraulic models, storm sewer assessment models and others similar tools use various data to evaluate flooding potential and design and evaluate stormwater infrastructure. Individual homeowners can also utilize some data to identify flooding issues and corrective actions on their property.

The follow sections provide an overview of technologies and data sources that can be used to evaluate the risk of urban flooding and examples of how these tools can be applied. Many of the data set discussed here were also utilized for the analyses found in the Prevalence and Cost section of this Report. Further analysis and findings may be found in Appendix F.

Key Findings

- Existing data and analyses tools such as GIS can be used for planning to identify areas having the potential for urban flooding.
- Communities can use high resolution topographic data to identify low lying areas.
- While some correlations between data sets can be found, the multiple combinations of factors that can cause urban flooding need to be considered on a case-by-case basis.
- GIS technology provides a ready tool for communities to track the age, location and size of stormwater infrastructure, as well as tracking flooding reports to assist with identifying high risk areas.
- The topographic wetness indices tool provided an accurate depiction of areas susceptible to urban flooding. This tool could be studied and developed further for the identification of urban flooding.

Census Data Analysis

United States Census Bureau compiles the most current census, economic, and governmental boundary data in GIS format in their Topologically Integrated Geographic Encoding and Referencing (TIGER) product and makes it available to the general public (USCB, 2014). The 2014 TIGER dataset includes demographic information from the 2010 census and economic data from 2012.

The TIGER data provides insight into the socioeconomic demographics of the urban landscape. For example, TIGER products can be used in combination with historical flood data, insurance claims data, or public polling to determine the impacts of urban flooding in a community with regard to age, gender, race, median household income, household development, or population density.

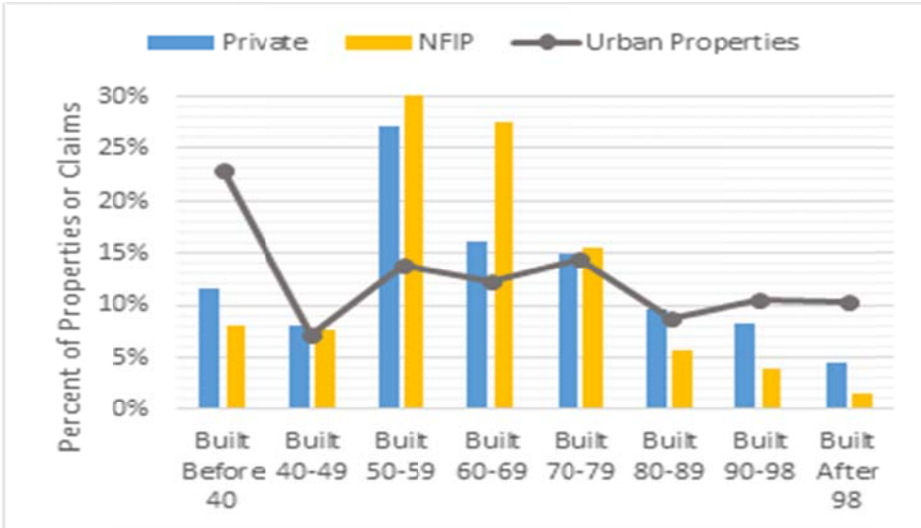


Figure 3.1: Percentage of private and NFIP claims and urban properties with regard to the decade in which the corresponding properties were built.

The TIGER data provides insight into the socioeconomic demographics of the urban landscape. For example, TIGER

An example of the use of TIGER products is provided in Figure 3.1, where the percentage of Private and NFIP claims and urban properties are plotted with regards to the decade in which the corresponding properties were built. Such information can be used in combination with locally specific information to determine the probable locations of urban flooding in a community. It is insightful to note that properties built between 1950 and 1969 while less than 30% of the total building stock, account for more than 40% of private claims and more than 50% of NFIP claims.

Topographic Data/LiDAR

Large scale topographic information is typically developed from light detection and ranging (LiDAR) data, LiDAR can be used to observe drainage patterns on the landscape (Figure 3.2). Airplanes and helicopters are the most commonly used platforms for acquiring LiDAR data over broad areas. Low lying areas can have an increased risk of urban flooding due to limited overland flow paths and susceptibility to ponding.

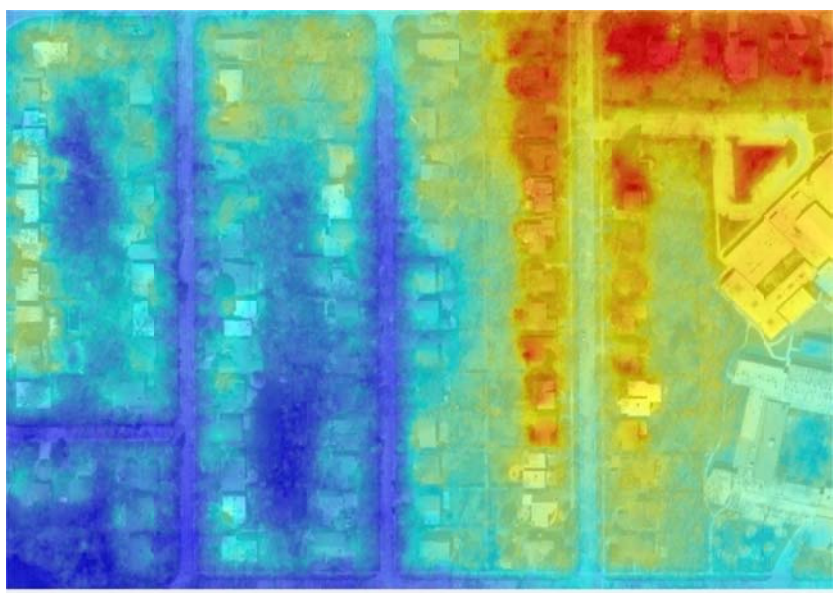


Figure 3.2: LiDAR topography displaying low lying areas (blue) that are susceptible to increased runoff and ponding. An orthophoto of an urban area that is susceptible to urban flooding has been overlaid on a Digital Elevation Model (DEM), a topographic LiDAR derivative.

LiDAR may also be utilized in the development of hydrologic and hydraulic models when producing engineering design plans and creating topographic wetness indices (see discussion of Topographic Wetness Index in this section).

Digital Floodplain Mapping

FEMA initiated the Flood Map Modernization Program (FMMP) in 2003. The goal of the national FMMP was to update paper Flood Insurance Rate Maps (FIRM) flood hazard data and mapping to create an accurate Digital Flood Insurance Rate Map (DFIRM) products to improve floodplain management. In 2010 FEMA initiated the Risk Mapping, Assessment, and Planning (Risk MAP) program to improve upon flood hazard data and mapping at a local and state wide level.

In Illinois 72 counties currently have an effective DFIRM, 6 counties have digital preliminary maps, and 21 counties are still without digital data (Figure 3.3). The digital data developed during these ongoing initiatives can be viewed through the National Flood Hazard Layer (NFHL). The NFHL can be accessed and downloaded through the FEMA Map Service Center.

Urban flooding, which may not be directly attributed to riverine flooding, can and does occur within developed urban floodplains. Floodplain extent, in conjunction with soils, land cover, and existing infrastructure data, help to determine this urban flooding risk.

For example, floodplain data, land cover data, and flood insurance claims data were used to determine the prevalence of urban flooding in relation to riverine floodplains in urban areas of Illinois (See Chapter 1: Prevalence and Cost).

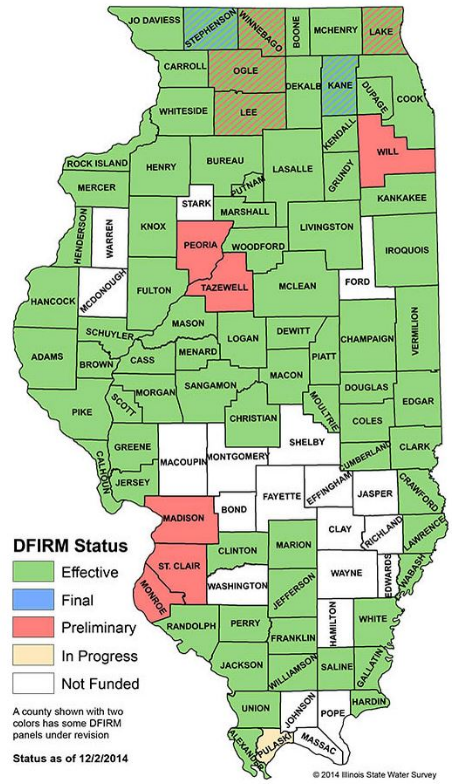


Figure 3.3: Illinois DFIRM Status: In Illinois 72 counties currently have an effective digital flood insurance map (DFIRM), 6 counties have digital preliminary maps, and 21 counties are still without digital data.

Land Cover Data

The National Land Cover Database (NLCD) is a nationwide, satellite-based, 30-meter resolution, land cover dataset. NLCD provides spatial reference and descriptive data for characteristics of the land surface such as urban, agriculture, grassland, and forest and is accessible through the Multi-Resolution Land Characteristics Consortium (Jin et al., 2013). The Multi-Resolution Land Characteristics Consortium (MRLC) has collected and categorized land cover datasets to 1992, 2001, 2006, and 2011.

With regards to urban flooding, this dataset can be utilized to determine urbanization rates, the prominence of land cover types within urban areas, and any correlation to insurance claims or documented locations of repeated flood damages. The land cover dataset could also be utilized for the development of hydrologic and hydraulic model development.

The population increase in Illinois over the course of the past two decades has resulted in a corresponding increase in urban area. Urban development activities such as removing vegetation and soil, grading the land surface, and constructing drainage networks all increase runoff which, with the associated decrease in natural areas to absorb these impacts, exacerbates urban flooding problems.

This expansion of the urbanizing areas can be seen in more detail in Figure 3.5. Figure 3.5 illustrates the land cover change from 1992-2011 within urban areas (as defined in this report). Based on the 2010 census, current urban area is 7.4% (4,170.45 square miles out of 56,349.74 square miles) of the total land area in Illinois. In 1992, within the current urban area, there were 1,815 square miles of land cover classified as developed urban and 2,354 square miles classified as undeveloped (forest, agriculture, et cetera) . In 2011, within the current urban area, there were 3,237.7 square miles of developed urban land cover and 931.4 square miles of undeveloped land cover, a 79.8% increase in developed area. Agricultural fields, wetlands, and forested areas decreased. The total depressional water storage areas and potential riverine areas decreased 14.42%.

Figure 3.4 uses claims data and land cover classifications to display the correlation between the two data sets. Developed land covers 77.67% of the urbanized areas and 99.03% of all insurance claims. The land cover to claim distribution is a follows: High Intensity areas (impervious surfaces account for 80-100% of total cover) consist of 7.48% of the urban area and 2.74% of claims; Medium Intensity areas (impervious surfaces account for 50-79% of total cover) consist of 17.44% of the urban area and 24.86% of claims; Low Intensity areas (impervious surfaces account for 20-49% of total cover) consist of 37.84% of urban areas and 59.44% of claims; open space (impervious surfaces account for less than 20% of total cover) consists of 15.12% of the urban area; open water consists of 2.11% of the urban area, and the undeveloped cover 20.22% of urban areas. As an artifact of the data resolution a small percentage of the claims are assigned to these land use types.

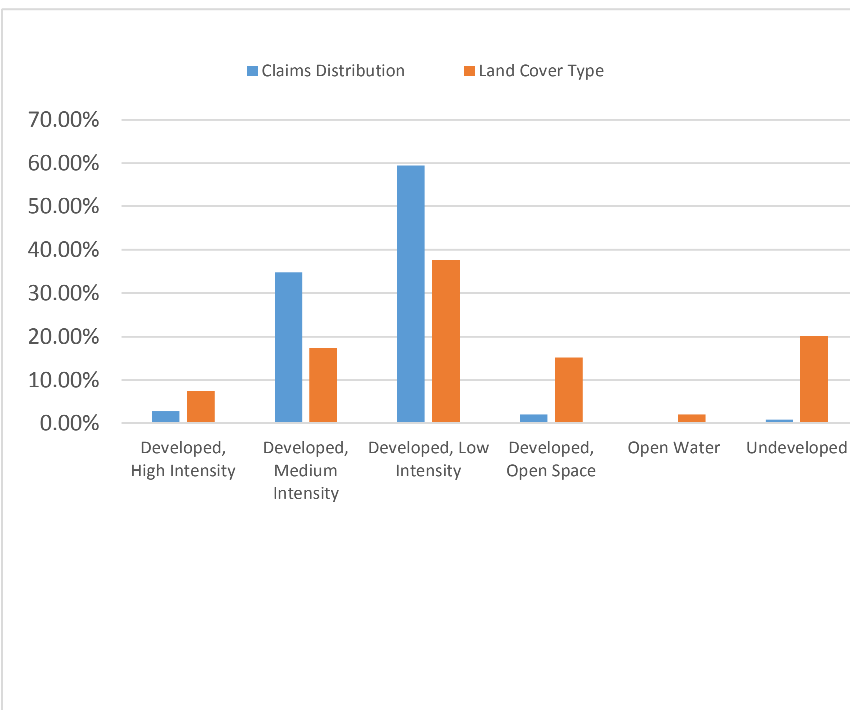


Figure 3.4: The percentage of NFIP and Private insurance claims and the land cover they fall within is shown. The graph also displays the percentage each land cover classification cover in the urban area. Developed land covers 77.67% of the urbanized areas and accounts for 99.03% of all insurance claims.

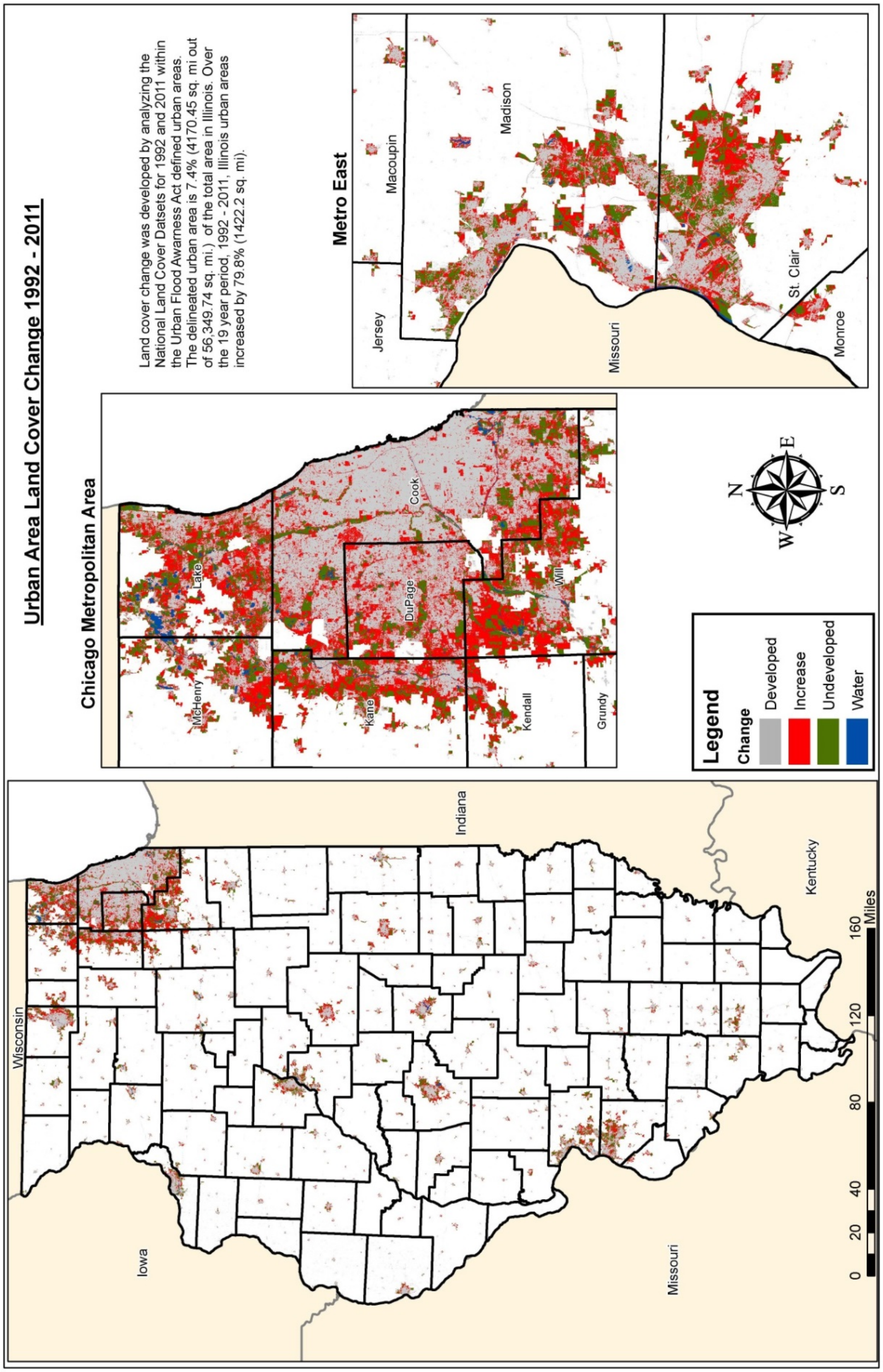


Figure 3.5: Land cover change within the defined urban areas from 1992 - 2011. Over this 19-year period developed areas have increased by 43.9%. Areas in grey represent areas developed in 1992, red represent areas developed as of 2011, blue areas represent water, and green are areas left undeveloped.

The NLCD was further analyzed with the best available 1% annual chance floodplain delineation to determine the number of square miles of development within the floodplain that is located within Illinois urban areas. The digital floodplain data used in these analyses was derived from the following sources: National Flood Hazard Layer (NFHL), preliminary Flood Insurance Rate Maps (FIRMs), and the 21 counties without digital regulatory floodplain data, which were digitized from historical paper FIRMs. Urban areas in Illinois cover 4,170 square miles.

Mapped floodplain covers 11.3% of urban areas (471.14 square miles of 1% annual chance floodplain). About half of the mapped floodplain within the Illinois urban areas, 241.4 square miles, is developed.

Soil Survey Data

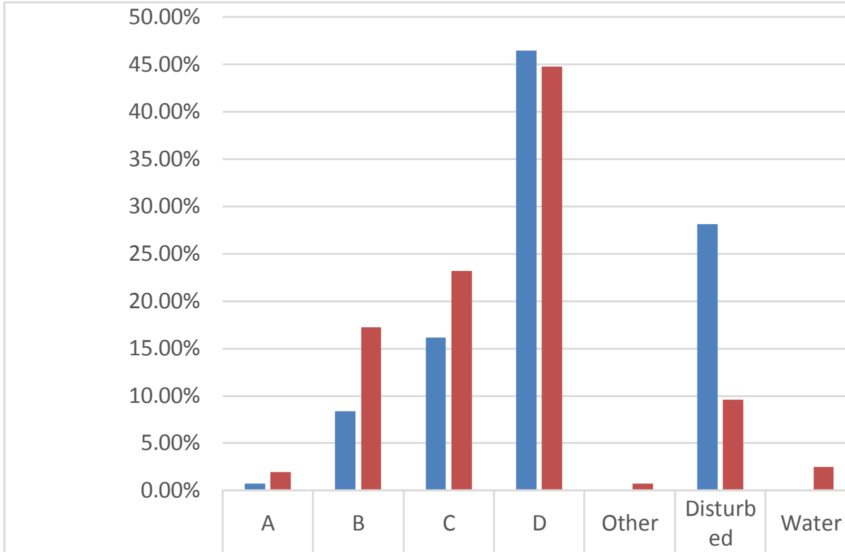
The U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) Soil Survey has developed a nationwide survey of the soils. These surveys provide descriptions of the soils based on their unique properties. Information gathered from the surveys has been incorporated into a Soil Survey Geographic database (SSURGO), which can be utilized for analyzing various soil attributes through maps and tables.

The SSURGO database contains the hydrologic soil group (HSG) for all soils. The HSG is determined based on a soil's minimum rate of infiltration corresponding to a subsequent period of rainfall. Hydrologic soils groups are split into four groups: A, B, C, and D. These groups are defined in Table 3.1. Through the process of urbanization, soil profiles in metropolitan areas have been significantly disturbed, and their original classifications no longer apply. These areas have been identified by the USDA and reclassified as "urban." Hydrologic soil groups are typically applied in hydrologic modeling when predicting water storage capacities and direct runoff rates of soils. The HSG can also be useful when assessing urban flooding, in identifying areas of flood-prone soils.

Table 3.1: Hydrologic soil groups in Illinois and their infiltration rates. All data from Technical Release 55, Urban Hydrology for Small Watersheds (USDA, 1986)

Hydrologic Soil Group	Description	Texture	Infiltration Rates (inches/hour)
A	Low runoff potential and high infiltration rates even when wetted	Sand, loamy sand, or sandy loam	>0.30
B	Moderate infiltration rates when wetted	Silt loam or loam	0.15-0.30
C	Low infiltration rates when wetted	Sandy clay loam	0.05-0.15
D	High runoff potential and very low infiltration when wetted	Clay loam, silty clay loam, sandy clay, silty clay or clay	0-0.05
Disturbed	Unidentifiable soils in urban areas		

Within the defined urban area 91% of the combined NFIP and private insurance flooding claims are distributed within C, D and Disturbed (urban) soil groupings, which cover 78% of the urban landscape, as seen in Figure 3.6. Hydrologic soil group C and D, soils with very low infiltration and high run off potential, are distributed over 68% of the defined urban area and accounts for 62.65% of the filed flooding claims. The disturbed urban areas, due to increased impervious surface areas, also have a potential for high runoff rates. Disturbed urban areas consist of 28.11% of urban claims distribution and 9.58% of the urban area. With the lack of soil infiltration and high runoff potential, it is highly recommended that below-grade construction be avoided in these areas without special design consideration.



	A	B	C	D	Other	Disturb ed	Water
Percent Claims	0.74%	8.42%	16.17%	46.48%	0.02%	28.11%	0.05%
Percent of Area	1.97%	17.26%	23.20%	44.80%	0.72%	9.58%	2.47%

Figure 3.6: Correlation of NFIP and private insurance claims and soil types within the defined urban area.

This analysis suggests that a disproportionate number of claims occur in the urban, disturbed soil group. However, this is a preliminary analysis with various data limitations. Other factors, such as old and inadequate infrastructure, high imperviousness, and economic considerations may have more to do with the high number of urban flooding claims than soil group.

Topographic Wetness Index

The topographic Wetness Index (TWI), also known as the Compound Wetness Index (CWI), is commonly used to estimate soil moisture conditions of a landscape similar to wetland areas. TWI is calculated by evaluating the flow accumulation, slope, and various geometric functions derived from GIS software. The end result is a GIS data layer (raster) that depicts areas with drainage depressions where water is likely to pond. TWI can also identify areas that are susceptible to higher water tables.

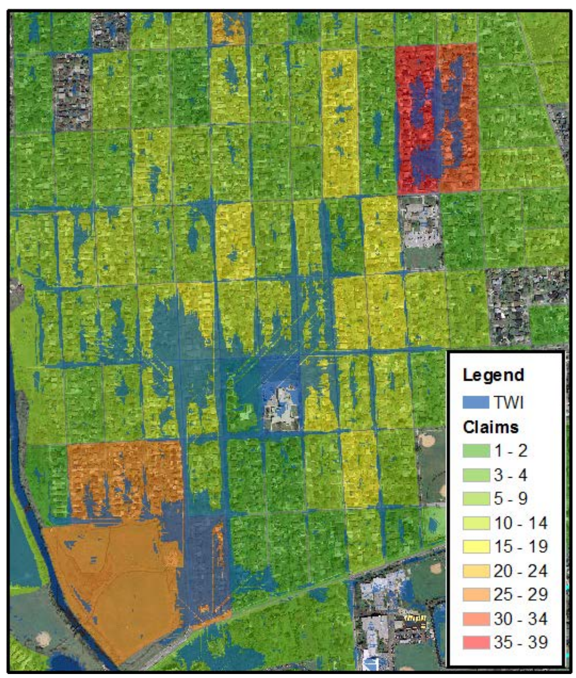


Figure 3.7: Example of a topographic wetness index compiled for DuPage County. The index was overlaid with the claims per census block.

Storm Sewer Infrastructure Spatial Data Inventory

Combined sewers are sewers that carry both sanitary and stormwater flows. During storm events, the combined sewer system can become overwhelmed and discharge the stormwater and sanitary water directly into bodies of water, called Combined Sewer Overflows, or back up into basements and crawlspaces (CMAP, 2008). Even in communities that have dedicated storm sewers, a large percentage of these storm sewers are aging, which increases the risk of flooding due to system failure or inadequate stormwater drainage as drainage demands outpace anticipated demands of outdated systems.

Detailed GIS mapping of existing stormwater infrastructure is a good tool for communitywide stormwater management. Accurate and detailed information about existing systems allows managers and engineers to more easily and cost effectively analyze and model the functionality of those systems. Proposed improvements can also more easily be incorporated and analyzed. Some communities also document and map existing and known flooding or sewer backup hotspots. This information can be used to validate models of the existing stormwater systems and prioritize the application of resources for system improvements. However, gathering accurate information about problem areas is dependent in many cases on the participation and awareness of the public, and databases of detailed information are only as useful as they are accurate.

Engineering Models

Hydrologic and hydraulic models allow engineers to identify flood prone areas by studying how a stream or section of stormwater infrastructure will respond to a given flow event given the current or proposed physical characteristics of a watershed, stream, and/or piece of infrastructure.

Some models are designed to be used with geographic information and drafting systems and have the ability to take into account sewer systems, detention and retention basins (layout, sewer size, materials, manholes, etc.), as well as hydrologic variables (topography, hydrologic soil groups, curve numbers, rainfall durations, etc.) to provide comprehensive analyses of sewer infrastructure.

Results from such models can then be associated with known urban flooding claim locations to determine weaknesses in an urban area's storm sewer infrastructure. These areas can be identified through historic flooding accounts and through the use of GIS to detect hot spot areas. With knowledge of these areas of vulnerability, municipalities can work to make improvements to the infrastructure. Funding options for such improvements can potentially come from sources identified in Chapter 4.

New Technology for Future Research

There are new forms of technology that are improving flood prevention and mitigation. Drones are now being used by some communities, such as the City of Rockford, to examine the extent of flooding in areas that are difficult to access instead of using costly helicopters or planes. Drones can operate more quickly, cheaply, and with greater flexibility than conventional aircraft and can easily send back real-time video to emergency response organizations (Figure 3.8). After recent severe flooding in various parts of the country, drones have assisted post flood by taking aerial photos to make damage assessment maps which help relief agencies coordinate their efforts while other aircraft are grounded due to weather. However, protocols for coordination of airspace with manned and unmanned aircraft need to be further developed. Currently, drones are only cleared by the FAA in limited cases to fly in the U.S., but as of February 15, 2015, the FAA proposed a framework of regulations that would allow routine use of certain small unmanned aircraft systems in today's aviation system (Federal Aviation Administration, 2015).

Figure 3.8: City of Rockford drone. Image courtesy of WREX13 news

Recent advances in remote sensing have enabled communities to better determine when flooding is about to occur in sewers, allowing managers to potentially prevent overflows or to document occurrences to inform future management decisions with real-time monitoring systems that can not only warn of impending sewer overflows but also provide information which enables more efficient management of the collection system as a whole (Quist, Drake, and Hobbs, 2010).

One such application of real-time monitoring is being utilized by the City of Decatur, which is using SmartCover real-time monitoring devices, which attach to the underside of manhole sewer covers and send alerts about impending overflows. This allows community officials to determine when a combined sewer overflow is beginning to flow or discharge water to a larger trunk sewer, providing additional implementation time for the community's emergency response plan.

Recommendations

1. The State of Illinois should provide funding to the Illinois State Water Survey to study and further develop the topographic wetness indices used for the identification of areas likely prone to urban flooding. This would afford communities the ability to identify areas requiring special consideration for below-ground construction.
2. Communities should consider real-time monitoring of combined storm sewer systems. When technology allows, they should update the monitoring with a reverse 911 system to alert property owners of imminent flooding.
3. Within a reasonable timeframe, communities should update their storm sewer atlas with storm sewer location, infrastructure sizes and design data to allow for evaluation of the effect of changing rainfall patterns on system capacity to more accurately identify areas at risk for urban flooding, and to better inform stormwater management planning.
4. Communities should consider adoption of ordinances to address drainage for below-grade construction, such as requiring sewers to exit structures within 2 to 3 feet of the finished exterior grade of buildings. Adoption of International Building Code Sections R405 and R406 for foundation drainage and waterproofing should also be considered.

Section 2

Effectiveness of Projects, Programs and Policies

This section examines current programs and practices at the community, county, state and federal level to explore their effectiveness. The first chapter includes a review of current stormwater management practices that are commonly adopted by communities and counties with an explanation of the rationale for current design standards. A review of countywide stormwater management programs that have been operational for a number of years provides insight into successes. This section concludes with an overview of state and federal programs that may impact urban flooding solutions.

Chapter 4: The Impact of Countywide Stormwater Programs on Urban Flooding over the Past Two Decades

Key Findings

- A number of counties with countywide stormwater management authority have profoundly impacted urban flooding through a myriad of programs and projects aimed to reduce stormwater runoff.
- Current county stormwater ordinances have common elements including providing safe passage for the 1% annual chance event, retaining runoff on-site, and requiring stormwater management for a certain area of disturbance or new impervious.
- Countywide stormwater management programs are able to address more efficiently stormwater program management issues in urban areas (e.g. permitting, inspections) than individual small communities, especially in a highly developed urban area.
- Counties are better able to facilitate watershed-based analysis of stormwater management issues.
- Counties have successfully implemented sources of funding that may not be viable for small communities.

Stormwater management in Illinois must be authorized by state legislation for county governments to possess the legal authority to manage stormwater in both unincorporated and incorporated areas, a.k.a. countywide authority. In the State of Illinois, the code currently used by authorized counties is 55 Illinois Compiled Statutes (ILCS) 5. Legislation 55 ILCS 5/5-1062 refers to the stormwater management authority that qualified counties may have. The purpose of the section is to "allow management and mitigation of the effects of urbanization on stormwater drainage in metropolitan counties located in the area…." The purpose is attained by three clear objectives: "(1) consolidating the existing stormwater management framework into a united, countywide structure, (2) setting minimum standards for floodplain and stormwater management, and (3) preparing a countywide plan for the management of stormwater runoff, including the management of natural and man-made drainageways. A stormwater management planning committee shall be established to oversee the implementation of stormwater management in the county."

Sixteen counties have the state-granted authority to manage and mitigate the effects of urbanization on stormwater drainage; they include: Boone County, Cook County (via the Metropolitan Water Reclamation District of Greater Chicago, authority does include the City of Chicago), DeKalb County, DuPage County, Grundy County, Kane County, Kankakee County, Kendall County, Lake County, LaSalle County, Madison County, McHenry County, Monroe County, Peoria County, St. Clair County, and Will County. Of the sixteen counties with authorization to manage stormwater, fourteen of them currently have stormwater ordinances. The remaining two counties (Grundy and LaSalle Counties) are presently developing ordinances for stormwater management. See Figure 4.1.

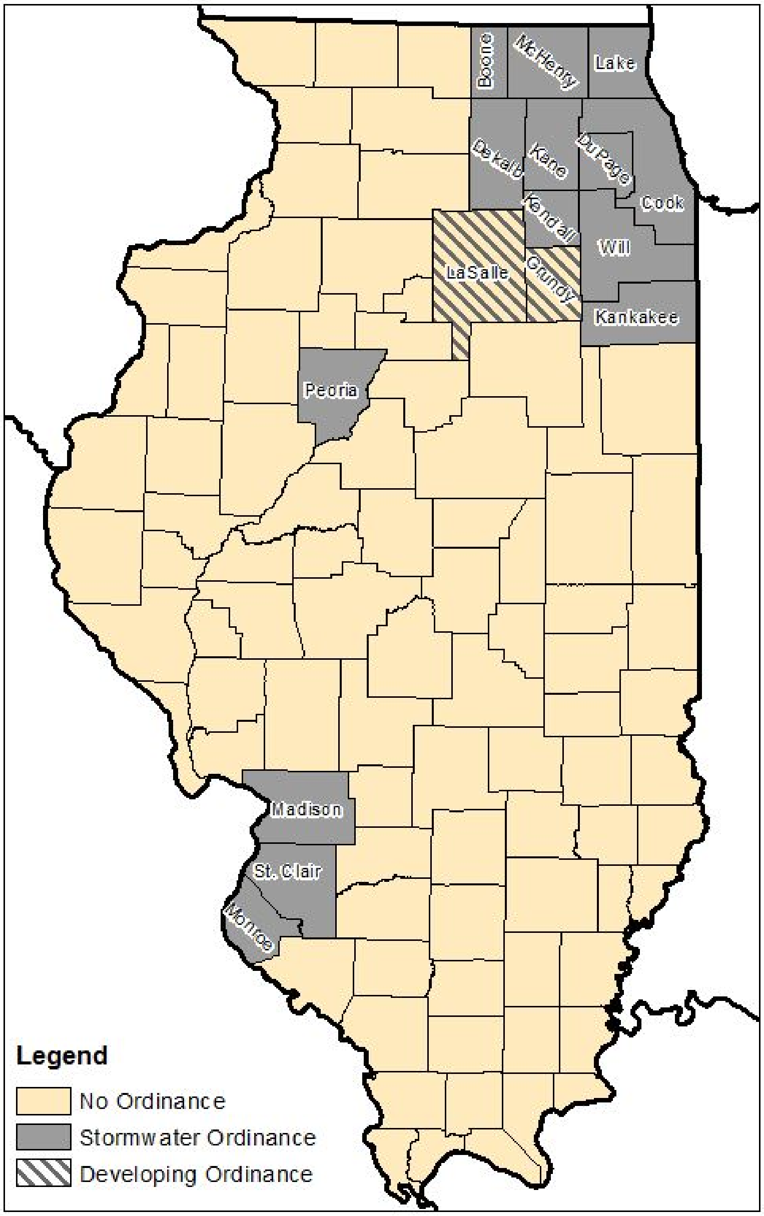


Figure 4.1: Counties indicated in gray have stormwater ordinances. Counties indicated with a hatch pattern are developing stormwater ordinances. The remaining counties are those without authorization to manage stormwater drainage.

Of the 102 Illinois counties, there are 86 counties that do not have authorization to manage and mitigate the effects of urbanization on stormwater runoff. The counties that do have stormwater management authorization are listed in Table 4.1. The specific legislation granting stormwater management authority is included as well as the stormwater ordinance date (if applicable) and the date of the most recent ordinance revision.

A number of the counties with authorization to manage stormwater have implemented programs, projects and regulations to prevent flooding, mitigate stormwater, and improve water quality. The following counties have profoundly impacted urban flooding through a myriad of programs and projects aimed to reduce stormwater runoff: Cook, DuPage, Grundy, Kane, and Lake Counties. Some of these projects were initiated under authorities other than those granted under the Stormwater Management Authority (55 ILCS 5/5-1062). Boone and Peoria Counties do not have any active programs or projects, because currently the municipalities within each county have stricter stormwater management plans than the county.

Many counties have initiated stormwater programs. A summary of all projects, programs, and regulations for the sixteen counties with stormwater authorization is found in Appendix G. The counties which have been most active have had the authority for the longest time.

Table 4.1: Counties with stormwater ordinances, the legislation that grants them authorization to provide stormwater management, and the date of their current ordinance and any subsequent revisions.

County Name	Legislation	Ordinance (y/n)	Date of Ordinance	Date of Revised Ordinance
Boone	55 ILCS 5/5-1062.2	n	NA	
Cook (MWRD has authority)	70 ILCS 2065/7h	y	2014	2014
DeKalb	55 ILCS 5/5-1062.2	y	2006	2010
DuPage	55 ILCS 5/5-1062	y	1991	2013
Grundy	55 ILCS 5/5-1062.2	n	NA	
Kane	55 ILCS 5/5-1062	y	2000	2009
Kankakee	55 ILCS 5/5-1062.2	y	2006	
Kendall	55 ILCS 5/5-1062	y	2015	
Lake	55 ILCS 5/5-1062	y	1992	2013
LaSalle	55 ILCS 5/5-1062.2	n	NA	
Madison	55 ILCS 5/5-1062.2	y	2000	2007
McHenry	55 ILCS 5/5-1062	y	2004	2014
Monroe	55 ILCS 5/5-1062.2	y	2004	2006
Peoria	55 ILCS 5/5-1062.3	y	1994	2013
St. Clair	55 ILCS 5/5-1062.2	y	2009	
Will	55 ILCS 5/5-1062	y	2004	2010

DUPAGE COUNTY
Stormwater Management
Currents

Stormwater Management Hosts Green Infrastructure Workshop MAY 2015

DuPage County Stormwater Management Committee Chairman Jim Zay welcomes workshop attendees.

Stormwater Management and The Conservation Foundation hosted a Green Infrastructure and Nature-Friendly Landscaping Workshop on April 30 at The Morton Arboretum in Lisle. Open to the public, this free workshop included expert speakers and exhibitors on hand to assist attendees in getting their green projects underway. Among topics featured was the benefits of permeable pavers and water detention system, such as underground cisterns. In addition, the Conservation@Home and Conservation@Work programs were discussed as an easy way to begin exploring native landscaping projects, as well as become accredited once the project is complete.

Figure 4.2: Countywide programs provide training opportunities such as workshops on green infrastructure.

Figure 4.3: The Round Lake Drain ecosystem restoration project is an example of a flooding mitigation project in Lake County. Photos courtesy of Lake County Stormwater Management Commission.

County Ordinances and Standards

The elements within each county's stormwater ordinance are similar. The design storm used for the stormwater conveyance system, detention requirements, and applicability for a stormwater permit are listed in Table 4.2. Counties either use the 100-year (1% annual chance) event or the 10-year (10% annual chance) event for the stormwater system design. The counties specifying the 10-year event require a safe overflow pathway for the 100-year event as well. The total precipitation over a 24-hour period that is expected to occur on average once every 100 years, is commonly referred to as the 100-year, 24-hour storm event. It is common to use this event for stormwater detention requirements. The thresholds for a stormwater permit requirement are somewhat varied, though several counties use 5,000 square feet, 10,000 square feet, or 1 acre as developed-area thresholds.

Overall, the ordinances, programs, and projects established by the counties given authority to manage stormwater provide a framework for controlling urban flooding. Stormwater runoff is controlled through the ordinance and permitting structure. Problem areas are targeted with specific projects and programs designed to reduce urban flooding and property damage.

Table 4.2: County Stormwater Ordinance summary of common elements

County	Design storm for stormwater systems	Retention/ Detention Requirements	Area of Development Thresholds			
			Residential	Multi-family	Non-Res	Open Space
Cook	100 year	First inch of runoff from impervious area = volume control storage	1 acre	0.5 acre	0.5 acre	0.5 acre
Kane	100 year	0.1 cfs/acre detention + 0.75" rainfall over impervious area of new development	2 or more homes on 3 or more acres	1 acre	1 acre	
DuPage	100 year	Pre-development peak discharges in a 2 year, 24 hour and 100 year event of critical duration up to a 24 hour duration	5,000 square feet, or 2,500 square feet of net new impervious			
Will	100 year	100 year, 24 hour	1 acre	1 acre	1 acre	1 acre
Lake	10 year	0.04 cfs/acre for the 2-year, 24-hour event; and 0.15 cfs/acre for the 100-year, 24-hour event	5,000 square feet of hydrologic disturbance; activities within a floodplain or create a wetland impact; drainage modifications with twenty (20) or more acres of tributary drainage area			
DeKalb	10 year	100 year, critical duration	Any land disturbing activity affecting more than 10,000 square feet; land disturbing activity within 100 feet of a waterway			
Kankakee	10 year	100 year	Construction adding more than 500 square feet of impervious surface, land disturbing activity affecting more than 5,000 square feet, activity within 25 feet of a waterway			

County	Design storm for stormwater systems	Retention/ Detention Requirements	Area of Development Thresholds			
			Residential	Multi-family	Non-Res	Open Space
Kendall	100 year	100 year, 24 hour	< 3acre	45,000 square feet of development or 32,000 square feet of impervious area		
Madison	100 year	100 year, 24 hour	10,000 square feet total impervious surface; any activity disturbing 10,000 square feet; any activity within 25 feet of a waterbody; any activity on a slope			
McHenry	10 year	100 year, critical duration	Development disturbing 5000 square feet or more; 50% or more of a parcel; 20,000 square feet additional impervious; or within a flood hazard area or wetland.			
Monroe	100 year	pre-development = post-development runoff	Any new development or redevelopment that will meet or exceed 5,000 square feet of total impervious surface; any land disturbance activity in excess of 5,000 square feet located in a business or industrial zoning district			
Peoria	2 year, 25 year	pre-development = post-development for 2-year and 25-year events	Land disturbing activity disturbing more than 5,000 square feet			
St. Clair	2 year,	100 year, 24 hour	Any new development or redevelopment that will meet or exceed 10,000 square feet of total impervious surface; any land disturbance activity in excess of 1 acre of land; land disturbing activity within 25 feet of any waterway			

County stormwater management programs are able to address stormwater program management issues at a larger scale than many small communities, especially in a highly dense urban area. Some county programs, such as those of DuPage and Lake Counties, provide permitting and regulation only when communities choose not to administer the program themselves. Many small communities benefit from a county's efficient use of resources to support and enforce stormwater regulation and avoid competitive lowering of stormwater management standards for economic benefit. Counties are better able to facilitate watershed-based analysis of stormwater management issues. Counties have successfully implemented sources of funding that may not be viable for small communities.

Figure 4.4: Countywide stormwater management can provide efficiencies for administration and enforcement of ordinances.

While county management provides many benefits for small communities in urban areas, there are limitations to addressing flooding caused by existing municipal infrastructure or a lack of overflow drainage path. Counties with stormwater management programs do not have jurisdiction over municipal sewer systems. Even the most active county stormwater programs typically stop short of addressing local storm and sanitary sewer issues that can cause urban flooding damages outside of the floodplain. County programs, including capital improvements and flood reduction strategies, generally address riverine flooding. While counties with stormwater management authority provide a support framework, the responsibility for maintenance of local stormwater infrastructure, such as storm sewers and combined sewers, still falls on the municipality.

In general, the aspect of county stormwater management programs with the most impact on stormwater flooding in urban areas is proactive design requirements for new development. Other programs addressing reduction of urban flooding outside of the floodplain vary by county. Some counties provide outreach about urban flooding risk or engineering analysis to support local flood reduction actions. Green infrastructure programs (see Chapter 9) in previously developed areas reduce local rainfall runoff volume. The Cook County Stormwater Management Plan Amendment recently provided the Metropolitan Water Reclamation District of Greater Chicago authority to allow planning, implementation and funding of local stormwater drainage projects, and several projects that will reduce urban flood damages are underway. The Kane County Cost Share Program provides funding to alleviate local urban flooding.

Stormwater Program Funding

A variety of funding mechanisms are used to support county stormwater programs. The access to property or other taxes and the use of these funds is dependent upon the specific authority of the program under the adopted ordinances and the specific authority of the local government. Agreements and responsibilities between the county and a community can vary. Kane County is in the unique position to use revenue from riverboats where gambling is permitted.

Recommendations

1. The authority to generate revenue from fees, to plan, implement and maintain stormwater management/drainage programs/facilities should be granted to all County Stormwater Planning and Management Agencies (55 ILCS 5/5-1062), counties (55 ILCS 5/Div. 5-15) and municipalities regardless of home rule status.
2. Stormwater Planning and Management authority should be granted to all Illinois counties to adopt countywide stormwater ordinances, projects and programs.
3. The Illinois Department of Natural Resources and Illinois State Water Survey should develop a state model local stormwater ordinance based on concepts in the report which can be used as a template by counties and local communities. The following should be included along with other actions to address urban drainage issues:

a. Incorporate green infrastructure into municipal and county development regulations by modifying regulations that restrict use of green infrastructure and add regulations to encourage use of green infrastructure in capital improvement projects when possible.
b. Stormwater infiltration, evapotranspiration and storage should be incorporated into new development and redevelopment wherever possible.
c. Developers and property owners should be incentivized to dedicate property for increased open space in developing areas, and current open space should be protected to allow for evapotranspiration, infiltration and stormwater storage.
d. Require a licensed plumber to inspect for sump pump and downspout connections to sanitary sewers when houses are sold.

Chapter 5: Evaluation of Design Standards for Stormwater Infrastructure

Stormwater runoff from precipitation or snowmelt can cause local flooding and flood related damage. Urbanization often increases the rate and volume stormwater runoff due to decreases in infiltration, and evapotranspiration. Storm sewer systems are constructed to collect and convey runoff from developed areas to minimize damages and inconvenience and keep transportation avenues open. A consequence of storm sewers efficiency is the delivery of higher peak runoff and larger volumes of runoff to streams and rivers and increased flooding. One of the goals of stormwater management which emerged in the 1970s is to reduce the peak runoff rate to streams and rivers and in some locations the runoff volume. Detention basins are commonly used to detain flow to reduce peaks and retention basins hold water on site to reduce water volume delivered to natural streams and rivers. Stormwater detention and retention is expected to mitigate the increase in peak flows and volume downstream in the watershed due to development upstream. Water quality can also be addressed as part of stormwater management.

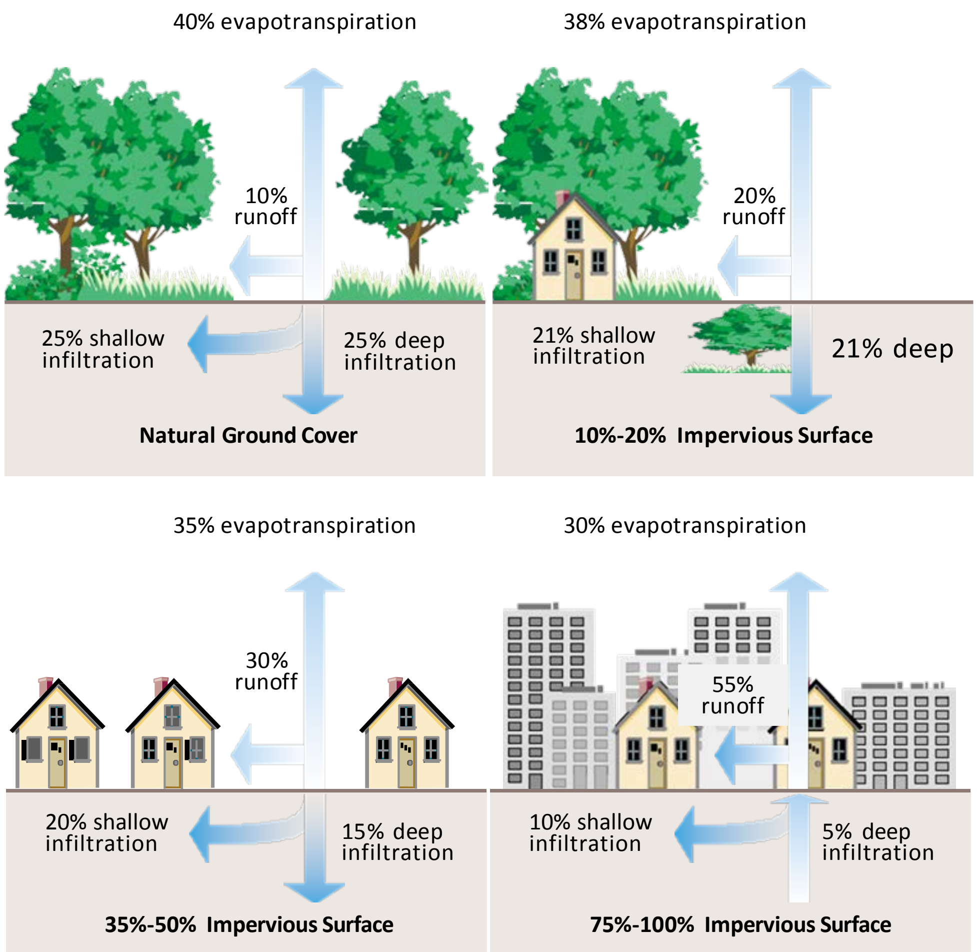


Figure 5.1: The effects of urbanization on evapotranspiration, infiltration, and total runoff (FISRWG, 2001).

Key Findings

- Safety, cost, and tolerance of the stormwater system capacity being exceeded and the resulting flooding are all considerations when a community sets design standards.
- The selection of a source for data used in design storm approach can greatly affect the design, functionality, and lifespan of the stormwater infrastructure. In some areas, a sewer designed to convey the 10-year storm based on rainfall data through 1960 would only carry the 6.6-year rainfall estimated from a data set extending to the 1980s.
- As more data is collected over the years, the expected values of rainfall for various durations and return periods may change, particularly for extreme events such as those having a 100-year return period.
- Stormwater design standards and implementation vary across the state:
    - Northern Illinois typically uses 10-year design storms for minor conveyance systems and dual-uniform stormwater release rates. Stormwater ordinances are implemented by the county, though the municipality can implement more restrictive requirements.
    - Southern and Central Illinois mandate 5-year or 10-year (sometimes 2-year) design storms for minor conveyance systems and post-development release rates are based on pre-development release rates. Stormwater ordinances are implemented by municipalities.
- The majority of detention facilities throughout Illinois are sized based on the 100-year, 24-hour design storm.
- Stormwater ordinances are generally focused on new development areas. Redevelopment and infill are not typically addressed in as much detail.
- While there are exceptions in Illinois, stormwater runoff volume reductions are not universally addressed in stormwater ordinances nor are techniques to achieve volume reduction.

Design Standards and Rainfall

Contemporary urban stormwater systems are commonly designed to have the capacity to convey events that occur on average once in five years or once in ten years. Excess runoff, which can result in flooding, is expected during larger events that would happen less frequently, e.g. 25–year, 50-year or 100-year events. Infrastructure with the capacity to convey these larger but less frequent events would require a larger conveyance system (pipes) and significantly higher costs than a system designed to convey relatively smaller, more frequent events.

Safety, cost, and tolerance of the system capacity being exceeded and resulting flooding are all considerations when a community sets design standards.

Design standards are not the same across the country, within a state, or even between contiguous municipalities but tend to be similar. Most current design standards were originally established at the recommendation of groups of experts in the 1960s-1970s and continue to be reviewed and debated today (ASFPM, 2004).

Design Storms

The design discharge is computed based on a design storm event (a design storm event used to compute the design discharge). Design storm events are typically defined by rainfall duration, total rainfall amount, and temporal distribution of rainfall in addition to the return period (as described above). The 10-year, 2-hour design storm was selected for examination in this report as representative of storm sewer design, and the 100-year, 24-hour storm is typical for detention basin design within Illinois.

RETURN PERIOD
Frequency of Occurrence in Hydrology

The return period is a way of expressing that the design discharge is expected to be equaled or exceeded on average once in the specified number of years, for example the 10-year rainfall. In the long term, the 10-year rainfall is expected to be equaled or exceeded 1 time in 10 years. It could happen 2 years in succession, then not again for 18 years. This can also be expressed as a probability, such as a 10% annual chance of occurrence, meaning it has a 10% chance of being equaled or exceeded every year.

Rainfall data are used to compute discharge and thus stormwater infrastructure size. Rainfall intensity-duration estimates are based on statistical analyses of long-term rain gauge data. The earliest published and widely used rainfall intensity duration data was the National Weather Service's "Technical Paper No. 40, Rainfall Frequency Atlas of the United States" (TP-40) (Hershfield, 1961). The rain gauge records spanned 1938-1957. The next source of intensity-duration estimates comes from the Illinois State Water Survey's "Bulletin 70: Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois" (Huff and Angel, 1989). The rain gauge records spanned 1901-1983. The latest published source of rainfall intensity-duration estimates is the National Oceanic and Atmospheric Administration's "Atlas 14: Precipitation-Frequency Atlas of the United States, Volume 2, Version 3.0: Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia" (Bonnin et al., 2006). The rain gauge records spanned 1891-2000.

Based on a statewide review, the current widely accepted state standard for rainfall intensity duration data is Bulletin 70. The Illinois Department of Natural Resources, Office of Water Resources requires the use of Bulletin 70 hydrology for flood studies requiring state permits, and most stormwater ordinances in Illinois recommend the use of Bulletin 70 for design. The Federal Emergency Management Agency likewise requires Bulletin 70 hydrology when mandated by the state. The Illinois Department of Transportation also recommends the used of Bulletin 70 precipitation for all hydrologic methods and modeling. However, prior to the publication of Bulletin 70 in 1989, the National Weather Service publication, Technical Paper No. 40, was the source of design rainfall data.

Prior to the publication of rainfall frequency estimates, design practices varied widely. Older areas of communities typically were designed with combined sanitary and storm sewers. Stormwater systems and infrastructure designed and constructed roughly between 1961 and the late 1980s is based on TP40 rainfall data. Cook County used TP40 data until 2014.

TP40 results are based on precipitation data that span a relatively dry period as compared to subsequent decades. In many areas of Illinois, the expected depth of rainfall during a less frequent (larger) storm event given in TP40 is less that the expected rainfall based on the results for the longer period of record presented in Bulletin 70. A comparison of TP40 and Bulletin 70 is provided in Figure 5.2 for the 10-year, 2-hour and 100-year, 24-hour events. In areas where Bulletin 70 rainfall depths are greater than TP40 rainfall depths, it is likely that storm sewer systems designed using TP40 data would be considered undersized based on Bulletin 70 data, the outcome being the system capacity would be exceeded more frequently than anticipated.

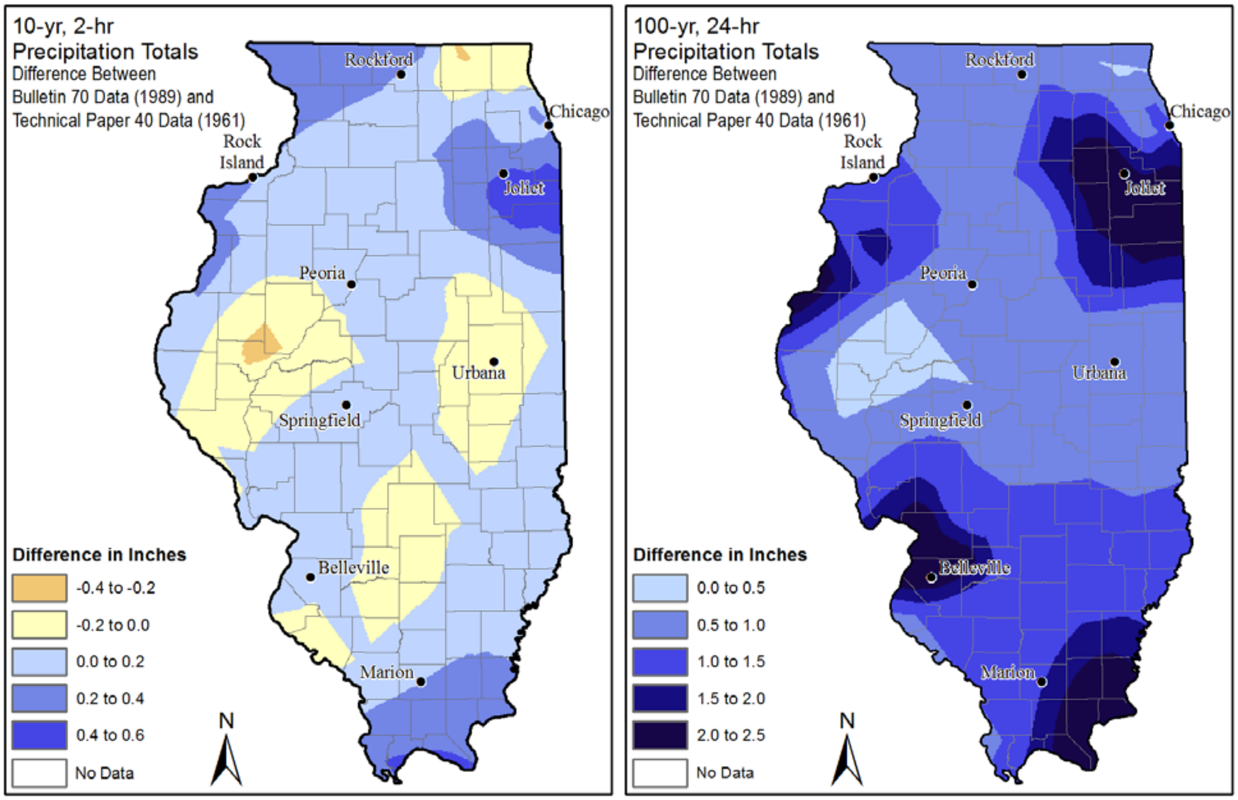


Figure 5.2: Differences between Bulletin 70 and TP-40 for the 10-year, 2-hour and 100-year, 24-hour design storms. Blue shows areas where Bulletin 70 has higher rainfall totals; yellow shows where TP-40 has higher totals. TP-40 shows lower rainfall totals than Bulletin 70 for the 100-year, 24-hour event across Illinois while the rainfall totals for the 10-year, 2-hour event are similar (within 0.5 inches).TP-40 was based on a shorter record earlier in the 20th century, which did not include large storms characteristic for the period after the 1950s.

Table 5.1 shows a comparison of average rainfall amounts recorded at O'Hare Airport in Cook County for the 10-year, 2-hour and 100-year, 24-hour design storms for TP-40, Bulletin 70, and Atlas 14. The 10-year, 2-hour design storm is generally representative for storm sewer design and the 100-year, 24-hour storm is typical for detention basin design within Illinois.

Table 5.1: Precipitation intensity-duration estimates for Northeastern Illinois (O'Hare Airport)

Design Storm	TP-40 (inches)	Bulletin 70 (inches)	Atlas-14 (inches)
10 year – 2 hour	2.37	2.64	2.48
100 year – 24 hour	5.75	7.58	7.22

The selection of a source for data used in design storm approach can greatly affect the design, functionality, and lifespan of the stormwater infrastructure. As indicated in Table 5.1, a storm sewer designed to accommodate the TP-40 10-year, 2-hour storm event would correspond to a sewer designed to convey only the 6.6-year, 2-hour Bulletin 70 design storm. A detention basin sized to accommodate the TP-40 100-year, 24-hour storm event would accommodate only the 31.3-year, 24-hour Bulletin 70 design storm. Compared to Atlas 14 rainfall values, the stormwater infrastructure would be designed to accommodate the 8-year, 2-hour and the 84-year, 24-hour Bulletin 70 design storms, respectively. This illustrates that stormwater infrastructure, which was designed properly based on one set of intensity-duration estimates may be undersized (10-year vs. 6.6-year design storm) compared to a design based on another set of intensity-duration estimates.

Stormwater infrastructure design is based on design storms derived from statistical analyses of observed rainfall. As more years of observation data become available, the inches of rainfall associated with recurrence intervals, e.g. 10-year storm, can change. The comparison of TP-40, Bulletin 70 and Atlas 14 indicates that rainfall and thus design storms is increasing in areas of Illinois. Bulletin 70 analyses, although similar to the tools used by the National Weather Service, takes into account known irregularities in precipitation and provides a finer tuned estimation of rainfall intensities and durations. It should continue to be used for stormwater infrastructure design; however, with 30 years of additional data available, an update of Bulletin 70 should be performed.

Existing Storm Sewer Design Standards in Illinois

In Illinois, the ordinances regarding stormwater system design vary across the state. In northeastern Illinois the standard requirement based on a review of local ordinances is for minor systems to convey the 10-year event and for major systems to convey the 100-year event. Outside of the Chicago Metropolitan Area, municipal requirements vary between the 5-year and 10-year events (a few require conveyance of a 2-year event) for minor systems; and the 50-year and 100-year events for major systems. The standards vary across the state. The Illinois Department of Transportation also requires minor conveyance systems along state roads to convey the 10-year event; depressed areas where runoff can only be removed by a storm sewer should be designed to convey the 50-year event. In addition, consideration should be given to traffic volume, type and use of roadway, speed limit, flood damage potential, and the needs of the local community (IDOT, 2011).

Evolution of Design Standards

Storm sewer design standards have changed over the years and these changes are apparent across Illinois urban areas. In the oldest urban areas, stormwater is often drained by combined sewers, which carry both wastewater and stormwater. Slightly newer areas may be drained by storm sewers designed for the 2-year event. The newest areas of a town may be drained by storm sewers designed for the 5-year or 10-year events. In this way, Illinois towns represent the evolution of stormwater conveyance system design. With time, information on rainfall has increased and expected values of rainfall for design storms have changed.

Existing Detention Release Rates Standards in Illinois

Figure 5.3: Regional detention basin in Champaign, IL. Photo courtesy of FOTH.

Many communities have adopted ordinances to require that new developments manage runoff from the developed area such that pre-development runoff peaks are not exceeded. To accomplish this requirement, detention basins are often constructed to detain runoff and slowly release it. The design standard for a detention facility and outlet structure is commonly expressed as an allowable release rate for a specified return interval event; for example, release from the structures shall not exceed 0.3 cfs per acre of development during a 100-year event, and the peak discharge from the detention structure must be less than pre-development 100-year peak discharge. How and why the prescribed release rate is determined and the corresponding magnitude varies regionally across Illinois. Figure 5.4 illustrates the impact on discharge downstream of a detention pond.

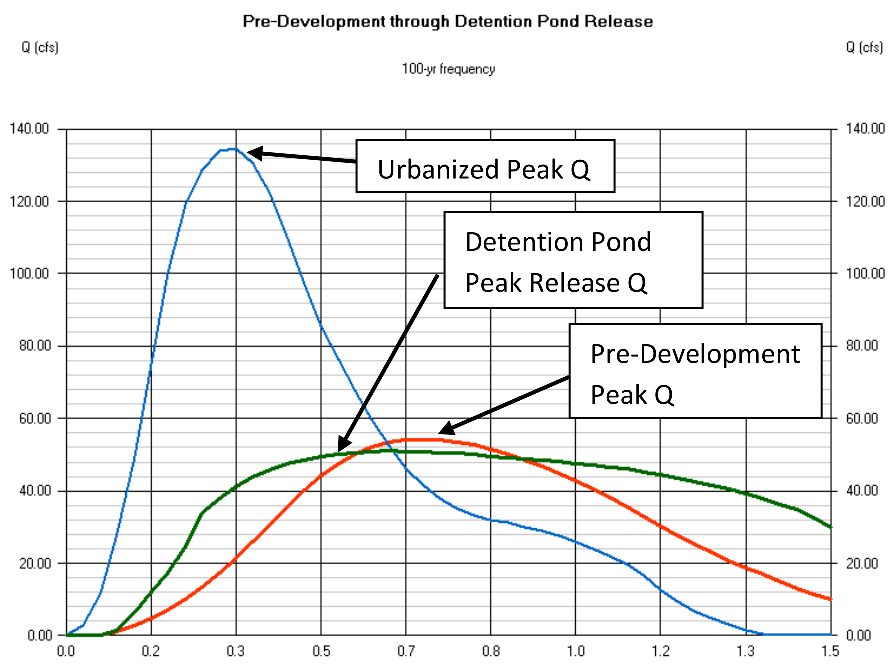


Figure 5.4: Pre-development (red), post-development (blue), and detention pond (green) hydrographs. The peak discharge increases due to urbanization and is reduced below pre-development conditions by the detention pond. The volume of runoff increases between the pre-development conditions and runoff released by the detention pond.

In northeastern Illinois, uniform stormwater release rates (such a 0.1 cfs/acre) have become standard and are implemented on a countywide basis as opposed to municipal-specific stormwater ordinances. In 1989, the Chicago Metropolitan Agency for Planning (CMAP) (formally Northeastern Illinois Planning Commission, NIPC) released a report call "Evaluation of Stormwater Detention Effectiveness in Northeastern Illinois," which led to the implementation of uniform stormwater release rates in northeastern Illinois (Dreher et al., 1989 and Dreher and Price, 1991). The study showed that detention basins designed to limit the design storm runoff peak (100-year event) to pre-development conditions resulted in increased downstream peaks in the northeastern Illinois area due to the large volume of stormwater runoff and coincident hydrographs downstream. From the study, CMAP recommended the implementation of a more restrictive uniform release rate (Maki, 2007b). CMAP determined that if local peak runoff is controlled below the pre-development runoff rate, then downstream peaks could more closely represent pre-development conditions for that event. CMAP released a Model On-Site Stormwater Detention Ordinance in which a dual-uniform release rate of 0.04 cfs/acre for the 2-year event and 0.15 cfs/acre for the 100-year event is suggested (CMAP, 1990 and 1994). Kendall County, Lake County, McHenry County, and Will County currently use these dual-uniform release rates. DuPage County uses a single uniform release rate of 0.01 cfs/acre for tributary areas under 100 acres and a dual standard for developments with a tributary area 100 acres or greater, and Kane County use a single-uniform release rate of 0.1 cfs/acre for the 100-year event. Municipalities within these counties can impose more restrictive stormwater release rate limits as desired.

The Southwestern Illinois Planning Commission (SIPC), which serves Madison, St. Clair, and Monroe Counties, produced a model ordinance similar to the CMAP model ordinance, which included the same dual-uniform release rates of 0.04 cfs/acre and 0.15 cfs/acre for the 2-year and 100-year events, respectively (SIPC, 1997). However, the dual-uniform release rates have not been widely implemented by the counties or local municipalities, where most ordinances refer to pre-development conditions.

Existing Volume Reduction Standards in Illinois

Modern stormwater ordinances have generally been effective at controlling the rate of stormwater runoff but have limited impact on reducing the total volume of runoff (CMAP, 2008). Detention basins can capture increased stormwater volume due to development and reduce the peak discharge, but eventually the extra stormwater volume is released downstream (Maki, 2007a). Reducing the volume of stormwater runoff can be especially important in areas with combined sewers. Combined sewers are sewers that carry both sanitary and stormwater flows. During storm events the combined sewer system can frequently become overwhelmed and discharge the stormwater and sanitary water directly into bodies of water, called Combined Sewer Overflows (CSOs), or back up into basement and crawlspaces (CMAP, 2008). If the amount of stormwater runoff can be reduced, the number of CSO discharge events and sewer backups can also be reduced.

Stormwater volume can be reduced by minimizing impervious surfaces on developed properties, infiltrating runoff on-site, and promoting temporary storage for secondary uses, such as irrigation. Several counties in northeastern Illinois, including DuPage, Kendall, Lake, and McHenry, have included a runoff volume reduction hierarchy in their countywide stormwater ordinances. Several other counties such as Kane County have included a list of best management practices (BMPs) for stormwater volume reduction. See Chapter 9 and Appendix J of this report for more information on stormwater BMP and green infrastructure uses and limitations.

Opportunities in Redeveloping Areas

Stormwater management and subsequent ordinance and standards adoption is relatively “new” starting in the 1970s compared to the establishment of communities dating back to the 1700s and 1800s. Of the 117 respondents to the survey (Appendix B), 39 (33%) stated that their community has combined sewers. Structures built between 1950 and 1969, while less than 30% of the total building stock in urban areas, account for more than 40% of private claims and more than 50% of NFIP claims (see Figure 3.1). These structures precede the common usage of stormwater design standards before the establishment of the NFIP. Communities have the opportunity to revitalize and update the stormwater infrastructure as well as mitigate open space and floodplain area losses as areas redevelop.

Recommendations

1. The State should fund the Illinois State Water Survey to update the existing rainfall frequency distribution information using the additional rainfall gauge data that are available with routine updates every 15 years. Future precipitation projections and also future land use should be included where it is available. When planning stormwater infrastructure modifications and enhancements, local governments should take into consideration these future precipitation trends and land use information.

2. Data collection is vital to all flood studies, project design and project operation; therefore, the Illinois General Assembly should continue to provide cost share funding to allow for the following:
    a. maintenance and expansion of the USGS stream and rain gage network by the Illinois Department of Natural Resources,
    b. continued monitoring of climate and flood data by the Illinois State Water Survey to better validate and fine tune the present climate projections and their effects on urban flooding; and
    c. continued monitoring of progress in climate model developments and new scientific approaches to account for climate and other uncertainties.

3. Communities should establish overland stormwater conveyance areas in all new development areas, and these flow paths should be maintained and regulated.

4. Communities should improve stormwater management in redeveloping areas by adopting stormwater ordinances that incentivize reduction of imperviousness and updating storm water systems, especially in known flood problem areas.

5. Communities should consider adoption of ordinances to address drainage for below-grade construction, such as requiring sewers to exit structures within 2 to 3 feet of the finished exterior grade of buildings. Adoption of International Building Code Sections R405 and R406 for foundation drainage and waterproofing should also be considered.

Chapter 6: Consistency of Criteria for State Funding of Flood Control Projects

Key Findings

- The distinct programs offered by the Illinois Department of Natural Resources (IDNR), the Illinois Emergency Management Agency (IEMA), the Illinois Department of Commerce and Economic Development (DCEO), and the Illinois Environmental Protection Agency (IEPA) each have their own funding sources and unique criteria for specific types of flood control.
- The IDNR has the only fully state-funded flood control program. The funding requirements for the federal matching fund programs are not controlled by the state.
- There is no state funding program that addresses individual basement mitigation because currently the State cannot spend State dollars on private property for private gain.
- Except for the IDNR program, prior planning is the key to funding speed. Fund disbursement is contingent on planning being complete.
- National Flood Insurance Program (NFIP) participation is required for all of the programs except for the DCEO program.

There are only a few criteria that are consistent between the agencies for eligibility requirements for different sources of funding as shown in Figure 6.1. One is that the local government requesting the project funding must participate in the NFIP to qualify for most of the programs (see Chapter 7 for more information about the NFIP). NFIP participation allows property to be protected from flooding damage that would otherwise be borne through these public funding programs again. Prior approved planning is another criterion that is required by most of the programs. Table 6.1 lists the different state programs and some of their specific criteria. The federal government also provides funds, or cost shares, for flood control projects in Illinois through many of these agencies.

Funding Sources, Criteria and Process

IDNR

The Office of Water Resources (OWR) has the only fully state-funded flood control program. OWR's Urban Flood Control program has been implemented for many decades under the authority of the Flood Control Act of 1945. Historically, the OWR has chosen to limit its participation to problems caused by out-of-bank riverine projects; OWR will develop and construct projects that provide an outlet for stormwater systems but has not participated in the development or construction of stormwater improvements.

Urban Flood Control Program: Local government requests for assistance to a severe flood problem are addressed through a study process as shown in Figure 6.1. If the initial feasibility is determined to be positive (out-of-bank flooding; likelihood of developing a feasible project) then a Strategic Planning Study is initiated. The Strategic Planning Study can take twelve months or longer to complete and are performed in-house, by consultants or by cost sharing/coordination with other governmental agencies or entities. The Flood Control Act of 1945 generally requires a favorable Benefit to Cost Ratio (B/C ratio equal or greater than 1.0) to proceed further.

Table 6.1: State funding programs and requirements

	IDNR/OWR UFC	IEMA FMA	IEMA PDM	IEMA HMGP	Direct Legislative Action	DCEO CDAP PI and Emergency PI	DCEO CDAP PI + Design	IEPA Revolving Loan
Types of Projects / Outcomes								
Storm Sewer Improvements		X	X	X	X	X	X	X
Combined Sewer Improvements					X	X	X	X
Conveyance Improvements	X	X	X	X	X			X
Levees	X				X			
Detention Basins	X	X	X	X	X			Potentially
Projects on Private Property		X	X	X				Potentially
Individual Basement Mitigation								
Repetitive Loss Structure Buyouts		X	X	X				
Planning Reports	X	X	X	X	X			Potentially
Program Outputs								
Project Specific Planning Documents	X				X		X	Potentially
Construction Documents	X				X	X	X	X
Construction Funding	X	X	X	X	X	X	X	X
Construction Engineering	X				X	X	X	X
Local Participation Requirements								
Operation and Maintenance	X	X	X	X	X	X	X	X
Utility Relocations	X							
Land Rights Acquisition	X							X
NFIP Participation	X	X	X	X		X	X	X
Emphasis on Low to Moderate Income						X	X	
Pre-Approved Planning		Mitigaiton Plan	Mitigaiton Plan	Mitigaiton Plan		X		
Program Funding								
Federal Disaster Declaration Required				X				
Local Cost Share		25%	25%	25%		25%	25%	Low interest loan
B/C Ratio	1.0 or greater	1.0 or greater	1.0 or greater	1.0 or greater	None	None	None	None
Funding Limits						$450,000 or $200,000 for Emergency	$450,000 max with $150,000 design included	None

UFC = Urban Flood Control, FMA = Flood Mitigation Assistance, PDM = Pre-Disaster Mitigation, HMGP = Hazard Mitigation Grant Program, CDAP= Community Development Assistance Program

Initial Feasiblity Determination	• Preliminary flood damage estimates are calculated and potential solutions are analyzed to determine feasiblity
Strategic Planning Study	• More accurate prediction of existing flood damages • Benefit calculations for each potential alternative project • Cost estimates for alternatives to determine if B/C Ratio > 1
Project Planning Study	• Local entity enters into an agreement accepting project terms • Detailed design, permitting, and construction documents completed • Funds are appropriated and project is ready for construction
Construction	• A construction contractor is chosen and contracts are completed • Engineering oversight is provided during construction • Construction is completed and project turned over to the local sponsor

Figure 6.1: OWR's Urban Flood Control Program Process

The general requirements of a local sponsor are listed in Table 6.1. If the local entity requesting assistance is willing to be a local sponsor for a selected alternative, a Project Planning Study is initiated. Project Planning Studies are more detailed engineering design studies that are only performed for projects scheduled to be constructed as OWR projects. Funding for these projects is appropriated to OWR from the General Assembly; the funds are usually from the sale of capital project bonds so the money can only be used for activity that directly leads to a project that has a physical life of 15 years or more.

IEMA

IEMA administers the Hazard Mitigation Assistance program for the Federal Emergency Management Agency (FEMA) in Illinois. This includes a flood mitigation assistance program, an all hazards pre-disaster mitigation program, and an all hazards grant program related to federal disaster declarations. The goal of these programs is to reduce the risk of loss of life and property due to natural hazards. All of these programs are competitive, require NFIP participation, and are 75% federally funded. In order for local governments to receive funding through these programs, they must apply through FEMA's web-based application system. All of the programs also require a mitigation plan for the type of hazard that is being mitigated. IEMA takes all of the applications and determines which projects get funded by analyzing which projects align best with the programs goals. Funding disbursement can take from 1.5 to 2 years for completion of all paperwork and analysis. If local governments are proactive and complete mitigation planning before a disaster, then funding will be available for rebuilding after a disaster instead of just planning. Details about what the programs will cover are listed in Table 6.1.

Flood Mitigation Assistance Program: The goals of the Flood Mitigation Assistance (FMA) are to reduce the long-term risk of flood damage and the number of repetitively damaged structures, to encourage long-term comprehensive mitigation planning, and to respond to the needs of communities in the NFIP. The FMA is a cost-share program through which communities can receive grants for the development of a comprehensive flood mitigation plan that is needed to receive grants for the implementation of flood mitigation projects through the FMA. The funds allocated to the state are based on the number of flood insurance policies in place statewide as well as the number of identified repetitive-loss properties. Typically-funded FMA projects are for the acquisition and demolition of repetitively flooded structures in the floodplain insured by the NFIP.

Pre-Disaster Mitigation Program: The Pre-Disaster Mitigation (PDM) program makes funding available to local and state governments to implement cost-effective hazard mitigation activities that complement a comprehensive mitigation program. Funding may be awarded for development of an all-hazards mitigation plan or for a cost-effective hazard mitigation project. Local governments must have an approved local mitigation plan. The applicant is responsible for 25% cost share. In-kind services may be used, but no other federal source of money may be used to fund the local share. They must also participate in and be in good standing with the NFIP if a Special Flood Hazard Area has been identified (see Chapter 8 for Special Flood Hazard Area information).

Hazard Mitigation Grant Program: The Hazard Mitigation Grant Program (HMGP) makes grants available to state and local governments as well as to eligible private, non-profit organizations to implement cost-effective and long-term mitigation measures following a major disaster declaration. The amount of funding made available is a percentage of total disaster costs and therefore will vary with each disaster, but a project does not have to be in a declared county to be eligible. Communities must have an approved all-hazards mitigation plan. The applicants are responsible for a 25% cost share. They must also participate in, and be in good standing with, the NFIP. Projects can protect either public or private property but must be environmentally sound, cost effective, solve a problem and prevent future disaster damages.

DCEO

DCEO has no specific flood control authority. They are able to fund storm sewer projects through the public infrastructure section of their Community Development Assistance Program.

Illinois Community Development Assistance Program: The Federal Community Development Block Grant: Small Cities program that DCEO is administering as the Illinois Community Development Assistance Program is designed to assist Illinois communities in meeting their greatest economic and community development needs, with an emphasis on helping communities with substantial low to moderate-income populations. The public infrastructure component of the program is used to eliminate conditions detrimental to public health, safety and public welfare in primarily residential areas. Local governments are able to request grants of up to $450,000 for public storm sewer projects. If they cannot afford to design the project, up to $150,000 may be taken out of the grant for design services. This program has a once a year deadline dictated by HUD when all applications are due. The applications are ranked based 50% on readiness to proceed, 25% on threat or need, and 25% on low to moderate-income population score, and the disbursement of funds occurs approximately six months later. None of the construction may take place until all approvals are in place, and they have two years to complete the project from the disbursal of funds. In an emergency, communities may also apply for grant funds of up to $200,000 to undertake emergency storm sewer projects that have occurred in the last 18 months. If their preliminary application is approved, then they are asked to turn in a full application, and the emergency project funds can be awarded in less than two months.

IEPA

Revolving Loan Program: IEPA gives out loans, through their revolving loan program, for flood relief if the projects are tied to water quality improvements. This program provides loans for projects constructed in a combined sewer service area intended to reduce or eliminate street, area and basement flooding. Combined sewer service projects include the construction of relief combined sewers and the renovation, repair or replacement of existing combined sewers. The required IEPA-approved plan must provide the drainage area, in acres, that are affected by the proposed project, the annual number of street and/or area flooding occurrences, the frequency and number of basements affected by flooding and the number of basements in the drainage area. Projects that meet the above criteria and are approved would be loaned project money at half the Bond Market Interest Rate for a twenty year repayment schedule. When loans are repaid, the fund is replenished and other loans can be disbursed.

Federal

The Stafford Act: The Robert T. Stafford Disaster Relief and Emergency Assistance Act is a federal act that gives the State of Illinois specific opportunities for funding from the federal government. The governor may request a Federal Disaster Declaration for flooding that would give a number of flood relief options to the citizens in the declared areas. One caveat for disaster funding is that no one can receive future assistance if they have previously received assistance and their required insurance was not maintained (i.e. flood insurance).

Federal assistance can be received for state or local government facility repair or for private critical facilities to reduce or prevent future damage. Public facilities may include flood control, navigation, water supply and distribution, watershed development or non-federal roads and parks. The state is allowed to be self-insured for state-owned buildings, but no federal assistance will be given if insurance would have covered the loss.

Issues for Local Governments

Some of the issues local governments deal with when looking for funding for flood control programs is the lack of programs that deal with individual basement flooding, the longer timeframe for receiving funding, difficulties in securing local cost share funding, and the sometimes confusing application processes.

The timeframe for disbursement of funds to local governments through each of these programs varies depending upon the program and the agency staffing level. All except the IDNR program require prior planning before fund distribution to ensure that the allocation is spent on eligible projects that have all the necessary elements to ensure success. All projects must complete engineering planning, obtain necessary state and federal permits, obtain land rights, create the construction bid documents, and choose a contractor before construction may begin. All of these requirements add to the public's perceived timeframe after a flood. The general planning that must be completed for the federal cost-share programs can be completed by local governments before a flood to speed up the post-flood timeframe.

There is a lack of funding for state programs that deal directly with basement flooding, primarily due to the fact that only IEMA programs may spend state dollars on private property. Local governments are successfully using overhead sewer conversion programs with local funding to cost share with homeowners to raise the elevation of basement sewer connections in order to reduce sewer backup (see Appendix J). Many local governments also have trouble budgeting for cost share dollars and other program participation requirements that are mandatory for many of the existing state programs.

The application process for flood control funds is sometimes confusing for local governments that are not used to applying for funding through these sources. All of the agencies work with applicants to help move their applications forward but after a large flood, these offices deal with a considerable number of applications. If communities have not planned ahead, the process can be time consuming. One of the best strategies that local governments can utilize to expedite funding approval is to be proactive about mitigation planning. The programs that fund the mitigation planning process are available even when there are no disasters. Pre-planning would give communities the opportunity to fully assess their needs and to communicate their plans to local stakeholders when there are no deadlines for vital funding. Planning will also help local governments conceptualize the potential flooding problems and make it easier to convey those issues to the public.

The Illinois Statewide Resiliency Team

The Illinois Statewide Resiliency Team consists of the IDNR, IEMA, DCEO, and the Illinois Historic Preservation Agency. In response to the Housing and Urban Development (HUD) National Disaster Resiliency competition, the State is coordinating the expansion of this group to include Illinois Department of Transportation (IDOT), Illinois State Water Survey, Illinois Department of Agriculture, Illinois Department on Aging, Illinois Capital Development Board, Illinois Commerce Commission, Illinois Economic Recovery Commission, Governor's Office, Lt. Governor's Office, Illinois Housing Development Authority, Illinois Department of Insurance, Illinois Department of Public Health and the Illinois State Toll Highway Authority. The purpose of this state agency team will be to:

- Encourage resiliency in all state-funded capital projects;
- Promote interagency communication and multi-purpose benefits across state agency programs in ongoing and future state funded community projects;
- Orchestrate resources to help communities plan and implement disaster recovery and preparedness that makes them more resilient to future threats while improving quality of life; and
- Leverage multi-agency funding; for example, a small community slated for an IDOT highway by-pass around town requiring extensive borrow and/or roadway embankment fill could utilize such work to also provide additional flood storage created by the borrow site and/or embankment.

Recommendations

1. The Illinois General Assembly should continue (and increase) its funding of flood hazard mitigation programs to allow state agencies to better leverage federal mitigation funds.
2. The State should provide grants or revolving loan opportunities to communities to support implementation of local cost sharing mitigation programs for residents impacted by urban flooding, to evaluate stormwater system capacity and flood risk, and to encourage stormwater management planning.
3. Local and county governments should be required to participate in the NFIP as a prerequisite for state funding and grant assistance for flood damage reduction-related activities.
4. The authorities for justification of state capital projects are currently inconsistent making it more difficult to seek funding from one state agency versus another for similar flood damage reduction purposes. Funding criteria should be made consistent across all state agencies.
5. To better utilize funding that is available through Illinois Emergency Management Agency for mitigation projects, communities are encouraged to complete pre-disaster planning.
6. The Illinois Mitigation Advisory Group should expand their mission with representatives from various state agencies to coordinate grant programs and projects to ensure consistent funding requirements, leverage state funding efficiencies, promote resiliency, and avoid project overlap. This group should identify and prioritize urban drainage flood mitigation planning in Illinois so existing mitigation actions can occur quickly and efficiently as funds become available.

Section 3
Strategies for Reducing Urban Flood Damages

There is no single solution for reducing the damages experienced due to urban flooding. However, there are multiple strategies that can be adopted to deal with root causes, enhance public awareness and understanding of insurance options, and encourage communities and individuals to take action to reduce losses and avoid increasing flood damages in the future. This section examines the options individuals have to transfer their risk of flooding through the purchase of homeowners insurance offered by private insurers and flood insurance available through the National Flood Insurance Program. The long-term strategy for truly reducing flood damages is to mitigate flooding for individual structures and for communities to take action by adopting policies and programs that alleviate the source of flooding.

The Normal, IL roundabout project combines green and gray infrastructure to provide an appealing community focal point with stormwater management. Photo credit: Scott Shigley

Chapter 7: Strategies and Practices to Increase the Availability, Affordability and Effectiveness of Flood Insurance and Basement Back-up Insurance

As evident with urban flooding, a home or business does not have to be in a high-risk flood area or be where major flooding has previously occurred to be damaged by water. However, a common misperception is that a typical homeowners or commercial insurance policy will cover the damage. Unfortunately, in most cases that is not true. A typical policy excludes damage caused by water from three sources: 1) flooding (e.g., rising water), 2) sewer or drain back-up or overflow from a sump, and 3) seepage through a structure.

To help provide additional financial protection, a separate flood insurance policy can be purchased through the National Flood Insurance Program (NFIP) or a private insurance company to cover the first exclusion and an endorsement ("Water Back-up") can be added to a homeowners or commercial policy for the second exclusion. With flooding being the number one disaster in the U.S. and purportedly 60% of homes possibly experiencing a wet basement at some time, these are two important coverages for a property owner to consider. This chapter will look into each of these coverages.

Key Findings

- Coverage for damage due to water/sewer back-up is readily available as an endorsement to an existing residential or commercial policy, and available as a separate policy through the NFIP or private carriers for damage due to flooding.
- Water/sewer back-up average annual costs range from $30-$300 for $5,000-$50,000 in coverage and can be financed.
- NFIP maximum coverage for 1-4 family residential building and contents is $250,000/$100,000; it is $500,000/$500,000 for non-residential coverage. There is limited coverage in basements in an NFIP policy.
- Flood insurance premiums can be quite low for properties in moderate-low risk areas but can be very expensive, especially for secondary homes and businesses in high-risk areas which were built before the community's first flood map became effective and/or if the first floor was built too low.
- Significant rate increases due to FEMA implementing reform bills passed by the U.S. Congress has created an affordability issue as well as a possible cause for significant drop in policy count.
- With an NFIP policy's total premium due at policy inception or by renewal, the ability for low- and fixed-income policyholders to pay can be quite challenging. Academia, associations and others have weighed in with affordability recommendations ranging from means-tested voucher programs, to property mitigation efforts supported by grants, loans, tax credits and rebate programs, to adopting and enforcing higher building standards.
- The insurance industry and state and local communities can work better together to increase residents' and business owners' awareness of coverages available, enhance education about their risk and work with them on ways to reduce the risk and their cost for insurance.

Availability and Effectiveness of Basement Back-up and Flood Insurance

Basement Back-up Insurance ("Water/Sewer Back-up")

The basement of any home or business can experience water/sewer back-up, seepage or flooding. And in most cases, the typical homeowners and commercial insurance policy will not cover the resulting damage. If the basement water is due to a flood, including a flood causing water to back up through drains in the basement, a separate flood insurance policy would provide limited coverage. If it is due to other conditions, including the failure of a sump pump, a low-cost endorsement could help cover the costs.

Other than an effect directly due to flooding, water/sewer back-up in basements can be a result of different causes including blockage from tree and shrub roots on or adjacent to the building owner's property and blockage in the community's adjoining sanitary or storm sewer line. Overwhelmed community stormwater drains from heavy rains could also result in a back-up. These back-ups could come through toilets, showers, washtubs, and sump pumps in a basement. Wet basements can also occur from water seeping into very small cracks after repeated heavy rains and a very saturated soil. In fact, as a building ages, the chance of seepage could actually increase through resulting small cracks and the basement floor and walls becoming less waterproof. Finally, the failure of a sump pump in the basement could result in the basement flooding.

While there is no requirement for insurance companies or agents to offer coverage, most homeowners insurance companies offer an optional water/sewer back-up and sump overflow endorsement, which can be added to the policy to cover this damage. A standard wording that many companies use (or a variant thereof) is the Insurance Services Offices (ISO's) endorsement (HO 04 95 01 14), which is filed with the Illinois Department of Insurance. The endorsement states that coverage will be up to the limit selected to cover direct physical loss caused by water which backs up through a sewer or drain or water that overflows or is discharged from a sump pump, even if it is a result of the sump pump not working. It does not cover the cost for mechanical breakdown of the pump, nor does it cover back-up due to flooding or for seepage through cracks in the wall or floor. Coverage limits can range from $5,000 to $50,000 with deductibles from $500 to $5,000, with the typical limit being $5,000 based on conversations with insurance carriers. Typically, any claim related to the building would be paid at replacement cost, and even possibly on the contents as well (as opposed to Actual Cash Value, which is the depreciated value). This, of course, varies by insurance company as does the number of times a company will pay such a claim before cancelling the policy. Taking into account the fear of potential cancellation for reporting a loss or too many losses, the actual of number of losses may be higher.

Each insurance company files their own rates, and costs can vary based upon location plus the limit and deductible chosen (e.g., $500 deductible for $5,000; $5,000 for $50,000). Some insurance companies in Illinois have also divided the state into zones based upon location. As a result, a premium for $5,000 might run from a low of $30 to a high of $125 depending on location and up to $300 for $50,000 in coverage. This endorsement's premium would be included with the total policy premium, which in many cases can then be financed (e.g., monthly, quarterly payments) with the insurance company or through the insurance agency, thus making it easier to pay and afford.

Flood Insurance[1]

While an endorsement to a homeowners or commercial policy could provide some coverage for basement flooding due to water/sewer back up, these policies typically do not cover damage due to flooding. However, a separate flood insurance policy through the NFIP is available to all Illinois renters, homeowners and business owners located in one of the 877 communities that participate in the NFIP (about 87% of all Illinois communities). It is sold by insurance agents who represent the NFIP directly or one of about 85 companies that have agreed to write the NFIP policy under their company name. Residential limits of coverage are available up to $250,000 for 1-4 family buildings and $100,000 for the contents; non-residential limits are $500,000 for the structure and $500,000 for contents. While the typical homeowners' policy provides for replacement cost for damages to the building and may also be available for the contents, replacement cost is only available for principal residences that are insured to at least 80% of their Replacement Cost Value (and residential condominium associations). Claims on contents and on non-principal residences and non-residential buildings are paid at Actual Cash Value (depreciated value). There are also some flood insurance programs through private carriers that provide similar coverage as the NFIP, many of which are written through Lloyds of London syndicates; additional coverage above the NFIP limits is also available through certain private insurance companies and Lloyds of London.[2] While a disaster needs to be presidentially-declared to receive federal disaster assistance, flood insurance is available even if the flooding is very local and there is no declaration, as long as it meets the definition of a flood. As opposed to a homeowners or commercial policy, an NFIP flood insurance policy cannot be cancelled or non-renewed due to too many claims.

The NFIP definition of a flood is very specific (see Appendix I), but basically just two or more properties need to be partially or completely inundated by the overflow of inland or tidal waters. So, if sewer backup occurs in the basement because of flooding, it is covered; otherwise, damages due to sewer backup are not covered by this policy. And like most policies, there are limitations and exclusions. For example, this policy has limited coverage in basements[3]. If a claim occurs on an NFIP policy, building coverage in the basement is limited to just basic structural items in the basement (e.g., foundation walls, staircases, drywall) and items to help "run" the building (e.g., circuit box, central air conditioning, furnace, water heater, sump pump); and if contents coverage is purchased, it will include washers, dryers and food freezers (not refrigerators). However, the policy will not cover items like paneling, bookcases, carpeting or tile, and most contents including items like TVs, sound systems, furniture, rugs and clothing. In other words, finished basements have limited coverage.

[1] A more detailed discussion about the NFIP's flood insurance program is provided in Appendix I.
[2] A listing of example primary, excess and force-placed flood insurance programs is provided in Appendix I.
[3] The NFIP policy defines a basement as any area of the building having its floor subgrade (below ground level) on all sides.

While the NFIP policy is available to residents and business owners in 87% of Illinois' communities, a very low percentage – when compared to the number of households – have this separate policy, even in high-risk areas (e.g., flood Zone A, AE) where flood insurance is to be required on all mortgages through federally insured and regulated lenders. A national study by RAND Corporation in 2006 showed that about 25% of property owners in a high-risk area with a mortgage did not have flood insurance and there was probably another 25% that did not have a loan and also had not purchased coverage. One reason some property owners do not choose to buy coverage is due to the limited amount of coverage provided for basements compared to what they have in their basement (e.g., fully furnished family room, bedroom, bathroom). Another main reason is many feel they are not at risk and therefore, it is not worth the cost. The NFIP policy count has dropped significantly since the implementation of significant rate increases in October 2013 as required by recent flood insurance legislation (discussed in the next section), with both nationally and in Illinois, losing about 5.6% of the policies-in-force (-310,000 policies and -2,800 policies, respectively).

Flood Insurance Cost

The majority of property owners in Illinois live in moderate-low risk areas (e.g., Zone X) and would qualify for the NFIP's lower-cost Preferred Risk Policy (PRP), with premiums starting as low as $162 for a primary residence ($20,000 in building and $8,000 in contents coverage). About 38% of the 47,105 NFIP policies in force in Illinois are written in moderate-low risk areas. Overall, since 1978, 20% of flood claims in Illinois come from policies in these moderate-low risk areas[4].

Flood insurance for properties in the mapped high-risk areas is typically more expensive. Premiums vary depending upon many factors but two major ones are:

1. the difference between the building's Lowest Floor Elevation (LFE) and where the flood waters are projected to rise to (known as the Base Flood Elevation or BFE), and
2. if the building was built before the first Flood Insurance Rate Map (pre-FIRM) or after (post-FIRM).

Most post-FIRM buildings in high-risk areas are elevation-rated and require an Elevation Certificate. The higher the LFE is above the BFE, the lower the premium (up to 4 feet above BFE). Conversely, the lower the LFE (which could be the basement floor for buildings with basements) is below the BFE, the premium becomes significantly higher (see Table 7.1). In Illinois, most communities strictly enforce floodplain regulations on new development in the floodplain (post-FIRM construction) and buildings are built with the lowest floor (including any basement) at or above the BFE.

Since pre-FIRM buildings were constructed before a community's first FIRM and there were no building regulations tied to a flood map, a building's lowest floor (e.g., basement) could very easily be below the current BFE. If that building was elevation-rated today like a post-FIRM building, the flood insurance premium would be quite high; however, when creating the NFIP in 1968, Congress allowed owners of pre-FIRM buildings to receive subsidized rates of 40-50% of the true rate. While Congress may have felt that over time the number of these buildings would decline to an insignificant number, as of 2013, close

[4] Nationally, 25% of the claims and about one-third of federal disaster claims are from moderate-low risk areas.

to 20% of the NFIP policies were on pre-FIRM buildings in high-risk areas, with that number being well over 50% in Illinois.

NFIP reform legislation passed by Congress in 2012 and 2014[5] had a focus on creating a more financially stable NFIP with one of its goals being the eventual removal of all subsidized rates. Consequently, implementation of the legislation has had an impact on premiums, especially pre-FIRM businesses and pre-FIRM non-primary residences as their rates increase 25% annually until they reach full-risk rate (i.e., elevation-rated) [6]. Even pre-FIRM primary residence rates are expected to increase each year by about 15% (a cap that HFIAA placed on annual rate increases). The long-term financial impact on a homeowner and business owner could be quite substantial.[7]

Table 7.1: Comparison of premiums ($200,000 residence on slab; $80,000 contents; Zone AE; April 2015 rates)

Difference Between Lowest Floor and Base Flood Elevations	Annual Elevation-rated Post-FIRM Premium (without HFIAA Surcharge)	Annual Pre-FIRM Premium (without HFIAA Surcharge)
+4'	$528	$3,296
+3'	$561	$3,296
+2'	$649	$3,296
+1'	$921	$3,296
0'	**$1,874**	**$3,296**
-1'	$4,376	$3,296
-2'	$6,371	$3,296
-3'	$8,316	$3,296

Strategies for Increasing Affordability of NFIP Flood Insurance

With the passage of the two reform bills, the cost of flood insurance for many has and will increase significantly both in Illinois and nationwide. As a result, affordability has become more of an issue, especially for the low or fixed income households, especially since the NFIP requires 100% of the annual premium paid at inception and by each subsequent renewal date (i.e., no premium payment plan). While Congress has asked FEMA to study methods to make flood insurance more affordable (the first of two reports was released March 2015), recommendations have already come from academia, associations and the Federal Government (Government Accountability Office). These have included:

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[5] Biggert-Waters Flood Insurance Reform Act of 2012 (Biggert-Waters); Homeowner Flood Insurance Affordability Act of 2014 (HFIAA)

[6] Included in HFIAA was a new HFIAA surcharge for all policies to financially balance out the new longer path pre-FIRM buildings would take to reach full-risk rates. An annual HFIAA surcharge of $25 for primary residences and $250 for all other buildings will be applied to all policies until all subsidized rates are eliminated. While this results in an additional financial burden to pre-FIRM secondary homes and business in high-risk areas whose rates are doubling every four years under the new legislation, there is also concern that those who voluntarily purchased flood insurance in the moderate-low risk areas (i.e., PRP) may drop their policy entirely.

[7] Using the example premiums in Table 1, a pre-FIRM primary residence's premium with a -3-foot difference in elevation has an equivalent full-risk (elevation-rated) premium today of $8,316. If the full-risk premium increases at 10% annually (for example) and the current pre-FIRM premium increases at 15% annually, the policy will finally reach the equivalent full-risk premium of about $61,500 in 21 years.

1. Create a voucher program that is independent of FEMA, funded by taxpayers, and based upon need; i.e., means-tested, like U.S. Department of Housing and Urban Development's (HUD's) Housing Choice Voucher program
2. Lower insurance premiums through mitigation efforts; e.g., elevate, install proper flood openings in enclosures, relocate the building. Sources of funding for these efforts potentially include: Small Business Administration Disaster loans, NFIP policy's Increased Cost of Compliance (ICC) coverage, FEMA's Hazard Mitigation Assistance Grant Program, HUD's Community Development Block Grants, and possible state tax credits for approved mitigation efforts
3. In-tandem use of vouchers and loans for mitigation efforts to more quickly and cost-effectively reduce risk and the cost of insurance
4. Provide a community-based rebate program for qualifying mitigation projects,
    a. Many Illinois communities offer a maximum $2,500 rebate for approved projects
5. Provide state-established low interest mitigation loans
    a. The State of Connecticut offers low-interest loans to coastal homeowners and small business up to $300,000 in their *Shore-Up Connecticut* program.
6. Adopt state floodplain regulations which require additional height above the BFE for new and substantially damaged/improved buildings. This not only reduces the risk and the rate, but communities participating in the Community Rating System (CRS) program (see Chapter 8 for additional CRS discussion) get credits, which could ultimately increase the discount policyholders receive.
7. Promote CRS more strongly, not only to existing communities to improve their class ranking and to communities in the CRS program.
    a. Currently, the highest discount offered to policyholders in high-risk areas in Illinois is 25%; the highest possible is 45%
8. Promote the use of HUD's FHA 203K Loan for mitigation projects. The Section 203(k) Program is the primary program for the repair and rehabilitation of single family properties and can be used for mitigation projects as long as the structure is not demolished.
9. Set up insurance policy funded state insurance pools for flood mitigation or catastrophic losses

Strategies for Increasing Awareness of Water/Sewer Back-Up and Flood Insurance

Flood insurance and water/sewer back-up insurance is readily available in Illinois. For less than $100 a year, homeowners can get some financial protection for water/sewer back-up damages and less than $200 a year get some coverage for flood damages (in moderate-low risk areas). The challenge is educating residents and business owners not only about the risk and the consequences, but what their options are to reduce the risk (and the cost). FEMA has a national marketing campaign (FloodSmart) that helps educate the property owner about their flood risk and the benefits of flood insurance. They also focus on educating the agents and other stakeholders (i.e., floodplain and stormwater managers) and providing them tools to help better communicate the risk of flooding. The State of Illinois could explore utilizing what FloodSmart does and modify the message to include urban flooding. The state could also launch an Illinois Flood Awareness week in conjunction with the National Flood Awareness Week (typically in March) to promote not only the awareness of the risk of flooding, but also the availability of these coverages.

At the local level, while an insurance agent should always offer their clients flood insurance and water/sewer back-up coverage to those with basements, there is no state or federal requirement to do so. To increase awareness of the availability and importance of these two coverages (and that the policy does not include either of these coverages), all insureds could be required by state law to sign a waiver that they did not want either coverage. In addition, an insert could be included in the policy mailing to highlight that the policy does not provide either of those coverages. While there are insurance companies and agents that do one or both of these, it is not universally done.

Research shows that a campaign is more successful when the intended audience hears the message from different sources. Increasing awareness of the risk of urban flooding is no different; it's a shared responsibility.

Recommendations

1. The Illinois General Assembly should allow the Illinois Department of Insurance to mandate continuing education specific to flood insurance for insurance agents.
2. The Illinois General Assembly should fund a state agency to develop an awareness campaign about the risks associated with urban flooding and options available for flood reduction and recovery. An educational flyer should be developed to provide to home buyers at closing. This flyer should provide basic information and resources on flood insurance, sewer backup insurance, flood mitigation, and available programs. Another flyer should be developed to inform renters of insurance coverages available to them. Education and outreach could also include a Flood Awareness week in conjunction with the National Flood Awareness Week.
3. The Illinois General Assembly should fund research to determine if lower income households have adequate private basement backup and flood insurance as they appear to have fewer private insurance claims than higher income households. If affordability is an issue with private basement coverage or flood insurance, incentive programs and insurance pools used by other states should be investigated.
4. Illinois' congressional delegation should encourage FEMA to consider state-based flood insurance underwriting to more accurately reflect flood loss history in Illinois and establish actuarial premiums within Illinois.
5. The Illinois Department of Natural Resources and Illinois Environmental Protection Agency should collaborate to appropriately expend portions of the state revolving fund for implementation of stormwater management measures.

Chapter 8: Strategies for Increasing Participation in the National Flood Insurance Program (NFIP) and Community Rating System (CRS)

Key Findings

- Nearly 87% of Illinois communities participate in the Federal Emergency Management Agency's National Flood Insurance Program (NFIP), or 877 communities. This is one of the highest levels of NFIP participation in the nation.
- Fifty-nine Illinois communities participate in the NFIP's voluntary Community Rating System (CRS) program and property owners in those communities receive flood insurance premium discounts. More Illinois communities should participate in the CRS.
- Illinois communities are able to achieve better CRS classification compared to much of the country due to (1) state efforts to reduce flood damages, (2) countywide stormwater management efforts in regions of the state, and (3) individual community initiatives.

As discussed in the Chapter 7, the NFIP makes federally-backed flood insurance available to property owners and residents within participating counties and municipalities. The Community Rating System (CRS) is a program within the NFIP that offers flood insurance premium discounts to communities for flood damage reduction activities that go above or beyond the minimum requirements of the NFIP. The NFIP and the CRS are administered by FEMA in coordination with the NFIP State Coordinator within the Illinois Department of Natural Resources, Office of Water Resources (IDNR-OWR).

Special Flood Hazard Areas (SFHA) and Flood Zones

Each community in the NFIP is provided with a Flood Insurance Rate Map or FIRM that identifies flood risk and shows the Special Flood Hazard Area (SFHA). The SFHA is shown on the FIRM as the area where a 100-year flood is likely to occur. This does NOT mean a flood will occur only once every 100 years. Rather, there is a 1% chance that flooding can occur in any given year within the SFHA. A 1% annual chance flood can occur in consecutive years, or twice in ten years, and so on.

The SFHA is generally the "A Zone" and the rest of the community outside the SFHA is generally an "X Zone" since flooding and significant flood damage can occur elsewhere in the community. Flood insurance is available in all flood zones, and as discussed in Chapter 7, the purchase of flood insurance with a federally backed mortgage in A Zones (i.e., SFHA) is required.

National Flood Insurance Program (NFIP)

The NFIP provides flood insurance to property owners while also requiring certain flood damage reduction activities by communities. Both the insurance aspects and the regulatory requirements of the NFIP are efforts to reduce taxpayers' burden for recovery from flood damage to buildings and building contents. Appendix I provides information about the NFIP and how communities can join the program.

Through a community's participation in the NFIP, flood insurance coverage is made available to *all* property owners and residents throughout the community. The NFIP requires communities to adopt and enforce certain minimum floodplain regulations to reduce damage to buildings in the Special Flood Hazard Area (SFHA). One of the minimum requirements is the lowest floor elevation, including the basement or crawlspace, must be at or above the base flood elevation (BFE) for all new construction or substantial improvement of existing building with in the SFHA. The NFIP requirements can be found in Chapter 44 of the Code of Federal Regulations (44 CFR).

NFIP Participation in Illinois

Almost 87% of Illinois communities participate in the NFIP, or 877 communities. This is one of the highest levels of NFIP participation in the nation. An NFIP community means both counties and municipalities. All DuPage County municipalities participate in the NFIP. In other urban counties, all except one or three municipalities in each county participate in the NFIP.

Floods and Flood Damage

Flooding along rivers and streams, and around lakes, is natural. The floodplain is nature's designated area to store and convey flood waters in any season of the year. The flood damage that occurs within the SFHA is due to buildings and infrastructure being placed within the SFHA. Urbanization increases the amount of floodwater that rivers and streams must convey (and floodwater the SFHA must store) – and increases the frequency that floodwater conveyance and storage is needed.

The Community Rating System (CRS)

The NFIP's Community Rating System (CRS) was created in 1990 and has three goals:

- Reduce and avoid flood damage to insurable property,
- Strengthen and support the insurance aspects of the NFIP, and
- Foster comprehensive floodplain management.

The CRS is a voluntary program. NFIP-compliant communities may participate in the CRS provided they meet several prerequisites. The CRS credits communities who implement floodplain and watershed management programs that exceed the minimum requirements of the NFIP. Communities can also receive credit for state and/or county programs. The number of CRS credits determines a community's CRS class, and NFIP flood insurance premium rates are discounted based the CRS class. Table 8.1 shows the CRS classes and the premium discounts for buildings located in and outside the SFHA. Class 1 requires the most credit points and gives the greatest premium reduction or discount. NFIP communities who do not participate in the CRS are Class 10 communities. The CRS rates a community for its current flood damage reduction efforts, and also provides incentives (i.e., flood insurance premium discounts) for additional flood damage reduction activities at the community, county and state levels of government.

The CRS program is "revenue neutral." This means that flood insurance premium discounts given within one community are flood insurance premium increases in another community. In 2014, the total CRS premium discount across the nation was around $330 million. In simple terms, based on the number of flood insurance policies around the county, a CRS Class 8 community is the revenue-neutral level, and the flood insurance policy holders in Class 10 and Class 9 communities pay for the discounts provided to Class 7 through 1 communities. This means communities who implement higher regulatory standards than the NFIP minimums and perform other flood damage reduction activities should join the CRS to avoid paying for discounts in other communities across the nation.

Table 8.1: CRS Classes, Credit Points and Premium Discounts.

CRS Class	Credit Points	Premium Reduction	
		In SFHA	Outside SFHA*
1	4,500+	45%	10%
2	4,000–4,499	40%	10%
3	3,500–3,999	35%	10%
4	3,000–3,499	30%	10%
5	2,500–2,999	25%	10%
6	2,000–2,499	20%	10%
7	1,500–1,999	15%	5%
8	1,000–1,499	10%	5%
9	500–999	5%	5%
10	0–499	0	0
Preferred Risk Policies and minus-rated policies are not eligible for CRS premium discounts.			
Source: *CRS Coordinator's Manual*, FEMA, 2013			

CRS communities are provided points or credit for implementing any of 19 creditable activities, organized in the four categories of public information (300 Series), mapping and regulations (400 Series), flood damage reduction (500 Series), and flood warning and response (600 Series). Most credits are for a community's floodplain management efforts within the SFHA; however, communities are encourages and are credited for the management of other flood prone areas and watershed areas. Also, many activities apply to and benefit the entire community, such as public information, preserving open space, stormwater management regulations, and flood warning and response. Most of the strategies presented in Chapter 7 can be eligible for CRS credit within one or more of the CRS creditable activities.

The CRS program and the CRS activities are presented in the CRS Coordinator's Manual (Manual). The Manual includes formulas and adjustment factors used to calculate credit points for each activity. A list of the creditable activities is included in Appendix I, and credits for community efforts within and outside the SFHA are noted.

Current CRS Participation Illinois

As of May 2015, 59 Illinois communities participate in the CRS, or about 6% of Illinois' NFIP communities. Only five other states have more communities participating in CRS (Florida, California, North Carolina, New Jersey and Texas). Figure 8.1 shows the location of Illinois communities that participate in the CRS.

Figure 8.2 shows the CRS participation and the CRS classifications in the nation and in Illinois. Six percent is the national average for NFIP community participation in the CRS, yet within the 6% of NFIP communities is 67% of the NFIP insurance policy base. This means that the majority of communities with the highest risk of flood damage across the country participate in the CRS discount in order to receive flood insurance premium discounts. Illinois communities are able to achieve better CRS classification compared to much of the country due to (1) state efforts to reduce flood damages, (2) countywide stormwater management efforts in regions of the State, and (3) individual community initiatives.

While the CRS is a community-based and community-driven program, state activities and initiatives can translate into CRS credits for communities provided the activities are enforced within the community. Table I.6 in Appendix I shows the CRS credit opportunities for communities based on IDNR-OWR programs.

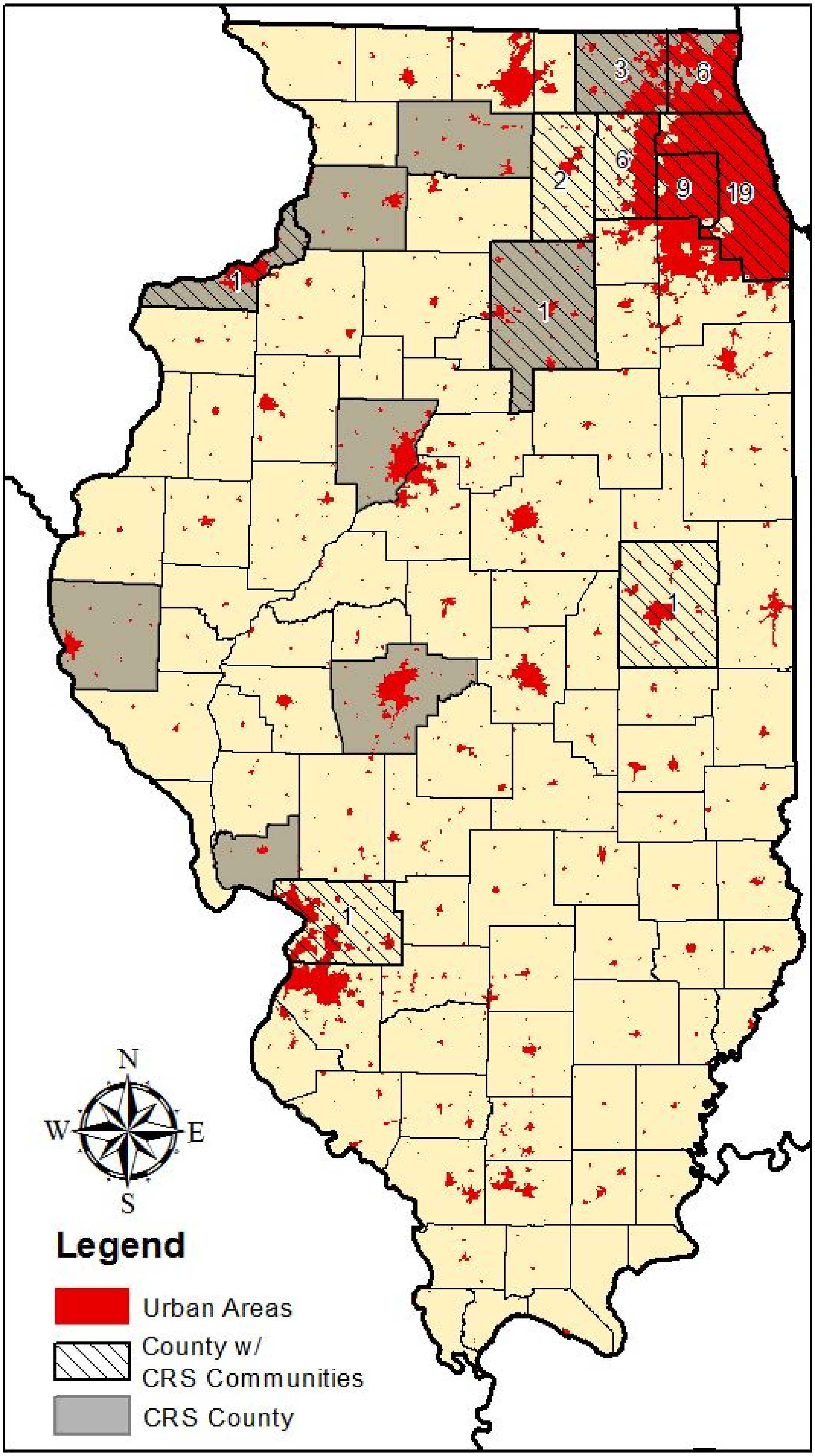
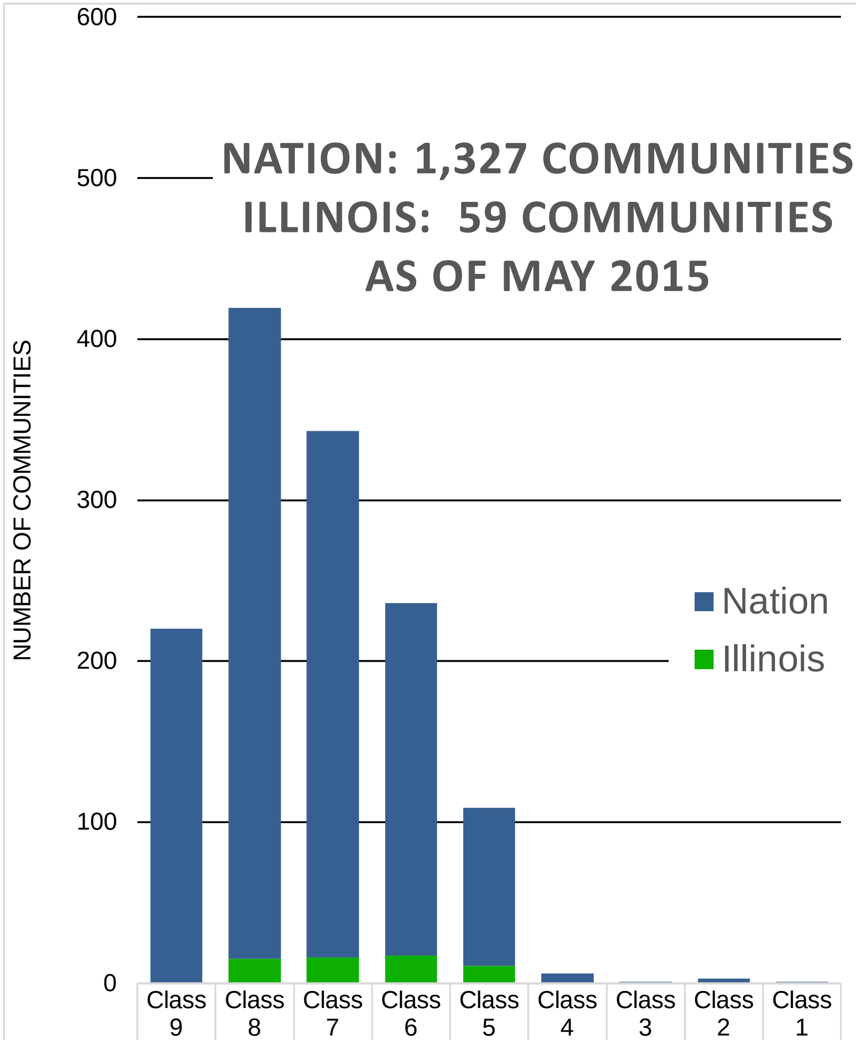


Figure 8.1: Location of Illinois communities that participate in the CRS.

Benefits of CRS Participation

Besides the benefit of reduced insurance rates, CRS floodplain and watershed management activities enhance public safety, reduce damages to property and public infrastructure, avoid economic disruption and losses, reduce human suffering, and protect the environment. CRS requires community staff time. However, when many of the CRS activities are already part of a community's ongoing services, the documentation and certification requirements can be incorporated into normal operating routines. CRS also helps to organize community incorporate flood damage reduction efforts into a comprehensive program.

While CRS credits focus on efforts within the SFHA, numerous activities benefit residents and property owners throughout the community. Community public information efforts (printed materials or websites) about floods and the potential for flood damage can reach the entire community. Protecting open space within the floodplain benefits everyone. Proper administration of building codes protects all buildings from flood damage. Effective flood warning and response programs reach floodplain residents, and also inform people that travel to work or school. More information on these activities, along with information on how a community applies for CRS participation is included in Appendix I.



	Class 9	Class 8	Class 7	Class 6	Class 5	Class 4	Class 3	Class 2	Class 1
Nation	220	472	327	219	98	6	1	3	1
Illinois	0	15	16	17	11	0	0	0	0

Figure 8.2: CRS participation and the CRS classes in the nation and in Illinois.

Table 8.2 provides a summary of flood insurance policies, the total annual premiums paid and the saving in premium rates achieved by Illinois' CRS communities. Over 13,000 flood insurance policy holders in Illinois benefit from the CRS. Over $1.9 million in flood insurance premium discounts or savings is provided to policy holders by Illinois community CRS participation.

Table 8.2: Policies, Premiums and CRS Savings for CRS Communities in Illinois.

Flood Insurance in Force	Flood Insurance Premiums Paid	CRS Total Premium Discount (or Savings)
13,090 Policies	$11,550,023	$1,909,075

Source: FEMA, as of May 2014

Strategies for Increasing NFIP and CRS Participation

Illinois community participation in the NFIP is very high. IDNR-OWR should continue to promote NFIP participation. No changes in IDNR-OWR current approach regarding NFIP participation is recommended in this report. IDNR-OWR and FEMA encourage community participation in the CRS with available staff and other resources. The following recommendations are aimed at improving Illinois community participation in CRS and for improving CRS classifications for current CRS communities.

Recommendations

1. Illinois' congressional delegation should encourage FEMA to allow Community Rating System (CRS) points for state flood damage reduction programs.
2. Illinois' congressional delegation should request that FEMA modify and expand their national CRS training to include Illinois-specific training.
3. Communities and counties participating in CRS should participate in the Illinois Association of Floodplain Managers (IAFSM) CRS users group.
4. Non-CRS municipalities should consider using CRS principles in stormwater management to make their communities more resilient.
5. The Illinois Department of Natural Resources should expand CRS resources to improve CRS outreach to communities as funding from FEMA is available.

Chapter 9: Strategies for Minimizing Damage to Property from Urban Flooding

This chapter provides information on strategies for minimizing damage to property from urban flooding, with a focus on rapid, low-cost approaches, such as non-structural and natural infrastructure, and methods for financing them.

The three most common types of urban flood damage reported in the survey of Illinois community officials (see Appendix B) are basement water seepage, basement sewer backup and water coming in through basement windows. Urban flooding is known to cause numerous public health and safety concerns, such as mold and sewage contamination in homes, and limited emergency vehicle access on city streets. Selecting appropriate strategies to reduce urban flood damages requires knowledge of the cause of the urban flooding.

Key Findings

- The three most common types of urban flood damage reported in the survey of Illinois community officials (see Appendix B) 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 level.
- There are a number of flood damage reduction strategies that can be used to reduce damages experienced by property owners, including many that are low cost. Identification of the source of flooding is fundamental to successfully mitigating future damages.
- Education and outreach on identification of root causes is 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 a neighborhood or community scale.
- Illinois' Residential Real Property Disclosure Act provides a comprehensive list of material defects that must be disclosed when property is sold.
- A home rule municipality stormwater utility program assesses a fee to all those who benefit from the stormwater infrastructure and services provided. Dedicated stormwater program fees provide a stable, dedicated source of funding.

Green and Gray Infrastructure

Strategies to reduce urban flooding are often described as either gray or green infrastructure. Gray infrastructure is used to describe traditional engineering methods including storm sewers and detention ponds—built systems employed to collect runoff and discharge it quickly through the system. Green infrastructure is used to describe methods that utilize the natural functions of soil infiltration, evaporation and transpiration, emphasizing the reduction of rainfall runoff where it is produced. Green infrastructure techniques common in Illinois include rain gardens, downspout disconnection, bioswales, stormwater trees, permeable pavement, and green roofs.

Typical stormwater management systems are based on traditional gray infrastructure solutions, such as road gutters, storm sewers, and retention ponds. Most urban communities have design requirements for these systems (see Chapters 4 and 5). Stormwater infrastructure designed to modern standards most often performs acceptably for many years. Capital projects for replacement of gray infrastructure are costly and, due to funding constraints, many communities cannot prioritize addressing appropriate maintenance needs of these systems until they fail.

> "The City is working hard to improve our aging infrastructure, but there are 4,400 miles of sewer main in Chicago, and mere replacement is not the answer. The key is to keep as much water out of the sewer as possible during the heaviest rains."
>
> City of Chicago Basement Flooding Partnership website

Green infrastructure has several advantages over traditional gray infrastructure as well as its own limitations. Prompted by the Clean Water Act and the regulation of post-construction stormwater quality, communities are already looking to green infrastructure to achieve multi-objective benefits. In 2009, the Illinois Environmental Protection Agency (IEPA) submitted several recommendations concerning green infrastructure as required by Public Act 96-26, and reported that green infrastructure is effective in achieving stormwater quality goals as well as being cost-effective when compared to other methods (Jaffee, 2009). Recent green infrastructure pilot projects completed across the country continue to support the cost saving benefits of using green infrastructure (Copeland, 2014). Most green infrastructure projects will have some impact on reducing stormwater runoff and the result can be significant in some cases. Several green infrastructure resources are available via the IEPA. The primary limitation of green infrastructure for urban flood reduction is the dependence on soil conditions. Once the soil is saturated, the excess runoff may still need to be controlled by gray infrastructure to avoid flood damages. Successful use of green infrastructure relies on several site-specific parameters including drainage area, groundwater table levels, soil type, ground slope and performance of maintenance. Green infrastructure is often less costly, but when used in areas that are already urbanized, successful green infrastructure projects may still require engineering design. Green infrastructure will be most successful addressing urban flooding caused by more frequent lower volume rainfall events and should be part of a comprehensive plan to reduce volume entering over-taxed drainage systems (Schueler et al, 2007).

Neither green nor gray infrastructure should be considered a single solution to urban flooding. Gray infrastructure is costly and does not typically address the reduction of stormwater runoff volume. Green infrastructure has the ability to reduce runoff volume but due to the influence of location-specific parameters, its potential to reduce urban flooding damages is difficult to evaluate on a large scale.

Single Property Flood Reduction Strategies

There are a number of flood damage reduction strategies that can be used by property owners, including many that are low cost. Identification of the source of flooding is fundamental to successfully mitigating future damages. Educating property owners about their flood risk is essential to correctly address property-specific flooding problems. Coordination with the local community officials is often required to identify and confirm the most appropriate flood reduction strategy.

Common Causes and Mitigation Options

A particular structure may experience "flooding" when storm runoff enters a structure as overland flow, infiltration, or sewer backup. Figure 9.1 identifies several of the typical ways water can enter a basement. Table 9.1 lists mitigation measures.

Table 9.1: Summary of basement flood risk reduction options to address damages on site.

	Cause of Flooding				
Mitigation Options	**Overland**	**Infiltration**	**Sewer backup**	**Damage reduction**	**Estimated Cost**
Structural Inspection					$250-$800 each
Raise utilities and other valuable items				x	
Insurance				x	Based on coverage
Gutter maintenance	o	x	o		
Downspout disconnection			x		
Site grading, downspout extension	o	x			
Rain gardens	o				$3-40 per square foot
Permeable/porous pavement	x				$2-$10 per square foot
Exterior drain tile		x			$185 per foot
Interior drain tile		x	x		$40-50 per foot
Seal wall and floor cracks		x	o		$300-$600 each
Sump pump with check valve	x	x	x		$400-$1,000 each
Sewer backup valves			x		$3,000-$5,000
Overhead sewer installation			x		$2,000-$10,000
x - primary reduction o - secondary reduction					

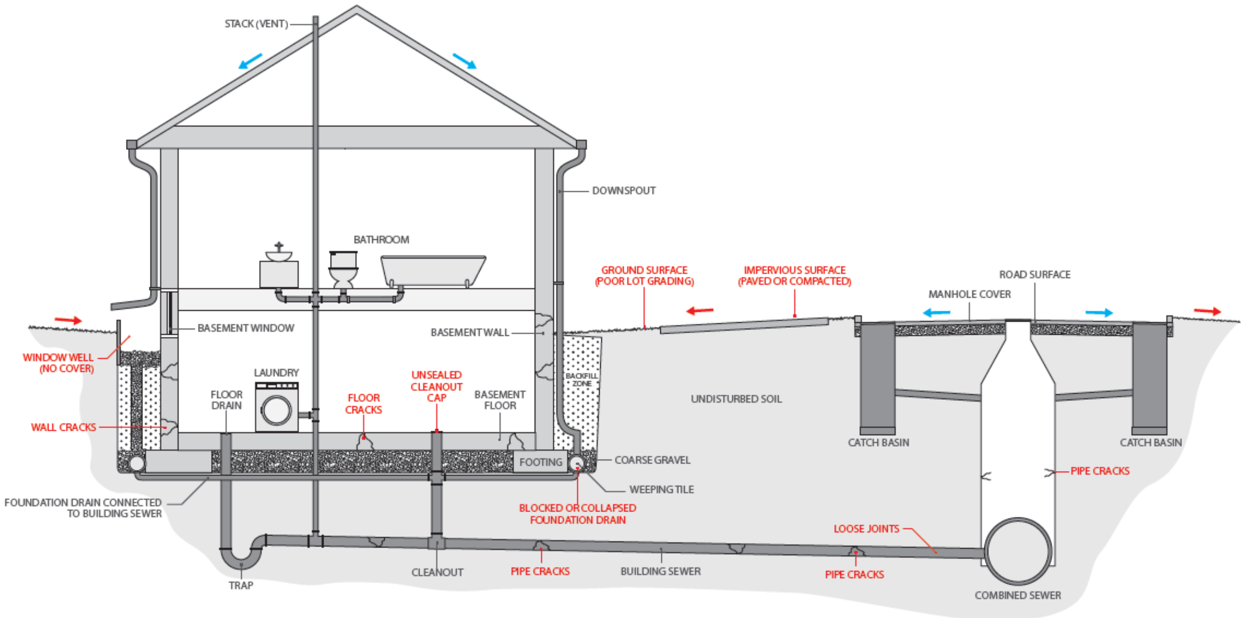


Figure 9.1: Types of urban flooding that can affect a residence. (Credit: Modified from Institute for Catastrophic Loss Reduction, 2009)

Educating Property Owners

Homeowners are often not prepared to evaluate the root cause of flooding and take action to mitigate. While several resources are available online that provide information on identification of problems and appropriate strategies for prevention and maintenance that may assist homeowners in evaluating their flood risk, such as the “Guide to Flood Protection in Northeastern Illinois” (IAFSM, 2006), additional tools and information specific to the local area are needed to reduce flood losses. Education and outreach on identification of root causes is necessary to empower homeowners to solve flooding issues that can only be addressed on their property. Some communities, such as the City of Wheaton, offer drainage reviews for their property owners free of charge, but many communities do not have the resources for such a program. “RainReady Home” (CNT, 2015) is a Center for Neighborhood Technology program that addresses this missing link and, upon completion of the preliminary phase, should be evaluated to document best practices for community response and outreach to urban flooding.

Limitations and Consequences to Reporting Flooding

Evaluation of flood risk should begin at the time of purchase of a property and continue over the ownership of the property. However, flood disclosure laws have gaps, and there is not always a mechanism to disseminate certain historical information. Unlike the Flood Insurance Rate Maps produced by FEMA for riverine flooding, there is not a similar risk evaluation tool for urban flooding issues.

The State of Illinois requires disclosure at sale of the seller’s knowledge of material defects to the property. Basement flood disclosure to renters is not explicitly required but is implied in the requirement to disclose any latent basement defect that would make it unfit for occupancy. Illinois' Residential Real Property Disclosure Act provides a comprehensive list of material defects that must be disclosed when property is sold. However, there is hesitancy on the part of property owners to report or disclose flooding issues typically due to a concern that it would lessen the property value. Renters are often uninformed of their risk. There are multiple consequences of not reporting flood issues: new owners do not have the information to mitigate potential flooding and may be caught unaware; renters may experience unexpected losses; communities do not have complete information to develop plans. The issue of communities disclosing full knowledge of historical or studied risk is controversial and has legal repercussions on both sides of the issue.

(765 ILCS 77/35The Residential Real Property Disclosure Act Sec. 35. Disclosure Report Form Excerpts

2. I am aware of flooding or recurring leakage problems in the crawl space or basement.
3. I am aware that the property is located in a flood plain or that I currently have flood hazard insurance on the property.
4. I am aware of material defects in the basement or foundation (including cracks and bulges).
8. I am aware of material defects in the plumbing system (includes such things as water heater, sump pump, water treatment system, sprinkler system, and swimming pool).

Community Level Flood Reduction Strategies

Other causes of urban flood damages must be mitigated at a neighborhood scale with assistance from the community. At this scale, urban flooding is the result of inadequate storm sewer maintenance or overland drainage patterns, and the community is in the best position to implement reduction strategies.

Solving community-level flooding issues can be achieved with some of the same methods, including runoff volume reduction and drainage system maintenance, used for private property but on a larger scale within the context of a comprehensive plan. Successful strategies for communities addressed here are not focused on a specific engineering analysis, which must be determined locally, but rather provide a framework to support local solutions to urban flooding. These strategies include planning, regulation, public-private partnerships and financing. Development of a comprehensive stormwater management plan is a key component in reducing urban flood damage at a neighborhood or community scale, just as it is critical for utilizing green infrastructure and addressing water quality issues (Kramer, 2014; American Rivers et al., 2012). Examples of successful community-based programs at the county level are provided in Chapter 4. These examples demonstrate the success of countywide stormwater authority and programs.

Communities can support sustainable growth economically with municipal regulations that incorporate the stormwater management goal of minimizing runoff volume and thereby reducing urban flooding. Communities should plan for flood routing and prioritize protecting areas of open space with high infiltration and runoff reduction value. The largest communities in Illinois already have stormwater ordinances regulating new development, but many of these could be updated to incorporate more sustainable, low impact development practices and to encourage green infrastructure methods.

Examples of low impact development regulations to address urban flooding issues are listed below.

- Incorporation of green infrastructure practices into stormwater regulations for development
- Maximum parking space requirements rather than minimum parking space requirements; reduce minimum road width to reduce impervious area
- Increase setbacks, increase landscaping requirements, add maximum lot coverage
- Requirement of holding first inch of rainfall
- Encourage re-development rather than new development

Communities should review local regulations to ensure current requirements are not limiting stormwater infiltration and green infrastructure practices. The Center for Watershed Protection published a Code and Ordinance Worksheet to evaluate how supportive a community's regulations are toward sustainable development. The adoption of International building codes (I-codes) assists communities by ensuring structures meet NFIP requirements through the flood provisions incorporated in the code, and providing consistent regulations.

In addition to regulation of new development, there is a need to address stormwater solutions in urban areas that are being redeveloped. Redevelopment can create more urban flooding if an appropriate plan is not in place to use the opportunity to reduce flooding. The Watershed Management Ordinance adopted in Cook County and the DuPage County Stormwater Ordinance requires runoff reduction in redevelopment areas. Additional local regulations can be enacted to address existing plumbing cross connections that direct stormwater into sanitary sewer systems with required inspection prior to closing of a home sale or building permit. However, often regulations do not utilize the opportunity to address urban flooding issues during redevelopment.

In some urban flood areas, public-private partnerships offer an opportunity to address historical flooding areas with solutions on private property. Community cost sharing programs encourage private property owners to implement runoff reduction measures that benefit the property owner and the neighborhood or "sewer-shed." Cost share programs are often used to address limited capacity sewer systems that easily become overwhelmed and back up into basements. These programs have been successful in reducing urban flood damages in communities such as Niles, Northbrook and Wheaton, which offer 50% grant funding to their residents up to $3,000 to $5,000. These programs benefit home owners and are often less expensive for the community than a larger capital improvement project. Program details from the City of Ottawa and the City of Bloomington have been included in Appendix J. The City of Chicago Basement Flooding Partnership (BFP) is a public private partnership that does not require financial contribution from residents and has a large focus on outreach and education.

Flood Routing of Excess Storm Runoff

Flood Route: "A designated strip or piece of land that will receive excess surface runoff not accommodated by storm sewers or other drainage facilities to provide conveyance through developed areas so as to minimize adverse effects of flooding. A flood route shall be provided through the proposed development. The flood route shall be designed for the runoff expected from a 100 year storm frequency in post development conditions or pre development conditions, whichever generates higher flow. Flood Routes shall be located in either public right-of-way, or a dedicated public drainage easement of sufficient width to contain and maintain the channel."
- City of Bloomington flood route requirement for new development

Financing Options

To combat urban flooding and support education and outreach to property owners experiencing flooding, a community must have funding to address local urban flooding issues. While some communities have a dedicated source of funding for stormwater management, many Illinois communities finance stormwater management initiatives out of general revenues at a project level without a consistent source of funding (Appendix B and Appendix C). USEPA recommendations for financing the increasing cost of stormwater management include:

- service fees (often stormwater utilities)
- property taxes/general funds, sales tax,
- special assessment districts,
- system development charges,
- municipal bonds and state grants, and
- low interest loans. (USEPA, 2009).

Table 9.2: Communities with utility fee assessments

Community	Fee Assessment	Year
Aurora	$3.45	1998
Bloomington	$4.35	2004
Champaign	$5.24	2012
Decatur	$3.67	2014
Downers Grove	$8.40	2012
East Moline	$2.61	2009
Freeport	$4.00	
Highland Park	$4.50	
Hoffman Estates	$2.00	2014
Moline	$3.75	2000
Morton	$4.74	2005
Normal	$4.60	2006
Northbrook	$9.00	
Palatine	$5.00	
Rantoul	$3.43	2001
Richton Park	$5.63	
Rock Island	$3.95	2002
Rolling Meadows	$3.36	2001
Tinley Park	$1.68	1983
Urbana	$4.75	2013
Winnetka	$29.67	2014

Consistent funding at an appropriate level enables communities to create stormwater management positions dedicated to comprehensive planning and education and outreach to accomplish urban flood risk reduction.

In recent years, there have been increases in the number of communities enacting stormwater utilities. Illinois still has fewer stormwater utilities than many neighboring Midwestern states (Campbell, 2013). Table 9.2 lists 21 communities with utility fee assessments.

Home-rule and non-home rule communities in Illinois have established stormwater utility programs. Article VIII, Section 6 of the Illinois Constitution established home-rule communities and enables implementation of stormwater fees. Home-rule communities have a more direct path to establishing stormwater utility programs, but non-home rule communities have set up stormwater utilities though they have not yet been challenged. The Illinois Municipal Code allows communities to operate utilities (CMAP, 2013), and townships also have the ability to create a stormwater program and assess a user fee per Public Works Statutes, Article 205 of the Township Code in the Illinois Compiled Statutes

(60 ILCS) (Tri-County Regional Planning Commission, 2013). A Tri-State stormwater utility feasibility study determined that, per 55 ILCS 5/5-1062.3, DuPage and Peoria Counties are able to create stormwater programs and assess fees only if approved by a voter referendum (TCRPC, 2013). The remaining counties in Illinois are currently more limited as the Public Works Statute does not include separate storm sewers.

The USEPA currently provides funds to the State of Illinois for the Clean Water State Revolving Fund, which provides low interest loans for projects that assist with meeting the Clean Water Act goals and better the quality of the watershed (USEPA, 1999). Borrowers include municipalities, communities, businesses, homeowners, and not-for-profit organizations.

While many projects reducing stormwater runoff may already meet the requirements for loans under the Water Pollution Control Loan Program, recent federal legislation expands authority to finance stormwater projects. These new authorities outlined in the Water Resources Reform and Development Act (WRRDA) of 2014 have not yet been adopted by the State of Illinois. Collaboration is required between the Illinois Department of Natural Resources and Illinois Environmental Protection Agency to appropriately expend portions of the state revolving fund for implementation of stormwater management measures.

Water Resources Reform and Development Act of 2014

Title V: Water Infrastructure Financing - Subtitle A: State Water Pollution Control Revolving Funds - (Sec. 5001) Amends the Federal Water Pollution Control Act (commonly known as the Clean Water Act [CWA]) to grant the EPA Administrator general authority to make capitalization grants to states to establish a water pollution control revolving fund to accomplish the objectives, goals, and policies of such Act.

Recommendations

1. The authority to generate revenue from fees, to plan, implement and maintain stormwater management/drainage programs/facilities should be granted to all County Stormwater Planning and Management Agencies (55 ILCS 5/5-1062), counties (55 ILCS 5/Div. 5-15) and municipalities regardless of home rule status.
2. Stormwater Planning and Management authority should be granted to all Illinois counties to adopt countywide stormwater ordinances, projects and programs.
3. The State should provide an annual funding stream for Illinois Department of Natural Resources to buy out both floodplain and urban flood prone repetitive flood loss properties statewide to reduce flood damages and create open space parcels, with deed restriction in perpetuity. The State should provide grants or revolving loan opportunities to communities to support local cost sharing programs for residents impacted by urban flooding for the implementation of mitigation activities.

4. The State should provide grants or revolving loan opportunities to communities to support implementation of local cost sharing mitigation programs for residents impacted by urban flooding, to evaluate stormwater system capacity and flood risk, and to encourage stormwater management planning.
5. Communities should investigate existing property evaluation programs to help homeowners analyze their homes for urban flooding potential and to identify flood damage reduction actions.
6. Communities should consider adoption of ordinances to address drainage for below-grade construction, such as requiring sewers to exit structures within 2 to 3 feet of the finished exterior grade of buildings. Adoption of International Building Code Sections R405 and R406 for foundation drainage and waterproofing should also be considered.
7. The Illinois Department of Natural Resources and Illinois State Water Survey should develop a state model local stormwater ordinance based on concepts in the report which can be used as a template by counties and local communities. The following should be included along with other actions to address urban drainage issues:
    a. Incorporate green infrastructure into municipal and county development regulations by modifying regulations that restrict use of green infrastructure and add regulations to encourage use of green infrastructure in capital improvement projects when possible.
    b. Stormwater infiltration, evapotranspiration and storage should be incorporated into new development and redevelopment wherever possible.
    c. Developers and property owners should be incentivized to dedicate property for increased open space in developing areas, and current open space should be protected to allow for evapotranspiration, infiltration and stormwater storage.
    d. Require a licensed plumber to inspect for sump pump and downspout connections to sanitary sewers when houses are sold.
8. The Illinois Department of Natural Resources and Illinois Environmental Protection Agency should collaborate to appropriately expend portions of the state revolving fund for implementation of stormwater management measures.
9. The State of Illinois should incorporate green infrastructure options in state funded capital improvement projects when practical.

Urban Flooding Awareness Act Report Recommendations

Illinois General Assembly

1. The authority to generate revenue from fees, to plan, implement and maintain stormwater management/drainage programs/facilities should be granted to all County Stormwater Planning and Management Agencies (55 ILCS 5/5-1062), counties (55 ILCS 5/Div. 5-15) and municipalities regardless of home rule status. (Chapters 4 and 9)
2. Stormwater Planning and Management authority should be granted to all Illinois counties to adopt countywide stormwater ordinances, projects and programs. (Chapters 4 and 9)
3. The Illinois General Assembly should allow the Illinois Department of Insurance to mandate continuing education specific to flood insurance for insurance agents. (Chapters 1 and 7)
4. The State should fund the Illinois State Water Survey to update the existing rainfall frequency distribution information using the additional rainfall gauge data that are available with routine updates every 15 years. Future precipitation projections and also future land use should be included where it is available. When planning stormwater infrastructure modifications and enhancements, local governments should take into consideration these future precipitation trends and land use information. (Chapters 2 and 5)
5. Data collection is vital to all flood studies, project design and project operation; therefore, the Illinois General Assembly should continue to provide cost share funding to allow for the following:
    a. maintenance and expansion of the USGS stream and rain gage network by the Illinois Department of Natural Resources;
    b. continued monitoring of climate and flood data by the Illinois State Water Survey to better validate and fine tune the present climate projections and their effects on urban flooding; and
    c. continued monitoring of progress in climate model developments and new scientific approaches to account for climate and other uncertainties. (Chapters 2 and 5)
6. The Illinois General Assembly should fund a state agency to develop an awareness campaign about the risks associated with urban flooding and options available for flood reduction and recovery. An educational flyer should be developed to provide to home buyers at closing. This flyer should provide basic information and resources on flood insurance, sewer backup insurance, flood mitigation, and available programs. Another flyer should be developed to inform renters of insurance coverages available to them. Education and outreach could also include a Flood Awareness week in conjunction with the National Flood Awareness Week. (Chapter 7)

7. The State should provide an annual funding stream for Illinois Department of Natural Resources to buy out both floodplain and urban flood prone repetitive flood loss properties statewide to reduce flood damages and create open space parcels, with deed restriction in perpetuity. (Chapter 9)
8. The Illinois General Assembly should continue (and increase) its funding of flood hazard mitigation programs to allow state agencies to better leverage federal mitigation funds. (Chapter 6)
9. The State should provide grants or revolving loan opportunities to communities to support implementation of local cost sharing mitigation programs for residents impacted by urban flooding, to evaluate stormwater system capacity and flood risk, and to encourage stormwater management planning. (Chapters 6 and 9)
10. Local and county governments should be required to participate in the NFIP as a prerequisite for state funding and grant assistance for flood damage reduction-related activities. (Chapter 6)
11. The State of Illinois should provide funding to the Illinois State Water Survey to study and further develop the topographic wetness indices used for the identification of areas likely prone to urban flooding. This would afford communities the ability to identify areas requiring special consideration for below-ground construction. (Chapter 3)
12. The authorities for justification of state capital projects are currently inconsistent making it more difficult to seek funding from one state agency versus another for similar flood damage reduction purposes. Funding criteria should be made consistent across all state agencies. (Chapter 6)
13. Insurance companies only retain claims data for eight years. The General Assembly should fund a program at the Illinois Department of Insurance to archive basement flood damage claims data from private insurers to maintain a long-term census block database of flooding claims for future analysis. (Chapter 1)
14. The Illinois General Assembly should fund research to determine if lower income households have adequate private basement backup and flood insurance as they appear to have fewer private insurance claims than higher income households. If affordability is an issue with private basement coverage or flood insurance, incentive programs and insurance pools used by other states should be investigated. (Chapter 1 and 7)
15. The Illinois General Assembly should direct research on a state Urban Flood Mitigation Pool funded from a very minimal surcharge on all homeowner's policies in Illinois. This mitigation funding stream could be granted to local governments to identify, study, and mitigate the most egregious urban flood areas in the state. (Chapter 1)

Illinois Congressional Delegation

16. Illinois' congressional delegation should encourage FEMA to allow Community Rating System (CRS) points for state flood damage reduction programs. (Chapter 8)
17. Illinois' congressional delegation should encourage FEMA to consider state-based flood insurance underwriting to more accurately reflect flood loss history in Illinois and establish actuarial premiums within Illinois. (Chapter 7)
18. Illinois' congressional delegation should request that FEMA modify and expand their national CRS training to include Illinois-specific training. (Chapter 8)

Local Government

19. To better utilize funding that is available through Illinois Emergency Management Agency for mitigation projects, communities are encouraged to complete pre-disaster planning. (Chapter 6)
20. Communities should establish overland stormwater conveyance areas in all new development areas, and these flow paths should be maintained and regulated. (Chapter 5)
21. Communities should investigate existing property evaluation programs to help homeowners analyze their homes for urban flooding potential and to identify flood damage reduction actions. (Chapter 9)
22. Communities should improve stormwater management in redeveloping areas by adopting stormwater ordinances that incentivize reduction of imperviousness and updating storm water systems, especially in known flood problem areas. (Chapter 5)
23. Communities should consider real-time monitoring of combined storm sewer systems. When technology allows, they should update the monitoring with a reverse 911 system to alert property owners of imminent flooding. (Chapter 3)
24. Within a reasonable timeframe, communities should update their storm sewer atlas with storm sewer location, infrastructure sizes and design data to allow for evaluation of the effect of changing rainfall patterns on system capacity to more accurately identify areas at risk for urban flooding, and to better inform stormwater management planning. (Chapter 3)
25. Communities should consider adoption of ordinances to address drainage for below-grade construction, such as requiring sewers to exit structures within 2 to 3 feet of the finished exterior grade of buildings. Adoption of International Building Code Sections R405 and R406 for foundation drainage and waterproofing should also be considered. (Chapters 3, 5, and 9)
26. Communities and counties participating in CRS should participate in the Illinois Association of Floodplain Managers (IAFSM) CRS users group. (Chapter 8)
27. Non-CRS municipalities should consider using CRS principles in stormwater management to make their communities more resilient. (Chapter 8)

State Government

28. The Illinois Department of Natural Resources and Illinois State Water Survey should develop a state model local stormwater ordinance based on concepts in the report which can be used as a template by counties and local communities. The following should be included along with other actions to address urban drainage issues:
    d. Incorporate green infrastructure into municipal and county development regulations by modifying regulations that restrict use of green infrastructure and add regulations to encourage use of green infrastructure in capital improvement projects when possible.
    e. Stormwater infiltration, evapotranspiration and storage should be incorporated into new development and redevelopment wherever possible.
    f. Developers and property owners should be incentivized to dedicate property for increased open space in developing areas, and current open space should be protected to allow for evapotranspiration, infiltration and stormwater storage.
    g. Require a licensed plumber to inspect for sump pump and downspout connections to sanitary sewers when houses are sold. (Chapters 4 and 9)
29. The Illinois Department of Natural Resources and Illinois Environmental Protection Agency should collaborate to appropriately expend portions of the state revolving fund for implementation of stormwater management measures. (Chapters 7 and 9)
30. The Illinois Mitigation Advisory Group should expand their mission with representatives from various state agencies to coordinate grant programs and projects to ensure consistent funding requirements, leverage state funding efficiencies, promote resiliency, and avoid project overlap. This group should identify and prioritize urban drainage flood mitigation planning in Illinois so existing mitigation actions can occur quickly and efficiently as funds become available. (Chapter 6)
31. The Illinois Department of Insurance should encourage outreach and education efforts at the local level to ensure that citizens understand the differences between flood insurance and sewer backup coverage. (Chapter 1)
32. The Illinois Department of Natural Resources should expand CRS resources to improve CRS outreach to communities as funding from FEMA is available. (Chapter 8)
33. The State of Illinois should incorporate green infrastructure options in state funded capital improvement projects when practical. (Chapter 9)

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Appendices

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Appendix C: Illinois Flood Risk Symposium Report

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Discussion Paper

Urban Flood Hazards: Challenges and Opportunities

ASFPM Stormwater Management Committee

INTRODUCTION:

This is a [DRAFT] discussion paper related to the topic of urban flood hazards, associated challenges, potential solutions, and recommendations to assist communities with identifying, managing, and mitigating urban flood hazards. This paper was prepared to provide background and discussion and it does not represent a position or policy of the Association of State Floodplain Managers (ASFPM), a non-profit organization dedicated to reducing flood losses and protecting floodplain functions and resources in the United States, without causing adverse impacts to others.

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SECTION 1: THE ISSUE

Congress established the National Flood Insurance Program (NFIP) in 1968 with passage of the National Flood Insurance Act, now codified in 44 CFR to partner with local governments and enable owners of real property in participating communities to purchase, federally-administered flood insurance.

In 1979, the Flood Insurance Administration (FIA) and the NFIP were moved under the Federal Emergency Management Agency (FEMA). Since the creation of the NFIP, the program has been actively mapping flood hazards throughout the United States to establish flood risk and insurance rates. These mapping efforts have primarily been focused on threats from both rivers and coastal storm surge. FEMA digitized legacy flood hazard mapping and completed new flood insurance studies (FIS) from 2003-2008 through Flood Map Modernization (Map Mod) and continued updating flood risk identification with Risk Mapping, Assessment, and Planning (Risk MAP) from 2009 to the present. To date, FEMA has mapped and established Special Flood Hazard Areas (SFHAs) for over 90% of the major population areas within the United States, identifying flood risk for both coastal and riverine environments.

Although FEMA has “modernized” floodplain mapping throughout the country there is still significant flood risk that has yet to be identified or mapped under the NFIP. Local floodplain and stormwater managers in highly urbanized areas understand that there is additional unmapped flood risk beyond the boundaries of the currently established SFHAs caused by urban stormwater runoff.

As cities grew over the last two centuries, many natural floodplains were channelized and filled in to accommodate population growth and community development. To those planning and developing these metropolitan areas the local drainageways may have appeared to be very small, posing relatively minor flood risks; the existing floodplains and their natural and beneficial stormwater management functions were often not a major consideration in the development and growth of these conurbations. To mitigate the flood risk stormwater pipe systems were designed and constructed to replace the lost conveyance that occurred due to filling and encroachment of the historic drainageways within the floodplain. Additionally, until recently the increased runoff from new impervious areas upstream of these stormwater systems has not been mitigated or controlled. Unfortunately, local stormwater systems in many developed watersheds are undersized, providing runoff conveyance for events with frequencies ranging from 1- to 10-years (100% - 10% chance events). When larger, less frequent events occur, the storm conveyance systems are overwhelmed, and the residual runoff remains on the ground resulting in flooding that inundates streets and sometimes existing structures. This is especially common in historic areas where infrastructure was not designed to meet current local drainage criteria. In addition to these existing systems being undersized, there has been an increase in the frequency and intensity of rainfall events, an indicator of climate change, resulting in more frequent and persistent flooding of the built environment. Many of these urban flood hazards are known by local managers and flood administrators due to their frequent flooding but remain unmapped and unregulated.

Over the past decade local government agencies and floodplain management professionals have taken a strong interest in identifying, mapping, managing, and mitigating urban flood hazards. Where these flood prone urban areas have been identified, strategies to address localized flooding typically come with very high capital improvement costs or feasibility challenges that are increasingly difficult to overcome. This discussion paper:

- Provides an overview of the challenges associated with urban flood hazards and opportunities for local floodplain and stormwater managers to utilize urban flooding best practices,
- Offers a framework to identify and manage urban flood hazard areas to reduce future flood damage, and
- Suggests recommendations on a national scale to assist communities with mapping and mitigating urban flood hazards.

SECTION 2: BACKGROUND

PRIMARY CAUSES OF URBAN FLOODING

Many communities have developed local drainage and stormwater criteria to address increased runoff due to development and for runoff conveyance systems to reduce flooding existing structures. Flood damages, however continue to be witnessed in cities throughout the country and in fact, flood damages to structures outside of the SFHA have been steadily increasing. The primary causes of flooding in these urban areas include: **Historic Loss of Natural Drainageways**: Before development, a significant portion of rainfall was infiltrated, and the remaining stormwater runoff was conveyed in swales, gulches, gullies, low lying drainageways, washes, creeks, rivers, and streams. Smaller natural drainageways were often filled or replaced by storm drainage systems that were only designed and constructed to convey small, frequent, rainfall events.

Figure 1: Construction of a brick storm drain system used to replace surface conveyance in a natural swale in the City and County of Denver circa 1920 (Denver Public Library).

Historic Development, Land Use, and Stormwater Management Criteria: Historic development occurred with minimal or no criteria for stormwater mitigation resulting in undersized stormwater drainage systems.

Inadequate Stormwater Management Criteria: Local criteria and design standards for stormwater infrastructure do not always address flooding from large rainfall events. Storm drain systems are typically designed only for the 2-year to 10-year rainfall events, thus rainfall in excess of the storm drain capacity must travel overland (on the surface) of drainage basins. Local criteria frequently account for this by specifying maximum flooding depths in streets, but this is a more recent regulatory development in stormwater criteria and doesn't address pre-existing and historic development. In other cases, sizing of stormwater systems to meet street conveyance capacity may be deemed too expensive or technically infeasible, leaving behind residual flooding hazards during and in the aftermath of larger storm events.

Increased Impervious Surfaces (Development) Upstream of Existing Stormwater Conveyance Systems: As development occurs upstream within watersheds, runoff increases due to increases in imperviousness and decreases in infiltration. These runoff increases are not always accounted for by stormwater regulations and criteria and typically were not accounted for in historic infrastructure construction.

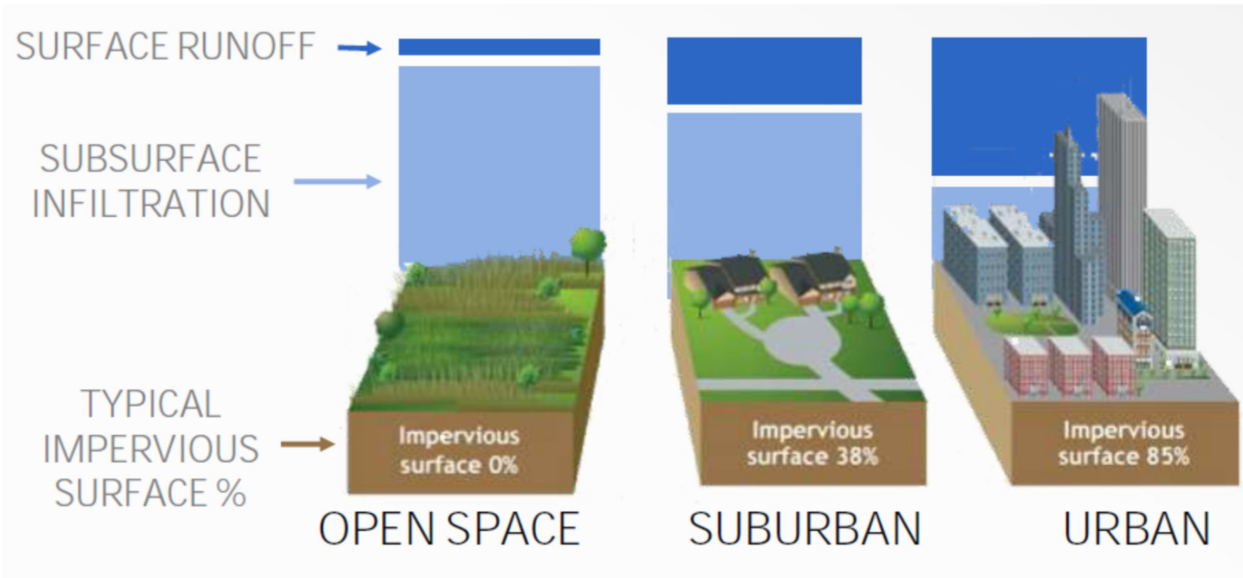

Figure 2: In more urban areas, less stormwater is infiltrated to the subsurface resulting in greater amounts of surface runoff (Image from Landscapeforlife.org).

Levee Systems and Residual Local Flooding: Where levee systems have been designed to keep river flooding out of urban areas, local stormwater can be backed up on the urbanized side of constructed levees creating residual flood zones if it wasn't planned for in the design of the system.

Combined Sewer Systems and Sewer Backups: In many communities east of the Mississippi, combined (sanitary and storm) sewer systems are common. These systems are not typically designed to accommodate all flood events, and when these systems are overwhelmed it can cause upstream flooding to structures, especially basement flooding. In addition, overflows of this type can be a violation of a communities NPDES permit for their treatment facility.

Insufficient maintenance: Constructed stormwater systems must be maintained to function as designed. Sediment or debris accumulation reduces the capacity of stormwater management systems and can eventually plug pipes or limit the efficiency of detention/retention facilities. If ditches are not mowed, the heavy vegetation reduces the capacity. If systems are not inspected and repaired, such as backflow prevention valves at discharge points into a river, stormwater will not be able to drain as intended. Having a consistent maintenance and inspection program and mapping the information can control the risk of urban flooding.

Climate Change: Climate change has resulted in alterations to the intensity and frequency of rainfall events around the globe. As a result, more frequent flooding is occurring in many locations and previously constructed stormwater systems no longer accommodate the increased frequency of the rainfall events for which they were designed. Climate change not only affects rainfall, it is also causing a rise in sea levels affecting local drainage systems in coastal areas. As sea levels increase, existing stormwater drainage systems may experience backwater affects that reduce conveyance capacity, ultimately flooding upstream streets and structures.

RISKS ASSOCIATED WITH UNMAPPED URBAN FLOOD HAZARDS

Unmapped urban flood hazards pose significant risk to the public and to property owners. These areas can flood during a variety of rainfall events, resulting in recurring flood damage and repetitive structural losses. Since urban flood hazards tend to be unmapped, property owners often do not purchase flood insurance and are therefore at risk of significant financial loss. Unmapped and uninsured risk with the potential for repetitive flood loss makes identifying these flood hazards and educating communities and their government representatives about the associated risks critically important to the floodplain administrators and stormwater managers. These flood risks have remained unmapped for a variety of reasons including:

- **No Obvious Risk of Flooding:** Urban flood risk is not always obvious. These flood prone areas are often developed with streets, homes, and businesses, with no apparent natural drainageways or conspicuous stormwater conveyance structures.
- **Status Quo NFIP Mapping Standards:** FEMA does not generally map areas considered local drainage tributaries. FEMA typically starts mapping flood hazards where the upstream watershed area exceeds 1 square mile. Although many of these urban flood hazard areas have watersheds in excess of 1 square mile, there are no natural drainageways or riverine conveyances that exist and thus these areas have not been identified by floodplain managers as locations that require floodplain mapping.
- **Identification and Mapping Complexities:** The hydrologic and hydraulic analyses associated with mapping urban flood risk are complex, requiring the combination of 1-dimensional (1-D) pipe system modeling with 2-dimensional (2-D) surface modeling. Studies typically required to accurately map these areas can be cost prohibitive.

SECTION 3: OPTIONS TO ADDRESS THE ISSUE

Flood hazards in our communities are often best understood by the long-time residents and community leaders. Floodplain stewards and stormwater managers face significant challenges communicating urban flood risk due to the technical and cost challenges associated with mapping these complex hazard areas. Even when the risk has been mapped, they can also face internal and external communication challenges to get the public, senior government leadership, and politicians to acknowledge the risk. These communication challenges range from clearly establishing that hazards and risks exists--even when it is mapped--to a lack of willingness to make flood map information available to the public because of concerns regarding negative perceptions of flood insurance requirements; adverse impact to property values; and public calls to fix the problem immediately in the absence of adequate government resources. Infrastructure solutions to address these urban flood hazards come at significant cost; simply upsizing a stormwater system is often not a viable answer when natural flood conveyance has been lost and upstream development has increased the coverage of impervious surfaces, and thus the amount and rate of water draining through the system. As weather patterns continue along a dynamic path and storm events increase in frequency and intensity, our communities need to be better equipped with the tools to communicate future urban flood risk and provide communities with the knowledge and understanding to drive change from the top down and from the bottom up.

IDENTIFICATION AND MAPPING OF URBAN FLOOD HAZARD AREAS

Identifying flood hazard areas in urban environments poses significant challenges. Among those challenges is understanding that a flood risk exists in a specific location. In the absence of previous studies and mapping, anecdotal evidence such as complaint records, photographs and videos, or data showing repetitive flood loss are often relied upon by local managers to identify areas with significant flood risk in urban communities. Historically, stormwater master plans or outfall plans have focused on the capacity of piped systems and their ability to meet local conveyance criteria. These plans often reveal that piped systems do not provide adequate capacity for large flood events and the residual surface flows were not well understood or even ignored. Some studies utilize 1-dimensional (1-D) hydraulic models to predict flooding depths and extents. In urban areas, however, stormwater flows are not best modeled in a 1-D environment as flows split at intersections; approximating the volume of stormwater that goes one way as opposed to another becomes arduous and inexact. From a regulatory perspective, FEMA's reliance on 1-D modeling methodologies hinders accurate mapping of urban flood risk. In general, 1-D hydraulic modeling programs are not sophisticated enough to accurately analyze overflow flooding in road networks that occur in urban areas. Figure 1 illustrates an urban area that is more suited to 2-dimensional (2-D) analysis. Knowing the limitations of 1-D modeling communities may be reticent to

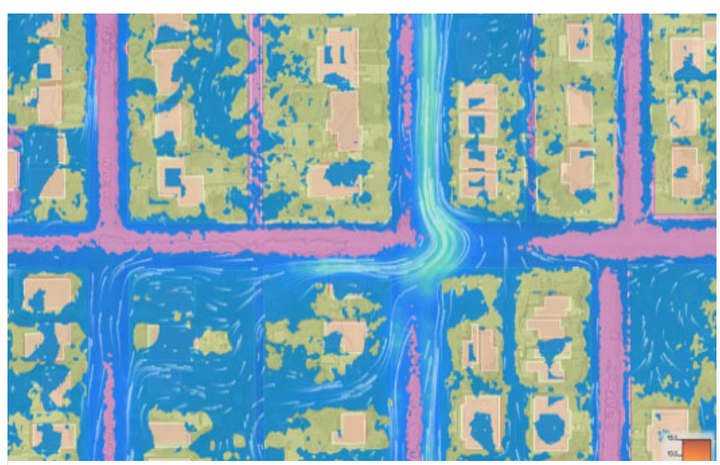

Figure 3- Image of a 2-dimensionsl rain on grid model with GIS layers of houses, roads, and grass separating each feature in the model.

request studies to model and map their urban flood risk, contributing to a resistance to regulate or require insurance in these areas,

Although 2-D modeling has been available since the mid 1990's, the complexity and cost associated with modeling urban areas and the finite resources of local agencies made such analysis cost prohibitive, infrequent, and unattainable. Over the last ten years, however, 2-D modeling has become much more prevalent and accessible to the engineering community, reducing the associated costs. Modern technologies for hydrologic and hydraulic modeling may offer more cost-effective methods to develop large scale urban inundation maps. Some of these modern technologies are now available at reduced or no cost, are user friendly, and can produce more accurate results than their 1-D predecessors. As a result of more readily available and accessible evaluation and modeling tools, urban inundation maps can be produced with relative ease by a knowledgeable, practicing flood hydraulic professional.

Specific Challenges Related to Mapping Urban Flood Hazard Risk

Although modeling urban stormwater inundation is becoming less cost prohibitive and more commonplace, it's costs may still exceed the limited resources of many communities around the country. There is also an array of other challenges, both technical and practical, with modeling urban flood risk:

1) **Cost and associated level of detail for flood modeling and mapping:** Urban flood risk modeling can be performed at a variety of levels and costs. Low resolution modeling to identify flood risk can be performed at a relatively low cost and in a timely manner. High resolution modeling requires detailed baseline data including detailed topographic mapping (typically LiDAR), building footprints, impervious footprints throughout the watershed, soils data, and detailed storm drainage infrastructure information. Not all local agencies have the detailed data necessary to perform complex hydrologic and hydraulic analyses, but there are options for agencies to consider, including:
    a. **Basic Analysis:** An approximated flooding estimate based on ponding depths at sumps and collected complaint databases. This type of analysis would primarily be meant to begin identification of urban flood hazards but could not be used for damage estimates or to fully communicate flood risk.
    b. **Better Analysis**: A basic 2-D model with large grids and without building detail or underlying infrastructure connectivity, i.e. storm drain systems. This type of analysis could provide a baseline for determining damage estimates and ponding depths but may not scientifically support local ordinances or development standards.
    c. **Best Analysis:** A detailed 2-D model that computes both runoff from gridded cells and downstream hydraulics of stormwater flow through a watershed. These models can incorporate building footprints and stormwater infrastructure via a 1-D interface. 2-D rainfall/runoff models can be calibrated to gage data when additional datasets exist, such as gage adjusted radar rainfall and downstream peak flows. This type of mapping could be used to estimate flood damage and begin to set water surface elevations for enforcing local ordinances requiring minimum first floor elevations and freeboard.

    All of the aforementioned methodologies can assist in the identification of urban flood risk and support the creation of inundation maps that can be used to educate the public and government officials. These analyses can also be used to estimate flood damages within a watershed based on various assumptions about future weather events. This information is critical for decision-makers, especially when considering benefit/cost ratios of alternative strategies.

Urban flooding presents a “new” cost for budgets already strained by maintaining and upgrading legacy systems, and the cost of completing these analyses can vary widely.

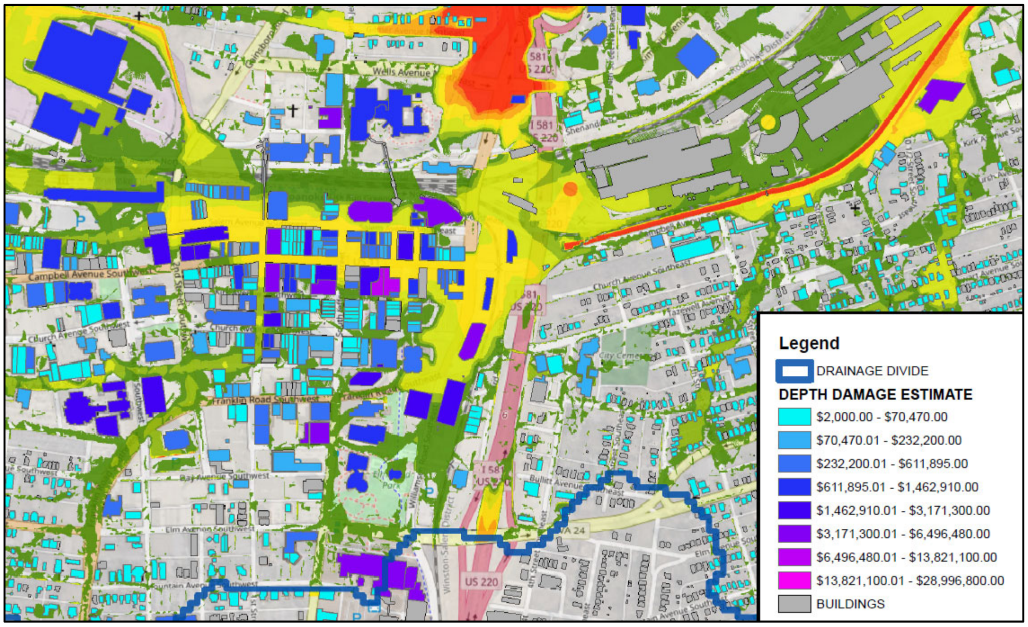

Figure 4: Screen Capture of Depth Damage Estimates for Buildings Affected by an Urban Flood Event

2) **Federal and local management of urban flood hazards:** Most urban flood inundation areas remain unmapped by FEMA. Some communities are developing local flood hazard maps for these areas but have not necessarily shared their mapping with FEMA to be incorporated into their FIRMs and the NFIP. Choosing to map and make publicly available previously unmapped urban flood risk zones comes with significant challenges including:
    a. **Acceptance by the community that the risk exists.** Residents may be aware of flooding within their communities, but the fact that these flooding areas are not being mapped by FEMA can create suspicion regarding the purpose of non-FIRM urban flood maps. The public may perceive the mapping justifies a capital improvement project that benefits developers rather than homeowners and residents or has been developed to deny development permits within a flood hazard area. Maps representing inundation areas modeled for large weather events, such as the 50-year or 100-year flood events, may be so extensive as to be “hard to believe”. Communicating risk beyond annual or semi-annual rainfall events has historically proven challenging for riverine and coastal flooding; urban flooding brings even more nuance to flood risk communication because these areas are not necessarily perceived as flood conveyance areas.
    b. **Willingness of elected officials to authorize sharing of flood data publicly.** Local government agencies may understand that urban flood risk exists, and may have already mapped that risk, but the data and mapping may not be made available to the public.

    Reasons this mapping may not be made public include:

i. Once the mapping is made public, residents believe their property values will be negatively impacted by the fact that the risk has been identified and published.
ii. Perceiving that an identified flood hazard will negatively impact property values, homeowners and business owners may demand that the flooding issue be addressed immediately. Unfortunately, the cost associated with directly eliminating these flood hazards—if possible--is great and most capital improvement budgets are inadequate to address such needs.
iii. Public perception can create political pressure for action to address these hazard areas, and meeting the costs associated with responsive activities may require unpopular tax increases or creation of special assessment districts to address urban flooding. Where funding mechanisms can be identified and implemented, the improvement projects—where feasible--are unlikely to be expedient.

If a local government agency can successfully navigate making the inundation data publicly available, the next question is whether the mapping should be regulatory, e.g., included under the NFIP and shown on FIRMs, or enforced by higher regulatory standards under a local ordinance. The positive outcome of making these maps regulatory is that the flood risk will be better understood and communicated with the public and private property owners may insure against future flood events. Potential negative outcomes may include negative impacts on property values in these areas and affordable flood insurance may be unavailable to property owners in an identified high-risk area. Regulatory maps may also remove leverage for local communities to address their urban flood hazards. For example, if flood risk is communicated to the public and alternatives to address the flooding--including mapping the area as a regulatory special flood hazard area, --are fully understood, residents may prefer to pool what resources might have gone to future flood insurance premiums and instead funnel that money toward infrastructure improvements to mitigate the flooding problem. If the risk is mapped as regulatory, incentives and opportunity to address the problem may be lost.

Directing resources towards mitigation may ultimately lead to more resilient communities and reduce future flood losses. As communities assess, identify, and plan to address their urban flood hazard, it's important to remember that different communities have diverse values, goals, and objectives and may choose to address their problems differently, but in a way that fits their vision of the future. Whatever the approach, community understanding of the risk and concerted action to address the hazard is a positive step towards resilience.

Another potential challenge of creating regulatory mapping of these urban inundation areas is map updates. Urban areas, by their nature, see physical change on a regular basis. For example, public works departments maintain streets and routinely implement pavement overlays. In addition, stormwater management improvements can be constructed locally or upstream within a basin that may directly impact the amount of flows entering a known hazard area. An area included in a FEMA FIRM would require that a Conditional Letter of Map Revision be completed followed by a Letter of Map Revision. Thus, in creating NFIP regulatory maps, local municipalities would face increased costs for maintenance of floodplain maps, stressing already underfunded public works CIP budgets. This issue may potentially be addressed by establishing comprehensive mapping standards, but the likelihood is that communities would be expending more of their stormwater or floodplain management budgets on updating these regulatory maps.

3) **Standards for studies and mapping**: FEMA develops mapping standards and requirements for riverine and coastal flooding. To date, standards have not been created for urban flood hazard areas. As previously noted, the costs of mapping these areas has been historically prohibitive, but the entry point for mapping is decreasing on an annual basis. The mapping produced in urban flood hazard areas will typically involve 2-D modeling with numerous split flows at roadway intersections. Flood depths will be impacted by urban street features such as medians, curbs, raised crosswalks, traffic calming devices, and other related impervious transportation infrastructure. Future development or redevelopment of these areas will also directly impact flood depths. New building footprints will displace water, increasing depths or velocities elsewhere within the basin. How to best update inundation maps of these ever-changing urban environments is an unanswered question. Other questions related to regulatory mapping include:
    a. Whether to incorporate underground stormwater infrastructure designed for more frequent flood events. Including infrastructure increases model complexity and associated analysis and mapping costs.
    b. Is stormwater infrastructure dependable to convey the water it is designed to convey, i.e. what if inlets or pipe systems become clogged? Conservative analysis might not consider underground systems for large events such as the 100-year but choose to include infrastructure up to a certain flood frequency.
    c. What will trigger the need for a mapping update?

    Mapping and modeling standards are necessary if urban flood inundation zones are to be regulatory. However, mapping standards should consider the cost implications to local governments and should be set up in such a way to encourage mapping and understanding of flood risk rather than creating a set of overwhelming and hard to implement rules and standards that make responsible preventative actions in these areas cost prohibitive.

CHALLENGES IN RISK COMMUNICATION AND EDUCATION

Risk communication and education come to the forefront following disasters in urban flood hazard areas. Events like Super Storm Sandy in 2012 that decimated the East Coast and Hurricane Harvey in 2017 that flooded large parts of Houston grab national lawmaker and media attention in the days and weeks immediately following the event. Those events are significant because they direct attention to flooding issues plaguing urban areas on a national level and provide an opportunity for other urban communities to discuss how those same flooding issues are also present in their communities. The problem has always been how local communities leverage that support into long-standing policy change and program initiatives when national and local attention wanes. Many communities have taken advantage of the opportunities to develop urban flood risk messaging and have established their own risk communication and outreach initiatives.

Outreach and Communication with the Public

Communicating urban flood risk to the public has many challenges including:

1) **A willingness on the part of local officials to make the flood risk data available**. As noted in the section on determining urban flood risk, although staff at local government agencies understand that flood risk exists and may have already mapped that risk, the data and mapping is not typically readily available to the public. Informing the public of the existing flood risk will certainly create unrest with watershed residents who have concerns about safety, property values, the potential cost of insurance premiums, and the expectation that someone address and eliminate the flood risk. Many local governments have chosen to make flood mapping data, including modeling, available to the development community on an as-needed basis, but have not always provided public maps showing the flood risk. Some communities are concerned that publicly making this data available will trigger FEMA to incorporate the mapping into NFIP FIRMs, limiting their options to address the risk in the future. The primary reason flood risk mapping in these areas is not shared is because of the public outcry that community officials believe will occur as a result. Communicating new understandings of flood risk requires intentional and well-thought out strategies within a framework of planning (to address the problem), and future implementation of capital improvements or ordinances/regulations that begin to address the problem. Communication of flood risk outside of a framework that involves addressing the problem leaves residents feeling uncertain and helpless about their future.
2) **Belief by the public that the risk actually exists.** The best flood maps detailing flood depths for various flood frequencies and depth-damage estimates do not immediately equate to public acceptance that a flood risk exists. The public often views new risk mapping with distrust. It may be perceived that showing this new risk is associated with a local government's desire to make room for new development or to devalue property in order to buy land for future projects such as parks or government facilities. Although many residents within a watershed may admit that flooding regularly occurs, they fear the outcomes of mapping that shows them living in a an area that frequently floods. Questions such as, "How will this affect my property value? Is my home safe? Why hasn't my local government addressed this problem?" and, "FEMA doesn't identify this as a floodplain, so it cannot be a real flood risk," will be faced by every local municipality attempting to communicate risk about urban flooding. Communication of urban flood risk must start with the basics including how the flood risk came into being in the first place.

   One invaluable tool for local administrators in communicating existing risk is historical evidence. Many of these urban flood hazard areas have a long-standing history of flooding. Researching news articles from local periodicals may turn up years of flood history that can assist in convincing the public that flood risk does indeed exist (see Figure 3).

Million Dollars Damage Done by Floods in Denver

—ROCKY MOUNTAIN NEWS— Denver, Colo., Friday, July 10, 1953

This is Colorado blvd. at E. 12th ave. a few minutes after 5 p. m. yesterday. Most of the hopelessly stuck cars have already been abandoned, their riders seeking whatever shelter they could find. A few minutes later, another wall of water from the east hit the cars, scattering them up on lawns.

—Rocky Mountain News Photo by Dick Davis.

Figure 5: Copy of news article in the Rocky Mountain News from 1953 regarding flooding in the Montclair Drainage basin. Additional research turned up articles from 1912, 1950, 2004, and 2011 for the same area. (Source: Colorado History Museum).

3) **An understanding of how the issue came into being.** Since urban flood hazard areas are not readily recognized as flood risks like riverine and coastal areas, some history is required to educate the public about why the risk exists. Explaining from an historical context how a city developed and the decisions that were made regarding development is critical to that understanding. Sharing historical maps prior to development can begin to enlighten residents that low lying areas before development conveyed runoff and were natural floodplains. Historical maps might include soils maps (see Figure 4) that indicate where streambeds previously existed; drainageway maps developed prior to development (see Figure 4) or city planning maps or plat maps that show how development occurred over time and at what dates natural drainages were filled in and/or replaced by stormwater infrastructure such as closed conduit pipe systems.

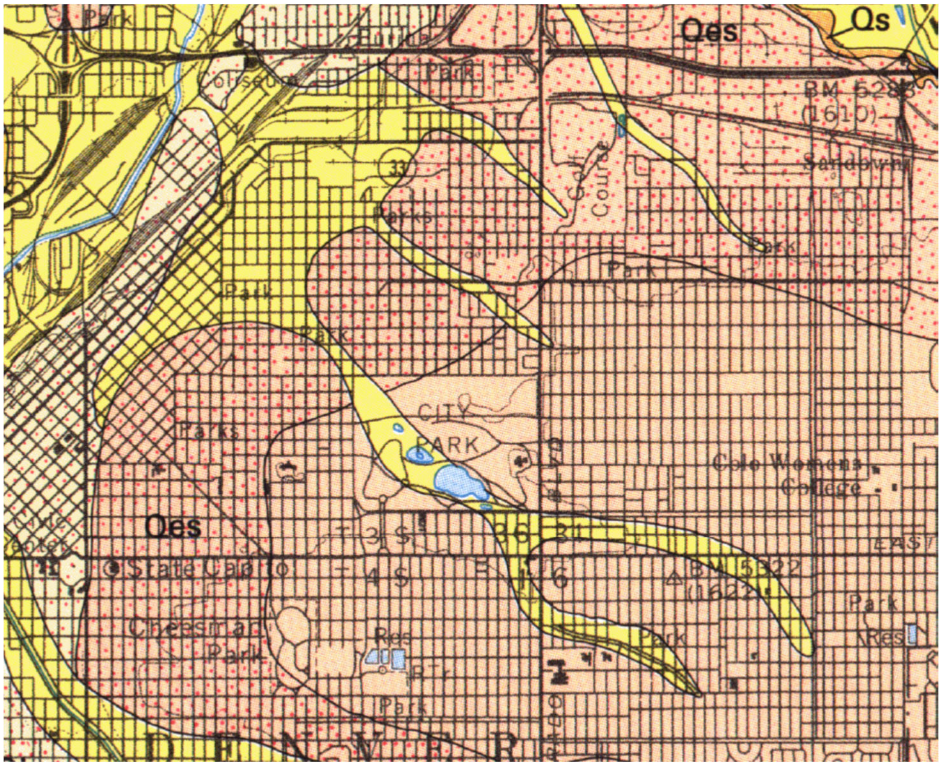

Figure 4: USGS soils map within the City and County of Denver showing alluvial stream deposits where historic drainageways used to exist.

4) **Why the issue hasn't been addressed by the local government agency.** Once residents understand and accept reality that urban flood risk does indeed exist, the next question that invariably will be asked is, "Why hasn't the issue been addressed by my local government?" This is an even more problematic issue when a local stormwater utility fee exists and the perception is that these types of issues should have been addressed with those monies. Government officials must often explain that routine maintenance and replacement of existing stormwater infrastructure consumes almost all of the funding available each year. Although capital improvements are identified in master plans, typically implementation of those plans is spread out over 10's of years. On top of that, most local stormwater master plans address conveyance for the 2-10 year events and don't directly address larger, less frequent flooding. Communication strategies to address this question must focus on what an agency is primarily tasked to do on an annual basis and the realities of available funding. In many cases, addressing urban flood hazard areas may require special districts or additional tax levies and municipal bonds due to the complexity and cost of addressing the specific problem.
5) **What living in these areas means for the local residents.** Residents who are educated about urban flooding want to understand what that means to them. Specifically, they want to know if they are safe or at risk, if they need to purchase insurance, what is being done to address the flooding and what they can do to address the problem. This is why communicating risk in a framework of planning and mitigation is critically important, i.e. just mapping risk leave the burden on local residents whereas involvement with planning and mitigation provides hope that the problem can be addressed, whether now or at some point in the future.

PLANNING AND IMPLEMENTATION STRATEGIES

Developing solutions to address urban flood risk is best addressed via a comprehensive and collaborative planning process that considers:

- Risk Identification and Mapping
- Risk Education and Outreach
- Community Goals and Objectives and a Strategic Framework
- Investigate, Identify, and Evaluate Solutions
    - Infrastructure Solutions
    - Non-structural, Planning, and Regulatory Solutions
- Development of a Strategic Implementation Plan and Community Toolbox

Development of a comprehensive plan is the crucial first step in addressing urban flooding, educating the public, and providing data and analysis to support proactive community action. A comprehensive plan will not only consider infrastructure type solutions but will seek to evaluate management and regulatory actions the community can take either in parallel with or separately from proposed capital projects. Nearly all problems in urban stormwater management are the result of land use and development policies and practice—or the unfortunate lack thereof. Gilbert White's maxim that "Floods are 'acts of God', but flood losses are largely acts of man" is particularly instructive for planning. After all, water will find a way to flow and will take the path of least resistance in the process, regardless of whether that area is developed or in a natural state. Human-scaled disasters most frequently occurred in areas where land is developed.

Plans are informed by public outreach and participation, and planners have much to learn from residents, businesses, property owners, and other citizens. When design professionals lack information about stormwater and runoff problems, they can seek public input in order to get a better sense of stormwater problems than they would have otherwise. In many cases, those who live, work, and play in a community are more familiar with drainage problems, nuisance flooding, and local topography than are professionals working with those issues conceptually. However, members of the public with knowledge about these topics may not be engaged or share their insights.

A Collaborative Team

In order to deliver a comprehensive, collaborative, and resilient plan to address urban flood risk the right professionals must be in the room and leading the effort. Often, stormwater or drainageway planning efforts have been the realm of engineers who have focused on grey infrastructure type solutions, building on the hydrologic and hydraulic analyses that determine the quantity and extent of flooding in an area of interest. Communities must now move beyond that model and ensure that teams are made up of specialists with expertise in:

- Planning and education
- Public outreach and involvement (including interaction with elected officials)
- Urban design and planning
- Landscape architecture
- Hydrologic and hydraulic modeling
- Stormwater systems design

- Ecosystem evaluations
- Finance and development

The above list is a starting place only, and additional expertise is likely needed and warranted depending on the scope of a given project. The key takeaway is that addressing urban flood risk in a resilient fashion requires a team of professionals of varying expertise rather than a specialized group of engineers.

Risk Identification and Mapping

Mapping and identification of urban flood inundation areas should be the first step in any community's action plan in addressing urban flood risk. As previously mentioned, these inundation areas are typically known, at least anecdotally, via complaints databases, maintenance crew observations, or by news reports during previous storm events. Once a community has determined that they have one or more of these hazard areas, they can start the process of budgeting for a more detailed analysis that will provide mapping of the areas at risk. It's important for local managers to discuss this process with locally elected officials at the front end of risk identification so as not to "surprise" anyone as risk becomes better identified. Throughout the country, many of these areas have been mapped through local programs, but are often not shared with the public due to the fear of public outcry and lack of a plan to address the problem. That's why it is important that a full planning process that includes the support of elected officials be in place before beginning the education and outreach actions.

Risk Education and Outreach

Preparing to Be Share Urban Flood Inundation Maps with the Public

As a professional community focused on flood risk and education, we have learned that simple inundation maps do not often satisfy the demands of citizens or even other planning professionals in assisting with a complete understanding of flood risk. At the start of the inundation mapping efforts for urban flood risk, city managers, engineers, and planners should discuss work products that may be produced that better inform and educate the public regarding flood risk. Questions that should be asked might include:

- **How can we explain how this problem was created?** Taking the time to show the history of the city including historic development over time, i.e. what did this area look like prior to development? When did development occur? What was the thought process regarding stormwater and drainage at the time of historic development? What has occurred upstream since that time?
- **How might this problem have been avoided?** This is a good opportunity to show how current land development regulations prevent the filling in of natural drainageways and/or limit discharge from development to pre-development conditions. This is also a good time to show a timeline of when stormwater rules and regulations were developed and implemented.
- **How often will flooding directly impact citizens?** Providing inundation maps for a variety of runoff events will help explain the frequency of flooding that citizens might expect.
- **How much damage can be expected when it floods?** In combination with inundation maps, developing depth-damage estimates for a variety of events will begin to establish the serious nature of the problem and why it needs to be addressed.

- **What is the plan to address the problem?** It's important that citizens understand that the mapping effort is only the beginning of the planning process that they will participate in. Sharing with them that they get to participate and develop the solutions in partnership will give them ownership in the process.
- **What can be done right now?** Being able to share with citizens and managers that although an infrastructure solution might not be something that can be constructed today, there are proactive actions that can be taken now including the purchase of Preferred Risk Policies through the NFIP as well as the development of local ordinances and regulations to ensure the situation doesn't get worse as new development occurs.

The stormwater manager and risk communication team should prepare a full presentation with figures, charts and graphs, mapping, and fact sheets to answer the questions above as well as several others prior to presenting risk data to other city managers, elected officials, and citizens. Creativity should be encouraged in thinking about how to connect risk data to people. There are many examples of creative solutions throughout the country. Included here is an example from Toledo that is a web-based tool for visualizing flood data and flood losses on an interactive map.

Figure 6: Toledo Flood Hazard Visualizer providing information regarding flood depths, potential flood losses, and regulatory floodplain data via the internet.

Communication with Municipal Managers

Once the hydrologic and hydraulic analyses have been completed and an inundation map(s) has been generated, a community's staff should sit down and thoroughly discuss the issue. These meetings should include transportation managers, stormwater engineers, city planners, parks and recreation staff, and zoning/development review professionals. The extent of the problem and it's effects on city infrastructure should be understood by all departments. The education of various departments regarding urban flood risk is foundational for future planning as a successful plan will address each one of these areas, not just stormwater or flooding. In other words, because of the nature of a city any one action will affect the function of another set of infrastructure. By engaging each different department, opportunities that may not have previously been considered may now become apparent. For example, a transportation plan may help inform locations where stormwater infrastructure may best be placed in the future and/or a parks and recreation plan might be integrated into a watershed-wide solution that includes green infrastructure implementation. While educating these departments about the extent o the problem early on is critically important, just as vital is their engagement in the overall planning process and in the development of goals, objectives, and solutions.

Communication with elected Officials

Local elected officials and decision makers typically take notice of urban flood risks following large flood events. Depending on geographic location and sensitivity to urban flood risk, some communities are likely to remain focused on these issues, for example communities at risk from a hurricanes. Areas in the arid west, like Phoenix and Denver, may have a more difficult time maintaining the attention of elected officials when it comes to urban flood risks. Local stormwater and floodplain managers should take every opportunity they have to educate officials and other influencers regarding the importance of flood risk outreach and communication and how government regulations and policies impact that mission.

Upon developing the first inundation maps of these areas, it’s important to engage and educate local elected officials regarding the problem. Because of the potential outcry from citizens when these areas are mapped, it is best to educate officials regarding how the problem came into being, how significant the problem is, and to explain the planning process to address the urban flood risk. Ultimately, these officials approve city budgets directly connected to any strategic plans that will be implemented and their ability to answer questions from their constituents will improve relationships and outcomes over time, i.e. they will know ahead of time what to expect and explain that they have proactively funded the planning process and support the long-term strategic plan developed by their public works staff in partnership with the citizens.

Communication and Partnerships with Other Jurisdictions within the Watershed

Many watersheds, both urban and rural, span multiple jurisdictions. This increases the number of challenges a local stormwater manager faces and limits their ability to directly regulate stormwater runoff that may be aggravating urban flood risk. As local managers educate various departments, elected officials, and the public, they must also reach out to adjacent jurisdictions, both upstream and downstream, in discussing and developing solutions to urban flood risk. Addressing urban flood risk and stormwater runoff will require a multi-jurisdictional approach. Such an approach to address, regulate, or manage stormwater can yield many benefits including being able to address water quality and quantity at a watershed scale. In some cases, development may be ongoing in an upstream jurisdiction and the ability to coordinate may provide opportunity to address excess stormwater runoff in a way that reduces, or at least doesn’t make worse, existing urban flood inundation areas. The development of watershed coalitions, groups comprised of representatives from various watershed stakeholders, is one approach that local managers should consider. These coalitions allow for a broader context in which to evaluate solutions that will benefit all residents in a watershed, while also maintaining a philosophy of “do no harm” when it comes to ongoing and future development. Watershed coalitions have had significant success in Louisiana and Colorado and may provide some guidance for local managers seeking to develop watershed solutions as part of addressing existing urban flood risk.

Communication with the Public

Due to the challenges previously stated, sharing urban flood risk with the public requires a well thought out strategy and plan to ensure local residents are not left feeling helpless once the information is shared. It's important that public works and floodplain managers already have a strategy in place to not only identify the areas at risk, but also have a follow-up set of specific actions to proactively address the identified problems. This is best done by a planning process that starts with one-on-one meetings with community leaders, such as neighborhood groups or homeowners associations, and builds towards smaller neighborhood meetings, and ultimately larger community meetings. The key to success in this type of outreach is to fully educate the public about the problem, how it came to exist, and what it means to them. Taking the time at the front end of the planning process to allow citizens to absorb the information is incredibly important. These are the places they live, work, and play and any future improvements will directly affect them, not only for the good, but in terms of construction impacts, land buyouts, right-of-way, community amenities, and so on. A successful implementation program will start with community trust building.

Many property owners think that because their property or neighborhood is located outside of the flood zone, they are immune to the effects of urban flooding. Road closures, infrastructure damage, limited access to emergency facilities due to urban flooding are some of the issues that should be taken seriously by all residents. Effective communication regarding the impacts urban flood hazards should be targeted to everyone within the watershed, not just people living in or near a flood zone. For example, flash flooding at low flow crossings are serious issues for residents and local officials in the Phoenix metro area. For a majority of the year, people drive through low flow crossings without fear of flooding. During the monsoon season, the low flow crossings become a serious hazard since flood waters rapidly rise in response to the flood events. Phoenix and the Flood Control District of Maricopa County post warnings at these crossings and continually remind residents of the flood hazards throughout the year – not just during the monsoon season. Communities might consider the installation of urban flooding signage that warns residents and visitors that streets may flood during storm events. Another idea might be to create a monument on the ground surface showing the primary flow path of flood waters through the basin during extreme events to serve as a reminder of the risk of flooding.

Using the fact sheets, inundation mapping, presentations and other materials, planners can communicate directly with citizens about urban flood risk. The importance of taking time to fully educate the public about urban flood risk cannot be understated. Jumping into the planning process before the community understands and takes ownership of the existing problem will likely lead to a flawed planning process with little to no public buy-in. Each community may choose to address their urban flood risks differently, so building a common understanding is paramount, and then building on that understanding a community can work together to develop goals and objectives that reflect community values. Ultimately, community members must be involved in the planning process from start to finish, from identification of the issue through strategic planning and long-term implementation. The success or failure of any plan is directly related to the amount of community support developed through the process.

Over time, regular and sustained communication with the public about these flood risks must be continued. Through the planning process and after, communities should develop communication plans that provide the most up to date hazard information and pending actions. This information might be tied to websites that already exist or be included in separate websites related directly to a specific neighborhood or community. Additionally, these websites should connect to already existing materials such as FloodSmarg.gov that is recognized as having current, accurate information that is specifically geared toward use by the public. Communities that are successful at communicating urban flood risk use a variety of methods to convey those messages; websites, social media, newspapers, and local television stations are effective ways to deliver information. Personalized messaging for property owners is likely the best way to communicate urban flood risk. Local communities can initiate opportunities to remind people to ask about their flood risk by presenting at fairs, neighborhood meetings, schools, and like- minded organizations such as the state ASFPM chapter. By becoming involved in residents' normal activities, local officials can integrate urban flood hazard messages in their daily lives. Mailouts[1] to inform property owners of changes in their flood risk are also effective. For specialized messaging like construction beginning on a new capital improvement project meant to alleviate flooding or a change in NFIP regulations, news releases in the newspaper or local television station may be required to relay this information to a wide audience.

Unfortunately, the same messages do not always necessarily reach renters of property in areas affected by urban flooding. Currently, property owners are not required to notify renters that there is a potential flood risk. Some cities in Texas are advocating that the state legislature pass reforms that require property owners to share flood risks with renters. Local agencies can develop local programs to provide information to the public or provide signs that indicate previous flood elevations in affected neighborhoods. Communities and organizations that provide information to renters include the City and County of Denver and Sacramento County. Other communities can take note of these actions and adopt them or modify to fit their local needs as necessary.

Community Goals and Objectives

Comprehensive planning must not only develop community goals and objectives that address urban flood risk, but those goals and objectives must meet the values of the communities at risk. Through a well thought out, process driven, and relatively time unlimited process of public outreach and education regarding the flood risk itself, planners can also begin to gather and compile a list of community values that may directly impact the outcome of a comprehensive planning process. This list of values very well may be unrelated to the urban flood risk but could affect proposed solutions. Some examples include:

- **Does a community desire more recreation or parks space?** This value might lead towards solutions that could be integrated with green infrastructure or traditional stormwater detention.
- **Is pedestrian or bicycle mobility within the community a significant concern?** This may be an opportunity to connect daylighting of storm drain systems with mobility solutions such as recreation paths along greenways.

[1] Metro Denver's Urban Drainage and Flood Control District sends a postcard to all property owners that are affected by changes in flood studies that may impact their flood hazard designation on the FIRMs. Property owners receive a postcard informing them if their flood risk has changed or remains the same.

- **How does the current land use within a neighborhood best meet the needs of citizens?** The values of the community might indicate that commercial development is not highly desirable. Alternatively, a community might determine that small commercial development connected by high mobility corridors could improve quality of life and reduce the need for driving.
- **Does the current transportation network meet future needs?** Varying street networks may provide opportunity to address urban flood risk in unique and creative ways and/or at least provide new corridors for pipe or stormwater infrastructure.
- **Is water quality a concern?** Communities that are directly concerned with water quality may determine that green infrastructure solutions are preferred as part of the long-term strategic plan. Additionally, these values could affect rules and regulations regarding future infill development.

This list of community values and priorities is almost endless. Thus, a planning team endeavoring to complete a comprehensive plan to address urban flood risk must start with determining a community's values and then integrating those with the goals and objectives that guide the alternatives development and overall planning process. As a starting place, the following guiding principals might be incorporated into the planning process to address urban flood risk:

- To minimize the impact of flooding associated with minor to moderate storm events;
- To think critically and creatively about stormwater resiliency in a built, urban environment;
- To increase public education and awareness role in adapting to flood conditions in the built environment;
- To examine basin characteristics as a test-case basin in order to identify implementable strategies that support a resilient community.

Ultimately, community engagement at multiple levels will determine the success of the developed plans to address urban flood risk. Developing an overall engagement plan that creates local ownership and understanding and establishes a systematic method of collaboration throughout the planning process is an important first step. Some suggested engagement strategies might include:

- Approaching neighborhoods with consistent, transparent, and responsive messaging and materials
- Creating opportunities for citizens to engage and collaborate with each other
- Convening a basin advisory group or working group that advises municipality on water related & community issues
- Coordinating with local business community

Investigate, Identify, and Evaluate Solutions

Historically, stormwater and floodplain management master plans have focused on infrastructure heavy solutions. Alternative screening often considered variations of the following:

- "Status Quo" – Maintain existing conditions
- Conveyance/capacity improvements
- Restoration of a natural type waterway
- Detention and/or water quality improvements
- Acquisition of flood prone properties

- Non-structural measures

While these alternatives are still valid and should be considered as part of every planning process, communities will want to consider how these alternatives integrate with a community's values and the goals and objectives developed at the front end of the planning process. Potential "add-on" considerations might include:

- Creation of new parks or open space in combination with acquisition of flood prone properties.
- Incorporation of green infrastructure on a local or regional scale that could affect streetscapes,
- Development of new greenway corridors in combination with restoration of natural drainageways.
- Restructuring of transportation networks or crossings that could create grade separated crossings for pedestrians and cyclists.
- Development of local land use regulations and ordinances as part of non-structural measures to limit or control development in a way that causes no adverse impact to existing flood risk.
- Flood risk zone mapping and/or special district assessments to help assist with future improvements.

A planner's toolbox is almost unlimited but must be informed by a community's desires and vision for the future. The following sections briefly discuss infrastructure solutions and local land use regulations that might be considered by planners, engineers, and managers addressing their urban flood risk. Also, because of the scale of improvements often required in areas of high urban flood risk, it's important to communicate with the public that it may take significant time to implement a full watershed level solution, i.e. one project is likely not going to solve the current urban flood risk issue. Explaining that there are multiple levels of implementation starting at the individual homeowner level (flood proofing and property improvements), moving up to the neighborhood level (neighborhood projects), and ultimately getting to the watershed/basin level (full-blown stormwater specific capital projects) will help citizens understand how improvements help to fix the problems that exist as a strategic plan is implemented.

Figure 7: Graphic showing how a resilient community might address urban flood risk starting at the individual level up through watershed solutions.

Potential Capital Improvements to Address Urban Flood Hazard Areas

New or upgraded stormwater infrastructure to address urban flood risk almost always requires significant expenditure. These costs vary wildly based on size of the watershed and whether the facilities are within previously developed or undeveloped areas. For previously developed areas, like those affected by urban flood risk, adding pipes to address runoff from upstream or infill development after little or no standards have been in place for decades can be extremely costly if not completely unattainable. Local managers face a daunting task of attempting to establish a need for such facilities, developing an adequate plan to address the urban flood risk itself, and providing justification of the associated costs.

Communities faced with addressing existing urban flood hazards have a variety of potential infrastructure improvements they can use to mitigate the existing risk to structures and emergency access.

Increase the Size and Capacity of Existing Stormwater Infrastructure: Through the planning process, communities may determine that replacing or adding to existing stormwater infrastructure could reduce the impacts of urban flood inundation. These types of options seek to either replace existing pipes or channels with ones that are larger in size and have more flow carrying capacity or ad parallel systems that convey additional stormwater runoff.

Daylighting/Drainageway Restoration: Restoring a natural conveyance system, that was previously filled in and/or converted to a piped conveyance system. The benefits of this type of solution include a return to a more natural flood conveyance system with more capacity than a piped system; the opportunity to provide community amenities such as trails and recreation areas; improved or recreated ecological function; and improved water quality.

Stormwater Detention/Retention: Traditional engineering strategy that seeks to store excess urban runoff volume, releasing runoff at historic peak rates. These facilities can reduce the peak flow rates entering downstream locations where existing stormwater infrastructure may be undersized or unable to handle large storm events.

Green Infrastructure (GI) or Low Impact Development (LID): Green infrastructure and low impact development seek to manage stormwater runoff via infiltration, mimicking natural systems that existed prior to development. These systems reduce peak runoff rates and volumes, increase infiltration and ground water recharge, increase evapotranspiration and reduce pollutants in-situ (Newcomer et al., 2014).

Property Buyouts and Greenway Development: City's may consider the purchase of properties within urban flood hazard inundation areas as an alternative to new stormwater infrastructure. In some cases, buyouts may prove to be more cost effective than new infrastructure. Buyouts provide opportunity for new public amenities such as parks or green space and/or may also be used to implement green infrastructure strategies.

All of these infrastructure solutions should be informed by other community plans related to transportation, mobility plans, parks and recreation, major utilities, and land use. Taking the time to ensure compatibility with future plans, community values, and goals and objectives to address flood risk will ultimately result in a plan that has more opportunity for implementation success.

Cost

Costs to implement infrastructure solutions to address urban flooding can be significant and potentially unattainable. When considering infrastructure solutions, it's important to develop a comprehensive benefit /cost analysis that can be used to make data driven decisions. To support this type of analysis, depth-damage estimates for a full range of storm events is critically important. Understanding the frequency and cost of flood damage should be a part of the inundation mapping effort on the front end of the planning process. The currently established methodology per FEMA Benefit Cost Analysis (BCA) is to assess damages using USACE Depth Damage Function (DDF) Curves. These DDFs assign a percentage damage relative to the depth of flooding and the value of the building and the contents. Although this approach can provide a good starting point for assessing damages, it does not allow for assessment of the many tangential costs for delivery of disaster recovery programs. It also doesn't consider benefits directly related to community values or lifestyle.

As an add-on to simply evaluating depth-damage estimates as part of the benefit-cost analysis, planners might consider the use of assigning value to ecosystem services that include such items as water quality, ecology, stream function, overall health within a community that is active vs. inactive, and values of homes within a community as affected by local amenities. Additionally, some indirect economic benefits might include social cohesion, public safety and traffic reduction, mental health benefits from green space, and social equity considerations. How does one quantify ecosystem services benefits? It largely depends on the community priorities and on the regulatory atmosphere or the community. The ability for a community to quantify this cost is going to be very different in a community with a high degree of state and federal oversight vs a community that is mostly self-regulated, i.e. a community in Washington State is going to have more value associated with salmonid habitat preservation vs. a community in Texas where stormwater quality permits are mostly written and enforced at a community level with very little state oversight. Some professional groups have begun to assign values to ecosystem services that may be able to be used for planning studies Through the planning process and as alternatives are developed, revised depth-damage estimates must be developed to understand the mitigation benefit of each proposed solution. Developed alternatives should include multiple scenarios, with different levels of protection, different long-term benefits, future maintenance considerations, and a buyout option that includes demo and relocations.

Finally, communities should consider multi-generational timeframes when considering benefit / cost analysis. Where urban flood risk exists and isn't addressed, flood damage will continue to occur generation after generation and at higher and higher costs due to inflationary pressures. Large scale projects that mitigate flooding for large storm events will have the long-term benefit of future generations being virtually free from costly flooding; ultimately creating a more resilient community.

Non-structural, Planning, and Regulatory Solutions

During the planning process and in working with community leaders, non-structural and regulatory solutions to address urban flooding should also be considered. If they haven't done so already, communities should adopt criteria and regulations regarding new development in the upstream watershed limiting site runoff to historic conditions. Additional regulations and non-structural solutions that should be considered include:

Local Floodplain Ordinances. Although urban flood inundation areas may not be mapped under the NFIP, nothing prevents communities from mapping and regulating these hazard areas. The City and County of Denver has created mapping for urban flood risk and designates those areas as Potential Areas of Inundation (PIA). In these areas the City has detailed 2-D hydraulic modeling and water surface elevation estimates. New development must be constructed so that the first floor elevation is either a minimum of 12" above the 100-year WSEL or at a level above 2 x100-year flow WSEL.

No Adverse Impact. Communities should specify that in areas of urban flood risk, any new development must not cause any adverse impact to other structures or public right of way. Practically, this means that new development would not cause any rise in WSEL on nearby structures and also wouldn't result in increased depths within the street right-of-way for emergency access considerations.

Insurance. Where urban flood risk exists, communities should encourage their constituents to obtain flood insurance from the NFIP. As originally noted, urban flooding has many causes such as overland ponding, inadequate sewer capacity, basement backups, and overbank flooding. Typical homeowner insurance policies do not insure against flood losses. Consequently, homeowners should consider purchasing flood insurance and additional relevant endorsements, i.e., a basement backup endorsement. Property owners should consider a holistic insurance approach to insure properties against flood damages. Different types of water intrusion are covered by different insurance policies. For example, a basement backup endorsement may cover the loss caused by sewer backups and a flood insurance policy covers against flood losses. The insurance premiums for these areas are often less expensive than properties within SFHAs.

SECTION 4: RECOMMENDATIONS

Recommendation 1: Identify and Map Urban Flood Hazard Areas

Although many stormwater and floodplain managers know there are highly developed areas that flood on a regular basis and cause flood damage within their communities, these areas often remain unmapped and not completely understood. It's imperative that local communities understand the current risk of flooding in unmapped urban areas.

- Local communities should begin setting aside funds to study and map urban flood risk.
- FEMA and States should consider the creation of an incentive-based model to fund mapping and mitigation.
- Federal legislators should make federal funding available to assist local communities in mapping urban flood risk but should not necessarily be tied to NFIP mapping. Local communities can better understand their mapping needs and how developed data will be used.
- National organizations such as ASFPM and the National Association of Flood & Stormwater Management Agencies should partner with FEMA and local agencies in developing modeling and mapping standards for urban flooding. Those standards must be developed in full coordination with local government agencies to ensure their effectiveness and their acceptance over time. Identifying unmapped flood risk has many significant challenges, so not only developing standards, but effective policies for managing the newly mapped risk will be imperative for local stormwater and floodplain managers.

Recommendation 2: Communicate Urban Flood Risk

Inform the public that not all flood risk is mapped or understood. Citizens outside of SFHA's believe there is no real flood risk to them or their property because NFIP maps do not show flood risk in many non-riverine, non-coastal, urban areas. Communicating this flood risk through programs such as FloodSMART, state agencies, and local agencies should be a priority to insure at-risk homeowners and business owners.

- Communities must communicate with landowners about actual flood risk and recommend purchase of insurance in areas outside of the SFHAs, but near unmapped urban flood risk.
- Nationwide best practices for communicating and educating the public regarding urban flood risk must be developed to be used by local communities as part of comprehensive and collaborative urban flood risk mitigation planning. ASFPM may consider how to support these efforts in developing how to guides for local managers addressing urban flood risk.
- Communities should create awareness and develop policies to help residents understand how funding and design standards reduce risk, but also the real value in maintaining infrastructure and their role in supporting these efforts.

Recommendation 3: Develop Local Building Construction Standards

Communities should regulate new development and redevelopment within urban flood inundation areas. In addition to developing standards for elevating new construction above identified flood risk, communities should anticipate the geophysical impacts that climate change portends—and develop strategies to respond to the variety of human decisions, perceptions, and reactions likely in post-disaster recovery and redevelopment scenarios.

Recommendation 4: Employ Multi-Generational Approaches to Implementing Improvements

Communities should consider long-term planning in urban flood zones that prioritizes buy-outs of flood prone properties over time, to support a strategy to restore the natural and beneficial functions of historic drainageways and provide for more resilient flood recovery. These buy-out properties can support various implementation strategies, including stormwater detention, green infrastructure, or daylighting or partial daylighting of pre-development drainageways. This approach will require communicating urban flood risk and limiting built environment engineering strategies such as increasing pipe capacity or elevating levees. Property buy-out may not occur before disasters, in the aftermath of which citizens are asking, “What’s next?” However, having resilient master planning documents that provide large-scale, comprehensive strategies is the first step to reducing losses due to urban flooding over time.

Benefit / Cost ratios should be considered over generations rather than just within one generation, one mortgage amortization, or one planning horizon. Communities that consider the cost of flood damage over an extended period can begin to realize the long-term cost to future generations and the potential savings from long-term future planning.

ASFPM should consider the development of how to guides that create a framework for local managers on how to manage urban flood risk addressing areas of identification, communication, planning, and implementation. Additionally, success stories from around the country could be made available on the internet through the Science Center in similar fashion to the Community Rating System success stories.

Recommendation 5: Identify Flood Mitigation Funding for Urban Flood Inundation Areas

Implementation costs for solutions to mitigate urban flood hazards are substantial. Before mapping these areas as part of NFIP, mitigation funding must be identified to reduce future flood damages and flood risk. Federal, state, and local government organizations have a duty to develop hazard mitigation programs and identify funding for implementing best management practices to reduce future damages due to urban flooding. This effort will involve numerous governmental and non-governmental organizations and will require the development of committees to capture ideas on how mitigation funding might be best created, combined, and distributed to communities addressing urban flood risk.

SECTION 5: RESOURCES

Section 1 References

The NFHL is made from effective flood maps and Letters of Map Change (LOMC) delivered to communities. NFHL digital data covers over 90 percent of the U.S. population. https://www.fema.gov/national-flood-hazard-layer-nfhl

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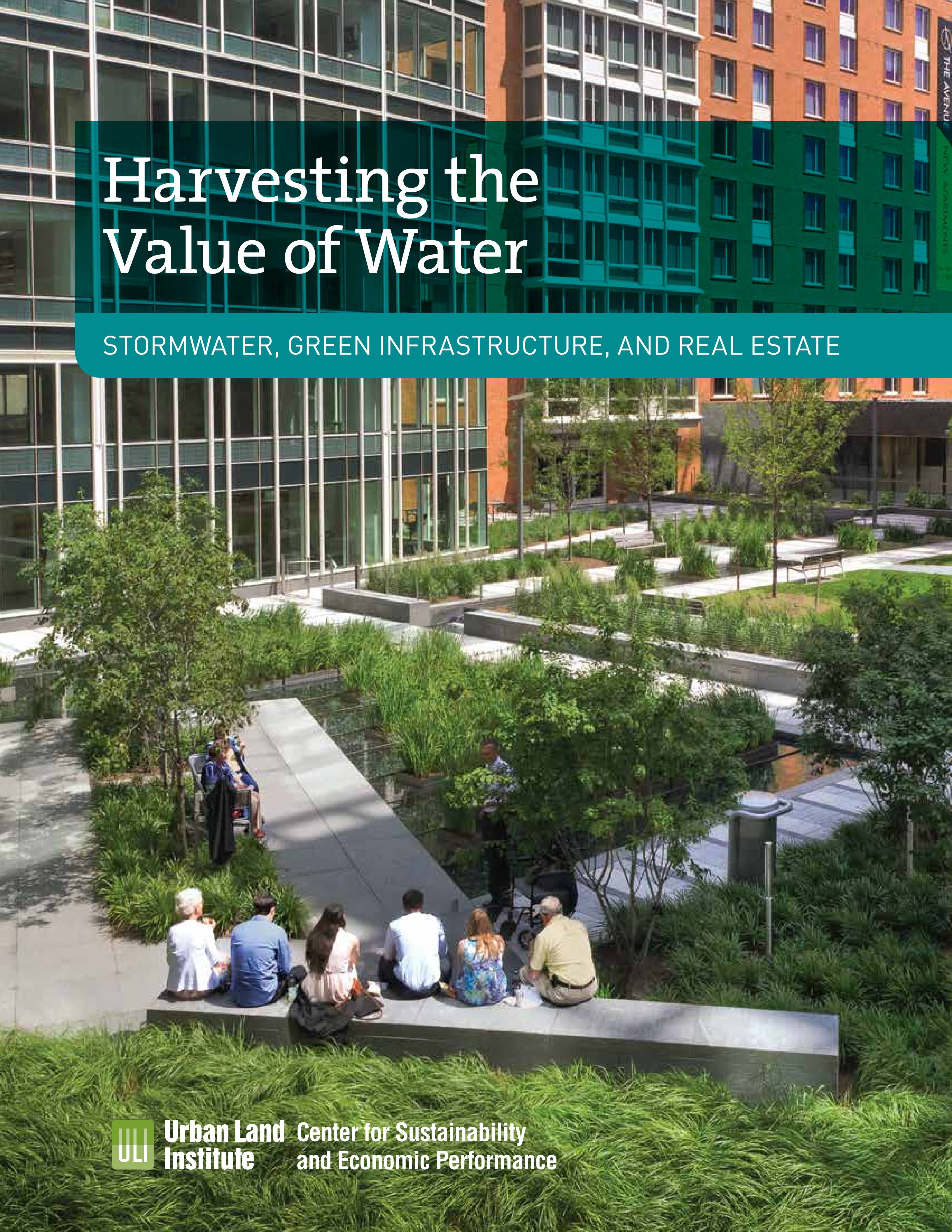

Harvesting the Value of Water

STORMWATER, GREEN INFRASTRUCTURE, AND REAL ESTATE

ULI Urban Land Institute Center for Sustainability and Economic Performance

On the cover: The Avenue, located in Washington, D.C., includes an inviting courtyard water feature that uses 100 percent reclaimed water. *(© 2012 Craig Kuhner)*

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Harvesting the Value of Water

STORMWATER, GREEN INFRASTRUCTURE, AND REAL ESTATE

Urban Land Institute Center for Sustainability and Economic Performance

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The ULI Center for Sustainability and Economic Performance is dedicated to driving more sustainable, environmentally responsible, and profitable outcomes in real estate development and investment, and to helping ULI members create healthy, resilient, and resource-efficient communities around the world. The Center advances knowledge and catalyzes adoption of transformative market practices and policies that lead to improved sustainability, health, resource efficiency, and resilience. ULI's stance on sustainability is grounded in the belief that, properly designed and implemented, these practices ultimately deliver stronger investment returns and improved fiscal performance.

Within the Center for Sustainability and Economic Performance, ULI's Urban Resilience Program aims to help ULI members and the public make their communities more resilient in the face of climate change. Through research, conferences and events, technical assistance projects, and its work with ULI's District Council network, the Urban Resilience Program focuses on opportunities relevant to the built environment, real estate markets, and the land use policy sector. Many of the Urban Resilience Program's projects have focused on the management of water in urban settings during peak and routine events, including methods for capturing water through green infrastructure.

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CONTENTS

ABOUT THIS REPORT

This report was made possible by the generous support of the Kresge Foundation. Numerous ULI members and staff contributed to the report and research process, including the Sustainable Development Council and the Responsible Property Investment Council.

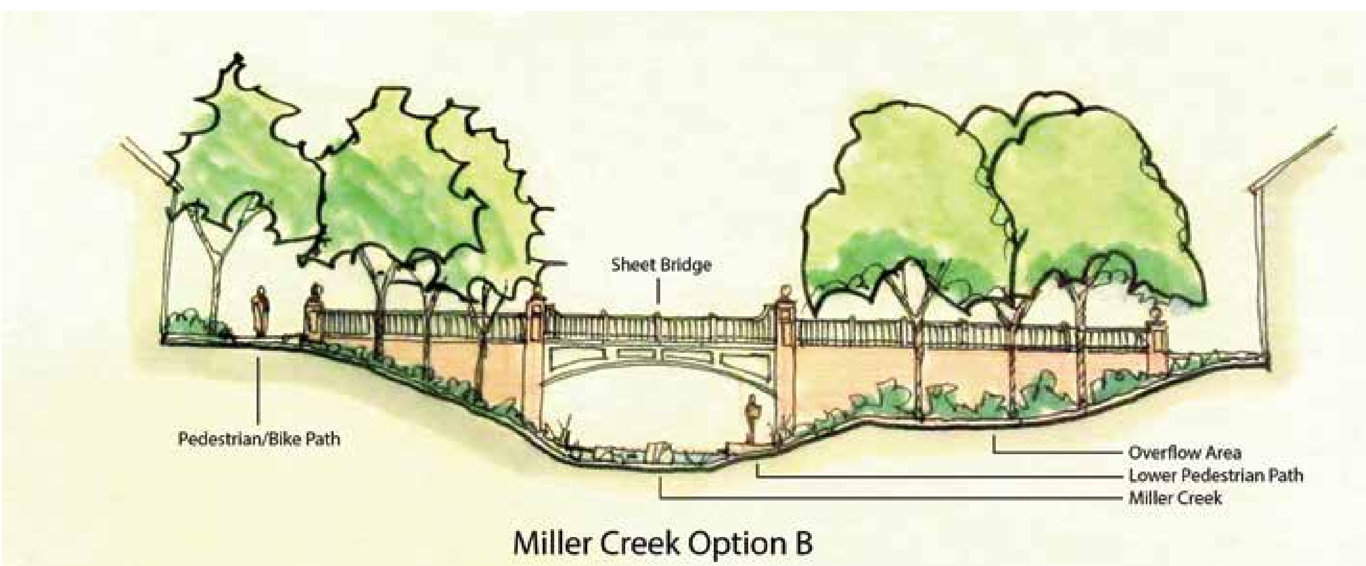
ULI's Urban Resilience Program undertook this research project in response to both policy trends and increased interest in water management among ULI member networks and communities. The research also builds from the program's recent work, including Advisory Services panels focused on resilient approaches to water management, *Returns on Resilience* case studies highlighting projects with innovative approaches to water management, and the 2015 Shaw Forum in Philadelphia, which brought together leaders in green infrastructure to explore best practices in stormwater management and low-impact development policies.

The 2015 Shaw Forum convened leaders in green infrastructure to discuss low-impact-development strategies and learn from the policies in place in Philadelphia. *(Jess Zimbabwe/Rose Center for Public Leadership)*

This report seeks to address a gap in today's research on stormwater management approaches. Although much has been written on the topic of green infrastructure and water management, most recent reports focus on stormwater policies or opportunities for capturing stormwater in the public realm. Fewer have focused on implications for private sector real estate developers.

This report brings together an analysis of the stormwater policy landscape and an introduction to a variety of real estate development projects that have responded to them. After outlining the reasons that stormwater management is important to cities, this report introduces a series of real estate case studies and a range of types of stormwater policies. The case studies come from locations across the United States and present both innovations in stormwater management and positive financial, operational, or design outcomes.

Discussions with real estate developers, policy makers, property managers, and designers greatly contributed to the development of this report. Numerous ULI members participated as interviewees and reviewers providing feedback on this paper and the overall project.



The Duluth, Minnesota, Resilience Advisory Services panel developed a series of options for the city to address recent flooding problems, such as the flash flooding in 2012, using green infrastructure and creek restoration projects. *(ULI)*

CHAPTER 1

Introduction

Water abundance and scarcity are topics of increasing importance in cities across America. With growing concern about flooding, weather-induced overflows from sewer systems, and extreme storms, communities are seeking strategies to better manage stormwater runoff, improve local water quality, and decrease pressure on overloaded sewer systems. At the same time, water is increasingly recognized as a community resource, one that can be harnessed to make cities more sustainable and livable.

Managing Water: The Real Estate Sector's Role

Private sector developers and designers are playing a growing role in meeting cities' water goals. Local regulations are seeking increased participation from the private sector, requiring or incentivizing the real estate community to incorporate enhanced water management mechanisms into new development projects. These water management mechanisms have the potential to create value for real estate projects by enhancing aesthetics, operational efficiency, and building user experience.

The courtyard of ECO Modern Flats in Fayetteville, Arkansas, prominently features green infrastructure, including a bioswale that filters runoff from parking areas. *(Timothy Hursley)*

Vegetation adds texture and aesthetic appeal to a green roof. *(PUSH Buffalo)*

At the heart of many new stormwater policies is the concept of *green infrastructure*. The phrase has emerged as a catch-all term for approaches to managing stormwater with natural systems as an alternative to traditional gray drainage infrastructure, such as pumps and pipes. Green infrastructure is intended to capture stormwater, enhance water and air quality, and create attractive green spaces. Visible green infrastructure, such as rain gardens, bioswales, and green roofs, are accompanied by unseen technologies for water reuse, such as cisterns and rainwater recycling systems. Approaches to green infrastructure, on both the citywide and project scale, also enhance urban resilience by using flexible interventions to improve preparedness for both flooding and drought.

Whereas the concept of green infrastructure is not new, the notion of municipal policies creating a coordinated citywide green infrastructure network—including both public and privately owned sites—is. These networks require extensive participation from the private sector, enforced through policy requirements for newly developed and refurbished sites. In short, municipalities envision the public sector incorporating green design into public spaces, buildings, and rights-of-way while the private sector does the same for privately owned buildings, open spaces, and roofs.

Municipalities are increasingly requiring or incentivizing this approach in real estate projects and encouraging reductions in impervious surfaces such as concrete. Local governments are also providing frameworks supporting citizens, community groups, and institutions interested in incorporating green infrastructure into their properties, whether through grant programs, big data projects, demonstration projects, or idea competitions.

Many real estate developers are responding to new regulations by incorporating the requirements into their business models. Indeed, some developers have successfully leveraged stormwater management mechanisms not only to reduce and manage runoff, but also to add value to their buildings.

Whether by increasing potential development yield, introducing tangible amenities for residents, reducing operating costs, or building on a broader placemaking strategy, innovative stormwater management strategies can create value and contribute to quality of life and resilience in cities.

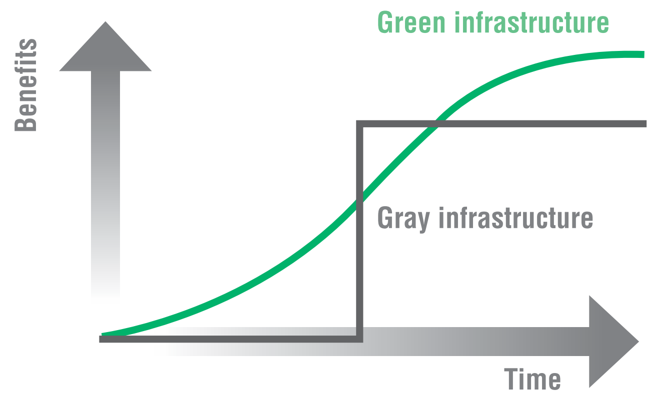
Case Studies

Developers across the United States are increasingly incorporating green infrastructure into their projects, whether on account of stormwater policy requirements or for other reasons that range from marketing value to compliance with green rating systems to cost savings.

Alongside an analysis of city policies, this report introduces the following real estate projects that have included green infrastructure and seen successful development outcomes:

- **Atlantic Wharf, Boston, Massachusetts**—a 31-story Class A office, retail, and residential development, described as "Boston's first green skyscraper," with a pioneering stormwater management system;
- **Burbank Water and Power EcoCampus, Burbank, California**—a campus for a community-owned utility site, which is the first power plant in the world to run on 100 percent recycled water;
- **Canal Park, Washington, D.C.**—a neighborhood park developed by a public/private partnership and located on the site of a former D.C. waterway, with 95 percent of the park's irrigation, fountain, toilet-flushing, and ice-rink water provided through rainwater recycling;
- **Encore!, Tampa, Florida**—a 28-acre public/private, mixed-use, mixed-income development with an 8,000-square-foot stormwater retention harvesting system and a stormwater vault designed as the centerpiece of a public park;
- **High Point, Seattle, Washington**—a HOPE VI redevelopment, currently the Seattle Housing Authority's largest residential project at 1,700 affordable and market-rate homes, with an extensive natural drainage system featuring bioswales and constructed wetlands;
- **Market at Colonnade, Raleigh, North Carolina**—a 57,000-square-foot commercial development capable of capturing up to 800,000 gallons of rainwater, including a Whole Foods Market that chose to include a visible cistern as part of its branding for the site;
- **Meier & Frank Delivery Depot, Portland, Oregon**—an office development in a National Register of Historic Places building in downtown Portland, with a rainwater recycling system that saves an estimated 193,000 gallons of water annually;
- **Penn Park, Philadelphia, Pennsylvania**—a community open space developed through public/private partnership by the University of Pennsylvania and designed in response to Philadelphia's *Green City, Clean Waters* plan and the university's Climate Action Plan;

- **Stonebrook Estates, Harris County, Texas**—a Houston-area residential development with a low-impact development approach that stood up to catastrophic flooding during the Tax Day floods of 2016;
- **The Avenue, Washington, D.C.**—a mixed-use, transit-oriented development in downtown Washington that features a robust stormwater management system set in an inviting residential courtyard; and
- **The Rose, Minneapolis, Minnesota**—a 90-unit mixed-income residential project designed for on-site treatment of all stormwater, with features that include a rain garden and cisterns.



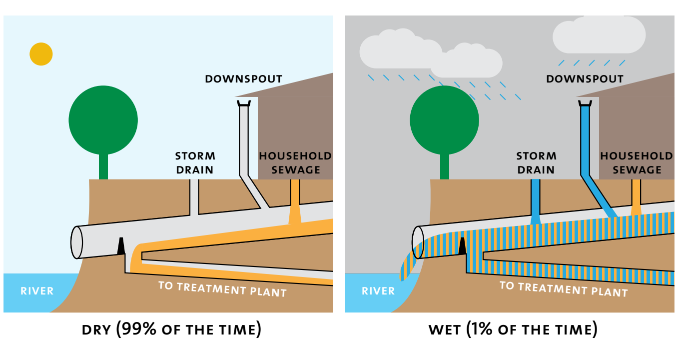
Over time, green infrastructure provides increasing benefits, in contrast with gray infrastructure. *(NYC Green Infrastructure Plan, Executive Summary)*

Lessons Learned

Cities often choose to incentivize or require stormwater management from the real estate sector because of top-down regulatory measures addressing water quality. Indeed, the U.S. Environmental Protection Agency (EPA) estimates that approximately 860 communities representing 40 million residents are affected by combined stormwater and sewage runoff in the United States.[1] Much of the municipal interest in enhanced stormwater management originates from regulatory measures addressing these water quality problems, such as the EPA's consent decrees to mitigate combined sewer overflows (CSOs). The 1972 Clean Water Act underpins these actions.

However, although the impetus to address stormwater management is often top-down, American cities' approaches to stormwater policy have differed across local markets, responding to differing markets conditions, annual rainfalls, and climate challenges. Conversations with real estate developers, designers, planners, and policy makers active in stormwater management shed light on numerous themes and lessons common to communities involving the real estate sector in stormwater management:

For cities, green infrastructure offers an opportunity to enhance environmental performance and save money, compared to costly gray infrastructure projects that do not offer other community benefits. Cities across the United States are embracing green infrastructure approaches because they offer social, economic, and environmental benefits while addressing water challenges. Green infrastructure cost-effectively reduces sewer system overflows and manages stormwater runoff, improves local water quality, decreases the use of potable water, reduces heat-island effects, improves public health, enhances recreational opportunities, increases employment, and stimulates economic growth—all at a lower cost than gray infrastructure solutions alone.



Combined sewer systems overflow during heavy storms, discharging raw sewage into designated water sources. *(Annemieke Beemster Leverenz/GrowNYC)*

Unlike large-scale CSO pipe-and-tunnel mitigation projects, a green infrastructure approach allows small-scale interventions and participation by private landowners. Lower upfront and maintenance costs can also make green infrastructure more accessible, resilient, and cost-effective than large-scale gray infrastructure investments.

For real estate developers, green infrastructure provides opportunities for cost saving by freeing up more developable land than traditional water management solutions. Using green infrastructure or low-impact development (LID) can be a more cost- and space-efficient means of achieving stormwater management requirements than gray infrastructure or traditional approaches such as detention ponds. Numerous projects profiled in this report chose to take innovative approaches to water management to free up space on constrained sites and achieve a larger developable area.

Green infrastructure can enhance the attractiveness and value of a property and reduce operating costs. Real estate developers, designers, and building operators interviewed for this report emphasized the multiple benefits that green infrastructure and stormwater management mechanisms have brought to their properties, often leading to increased real estate value.

From improving the design of the public realm to creating educational opportunities and amenities, many interviewees saw green infrastructure as offering social and community benefits

> "When we look at the amount of work that needs to be done to manage stormwater in the District—the vast area of public and private land that needs to be retrofitted as well as the money and time involved—we realize that we can't accomplish our water quality goals by only implementing public projects. Incentive programs that encourage voluntary retrofit are a huge piece of the puzzle."
>
> JEFFREY SELTZER, ASSOCIATE DIRECTOR, DEPARTMENT OF ENERGY & ENVIRONMENT, WASHINGTON, D.C.

Canal Park was a key part of a neighborhood-wide redevelopment strategy, enhancing attractiveness and adding a significant amenity for current and future residents and office workers. *(© Bruce Damonte)*

that contribute to real estate value and marketing opportunities. Many also spoke of the opportunities to operationalize green infrastructure, generating savings on utilities, maintenance, water use, and upkeep.

The emerging range of green infrastructure policies and strategies works in different markets and contexts. Cities across the country have used policies in different combinations appropriate to their local market conditions and environmental needs. Real estate projects profiled in this report include historic buildings and high-density developments as well as open space–rich and suburban projects.

Green infrastructure mechanisms can be effectively implemented in scenarios when space is at a premium. Stormwater credit-trading systems, such as the system recently launched in Washington, D.C., offer an alternative strategy for achieving compliance in densely developed areas by supporting off-site green infrastructure within the same watershed.

Green infrastructure may require an initial learning curve, but the payoff can be large. Interviewed policy makers and city-planning practitioners indicated that the real estate community is often initially hesitant about new stormwater policies. Property developers and owners also indicated that design and operation of stormwater projects requires a learning curve, particularly in terms of landscape maintenance for green infrastructure installations such as bioswales and rain gardens.

However, after local designers and developers had learned how to accommodate green infrastructure requirements and work them into the initial stages of the design process, incorporating green infrastructure became part of business as usual.

With this increasing familiarity, the real estate community also recognized the opportunities for improved amenities, aesthetics, and marketing appeal that can be derived from green infrastructure. As stormwater management policies continue to gain traction, cities and developers can learn from each other and gauge the success of different models through research and practitioner networking programs.

Real estate owners and operators value green infrastructure's performance during peak weather events and the added security this brings to their investments. Green infrastructure can be a particularly valuable investment during peak weather events such as floods, which can damage properties and shut down day-to-day activities across communities. In this way, investment in stormwater management can enhance the resilience of buildings, neighborhoods, and communities, thereby ensuring that lives and livelihoods are not interrupted while also improving quality of life and environmental performance on a day-to-day basis.

CHAPTER 2

The Root of the Problem

Water is a critical natural resource, vital to human and environmental health. Water is essential for cities, many of which are situated on the coasts or at the confluence of major rivers or waterways.

For example, Chicago's 2014 *Green Infrastructure Strategy* opens with commentary on the importance of water to Chicago, not only emphasizing the need for clean drinking water and water access, but also detailing the recreational, economic, tourism, and quality-of-life importance of having clean waterways.[1] Efforts to better manage stormwater are increasingly framed in this way, ensuring that citizens, policy makers, and members of the business community recognize stormwater as an issue bigger than the consequences of an occasional large rainfall.

A combination of environmental factors and built conditions has led to today's concerns about stormwater. The increased frequency of rainfall in many parts of the country, urbanization, aging infrastructure, and the proliferation of impervious surfaces have all contributed to the severity of the problem. Budgetary concerns and the high cost of capital projects and day-to-day city maintenance of water infrastructure have led cities to seek opportunities for private sector action.

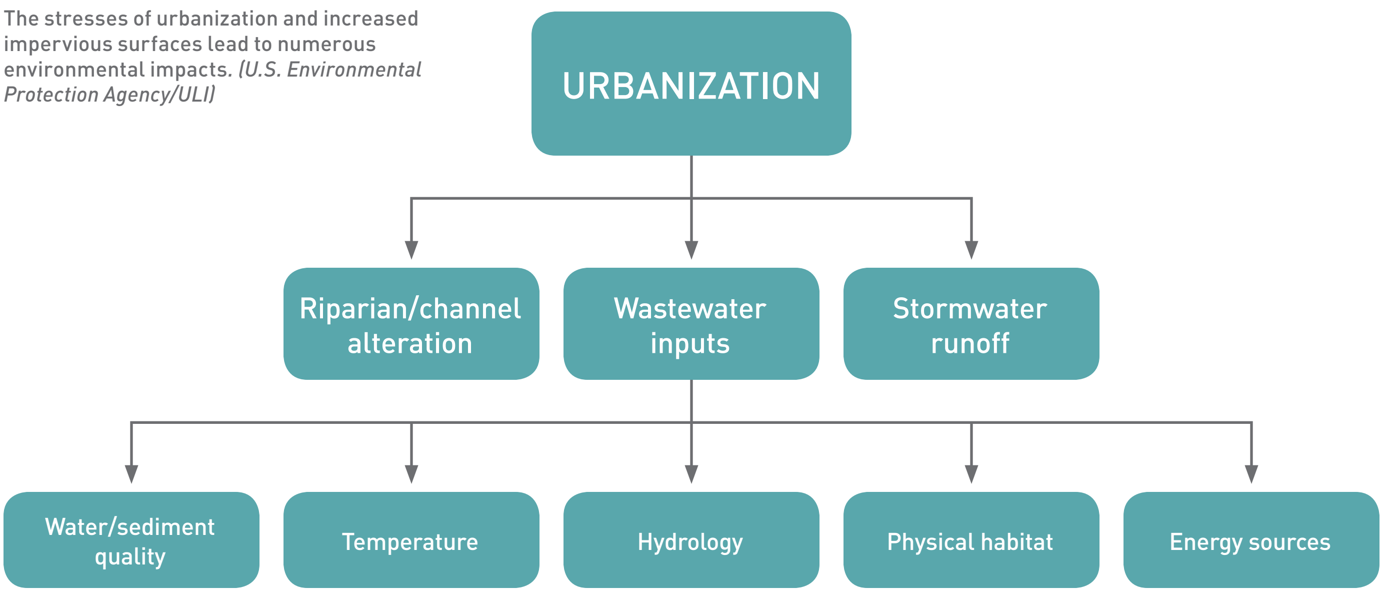
Cities and Water

By 2050, more than two-thirds of the world's population will be living in urban areas.[2] North America is already one of the most urbanized areas in the world, with 82 percent of residents living in urban areas in 2014, according to the United Nations *World Urbanization Prospects* highlights.[3]

With urban development comes an increase in impervious surfaces, such as roads, sidewalks, parking lots, and roofs. Replacing the natural landscape with these surfaces leads to fewer opportunities for water infiltration, which in turn generates more runoff.[4]

The U.S. National Research Council has asserted that stormwater management is one of the more pressing environmental concerns for the country because stormwater is one of the most consistent pollution sources of rivers, lakes, and streams.[5] The EPA also explains that an increase in impervious surfaces generally leads to "more frequent, larger magnitude and shorter duration" peak flows, ultimately altering urban stream-channel morphology, increasing erosion, and decreasing water quality.[6]

The stresses of urbanization and increased impervious surfaces lead to numerous environmental impacts. *(U.S. Environmental Protection Agency/ULI)*



Impervious surfaces, such as this sloped alleyway in Washington, D.C., reduce opportunities for infiltration, thereby increasing the speed of runoff and the likelihood of flooding while reducing water quality. *(ULI Washington)*

As stormwater carries pollutants such as oil, grease, fertilizer, sediment, and pesticides into the sewage system or nearby bodies of water, water quality is compromised.

An increased volume of runoff, if unmitigated, can lead to an increased likelihood of flooding, and in older combined sewer systems can result in frequent overflows of those systems and attendant surface-water quality concerns.

Infrastructure plays a key role. In the United States, contemporary water challenges can be traced at least in part to the legacy of car-centric planning, which transformed undeveloped, vegetated, and uneven land into impermeable flat surfaces.[7] Building and financing new hard infrastructure to address flooding, rainfall, and sewage needs is a challenge for most American cities, particularly given that many struggle with the upkeep of their existing infrastructure.

In addition, many older cities were built with CSO systems that carry both sanitary wastewater and stormwater. These systems can overflow during rain events and discharge untreated sewage to nearby creeks, rivers, and lakes, potentially causing disease outbreaks and compromising water quality, wildlife habitats, and health.

Environmental Regulations

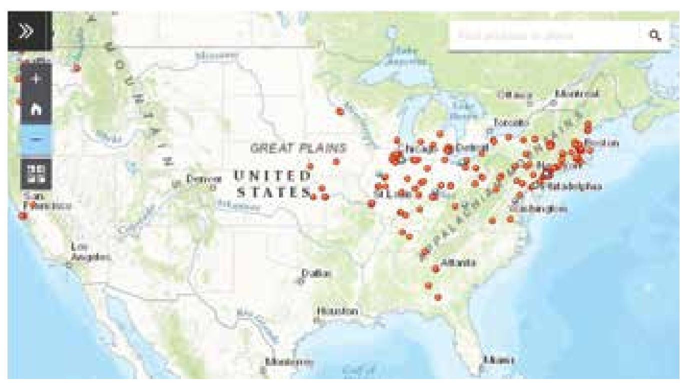
The management of stormwater quality in the United States began in 1987, when Congress amended the Federal Water Pollution Control Act of 1972 (more commonly known as the Clean Water Act) to expand the regulation of stormwater runoff. Before then, nonpoint sources and industrial, construction, and municipal stormwater point sources were unregulated, despite being the cause of significant surface-water quality issues. Even small storms could dramatically affect water quality.[8] After the 1987 amendment, the EPA promulgated a series of regulations, and, with the states, began issuing permits to industrial, construction, and municipal stormwater dischargers.

The Clean Water Act requires that any person must have a permit to discharge a pollutant to waters of the United States. The EPA and the states issue permits to a host of different entities, requiring that pollutants be managed before discharge to water bodies so that the nation's creeks, rivers, lakes, and beaches remain fishable and swimmable.

Wastewater from cities and factories is typically treated in a central wastewater treatment plant. Stormwater pollutants are usually addressed using a combination of education, operational approaches, good housekeeping practices, and some engineered systems.

The CSO issue began to get EPA's attention in 1994. Today, EPA consent decrees—which are legally binding agreements between a city, the EPA, and the U.S. Department of Justice—are forcing cities across the country to address their CSOs through a combination of sewer system improvements, large-diameter tunnel storage systems, and green infrastructure and LID to reduce the volume of stormwater runoff that enters the combined sewer.

More than 700 U.S. cities with such systems have entered into consent decrees.[9] The EPA and states also issue cities Municipal Separate Storm Sewer System (MS4) Permits that often include LID or green infrastructure requirements.



The EPA tracks U.S. CSOs serving a population of 50,000 and provides the status of their consent decrees, if applicable. *(U.S. Environmental Protection Agency)*

STORMWATER AND HEALTH

Stormwater and health are inextricably linked. When stormwater is effectively managed as a community asset, a key benefit is a healthier environment for humans and animals, including improved air quality and cleaner water for consumption, recreation, and wildlife. Green infrastructure strategies provide opportunities for enhanced community parks and recreation areas, offer places to grow food, and help mitigate urban heat-island effects and their public health challenges.[i]

However, many communities struggle to manage stormwater. One key challenge is combined sewer overflow systems, which mix sewage with stormwater runoff during high rain events, thereby allowing untreated sewage to spill directly into waterways. The EPA estimates approximately 860 communities representing 40 million residents are impacted by combined stormwater and sewage runoff in the United States.[ii]

Localized flooding and inundation of roadways can lead to traffic accidents, increased mosquito breeding, and other issues. Flood water can carry pathogens and spread toxic materials, road oil, and pollutants as well as contaminate water sources. Waterborne contaminants from everyday products such as fertilizers and pharmaceuticals pose public health concerns and are especially dangerous for pregnant women and children. Water that enters homes can compromise building structures, lead to mold and fungus growth, contaminate living spaces, and create the risk of electrical failure and shock.[iii]

Poor communities are more likely to be affected by water challenges because they are often located in low-lying areas prone to flooding and close to high-capacity drainage and retention sites.[iv] Their residents are more likely to swim or fish in polluted water sources. People with low incomes are also more likely to have chronic health challenges, such as asthma, which can be exacerbated by water issues. People of color and poor people are less likely to have the financial resources to quickly recover from the effects of disease and the loss of productivity that water-related challenges can bring.

Strategies explored in this report show how communities can avoid health-related hazards and maximize the potential of water management strategies that are win-wins for the environment and for health. For this potential to be realized, it is essential that stormwater solutions be equitably distributed.

i. V. Jennings et al., "Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health," *International Journal of Environmental Research and Public Health* 13, no. 2 (2016): 196.

ii. U.S. Environmental Protection Agency, "Combined Sewer Overflow Frequent Questions," National Pollutant Discharge Elimination System (NPDES) website.

iii. Adam Smith, "2016: A Historic Year for Billion-Dollar Weather and Climate Disasters in U.S.," U.S. National Oceanic and Atmospheric Administration, Climate, January 9, 2017.

iv. Cathleen Kelly and Tracey Ross, *One Storm Shy of Despair: A Climate-Smart Plan for the Administration to Help Low-Income Communities* (Center for American Progress, 2014).

"The *100-year storm event* is really a misleading term because it implies that the event will happen only once every 100 years. Really, we should call it the *1 percent chance storm*—because there is a 1 percent chance it will occur in a specific location every year. In the Houston region, the 1 percent storm is about 12 inches or 13 inches of rain in 24 hours."

RANDY JONES, PRINCIPAL, TERRA VISIONS LLC

Major rain events are becoming more likely to occur, creating an increased need to invest in alternative approaches to managing stormwater. *(© Willowpix/iStock)*

HEALTH BENEFITS OF SUSTAINABLE STORMWATER MANAGEMENT PRACTICES

How reducing and treating stormwater at its source—through bioswales, community gardens, porous pavement, and other measures—can benefit environmental, physical, and mental health

Environmental health	Physical health	Mental health
• **Habitats are stabilized** for pollinators, fish, and other wildlife, essential for biodiversity and food production, to thrive.[a] • **Air and water are filtered** from contaminants found in mold, standing water, human-produced waste, toxic piping, and other sources of disease.[b] • **Local water supplies can be replenished** through stormwater reuse and reclamation.[c]	• **Recreational spaces are created** for physical activity, which can reduce the prevalence of cardiovascular disease.[d] • **Access to healthy food is expanded** through community and rooftop gardening and beekeeping.[e] • **Physical safety can be promoted** through "greened, openly visible, and ordered spaces," which may reduce opportunities for violence and crime.[d]	• **Relaxation and feelings of well-being are enhanced** by green spaces that mitigate stressful environmental factors, including noise, building vacancies, and pollution.[d] • **Civic participation can increase** through urban greening projects that promote inclusive community involvement.[f] • **Neighborhood prosperity can be fostered** by green jobs, increased property values, and decreased costs for infrastructure, heating, and cooling.[g]

[a] U.S. Environmental Protection Agency, "Problems with Stormwater Pollution," Stormwater Program webpage.

[b] World Health Organization, *Guidelines for Drinking-Water Quality*, 4th ed. (Geneva: WHO, 2011).

[c] J. Lee et al., *Arid Green Infrastructure for Water Control and Conservation: State of the Science and Research Needs for Arid/Semi-Arid Regions* (Washington, DC: EPA, 2016).

[d] M.C. Kondo et al., "The Impact of Green Stormwater Infrastructure Installation on Surrounding Health and Safety," *American Journal of Public Health* 105, no. 3 (2015): e114–e121.

[e] R.J. McLain et al., "Gathering 'Wild' Food in the City: Rethinking the Role of Foraging in Urban Ecosystem Planning and Management," *International Journal of Justice and Sustainability* 19, no. 2: 220–40 (2014).

[f] V. Jennings et al., "Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health," *International Journal of Environmental Research and Public Health* 13, no. 2 (2016): 196.

[g] U.S. Environmental Protection Agency, "Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices," (Washington, DC: EPA, 2007).

The Climate Change Connection

Extreme rainfall is also more of a concern than it once was: for example, the number of days with heavy precipitation rose by 58 percent in the U.S. Northeast between 1958 and 2007.[10] As the world warms, warmer air can hold increased moisture, meaning heavier precipitation is likely.[11]

The EPA notes that among the impacts of climate change, precipitation has increased by an average of over an eighth of an inch per decade across the lower 48 states, with a higher percentage of precipitation coming through single-day events and eight of the top ten years for extreme one-day storm events occurring since 1990.[12]

Extreme storms are also likely to become more regular with climate change. In 2016, the Environmental Defense Fund noted that the United States saw four 1,000-year floods in five months in the diverse geographic areas of Texas, West Virginia, Maryland, and Louisiana.[13] With this level of frequency, the term *1,000-year storm* is becoming increasingly misleading: these storms are named for the statistical probability that they will occur, but the probability is computed using data from the past.

Even places plagued by drought face the risk of flooding because hard-packed soil can lead to its inability to absorb water and thus create flash floods. Climate change also brings the likelihood of increased heat to many regions of the country, meaning that intensified heat in cities, known as urban heat-island effect, is likely to continue to worsen.

In short, the challenges of urbanization and managing extreme precipitation, combined with the cost of aging infrastructure, strapped public budgets, and pressure from federal agencies such as the EPA, have led cities to look for alternative approaches to managing stormwater.

CHAPTER 3

Defining Green Infrastructure

Green infrastructure offers an alternative to the gray infrastructure that cities have traditionally used to manage water during everyday and peak storm events.

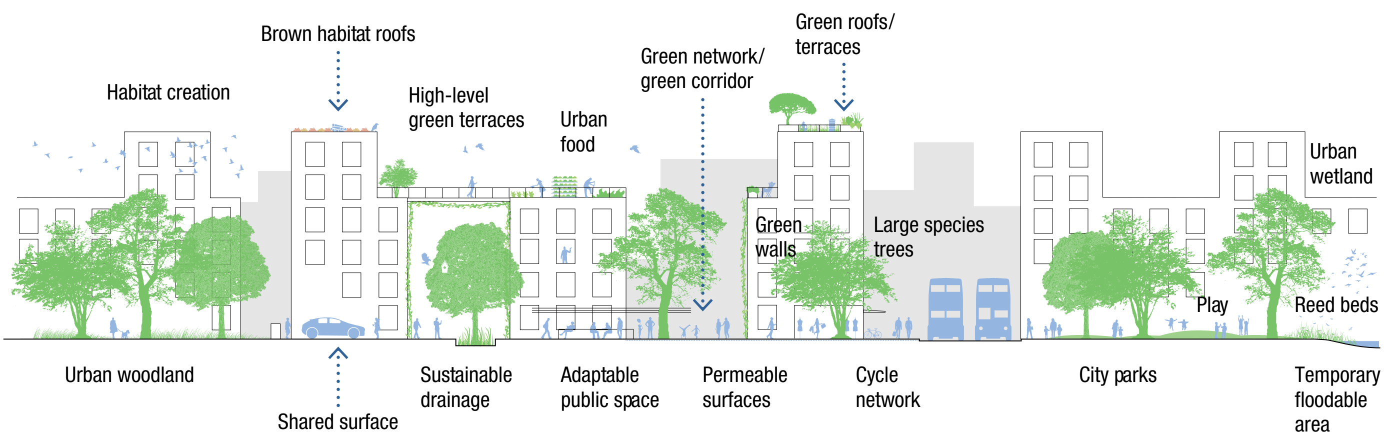
Gray infrastructure includes hard roofs, pavement, and pipes that are designed to convey stormwater away from a developed area. This approach treats water as a nuisance substance: a waste to be disposed of quickly and sent through pipes to detention basins.

Green infrastructure instead uses natural systems to slow water down, use it as a resource, convey it in landscape amenities, and as a result reduce potable water use. Natural drainage systems mimic the natural flow of water, creating bayous and corridors that can serve as attractive open spaces as well as water channels. According to the advocacy and conservation organization American Rivers, taking this approach can "provide clean water, conserve ecosystem values and functions, and provide a wide array of benefits to people and wildlife."[1]

A broad term, *green infrastructure* can refer both to site-specific measures and a community-wide or regional green network. The American Planning Association explains that "at the city and regional scales, [green infrastructure] has been defined as a multifunctional open-space network. At the local and site scales, it has been defined as a stormwater management approach that mimics natural hydrologic processes."[2]

The EPA describes green infrastructure as a strategy to achieve triple-bottom-line benefits, explaining: "Green infrastructure is 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."[3]

At the scale of a real estate project, green infrastructure often refers to design features that can capture, retain, and slow the release of stormwater during routine and peak events, using the



Green infrastructure can take on a range of forms, shapes, and sizes depending on the stormwater management goals, building types, and surrounding development context. *(© ARUP)*

Paseo Verde, a 120-unit mixed-income development in North Philadelphia, has a green roof over the first level that minimizes runoff and doubles as garden courtyards, an attractive amenity for residents. *(Halkin Mason Photography)*

storage, infiltration, evaporation, and carrying capacity of distributed elements rather than buried pipes and centralized, end-of-pipe detention basins. These distributed system elements can include green roofs, bioswales, berms, rain gardens, permeable paving, cisterns, and other aspects of a "rain chain."

Whether implemented together or separately, on building surfaces or in outdoor spaces, these design mechanisms can capture water, support natural infiltration, and enhance local ecosystems. Frequently, green infrastructure reduces the need for buried storm sewer systems and end-of-pipe detention systems, thus lowering infrastructure costs and providing more developable land.

These design interventions can also be a key aspect of park and public space design, creating spaces that are both attractive gathering places and capable stormwater management systems. Creating these types of balanced spaces, which can both hum with human activity and support cycles of natural ecosystems, is the specialty of many of today's landscape architects.

Benefits of Green Infrastructure

Implementing green infrastructure, particularly in conjunction with the private development community, is first and foremost attractive to cities because it costs less than traditional stormwater management approaches. For example, before initiating the ambitious *Green City, Clean Waters* plan, decision makers in Philadelphia learned that a new sewage pipe under the Delaware River would likely cost $10 billion.[4]

Likewise, New York City evaluated two stormwater management strategies and found that a green infrastructure plan, including green roofs, stream restoration, and bioswales, would save $1.5 billion compared to a gray infrastructure plan composed of tunnels, pumps, and storm drains.[5] The green infrastructure plan was projected to offer more long-term environmental, social, and economic benefits to the city.[6] The World Resources Institute has reported that decision makers in Idaho and North Carolina came to similar conclusions after evaluating comparable scenarios.[7]

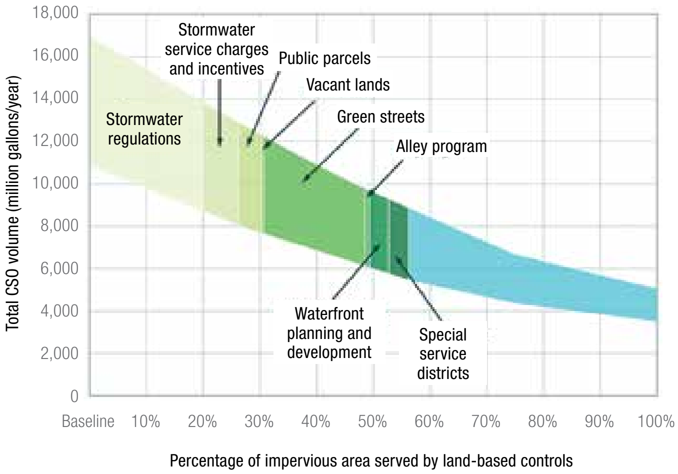
Philadelphia, Washington, D.C., and Seattle are national leaders in crafting policies to promote and create green infrastructure, with many other cities following suit. In most cases, the policies will eventually create a patchwork of green interventions across the city, implemented by both the private and public

GREEN INFRASTRUCTURE BENEFITS

The U.S. Environmental Protection Agency's 2016 report on green infrastructure solutions for downtown sites, *City Green*, cites the following potential benefits of green infrastructure:

- Improved water quality
- Reduced municipal water use
- Groundwater recharge
- Flood risk mitigation for small storms
- Increased resilience to climate change impacts such as heavier rainfalls and higher temperatures
- Reduced ground-level ozone
- Reduced particulate pollution
- Reduced air temperatures in developed areas
- Reduced energy use and associated greenhouse gas emissions
- Increased or improved wildlife habitat
- Improved public health from reduced air pollution and increased physical activity
- Increased recreation space
- Improved community aesthetics
- Cost savings
- Green jobs
- Increased property values

U.S. Environmental Protection Agency, *City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations* (Washington, DC: EPA, 2016), 1, Exhibit 1, https://www.epa.gov/sites/production/files/2016-06/documents/city_green_0.pdf.



Philadelphia is using a wide range of policies and programs to decrease the amount of impervious area in the city and encourage the use of green infrastructure to decrease the volume of combined sewer overflow and achieve other benefits. *(U.S. Environmental Protection Agency)*

sectors, forming full green networks that can manage stormwater on a citywide scale.

Beyond cost savings, a citywide network of green infrastructure can generate many nonfinancial benefits. As green infrastructure has become a more common approach, numerous public sector and research groups have sought to quantify and monetize its environmental, social, and economic impacts beyond typical cost/benefit analyses. Studying the citywide impact of green infrastructure investments is a burgeoning field.

Some studies have monetized the reductions in energy use associated with green infrastructure, as well as benefits such as improved air quality and reduced levels of atmospheric carbon dioxide,[8] and explored other benefits, including community cohesion, improved public health, carbon sequestration, real estate uplift, and economic development.

Philadelphia uses a triple-bottom-line approach, considering social and environmental benefits alongside financial benefits.[9] Five years into Philadelphia's 25-year *Green City, Clean Waters* plan, a Sustainable Business Network study found that the green infrastructure industry catalyzed by the plan represented a $60 million positive economic impact, supporting 430 jobs and $1 million in tax revenue.[10] Beyond this, the city's public investment in green infrastructure has made a $3.1 billion positive impact, supporting 1,000 jobs.[11]

GREEN INFRASTRUCTURE AND WATER MANAGEMENT STRATEGIES

Many of today's stormwater policies encourage or require a range of water management and green infrastructure strategies. Real estate developers who are conversant with the full suite of options will be able to leverage the tools most beneficial to their work. Key green infrastructure tools include the following:

Bioswales

(© Aaron Volkening, Flickr)

Green areas that are similar to rain gardens, bioswales are used to reduce stormwater runoff through infiltration, storage, or both. However, unlike rain gardens, bioswales are designed to manage runoff from a large impervious area like a parking lot or street. Bioswales are deeper than rain gardens and often require engineered soils that can filter and handle larger stormwater flow rates.[i]

Blue roofs

Blue roofs are designed to store rainwater within detention systems on roofs, thus preventing stormwater from initially entering the sewer system after a storm.

Cisterns

(© Regency Centers)

Large storage facilities, often built below ground, at ground level, in parking facilities, or on rooftops, cisterns store stormwater, often for reuse.

Curb cuts

(© Center for Neighborhood Technology, Flickr)

A curb cut is part of a street curb removed to connect the street level with another surface, often a stormwater management or green infrastructure mechanism that can absorb water in place of the traditional drainage system.

Green roofs

(© Joyfnp/iStock)

Green roofs use rooftop vegetation to absorb rainwater and heat. In addition to managing stormwater and cooling surrounding ambient air, green roofs help decrease energy needs for the building and improve overall air quality.[ii]

Permeable surfaces

(© Giodoalf/iStock)

Permeable surfaces include porous asphalt, porous concrete, and porous interlocking paving bricks that allow flowing water to infiltrate through the surface into the ground below. Permeable surfaces can be used for sidewalks, parking lots, alleys, and streets and have cooling properties caused by their reduced heat storage compared to regular pavement.[iii] The porous asphalt, concrete, and interlocking paver industries offer design and installation credentialing programs.

Rain gardens

(© Chris Hamby, Flickr)

Rain gardens are small plots of vegetation that are designed to reduce stormwater runoff through infiltration, storage, or both. They are typically placed where stormwater naturally flows and are commonly incorporated in other landscape designs or streetscapes.[iv] In parts of the country where soils do not allow natural infiltration because of their clay content, underdrains or pipes can send cleaned water into nearby creeks, bayous, or storm sewers.

Rainwater harvesting

(© Kodachrome25/iStock)

Rainwater harvesting is the collection and storage of rainwater in containers; the water is then released into the stormwater management system or desired location for filtration. Rainwater harvesting systems can be created on a small scale, for example, by using roof downspouts, or on a large scale, depending on the needs of the stormwater management system.

Stormwater vaults

(© Arbitrarily0)

This type of detention basin or subsurface facility, commonly made of concrete, steel, or fiberglass, manages stormwater in an urban setting.

Tree pits

Tree pits perform like small reservoirs, capturing and purifying runoff that flows into the uncompacted soil, which then diverts the water into a stormwater management system.[v]

The following frameworks for real estate development and design advocate for many of the preceding green infrastructure tools:

- **Low-impact development (LID):** A land planning and design approach that emphasizes mimicking natural system processes to store, infiltrate, retain, and detain precipitation and rainfall as close to its source as possible; and
- **Stormwater best management practices (BMPs):** Methods that have proven to be the most effective, practical means of preventing or reducing pollution from a source that needs to be controlled, such as stormwater runoff.[vi] BMPs provide a basis for estimating the performance, costs, and economic impacts of achieving management quotas and policies.

i. Soil Science Society of America website, "Rain Gardens and Bioswales," https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/rain-gardens-bioswales.

ii. Georgetown Climate Center, *Green Infrastructure Toolkit*, www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/green-infrastructure-strategies-and-techniques.html.

iii. Soil Science Society of America, "Rain Gardens and Bioswales."

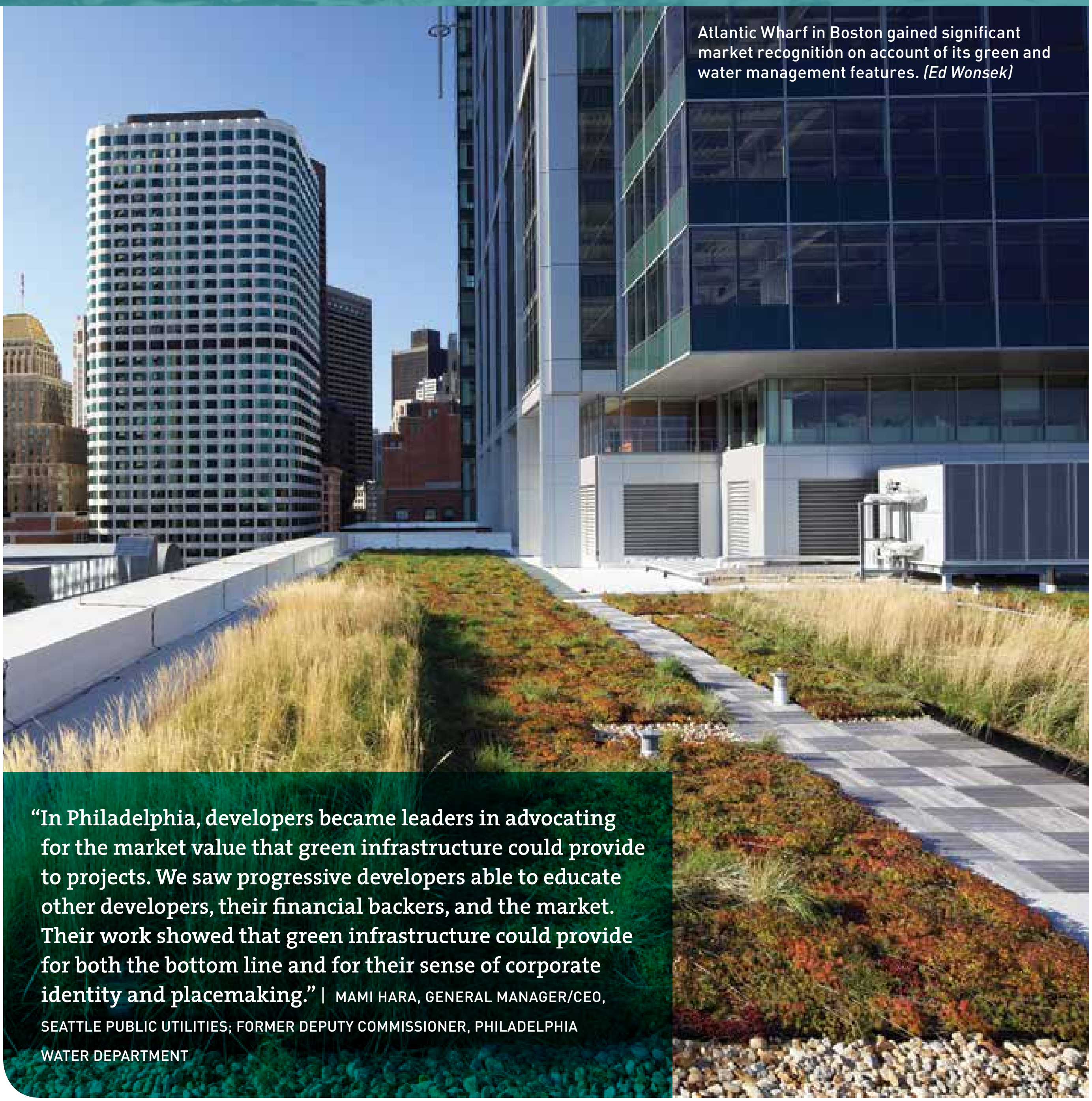
iv. Ibid.

v. Lisa Nisenson, *Using Smart Growth Techniques as Stormwater Best Management Practices* (Washington, DC: U.S. Environmental Protection Agency, 2014), https://www.epa.gov/sites/production/files/2014-04/documents/stormwater-best-management-practices.pdf.

vi. Ibid.

CHAPTER 4

Opportunities for Real Estate



Atlantic Wharf in Boston gained significant market recognition on account of its green and water management features. *(Ed Wonsek)*

"In Philadelphia, developers became leaders in advocating for the market value that green infrastructure could provide to projects. We saw progressive developers able to educate other developers, their financial backers, and the market. Their work showed that green infrastructure could provide for both the bottom line and for their sense of corporate identity and placemaking." | MAMI HARA, GENERAL MANAGER/CEO, SEATTLE PUBLIC UTILITIES; FORMER DEPUTY COMMISSIONER, PHILADELPHIA WATER DEPARTMENT

As cities increasingly require private developments to incorporate stormwater management mechanisms, green infrastructure is likely to become part of business as usual. Real estate projects that harness the opportunities presented by stormwater management systems will see the benefits, particularly in terms of the design of public and outdoor spaces and opportunities for operational and land use efficiencies.

Many developers who have responded to stringent stormwater regulations have had an overall positive experience, according to a recent study.[1] Whereas most indicated that the new policies required creative thinking and led to some complexities, the overall results were positive because of market interest in green design and the lower costs of green infrastructure in comparison with conventional stormwater controls.

None indicated that stormwater requirements would deter them from involvement in future projects, particularly given that each considered "the cost of implementing stormwater controls [to be] minor compared to the other economic factors they considered in deciding whether or not to pursue a project."[2]

Financial Opportunities

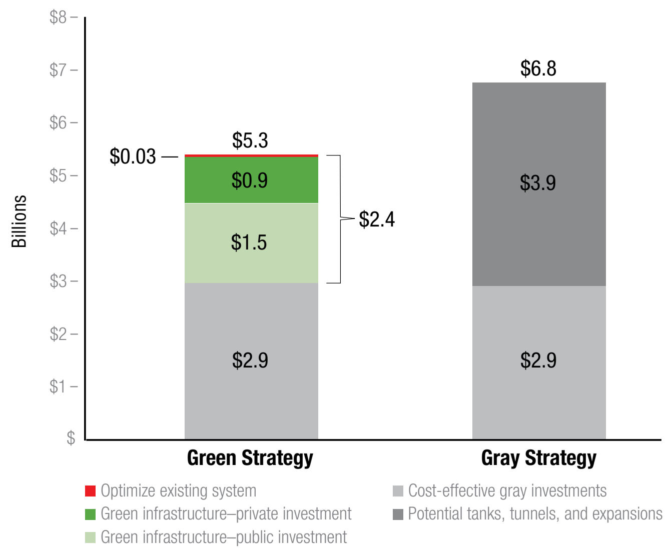
The cost of stormwater controls is extremely variable, particularly for redevelopment or infill projects.[3] Indeed, developers interviewed for the study cited above were "unable or unwilling to provide specific 'rules of thumb' for either the proportional costs of stormwater relative to overall development costs or the difference in costs to implement stormwater controls between redevelopment and greenfield projects."[4]

Many of the real estate developers interviewed for this report found that the investment in green infrastructure allowed them to free developable land on constrained sites, making the costs of the stormwater technologies a sound investment. This was particularly the case for projects that would have traditionally accommodated stormwater requirements by creating detention ponds.

Houston-based engineer Michael Bloom explains that wisely placed green infrastructure "allows a development site to accommodate a higher number of homes or commercial buildings, reduces drainage system costs, and provides for an open-space amenity, such as parks or trails."[5]

MAXIMIZING WATER VALUE

Developers familiar with green infrastructure emphasized in interviews that, if executed well, an investment in stormwater management should be able to improve the bottom line for real estate projects. A 2013 report by the National Resources Defense Council (NRDC) describes how green infrastructure can become a "quality benchmark for the private sector," contributing to properties that command higher rents, enhancing property values, decreasing energy and water costs, reducing maintenance costs, and improving occupant health.[6]



The estimated costs for managing New York City's CSO scenarios were far lower using a green rather than a gray strategy, according to the New York City Green Infrastructure Plan. *(NYC Green Infrastructure Strategy, p. 9/ULI)*

Case study prototypes in the NRDC report include a 40,000-square-foot retail center with green infrastructure that is capable of generating $24.7 million in benefits over a 40-year analysis period, including roughly $23 million in improved sales for tenants, and a 33,700-square-foot apartment building, generating $1.7 million in benefits for the building owner. [7] For constrained urban sites, this value may come from attractive landscaping; for suburban or green sites, the value may come from the integration of open spaces and trails designed with LID techniques.

A key design implication of green infrastructure policies is a focus on green rather than impervious surfaces. Roofs, community spaces, street frontages, and parking lots feature native plantings, bioswales, and permeable surfaces. These aspects may contribute to the aesthetics and marketing for a development project and can form key parts of a development's amenity package.

In Boston, the 1330 Boylston apartment complex developed by Samuels & Associates saw rent increases of $300 to $500 per month for units overlooking a $112,500 green roof, soon netting about $120,000 per year. Accordingly, potential exists for revenue enhancement if the landscape aspects can be marketed as added value. "How you incorporate stormwater management into a home or community land plan can be a huge aesthetic boon, turning the property into a visual asset for the community," notes Chuck Ellison, past chair of the National Association of Home Builders Resiliency Working Group.

STORMWATER AND DESIGN: USC VILLAGE

The USC Village expansion project uses dry wells to capture 85 percent of rainwater runoff on its densely developed site. *(USC/ Harley Ellis Deveraux)*

USC Village at the University of Southern California (USC) in Los Angeles is an ambitious campus expansion project, including a total of nine residential, retail, and academic buildings on a 15-acre site adjacent to the main campus. The first phase includes six buildings comprising 2,600 beds of undergraduate housing, situated on a 130,000-square-foot retail podium including Trader Joe's, Target, Starbucks, and Bank of America. The first phase of the $650 million project will open in fall 2017.

The project was USC's first development to respond to the city of Los Angeles's new LID requirements mandating that 85 percent of rainwater be captured on site. These requirements, along with others from CalGreen, the state's green building code, were critical to the project's design process and arrival at the stormwater solution: six 26,000-cubic-foot dry wells, each of which is roughly six feet in diameter and 55 to 60 feet deep. Each dry well captures water and sends it into the groundwater aquifer, with water first running through a filter, followed by a 20-foot manhole, and then through 35 to 40 feet of rock filtration. The system is unlike anything the university has built previously.

Director of capital construction development William Marsh explains that the design team initially considered finding a way to recycle and reuse the captured water, but "it didn't pencil out from an economic point of view. When you look at all nine buildings and the amount of landscaping and plant material we would have needed, we just did not have enough groundcover."

The dry wells proved to be the best solution for the desired density, as well as the best option from a utility and cost perspective. According to Marsh, the dry wells ultimately had "a very low dollar impact on the project," given that the university was already laying the utilities for the site. However, Marsh notes that the approach would not have been appropriate for a constrained urban environment with existing infrastructure.

Ultimately, the dry wells became a critical part of the USC Village concept, including during the construction process, when the team set up temporary dry wells to manage construction runoff. "During the design, NOAA [National Oceanic and Atmospheric Administration] was predicting one of the largest El Niños to hit southern California in history," explains Marsh. "We were looking at dry wells and realizing that they might become really valuable to us sooner than we realized."

STORMWATER AND DESIGN: THE STANDARD

The Standard is a $75 million condominium building developed by the Domain Companies in New Orleans's new South Market District. The five-block area sits at the intersection of the Central Business, Warehouse/Arts, Sports/Entertainment, and Medical districts. The Medical District is experiencing redevelopment with the creation of two top cutting-edge hospital facilities.

Domain Companies has an extensive development portfolio in New Orleans, but the Standard was the company's first project built after the city revised its Comprehensive Zoning Ordinance, which includes a stormwater retention requirement. According to Chris Papamichael, principal at Domain Companies, "This was the first project where we had these new guidelines in place . . . To find a cost-effective solution, we needed to think about it in the early stages of planning."

The development team decided to use an already planned amenity deck to manage the stormwater detention requirement, incorporating a blue roof designed to store water. Papamichael describes this approach as "an easy and cost-effective way to do it . . . Given the large amenity deck footprint that we had—about 30,000 square feet of a 45,000-square-foot site—we were able to use a good portion of the amenity deck as a detention area." The development team had used similar approaches for projects in New York City and had experience with the necessary technologies, which Papamichael estimated added $200,000 to $250,000 to the project cost.

For the Domain Companies, complying with the stormwater management requirements was ultimately a case of determining what worked best for its particular site and project. "Each site is different, and each building is different," explains Papamichael, noting that cost-effective approaches will vary widely for new construction versus redevelopment projects. However, in all cases, managing stormwater on site will ensure that the building and residents are less vulnerable to flash flooding, which is of particular concern in New Orleans.

Tyler Antrup, urban water program manager for the city of New Orleans, notes that integration of stormwater management best practice is taking off in the city but is "still somewhat experimental for us." However, the stormwater provisions in the zoning ordinance have led local and national firms to find creative ways to incorporate green infrastructure into real estate projects, thus increasing the capacity of the local construction industry and transforming water management into business as usual. "We are starting to finally see what we had hoped to see," says Antrup. "Designers are really thinking about stormwater management at the beginning of a project and designing their projects in a way that integrates stormwater [management] into the development."

A rendering of the Standard's amenity deck, which uses a blue roof to meet new city of New Orleans detention requirements. *(Domain Companies)*

This redesigned space at Symantec's Research and Development Complex in Chengdu, China, incorporates an extensive filtration garden while creating a functional outdoor space that connects the complex to the surrounding city. *(© SWA by Tom Fox)*

DESIGN SOLUTIONS

Landscape architects and designers thrive on finding ways to derive value and create inviting environments through green infrastructure, achieving stormwater management targets along the way. Laura Marett, a senior associate at landscape architects Sasaki, explains: "As stormwater regulations become more stringent in many of the cities where we work, we find that stormwater management is increasingly a driver of implementation for landscape projects. Clients often assume that incorporating best management practices will increase the cost of a project; however, often system-level stormwater approaches offer both environmental benefit and a better return on investment than conventional approaches."

Yet incorporation of stormwater controls could lead to an opportunity cost if potential amenities are lost to the requirement for green, permeable spaces. Cisterns may take up space once reserved for underground parking, or permeable green roof space may occupy what might have been a purely recreation-driven roof deck.

However, creative and resourceful design can address some of these concerns. Well-designed green infrastructure elements should create attractive green spaces and lower costs through savings in long-term operations and maintenance. For example, green roofs should absorb heat and lower energy costs and long-term roof maintenance costs, and bioswales and absorbent natural landscaping should both improve the aesthetics of a building and shift long-term landscape costs, potentially resulting in cost reductions. Zach Christo, a principal at Sasaki, describes the new stormwater policies as encouraging innovation and efficiency by "forcing designers to think about the dual purposes of different surfaces. A sidewalk is no longer just a sidewalk for walking; it's also taking on a function for stormwater management."

Green Infrastructure Learning Curve

Although implementation of green infrastructure requires a learning curve for maintenance, the costs and amount of time required are generally lower than those for maintenance of gray infrastructure systems.

Gardeners and maintenance staff may need training to manage new types of landscaping, particularly given that it often requires more selective weeding and watering practices. For example, bioswale maintenance would entail weeding and landscaping, rather than parking lot sweeping, sediment removal, and grouting and sealing of concrete structures.

David Hollenberg, university architect for the University of Pennsylvania, explains that training for the management of the bioswales and meadows of Penn Park required a substantial learning curve for the campus maintenance crew. "These are landscape typologies that we had not had on the campus before," explains Hollenberg. "They are quite beautiful, but they initially were not in our management vocabulary."

Describing the New York City experience with stormwater management–focused green streets, Nette Compton notes that contractors managing the city's first green streets with a stormwater management component quickly recognized that the sites required reduced maintenance compared with other green streets.

Use of reclaimed water on site can also reduce long-term maintenance costs, as is done at the Residences at La Cantera, a residential project in San Antonio that incorporated a rainwater recycling system to water the development's signature central park.[8]

In short, after an initial investment in training, the cost and maintenance time required for green infrastructure systems is typically lower than that for traditional, turf-based landscapes that require frequent mowing.

Some developers indicated that incorporating green infrastructure is likely to become easier over time, because of the increased number of approaches likely to be developed and the potential for more widespread availability and greater affordability of materials, such as porous pavers and cisterns.[9]

CREATIVE PLACEMAKING AND WATER

Creative placemaking, an approach that engages art and culture in place-based design, can enhance the value of green infrastructure solutions. Artful approaches can not only address the practical issue of stormwater management, but also enhance aesthetics, which may lead to greater economic value. Creative placemaking for water can help establish a sense of place that is appealing and attractive, inviting people to engage with their surroundings, community, and environmental values.

When aligned with cultural landscape preferences, creative stormwater management features can serve the purposes of public relations, recreation, education, and social interaction as well as drainage and filtration. These elements, in turn, increase the success and longevity of the projects themselves.

Stuart Echols and Eliza Pennypacker, professors of landscape architecture at Pennsylvania State University, are proponents of artful rainwater design (ARD). ARD aims to prompt a shift in mindset: rather than viewing stormwater as a problem, designers, developers, and others think of it as an opportunity. Within this framework, rainwater is celebrated as a resource, and rainwater management is embraced as a chance to provide an aesthetic or artful experience.

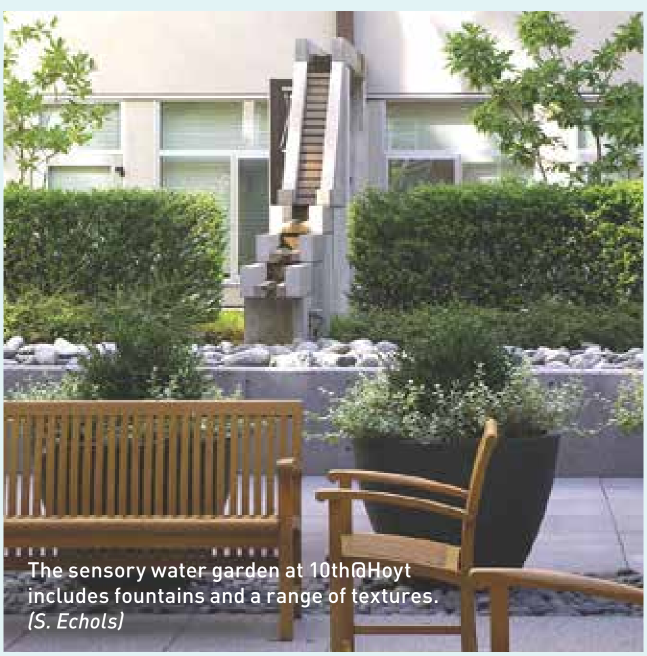
Some of the main principles of ARD include daylighting (bringing out in the open rather than hiding) features such as basins, bioswales, and green roofs; integrating educational materials into the design; and using stormwater management as the basis of public relations, which generates interest and increases the likelihood of tenant retention.

A few examples bring ARD principles to light. At the High Point residential community in Seattle, Washington, developed by the Seattle Housing Authority, drainage, filtration, and transference occur throughout the site in creative ways, with markers that explain the function and importance of each element.

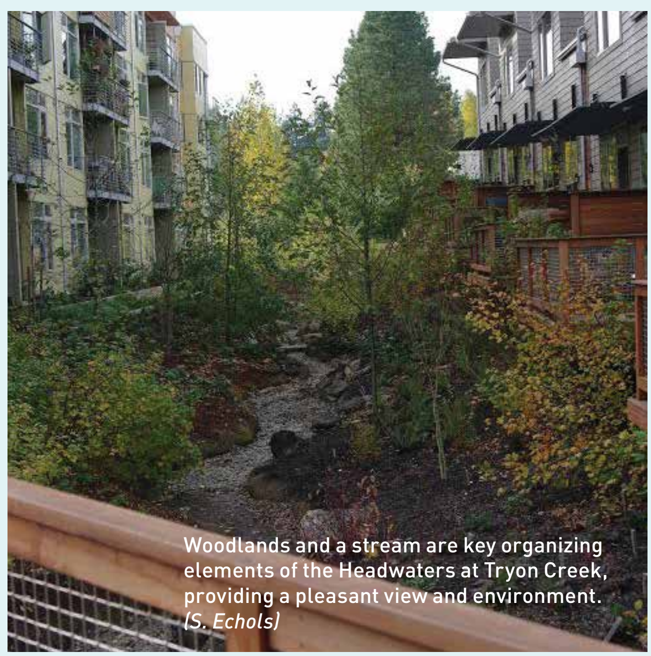
At 10th@Hoyt, an apartment complex developed by Prometheus Real Estate Group, located in Portland, Oregon, roof runoff is mitigated by transforming an interior courtyard into a sensory water garden. A carefully crafted rain-receiving system guides water from roof to garden and then is reused in playful fountains. Plantings offer texture, color, and filtration simultaneously. The developer of 10th@Hoyt made the courtyard into a selling point, turning the complex into a lucrative investment.

At Headwaters at Tryon Creek, a multifamily development in Portland, Oregon, a connecting stream both conveys rainwater and ties together various buildings within the same site, thus creating a sense of cohesiveness and community.

Creative and thoughtful designs increase well-being, facilitate communication, and provide a connection to place and community. Through close attention to aesthetics and creative placemaking, stormwater management becomes a conduit for much more than rain.



The sensory water garden at 10th@Hoyt includes fountains and a range of textures. *(S. Echols)*



Woodlands and a stream are key organizing elements of the Headwaters at Tryon Creek, providing a pleasant view and environment. *(S. Echols)*

CHAPTER 5

Case Studies in Green Infrastructure

Real estate developers across the United States are increasingly incorporating green infrastructure into their projects, driven by stormwater regulations, marketing value, green rating systems, cost savings, or other reasons.

This chapter introduces a selection of real estate projects that have prioritized green infrastructure with successful development outcomes, such as the following:

- Increased developable land;
- Increased market value, sometimes described as a "sustainability premium";
- Enhanced marketing opportunities;
- Placemaking opportunities, amenity value, and improved building user experience;
- A smooth permitting process;
- Avoided losses in peak weather events;
- Reduced operating and maintenance costs; and
- Decreased potable water use.

These projects comprise a variety of densities and uses, including mixed-use, urban developments; master-planned residential projects; commercial and office developments; parks and institutional projects; and affordable or mixed-income projects. All have used green infrastructure and stormwater management technologies with varying approaches, depending on the building types, locations, and climates.

Although the context and development conditions for these projects are diverse, many common themes and lessons learned have emerged. A key message is the value proposition: innovative approaches to stormwater management created value, improved building user experience, and differentiated the product from others in the local market.

GREEN STORMWATER INFRASTRUCTURE[a]

Property	Bioretention swales	Detention basin	Efficient fixtures or irrigation	Filtration systems[b]	Green roofs	Monitoring system
Atlantic Wharf			•	•	•	
Burbank Water and Power EcoCampus		•		•	•	
Canal Park	•			•	•	
Encore!				•		
High Point	•					
Market at Colonnade	•	•	•	•		•
Meier & Frank Delivery Depot	•		•	•	•	•
Penn Park	•					•
Stonebrook Estates	•	•		•		
The Avenue				•	•	
The Rose			•	•		

[a]See Glossary on page 60 for definition of green stormwater infrastructure terms.

[b]Filtration systems include biofiltration, filtration planters, automatic filtration systems, baffle boxes, and subsurface infiltration systems.

A decommissioned electrical substation on Burbank Water and Power's EcoCampus in Burbank, California, has been transformed into a shaded community area that provides a green space for employees and houses filtration systems. *(Sibylle Allgaier, Heliphoto)*

	Native plants and trees	Natural drainage system	Permeable pavers	Rain gardens	Rainwater cistern	Retention pond or ice rink	Reuse systems	Stormwater vault	Tree boxes
	•				•		•		
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Atlantic Wharf

QUICK FACTS

Location: Boston, Massachusetts

Project type: Mixed-use redevelopment

Status: Purchased in 2007, opened in 2011

Project cost: $280 million

Site size: 2.1 acres

Development size: 27.5 acres

Development program: 16,000 square feet of indoor public space, 23,300-square-foot urban park, 776,000 square feet of office space, 25,000 square feet of ground-floor retail/restaurant space, 88 market-rate residential units

Developer: Boston Properties

Design team: Halvorson Design Partnership, CBT Architects

Water management features: Efficient fixtures, filtration system, green roofs, native plants or trees, rainwater cistern, reuse system

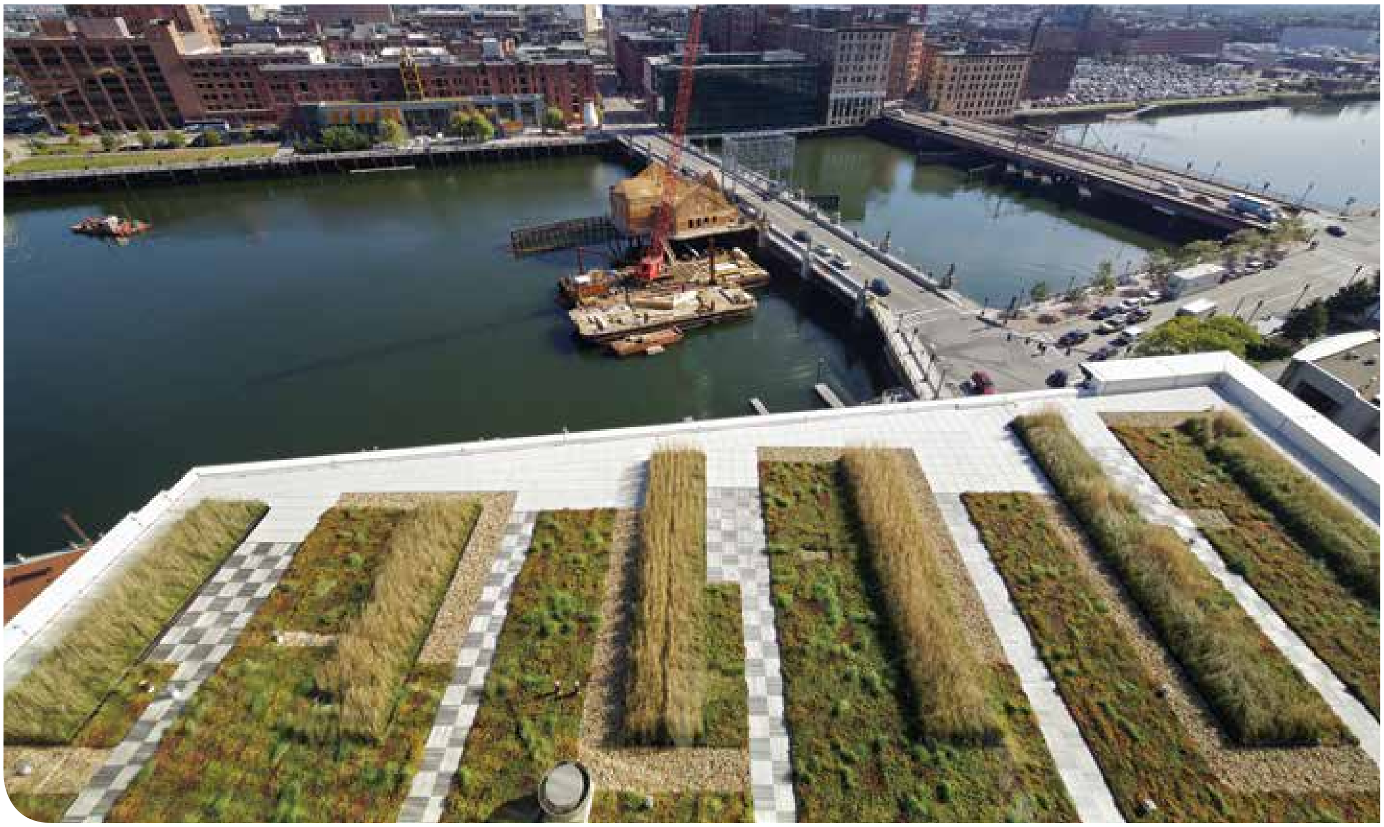
Atlantic Wharf is a 1.2 million-square-foot mixed-use redevelopment of the historic Russia Wharf in Boston's Waterfront District, adjacent to downtown. Developed by Boston Properties (BXP), Atlantic Wharf was 100 percent leased within the first year of opening, outperforming the local market for office, residential, and retail spaces. The development includes a mix of office, residential, retail, art, and public space and the restoration of three historic 19th-century facades.[1] Innovative stormwater management features helped it become known as Boston's first green skyscraper.

Context

In 2007, developer BXP used the nation's first green building standard, Article 37 of the Boston Municipal Zoning Code, to create Boston's first sustainable high rise, Atlantic Wharf, which opened in 2011.[2] Specifically, Article 37 incentivizes applicants with one Leadership in Energy and Environmental Design (LEED) credit if they submit calculations for groundwater area absorption and retention rates.[3]

Atlantic Wharf is situated between the historic Fort Point Channel, renowned for the Boston Tea Party; the downtown Financial District, home to Boston's financial centers; and the Rose Kennedy Greenway, a series of linear parks and gardens.[4,5] The building's design preserves and integrates about 40 percent of the existing historic structures on the site and created 23,300 square feet of urban parks and plazas.[6]

Atlantic Wharf's roof includes 18,000 square feet of rooftop gardens, formed of preplanted grids with native and adapted landscaping. *(© Ed Wonsek)*



Atlantic Wharf, Boston's first green skyscraper, renovated and integrated 42 percent of the existing historic structures, including streetscapes and facades. *(Anton Grassl/Esto)*

"We have been inspired by the mayor's vision to make Boston the greenest city in the country and our customers' commitment to a sustainable workplace," Bryan Koop of BXP said at the LEED plaque awards ceremony. "Atlantic Wharf is a model proving that development can be done with a conscious regard for the environment."[7]

Atlantic Wharf was certified as LEED Platinum shortly after its completion.[8] BXP's commitment to sustainability and historic preservation has been recognized by a number of award programs: Atlantic Wharf was a 2012 finalist for the ULI Global Awards for Excellence, received the 2012 Brick in Architecture Award, and won the 2012 International Facility Management Association Large Project Award.[9]

Innovative Water Management Features

- **Rooftop garden.** An 18,000-square-foot garden of modular, preplanted grids with native and adapted landscaping allows stormwater filtration, permits easy repair and maintenance access to the roof, reduces the heat-island effect, and minimizes impact on the microclimate.[10]
- **Rainwater cistern.** Seventy-one drainage points and over a half mile of piping funnel stormwater from the roof to a 40,000-gallon-capacity storage tank.
- **Automatic filtration system.** Environmental pollutants in the stormwater are cleaned and collected from the rooftop rainwater harvesting system.
- **Rooftop cooling tower.** Filtered stormwater is used for irrigating the rooftop garden and for replacing water lost because of evaporation, leaks, or discharge in the cooling system.[11]
- **Public parks and plazas.** Over 30 percent of the site area contains native and adapted planting, not only on the green roof, but also in the public Waterfront Plaza and promenade, where programming is provided throughout the year.
- **Water-efficient fixtures.** Low-flow plumbing fixtures, such as shower heads, sinks, and dual-flush toilets, are included in all units, and similar fixtures are required for all office tenants.[12]

Value Proposition

Atlantic Wharf's LEED Platinum certification level has translated into significant operational savings and increased market demand for its commercial and residential units. Within the first year of opening, Atlantic Wharf was 100 percent leased, outperforming the local market for office, residential, and retail spaces.[13] By July 2012, residential rental rates were some of the highest in the city, averaging $4.24 per square foot, and all four restaurants reported higher-than-forecast sales.[14]

Atlantic Wharf's resource- and water-efficient design has also led to cost and resource savings. Potable water use for irrigation has been reduced by more than 60 percent through native planting and rainwater harvesting systems on the rooftop and in the public spaces.[15] The development's rooftop cooling tower, which uses rainwater, saves 15 percent in process water compared to conventional HVAC systems.[16]

LESSONS LEARNED

- **Innovative water and environmental features can aid in leasing high-density developments and provide marketing value.** Within its first year of opening, Atlantic Wharf was 100 percent leased and had some of the highest residential rents in the city.
- **Historic preservation can be achieved while realizing gains in water efficiency.** Atlantic Wharf, Boston's first green skyscraper, renovated and integrated 42 percent of the existing historic structures, including streetscapes and facades. The innovative water management system decreased potable water use for on-site irrigation by over 60 percent and saved 15 percent in process water in its cooling systems.
- **Public space is an asset for filtering stormwater runoff and increasing the marketability of a site.** At Atlantic Wharf, 23,300 square feet of urban parks and plazas absorb and filter stormwater between the modern Financial District and the historic Fort Point Channel.

Burbank Water and Power EcoCampus

QUICK FACTS

Location: Burbank, California

Project type: Community-owned public utility site

Status: Completed

Site size: 3.2 acres

Developer: City of Burbank (community owned)

Designers: AHBE Landscape Architects, Tyler Gonzalez Architects, Leo A Daly Civil Engineering, Fuscoe Engineering

Water management features: Detention basin, filtration system, green roof, native plants or trees, permeable pavers, reuse system, tree boxes

A community-owned public utility site, the Magnolia Power Project at Burbank Water and Power (BWP) EcoCampus is the first power plant in the world to operate on 100 percent recycled water. The surrounding landscaping of the 3.2-acre campus, designed by AHBE Landscape Architects, incorporates a wide range of green infrastructure techniques that retain and manage stormwater, filtering it through a treatment system that recycles the water to assist in efficient, cost-effective electricity generation for the municipality. At a time of drought in California, BWP's leadership in water management has set an example and shown that sustainable design can thrive in an urban industrial context.

Context

Burbank Water and Power has served Burbank for more than 100 years. In the late 1990s, facilities were aging, increasing maintenance costs and resulting in inefficiencies and higher utility rates for residents and businesses. In fact, rates in 2000 were near the top in the region as compared to other municipal-owned utilities.[17] The site was also more than 79 percent impervious surfaces and the high temperatures and low precipitation meant that few plants could survive on site.[18]

The campus invested in a major redesign in 2000 to modernize to an efficient utility operation incorporating green infrastructure to achieve goals of lower operating costs and keep rate increases under the rate of inflation while creating

The SITES-certified courtyard is a space for community building among employees and has served as a recruiting tool. *(Sibylle Allgaier, Heliphoto)*

"[BWP] realized that new generations were in tune with the environment and that the younger generation wanted to work for an organization that had values similar to theirs."

JOE FLORES, MARKETING AND PUBLIC INFORMATION OFFICER, BURBANK WATER AND POWER

An aerial view of Burbank Water and Power shows the dynamic campus, which includes green roofs, solar panels, and an interior courtyard. *(Sibylle Allgaier, Heliphoto)*

a competitive employment advantage. Today, BWP boasts some of the lowest rates for utilities in southern California. The utility also sees the campus redevelopment project as enhancing its brand, improving its recruitment capabilities, particularly given the utility's high visibility on an urban site.

The campus redesign responded to the new city development codes, including on-site mitigation requirements, requiring projects to retain 0.75 inches during a 24-hour rain event. The 15-year project adjusted its design based on the industry's understanding of sustainability to maintain efficient operations.

Innovative Water Management Features

Today's BWP's EcoCampus ecologically manages stormwater, uses solar power, reduces urban heat-island effects, and reuses materials throughout the campus. In total, the campus uses five different water filtration technologies: detention, rainwater capture, infiltration, flow-through cells, and tree root cells.[19]

Key aspects of the campus landscape redesign included primary landscaping, a green street implemented in 2010, and an employee courtyard that repurposes old industrial structures from a decommissioned electrical substation. Campus facilities include three LEED Platinum buildings topped with white and green roofs. Water management features within the EcoCampus include the following:

- **Recycled water treatment system.** The Magnolia Power Project's recycled water treatment system eliminates use of more than 1 million gallons a day for cooling towers and steam turbine generation with no discharge into the Pacific Ocean.
- **Green street.** Lake Street was initially a green street demonstration project, serving as an educational tool about sustainable design and demonstrating how green infrastructure can be artfully incorporated. The street includes permeable pavers and filtration planters.

Value Proposition

The key success factor for BWP was the improved operations, which led to more affordable utility rates for the citizens of Burbank, who are customer-owners of the utility. Burbank's investment in green infrastructure has also led to net-zero stormwater runoff from the campus and 100 percent recycled water use for all landscaping, reducing piped water use by as much as 100,000 gallons per day. Green roofs, which absorb up to 70 percent of rainwater, help the facility save an estimated $14,000 per year.

Burbank's leadership has linked improved morale and recruiting to the campus enhancements. Previously, the campus lacked green space and spaces for employees to gather and exchange ideas. The improved campus has contributed to success in recruiting a younger generation of talent and generated substantial publicity for the utility, including numerous awards, certification by the Sustainable Sites Initiative, and regular visits from the global business community.

LESSONS LEARNED

- **Investment in a green facility positively affected the bottom line and prices for consumers.** Burbank's investment in using recycled water and sustainable design measures has been incorporated into operational efficiencies that contribute to the bottom line and ultimately to some of the lowest utility rates in southern California.
- **Green design can contribute to corporate identity, branding, and talent retention.** BWP has attributed recent recruiting and talent attraction to the brand recognition that in part has come from the green campus.
- **Green infrastructure can be effectively incorporated into a tightly constrained urban site.** The project sought to not only educate the public on green infrastructure, but also show what could be possible in both an urban and industrial context, preserving industrial structures within the campus.
- **BWP's leadership in green design and water management has helped the city at a time of water scarcity.** Burbank met the "billion-gallon challenge" for water savings ahead of schedule after Governor Jerry Brown's call for water conservation in the face of the state's drought crisis.[20] BWP's example has been part of this city and statewide focus on water conservation and stewardship.

Canal Park

QUICK FACTS

Location: Washington, D.C.

Project type: Park, adjacent to office and residential development sites

Status: Completed in 2012

Project cost: $20 million

Site size: 3 acres

Developer: WC Smith

Designers: OLIN, Studios Architecture, Vika Capitol, Nitsch Engineering, SK&A Structural Engineering, Atelier Ten, Joseph Loring & Associates

Water management features: Bioretention swales, filtration system, green roof, rain gardens, rainwater cistern, ice rink, reuse system, tree boxes

Located along a portion of Washington, D.C.'s historic canal system, Canal Park uses innovative water management practices and has been a catalyst for the broader revitalization of the bustling Navy Yard neighborhood. A stormwater system including cisterns, rain gardens, and bioretention tree pits captures, treats, and reuses water for up to 95 percent of the park's needs, including irrigation, splash park–style fountains, and an ice rink. The park has become a key focal point of activity in the city, hosting regular events and seasonal festivities.

Context

Developer and property manager WC Smith led the creation of the park as a component of the District of Columbia's Anacostia Waterfront Initiative, which sought to reinvigorate the neighborhood and improve water quality in the Anacostia watershed. Today, WC Smith retains interest in the park and anticipates that the park will mitigate stormwater for the development of an adjacent multifamily property to be developed by the company.

Canal Park's origins date to 1999, when WC Smith was acquiring properties in the neighborhood. At the time, the paved site was a parking lot for school buses, but it was once part of the Washington City Canal System that connected the Potomac and Anacostia rivers and ran through the National Mall.[21] The park proposal later became a key part of the Anacostia Waterfront Initiative and a demonstration project for the District's Department of Energy & Environment.

A view from WC Smith's office building shows Canal Park (on the lower diagonal) and the adjacent parking lot, which will also be developed by WC Smith. *(© Olin/Karl-Rainer Blumenthal)*

"Canal Park is a popular meeting spot for residents, workers, and visitors. The project would not have been successful without the partnerships with private developers, the city and federal governments, and the Capitol Riverfront BID." | BRAD FENNELL, SENIOR VICE PRESIDENT OF DEVELOPMENT, WC SMITH

In winter months, rainwater collected in underground cisterns is used to replenish the park's ice-skating rink. *(© OLIN/Sahar Coston-Hardy)*

To pursue a public/private partnership for the park construction, WC Smith formed the Canal Park Development Association (CPDA) in 2000, which ultimately secured the site from the city and led the development process. A design competition led by CPDA, along with the Anacostia Waterfront Corporation and the District's deputy mayor for planning and economic development, chose OLIN as the design team to advance the project.[22]

Given the site's history and the ongoing water quality concerns with the Anacostia River (partially because of combined sewer overflow), water management was a top priority in the design competition. "The park naturally became a focal point of sustainability and a regional stormwater facility," explains Brad Fennell, senior vice president of development at WC Smith. The potential for the site as a community and social hub also evolved as a number of catalytic developments occurred in the area, including the Washington Nationals ballpark, the U.S. Department of Transportation headquarters, and the redevelopment of an adjacent public housing site.

Today, WC Smith maintains connections to the park, while the local business improvement district (BID), Capitol Riverfront, manages day-to-day maintenance and programming. WC Smith has continued development momentum around the park and anticipates using the water management capabilities of the park to adhere to the District's on-site water retention requirements for the development of an adjacent parcel. "We are really excited for the next ten years, when you will see more buildings fronting on the park and the development of new retail in the area," says Fennell.

Innovative Water Management Features

- **Stormwater collection and reuse system.** Stormwater that falls on site is collected and treated through a bioretention, ultraviolet disinfection, and filtration system that removes 100 percent of biological pollutants and reduces total suspended solids.[23] Collected stormwater then meets up to 95 percent of the park's needs for irrigation, its ice rink, and its fountain, saving an estimated 1.5 million gallons per year.
- **Rain gardens and bioretention tree pits.** Rain gardens run along the eastern edge of the park, and captured rain is subsequently filtered and reused. Forty-six bioretention tree pits also filter out contaminants.[24]
- **Cisterns.** Two underground cisterns hold 80,000 gallons of water, in addition to the roughly 8,500 gallons that the rain gardens can hold.
- **Ice rink and water features.** The ice rink and 42-jet fountain splash park are among the most popular aspects of the park—and their water needs are met entirely by stormwater.

Value Proposition

Canal Park has greatly contributed to the revival of the Capitol Riverfront neighborhood. Perceptions of the neighborhood have changed with this revitalization; for example, a survey by the BID found that 90 percent of local residents considered the area "clean and safe" in 2015, compared with 30 percent in 2009. For WC Smith, the investment in Canal Park has enhanced the value of adjacent properties, which now overlook a valuable and vibrant public amenity. The park's ability to manage stormwater for a future adjacent development has been an added bonus.

LESSONS LEARNED

- **Public/private partnerships can be excellent vehicles for delivering innovation in stormwater management.** The Anacostia Waterfront Initiative provided the initial vision for the area's revitalization, and Canal Park came to fruition through a public/private partnership with funds from tax increment financing and New Markets Tax Credits. Today, the Capitol Riverfront BID manages a robust program of activities that draw people to the park from both the neighborhood and the city at large. Fennell describes the BID's work as contributing to the "energy that helps make the park a special place."
- **Water management can inspire community engagement and local conservation.** "The whole concept of environmental conservation in the park is what has captured people who live around here," explains Janet Weston, the park manager at WC Smith. The design and development team proactively developed educational signage about the park's stormwater management functions and has worked with the BID to get the message out to a wider audience.

Encore!

QUICK FACTS

Location: Tampa, Florida

Project type: Mixed-use, mixed-income, master-planned community

Status: Underway

Project cost: $425 million

Site size: 28 acres with a planned total of 180,000 square feet of office space, 300-plus hotel rooms, 1,500-plus residential units, and 50,000 square feet of retail space; 662 units in four buildings and the stormwater infrastructure at the Technology Park have been built to date

Developer: Public/private partnership between the Tampa Housing Authority and Bank of America Community Development Corporation

Designers: Baker Barrios Architect, Cardno TBE

Water management features: Filtration systems, native plants or trees, permeable pavers, reuse system, stormwater vault

Encore! is a mixed-use, mixed-income development including multifamily housing, senior housing, retail, and office space on the site of a previously isolated public housing development. Developed through a public/private partnership between Bank of America Community Development Corporation and the Tampa Housing Authority, Encore! incorporates advanced stormwater management as part of its efforts to achieve Leadership in Energy and Environmental Design for Neighborhood Development (LEED ND) certification. Water management has been a key component of the development strategy, with early infrastructural investments including an 18,000-square-foot water retention vault.

Context

Situated between Old Tampa Bay and Hillsborough Bay, Tampa is surrounded by water, which ultimately flows into Tampa Bay and the Gulf of Mexico. Although Tampa does not have combined sewers or the requirements of a federal consent decree, stormwater management is a priority given the city's frequent flooding and low elevation of three or four feet above sea level.[25]

Encore! sought to protect residents from flooding through the incorporation of district-scale water management that would capture all stormwater on site. "When you control runoff and cut down on erosion problems, . . . you don't have that fear of standing water and flooding," explains Leroy Moore, the Tampa Housing Authority

Topped with solar panels and green space, the vault is the centerpiece of Technology Park. *(Tampa Housing Authority)*

"We decided to put our dollars into infrastructure that would allow us to go vertical on our buildings when the market turned back." | LEROY MOORE, SENIOR VICE PRESIDENT AND CHIEF OPERATING OFFICER, TAMPA HOUSING AUTHORITY

Encore! is a mixed-use, mixed-income development in Tampa's Central Avenue business district. *(Tampa Housing Authority)*

senior vice president and chief operating officer. "It keeps the site safe, clean, and healthy."

The centerpiece of the water management system is a water-retention vault that accommodates 33,000 cubic feet of water. The chamber is roughly 12 feet below ground, with a three-foot rock layer below the chambers. "It is the slickest, coolest feature that we've done from a sustainability perspective. . . . It is one of the most unique stormwater management systems in the state on account of its size," explains Marc Mariano, then assistant director of site development for Cardno TBE. All surface stormwater is collected from the site in the vault and then treated through a system of nutrient-separating baffle boxes and sediment chambers that capture pollutants. Water is then stored for irrigation use. When the vault is at capacity, stormwater runoff is filtered through sand before reaching Tampa Bay. Over several years, water has yet to leave the site or be piped in for irrigation.

The project also reduces stormwater runoff through permeable pavers, native plants, and other elements. Land above the water-retention vault has been transformed into Technology Park, a passive educational park that serves to explain Encore!'s green building practices to area residents.

Innovative Water Management Features

- **Stormwater vault and baffle boxes.** The 18,000-square-foot stormwater vault is structured with five-foot individual cubes that together hold up to 33,000 cubic feet of stormwater. Stormwater then flows through two baffle boxes for pretreatment before being used for landscaping irrigation.
- **Permeable pavers and native plants.** Encore! manages stormwater in an urban setting by using permeable pavers and native plants that are not irrigation intensive. Pavers on the hardscapes and the median of the central street through Encore! contribute to stormwater management and create visibility for the stormwater system. The landscape palette is estimated to reduce water needs for landscaping by 50 percent.
- **Park with educational signage.** Technology Park, a 16,000-square-foot park located above the stormwater vault, features educational kiosks, solar public art, and the district chiller. Visitors often watch the fluctuation of water in and out. "Once you draw people to the vault, you can educate them about it and the many sustainability features built into Encore!," explains Moore.

Value Proposition

The investment in cutting-edge stormwater management features allowed Encore! to maximize the developable land on the site. A traditional retention pond and water collection system would have required six acres: the net gain of developable land from having used a half-acre vault is three city blocks, or about a quarter of the full site. Moore explains, "We were motivated by not having to consume a lot of that land with surface retention." Investing in stormwater technologies allowed Encore! to be "a more valuable project and an urban scale," according to Moore.

Encore! also benefited greatly from federal government funding available at the time of development. As Moore explains, "The recession hit and everything was put on hold, but we had the most shovel-ready site in the country." The development team initially committed to district-scale green and stormwater infrastructure when it planned to use tax increment financing. However, instead of using that approach, the development team leveraged a $28 million stimulus grant to complete the site's district-scale infrastructure.

Today, the Tampa Housing Authority is investigating district-cale infrastructure opportunities for another public/private redevelopment, the $2 billion Tampa Live project.

LESSONS LEARNED

- **District-scale stormwater management can free up developable land and create a more urban development product.** Using a stormwater vault rather than a retention pond not only ensured that the maximum portion of the site was available for development, but also fostered the creation of a better-connected street network.
- **District-scale sustainable utilities were a part of the marketing draw for the site.** The market-rate units at Encore! were leased up before the affordable units, which the development team attributes to the location, competitive pricing, and branding. "All of our indications show that market-rate residents want to live in sustainable communities," explains Moore.
- **Stormwater infrastructure provides an opportunity to educate and inspire.** Stormwater infrastructure is celebrated in the park topping the stormwater vault.

High Point

QUICK FACTS

Location: Seattle, Washington

Project type: Mixed-income housing; redevelopment

Status: Opened 2004, planned completion 2018

Project cost: $550 million

Site size: 129 acres

Development size: 80 acres

Development program: 1,529 units (798 market rate, 731 affordable) for sale and rent for seniors, low-income and very low-income households

Developer: Seattle Housing Authority

Design team: Mithun, SvR Design Company, Nakano Associates

Water management features: Biorention swales, native plants or trees, natural drainage system, permeable pavers, rain gardens, retention pond

High Point creates a vibrant mixed-income community of 1,529 market-rate and affordable homes on a former public housing complex once marked by crime and unemployment. A HOPE VI redevelopment, High Point is noted for being the first dense urban development in the nation to achieve sustainable, low-impact design at a large scale.[26] On a site that was formerly 65 percent impervious, High Point's natural drainage system infiltrates 75 to 80 percent of stormwater runoff.[27]

Context

High Point has been cited as "a new model of cooperation" between residents, private developers, and government agencies to create a more sustainable and inclusive community for one of Seattle's most demographically diverse neighborhoods.[28] This innovative partnership between the Seattle Housing Authority; the departments of Planning, Development, and Transportation; and Seattle Public Utilities was formed to improve water quality for residents of this mixed-income community while protecting the endangered salmon run downstream in Longfellow Creek—one of the last four runs remaining in the city.[29]

To accommodate this cross-sector partnership, in 2003, Seattle passed a special ordinance to permit low-impact-development features throughout the redevelopment of High Point, which would expand to include 1,529 units, 48 percent

Four miles of bioretention swales, like this one on 30th Avenue SW, improve water quality and protect wildlife at High Point, which was formerly 65 percent impervious. *(MIG | SvR)*

"There was a magical match between people who embraced the ideals and virtues of green living and those who desired to live in a community that looked like America—not segregated, not one color, but a real mix of peoples, cultures, backgrounds, income levels, and so on. That was one of the drivers of pushing, from a marketing perspective, for a green, sustainable community. We saw that those buyers had more than one reason to take note of this new community." | GEORGE NÉMETH, SENIOR HOUSING DEVELOPER, SEATTLE HOUSING AUTHORITY

Located on the site of a former public housing complex once marked by crime and unemployment, High Point includes more than 1,500 homes, of which 48 percent are affordable for low-income families. *(© Juan Hernandez for Mithun)*

of which were affordable to low-income families to buy or rent.[30] To balance concerns for neighborhood green space, pedestrian safety, and water quality, the entire street grid was raised and replaced by a natural drainage system that uses a new street network including pedestrian circulation, bioswales, a storm-water pond, porous streets and sidewalks, and multifunctional open spaces to create a positive net impact on the environment.[31]

Innovative Water Management Features

- **Pedestrian-friendly streets.** Narrowed streets, shortened blocks, strategic alley connections, porches, hidden parking lots, landscaped sidewalks, new utilities, mature and newly planted street trees, and walking groups highlight the aesthetics of stormwater features and promote physical activity.
- **Integrated stormwater management system.** High Point was the first community in the state to feature permeable pavements in residential streets, sidewalks, parking lots, sidewalks, and basketball courts. A quarter-mile walking trail and gathering space was constructed around a 22-acre-foot retention pond and connected by four miles of grass and vegetated bioswales to naturally manage stormwater, improve water quality, and protect the wildlife habitat on site and nearby.
- **Sustainable landscaping.** Organic landscaping methods were introduced on more than 20 acres of open space, including front and back yards, gardens, and pocket and neighborhood parks. Over 100 mature trees have been saved at High Point, valued at more than $1.5 million. Approximately 3,000 trees were planted in High Point as part of the site's redevelopment.
- **Green building standards.** Public and private developers were held to Built Green standards, a construction checklist and rating system verified by the local Master Builders Association, which included the use of recycled or reused building materials, topsoil, and pavement in the construction of housing and trenches. At a small incremental cost, energy-efficient appliances, windows, doors, and insulation were installed in all units. High Point features 60 Breathe Easy Homes®, independently verified units structurally enhanced to improve interior air quality for residents suffering from asthma.

Value Proposition

After integrating innovative stormwater features, High Point's public and private developers achieved faster-than-anticipated sales and lease-up rates. Market-rate home and land sale proceeds have added revenue back to the city for neighborhood improvements through property taxes and to the Seattle Housing Authority for the construction of low-income housing through a profit-sharing model with private developers.

High Point's success in improving the physical, mental, and environmental health of its residents has been reported by several National Institutes of Health studies and served as the model for green building standards in future developments at the Seattle Housing Authority.[32] The community's commitment to sustainable design and community development for residents of all incomes has garnered numerous awards and documentaries, including a 2007 ULI Global Award for Excellence.

LESSONS LEARNED

- **Large-scale affordable and market-rate housing developments can integrate a high-quality, low-impact design.** High Point achieved faster-than-anticipated sales and lease-up rates for over 1,500 mixed-income homes while developing a natural drainage system that infiltrates 75 to 80 percent of stormwater runoff.
- **Street grids can manage stormwater runoff while creating a safer pedestrian environment.** High Point created an entirely new street grid lined by four miles of vegetated bioswales, more than 2,000 new trees, porous sidewalks, a quarter-mile recreational trail, and multiple traffic-calming measures, supported by walking groups.
- **Endangered species can be protected from contaminants through stormwater management.** On a site that was formerly 65 percent impervious, High Point contributed to the protection of one of the last four salmon runs in Seattle, Longfellow Creek.

Market at Colonnade

QUICK FACTS

Location: Raleigh, North Carolina

Project type: Retail

Status: Completed

Project cost: $16.5 million, including about $727,000 toward stormwater management

Site size: 6.25 acres

Development program: 57,000 square feet of commercial space, including a Whole Foods Market

Developer: Regency Centers

Designers: CMH Architects Inc., Kimley-Horn & Associates Inc., Soil & Environmental Consultants PA

Water management features: Bioretention swales, detention basin, efficient irrigation system, filtration systems, monitoring system, rainwater cistern, reuse system

An infill retail project developed by Regency Centers, the Market at Colonnade uses water management and reuse technologies on a largely impervious site in North Carolina's Research Triangle area. The development's innovative stormwater management approach was a key part of achieving a rezoning for commercial development and became part of the project's branding, as tenant Whole Foods Market embraced an above-ground cistern.

Context

The Colonnade site is located adjacent to the Falls Lake watershed, which is largely restricted from commercial development. The site required rezoning from office and institutional to commercial use, and stormwater runoff and water quality were key concerns for community members. "What led us down this path was the zoning and the desire for community support and support from the elected officials," explains Chris Widmayer, vice president of investments for Regency Centers. The small site also did not have space to accommodate a traditional stormwater management device such as a surface stormwater pond or wetland and still achieve the development objectives.

The engineering solution was a rain chain, linking a number of stormwater management practices to capture, detain, treat, infiltrate, and reuse stormwater. The approach reduced runoff from the predevelopment condition by roughly 98 percent. "The holy grail of stormwater is that a drop of rain infiltrates the

The above-ground cistern, next to tenant Whole Foods Market, benefits the development as a marketing tool in addition to collecting rainwater. *(© Regency Centers)*

"This shopping center has less stormwater runoff than my house—and, actually, a lot less. Almost all of it gets captured by the system on site. Not only do you have the volume captured, but also the associated pollutants that have a negative impact on our drinking water." | CHRIS WIDMAYER, VICE PRESIDENT OF INVESTMENTS, REGENCY CENTERS ground generally where it falls . . . and recharges the aquifer there. That was the ultimate goal," explains Widmayer. The team sought to capture all runoff from a one-inch rain event and infiltrate it into the underlying soils and detain runoff from both two-year and ten-year design storms. By infiltrating the "first-flush" runoff, the stormwater system exceeds water quality requirements. The system was also designed to reuse harvested rooftop rainwater for both landscape irrigation and indoor use in the toilet system.

Regency Centers used a North Carolina Clean Water Management Trust Fund grant for the project's green infrastructure features. This grant contributed toward the cost of the stormwater components of the project, which totaled roughly $727,000.

Innovative Water Management Features

- **Cisterns.** Three rainwater-harvesting cisterns—one above ground and two subsurface—can collect up to 43,000 gallons of stormwater runoff. Water from the above-ground cistern is reused within Whole Foods Market for toilet flushing, while water from the below-ground cisterns is used for landscaping.
- **Subsurface infiltration system.** The subsurface infiltration system includes 2,500 linear feet of gravel and pipe trench, typically four feet wide and 3.5 feet deep. The system allows approximately 15,000 cubic feet of temporary storage, permitting infiltration into the underlying sandy loam soils.
- **Bioswales and bioretention space.** A 250-square-foot grass-lined bioretention area and 450 feet of bioswale capture and treat runoff from the shopping center's parking lot and further promote infiltration.
- **Landscape irrigation system.** The landscape irrigation system uses harvested water from the underground cisterns to irrigate turf and landscaped areas on the site, as well as provides for additional infiltration and groundwater recharge within the remaining wooded area on site.
- **Underground detention chamber.** An additional 350,000 gallons of rainwater can be temporarily stored in the 48,100-cubic-foot underground detention chamber.

Value Proposition

Although proud of the environmental accomplishments of the site, the development team also describes its investment in stormwater technology as a savvy means of achieving the land's highest and best use. Mark Peternell, Regency Centers vice president for sustainability, explains that "by avoiding the need for an above-ground pond, we had the buildable space we needed to construct a profitable retail center." Widmayer also emphasizes that the approach works "to enhance development rights and provide density with much cleaner outcomes and cleaner water."

The Regency Centers team credits its environmental consultants for developing a sophisticated and innovative response to the needs of the constrained site. The team has since received detailed information on how the stormwater management mechanisms have functioned from North Carolina State University researchers, who monitored the site 12 months after its installation and compared its performance to that of sites with similar development conditions. The researchers found that the system took in approximately 130 percent more stormwater than a traditional system, with less than 5 percent of water flowing out, compared to a traditional system. Monitoring results indicated that in the first year a total of 30.6 inches of rainfall was measured on the site, of which only 0.6 inches was released from the site, the difference being infiltrated or reused on site.

LESSONS LEARNED

- **Visible green infrastructure can be a marketing boon for a sustainability-minded tenant.** Whole Foods chose to feature the above-ground cistern next to its entrance. The cistern became a memorable symbol of the retailer's values and commitment to sustainability.
- **Stormwater can be harvested and managed even on highly impervious sites.** Although the site was 80 percent impervious after development, the stormwater management system captures the one-inch rainfall without discharge and can detain up to a ten-year design storm. Researchers from North Carolina State found that the site greatly outperforms nearby sites with higher percentages of permeable surface.
- **Green infrastructure can save space and free up developable land, particularly in comparison to a retention pond alternative.** Green infrastructure made retail development feasible on this 6.25-acre site, which could not have accommodated a traditional wet detention pond, the retail facilities, and parking.
- **Water management mechanisms can be an effective part of a real estate project's community engagement strategy, particularly in environmentally sensitive areas.** The need for rezoning initially inspired the development team to take an innovative approach to stormwater management. Using stormwater technologies allowed the site to meet environmental requirements and achieve support from the surrounding community.

Meier & Frank Delivery Depot

QUICK FACTS

Location: Portland, Oregon

Project type: Commercial office building

Status: Completed; LEED Platinum certified

Project cost: $66 million

Site size: 200-by-200-foot city block

Developer: Gerding Edlen

Designer/construction team: GBD Architects, Skanska, Ankrom Moisan Architects, Howard S. Wright Construction, Glumac Engineers

Water management features: Bioretention swales, efficient fixtures, filtration systems, green roof, monitoring system, rainwater cistern, reuse system

On the National Register of Historic Places, the Meier & Frank Delivery Depot now houses the North American headquarters of Vestas, a global energy company specializing in wind power, as well as Gerding Edlen's headquarters and tech firm Urban Airship. Redeveloped to showcase energy and water efficiency, the building has a very robust stormwater management system. Water is collected from the green roof and captured in a 169,000-gallon concrete cistern, which saves an estimated 193,000 gallons[33] of water per year and provides 100 percent of the water needed for irrigation, cooling tower makeup, and toilet flushing.[34] Filtration planters and bioswales surround the perimeter of the building and filter runoff directly into the ground.

Context

The combined sewer system in Portland strains the area's watersheds, forcing the city to invest in pipe expansion projects in hopes of protecting its rivers for salmon and other sensitive local species.[35] Renee Loveland, the sustainability manager at Gerding Edlen, explains that "dealing with stormwater has always been a sensitive issue and a priority for the city." Redevelopment of the historic Meier & Frank depot was an opportunity for the redevelopment team and the building's tenants to promote green infrastructure and endorse best practices in stormwater

The green roof adds aesthetic value to the outdoor terrace and collects stormwater that is eventually reused throughout the building. *(Photography by Jeremy Bittermann)*

"Targeting a goal of no potable water use for nonpotable needs led to creative thinking, such as building a large concrete cistern in the exposed basement instead of purchasing a metal tank, which in turn made the system more cost-effective. The environmental benefits associated with the large volumes of water reused will benefit the community for years to come." | RENEE LOVELAND, SUSTAINABILITY MANAGER, GERDING EDLEN management. Construction was completed in 2012, resulting in an extremely high-functioning building and LEED Platinum certification.[36] Although going above LEED Gold standards cost roughly 2 percent of the total construction budget, incentives related to energy and water efficiency, which accrued to the project, resulted in a payback period of only seven and a half years.

Located in the Pearl District of downtown Portland, today's Meier & Frank depot is a beautiful blend of historic preservation and innovative stormwater management technologies. A top priority was maintaining the integrity of the building's 1928 facade through the retrofit process. To that end, double-paned, energy-efficient replicas of the old single-paned historic windows were commissioned from a local glazing fabricator, and the original penthouse addition on level five was scaled back to comply with historic sightline requirements.

Vestas, a renewable energy system producer, manages and occupies most of the building, which is home to its North American headquarters.

Innovative Water Management Features

- **Concrete cistern.** The 169,000-gallon cistern collects water from the green roof for reuse both outside and within the building. A new floor had to be poured at grade after interior demolition was complete, so using the space below to install a basic concrete cistern was a cost-effective and practical strategy.
- **Real-time monitoring.** Vestas installed extensive submetering to track equipment performance and follow the building's consumption patterns. The monitoring system allowed the company to identify at least one contractor error early on, resulting in significant avoided losses compared to identifying the problem from a spike in utility bills.
- **Bioswales and urban landscaping.** The building comprises a full 200-by-200-foot city block and is surrounded by bioswales on all four sides. These were partially funded by a Green Investment Fund operating through the local Bureau of Environmental Services.

Value Proposition

Gerding Edlen asserts that investment in green infrastructure and the building's energy-efficient design have added value to the Meier & Frank depot and introduced opportunities for operational cost savings. The real-time monitoring has helped track energy and water consumption patterns for the building, keeping extra costs associated with high resource use to a minimum. Reusing captured water for three major nonpotable uses also lowers operational costs.

The redevelopment of the Meier & Frank depot and the arrival of Vestas also represented a value proposition for Portland. The city sought to attract the tenant and was partially successful because of its offer of the historic Meier & Frank depot as a headquarters building. After making the decision to open its North American headquarters in Portland, Vestas was heavily involved in the redevelopment process, taking a more hands-on role than a typical commercial tenant.

LESSONS LEARNED

- **Innovative water management and recycling techniques can be achieved in the context of a historic building.** The Meier & Frank Delivery Depot maintains its historic facade and charm while incorporating innovative water management technologies, some of which are invisible to passers-by.
- **Stormwater management can be part of a holistic workplace health philosophy.** According to Loveland, Vestas "took a European approach to healthy work-places, which is becoming more and more the type of design approach for highly sustainable buildings in this market." Along with water management, healthy workplace practices include prioritizing natural light; incorporating visible, enticing staircases; and providing employees with direct views of the outdoors.
- **Water reuse strategies need to consider the building occupant.** When the building first opened, reused water in the building was treated according to code requirements but was discolored, making users uncomfortable. The building switched to piped water for about a month while the tank was cleaned, which removed residue that had accumulated during construction. Since then, only minor variations in color have occurred and no further complaints have been heard. Building management also markets the green efforts, including signs reading "We flush with rainwater" to raise awareness about this environmental accomplishment at the building.
- **The opportunity for a green, resource-efficient building won Portland a high-profile new company.** The vision for the Meier & Frank depot, including the water management strategy, ultimately was a successful economic development tool for the city. The water and energy-efficient vision for the Meier & Frank depot paralleled priorities of a high-profile company, becoming a successful economic development tool for the city.

Penn Park

QUICK FACTS

Location: Philadelphia, Pennsylvania

Project type: Public park on a university campus within a larger public/private partnership development

Status: Completed

Project cost: $46.5 million

Site size: 24 acres

Developer: University of Pennsylvania

Designer: Michael van Valkenburgh Associates

Water management features: Bioretention swales, monitoring system, native plants or trees, rain gardens, rainwater cistern, reuse system

Penn Park has transformed an unappealing "leftover space" into an active part of the University of Pennsylvania campus and a green visual connection to Center City Philadelphia. The university developed the park as part of the *Penn Connects* master plan, and its innovative green infrastructure goes beyond the city of Philadelphia's *Green City, Clean Waters* plan requirements for stormwater absorption. The stormwater management features not only serve an environmental function, but also contribute to the park's sense of place while presenting research and educational opportunities. "It's a natural environment in what we all remember as a vast and inaccessible Postal Service parking and storage yard," says university architect David Hollenberg. "It really is an incredible thing."

Context

The University of Pennsylvania acquired the Penn Park site primarily from the U.S. Postal Service (USPS). The park site was part of a larger surplus property disposal deal with the USPS, when the agency downgraded its landholdings in Philadelphia. The park site was previously used for a vehicle maintenance facility and parking lot and included or bordered a web of infrastructure, including a high-speed-rail track, a commuter-train line, freight-train tracks, and two major downtown connections.

The meadow in Penn Park includes over 500 trees and reclaims about an inch and a half of rainwater. *(Michael Van Valkenburgh Associates)*

"We could manage our stormwater requirements on campus by putting everything out of sight and underground. But we recognize that the rain gardens and the visible green roofs are a way to convey to people that we are taking water seriously even to the extent of introducing new landscape typologies to the campus." | DAVID HOLLENBERG, UNIVERSITY ARCHITECT, UNIVERSITY OF PENNSYLVANIA

USPS disposed of its 30th Street holdings as one parcel rather than subdividing contiguous properties. The university retained and developed the open parking and storage component of the disposed properties as Penn Park. For the remainder, the university entered into a ground lease arrangement with Brandywine Realty Trust, which has constructed a residential tower, a garage rooftop park, and the mixed-use corporate FMC Tower. Finally, the historic circa 1930 post office was fully turned over from Penn to the trust, which has restored and rehabilitated it for use as offices for the Internal Revenue Service.

The new park would support adjacent recreational and athletic facilities and also presented the opportunity to innovate with water management. "Penn Park was one of a handful of early examples of following Philadelphia Water's stormwater regulations," explains Hollenberg. "We were a big and visible early example of the kind of stormwater management the Philadelphia Water Department wanted to implement." The design of the park would also respond to the university's first Climate Action Plan, which included water management objectives. In addition, a separate Stormwater Management Plan explored possible sites, tools, and best practices for the entire campus.

Today, Penn Park includes passive park space, two multi-purpose turf fields, 12 tennis courts, a natural-grass hockey field, a softball field, concessions space, a press box, spectator stands, a food orchard, and a student-run apiary. The entire park is open to the public, and community members can rent field and recreational space. Sculptural landforms connect the different functions and grade levels, creating a pedestrian circulation network that showcases the historic infrastructural forms remaining—in particular, the CSX train trestle overhead, still in active use on the site.

Innovative Water Management Features

- **Bioswales, rain gardens, and meadows.** The park can reclaim about an inch and a half of rainwater. Natural features of the park designed to capture stormwater include meadow plantings, bioswales that cover roughly three-quarters of an acre, and nearly 570 newly planted trees. The meadow aesthetic was new to the campus.
- **Cistern and associated underground infrastructure.** An underground 300,000-gallon cistern collects runoff from the adjacent turf athletic fields, which are porous and collect roughly 2 million gallons of stormwater per year.[37] In the first five years of use, the cistern has never needed to be emptied manually on account of filling to capacity. The park also includes further underground infrastructure to accommodate its location: for example, an underground support system ensures that the weight from the berms and meadow plantings is evenly distributed and does not disrupt the adjacent rail line.

Value Proposition

The park has helped the university achieve some of its master-planning goals, creating new open space and better connecting the campus and the community. Today, the park hums with activity and offers commuters a scenic link across a previously fenced-off, inaccessible site. The park has also become a site for student and faculty environmental research and pilot projects such as the orchard and apiary. Faculty members and students are continuing to identify new opportunities for on-site research and are currently looking into adding groundwater monitoring wells.

A first test of the park's water management mechanisms came in 2011 in the month before the ribbon-cutting, when Philadelphia experienced 13.6 inches of rain, a city record for rainfall in a month. Shortly afterward, Hurricane Irene brought nearly six inches of rainfall in 12 hours, bringing the Schuylkill River to its highest level in 140 years.[38] University president Amy Guttman notes that "our state-of-the-art drainage system had obviously worked. . . . It was put to the ultimate test with Irene far sooner than we could have expected, and it passed with flying colors."[39]

LESSONS LEARNED

- **Maintenance required a significant learning curve.** The water-rich bioswales of Penn Park, as well as the monitoring systems in place, were new to the campus and initially presented challenges to the university's grounds crew. "It's a full-time job to keep it managed and operated," explains Bob Lundgren, the university landscape architect. "We're always learning more." Challenges have included:
  - **Monitoring systems.** Instruments that measure the dryness and wetness of soil require fluency with the system for all involved. "It's great to have a smart system, but you have to remember to turn things on and off, and if you don't reboot it, it's not going to work," explains Lundgren, recounting an instance when a stuck-open valve led to significant water loss.
  - **Bioswale and meadow landscapes.** Bioswales, which hold water and allow it to seep into the earth, require a very different maintenance approach from grass surfaces. Penn Park's bioswales sit within a meadow, featuring a range of upland plantings. When disturbances occur and soils erode, weeds can become prevalent and spread, which is a particular challenge for the university, given policies against pesticides or herbicides.
  - **Deicing.** The university uses EnvironMelt, a less caustic deicing material, instead of rock salts that might contaminate the water in the cistern.

Stonebrook Estates

QUICK FACTS

Location: Harris County, Texas

Project type: Residential community

Status: Civil infrastructure and lots completed; homes currently under construction (approximately 52 percent completed)

Project cost: $11.4 million

Site size: 51.4 acres

Development size: 135 lots (lot sizes included two offerings: one 70 feet wide by 125 feet deep and the other 80 feet wide by 130 feet deep)

Developer: Terra Visions LLC

Designers: Aguirre & Fields LP (LID component), R.G. Miller Engineers Inc.

Stormwater management features: Bioretention swales, detention basin, filtration systems, natural drainage system

Stonebrook Estates is a 51.4-acre, single-family residential, low-impact development located north of Houston in Harris County. The 135-lot community, currently made up of about 70 completed homes averaging sale prices upward of $500,000 each, offers an example of a hybrid stormwater management system that uses both natural drainage systems and traditional storm sewers to effectively convey stormwater around and away from homes. In addition to adding green amenities to the community, the investment in low-impact development has ensured avoided losses by proving to effectively handle the Tax Day and Memorial Day floods of 2016.

Context

Adopted in 2011, Harris County's Low Impact Development and Green Infrastructure (LID/GI) Design Criteria provide detailed guidelines and requirements that enable real estate development projects using LID/GI techniques to obtain development permits in the unincorporated portions of the county. Stonebrook Estates was among the first in the Houston area to implement LID principles.

Stonebrook Estates developer Terra Visions LLC could have managed drainage on the site by using a six- to seven-acre detention pond, but instead chose to pursue the LID techniques as part of the overall amenity offering for the development. The development entry features a green, landscaped drainage corridor designed to serve as a gateway to the homes. LID features also provide residents with more

A key feature of Stonebrook Estates' low-impact-design approach is a bioswale, which creates a welcoming green space at the entrance to the development. *(Terra Visions LLC)*

"We could have put a six- to seven-acre detention pond on the far side of the development and gone off without thinking about using the drainage system as an amenity. But the idea was to be different. We chose to use the facility as landscaping and give it a look that's not an ugly ditch." | RANDY JONES, PRINCIPAL, TERRA VISIONS LLC

Stonebrook Estates' natural drainage system managed the waters from the Tax Day Flood of 2016, which severely affected Houston. *(Terra Visions LLC)*

green space, a trail system, and a water feature that naturally guides stormwater to two 50-foot-wide detention channels that then filter the flows to an interior detention basin. The basin manages the release of water at a rate and quality that is safe for the surrounding environment.

Innovative Water Management Features

- **Natural drainage system.** The natural drainage system at Stonebrook mimics the natural flow of water across a green landscape, directing stormwater into linear and lake-style detention basins; from there, stormwater is slowly released to nearby channels and bayous.
- **Engineered soils.** The first inch of stormwater runoff from the development is routed through engineered soil filters that remove pollutants from the runoff and ensure that the development complies with local postconstruction stormwater quality management regulations. The engineered soil filters (known as biofiltration) are designed to provide a very high filtration rate, thus avoiding surface ponding.[40]
- **Curb cuts and false-back inlets.** Roadways are sloped and use "false-back inlets" on the curbs to drain stormwater into bioswales instead of traditional precast concrete storm sewer pipes.

Value Proposition

Randy Jones, Terra Visions LLC principal, describes the LID features as a key part of the development's sense of place. After Houston's 2014 downturn caused by falling oil prices, the developer worried the homes would be priced too high for the market. However, although sales volume and absorption were initially lower, the development fared well, with average home prices about 25 percent higher than expected. Jones describes the community as a "complete blend" that was attractive to the suburban Houston market. "It's on a private street, a gated neighborhood, and well landscaped with LID components right at the front door. When you put all the pieces together, the market likes it," he explains.

The site engineer, Michael Bloom with R.G. Miller Engineers, estimates that the natural drainage system, which is used only in a portion of the development, reduced the site detention requirement by 24 percent, which increased lot yield.[41]

Stonebrook's natural drainage system was put to the test during the Tax Day Flood of April 2016. Stonebrook received approximately 12 inches of rainfall in a 24-hour period, which is about equal to the 100-year rainfall for the area. The stormwater management system at Stonebrook "functioned better than anticipated given the rain storm intensity," says Jones. "I was absolutely amazed that the stormwater stayed in the system and didn't flow into the streets or yards." The natural drainage system was able to capture then convey the rainfall and runoff, and both the linear and lake-style detention basins successfully released the design flow to the nearby channels and bayous.

LESSONS LEARNED

- **A low-impact development framework presents an opportunity to fulfill market demand for environmentally friendly communities.** LID principles inherently include natural amenities that are attractive to homeowners, such as trail systems and open space. Jones described green infrastructure as a key component of a well-rounded community desirable to homebuyers.
- **Natural drainage systems can cut costs of drainage facilities.** Stonebrook Estates' drainage corridor is part of the landscape of the community—and is a more cost-effective alternative for the community's utilities, given the limited access to the drainage piping system.
- **Green infrastructure can mitigate risk and avoid losses.** Stonebrook Estates has already survived a major storm, the Tax Day Flood. Infrastructure in this community has proven to be resilient and protected its community members.

The Avenue

QUICK FACTS

Location: Washington, D.C.

Project type: Mixed use

Status: Completed

Project cost: $336 million

Site size: 3.5 acres

Developer: Boston Properties Inc.; site now owned by Boston Properties (commercial) and Bozzuto (residential)

Designers: Sasaki Associates Inc., Pelli Clarke Pelli Architects/Landscape, Hickok Warner Cole Architects, Thornton-Tomasetti Group, TOLK, KTA Group, Wiles Mensch Corporation, Clark Construction

Water management features: Filtration systems, green roof, rainwater cistern, retention pond, reuse systems

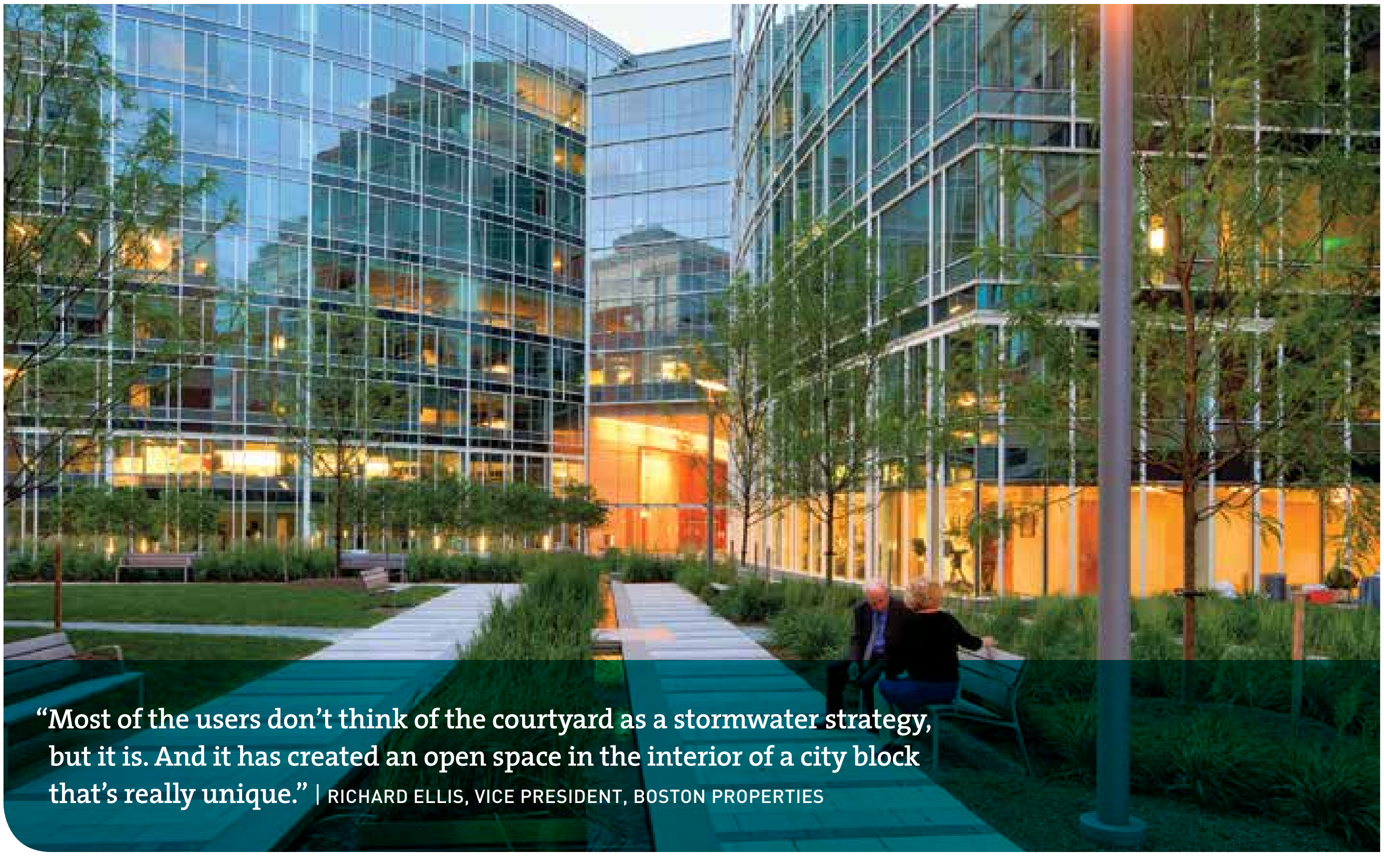
The Avenue is a mixed-use, transit-oriented development steps away from the George Washington University campus and hospital in Washington, D.C. The 3.5-acre development includes 335 residential units, 460,000 square feet of commercial office space, a Whole Foods Market, six eateries, and public and private green space. Upon completion in 2011, the residential building achieved the highest rents in the city for a project of its size and leased up in 11 months. Central to the residential and office space is an attractive interior courtyard, with a water feature that operates with a stormwater management system and uses 100 percent reclaimed water.

Context

Completed in 2011, the Avenue has an active streetscape that has become a popular destination for visitors, office workers, residents, and students in downtown Washington. The project came out of an urban design study for the disused parcel that previously held the George Washington University Hospital, which was also Square 54 of the original Washington plan.

The project is the result of a partnership between George Washington University and Boston Properties Inc. under a 60-year lease that has since provided funding for the construction of the university's Science and Engineering Hall and contributed an estimated $11.5 million in annual city tax revenues.[42,43] The ground

The Avenue's courtyard is an inviting space for visitors, office workers, residents, and others. *(Sasaki)*



The attractive courtyard water feature holds captured runoff from the roof after it has been cleansed by the treatment system. *(Sasaki)*

lease terms were based on the amount of developable space rather than the possible floor/area ratio (FAR), which led the development team to create a courtyard concept slightly below FAR opportunities. A key requirement for the design of the building was a below-grade loading dock, which also created the opportunity for an interior courtyard above it.

Sustainable design can be found throughout the Avenue. Green and lightly colored roofs absorb less heat than conventional black roofs, thereby decreasing peak roof surface temperature by approximately 40 degrees Fahrenheit. The Avenue also uses a high-efficiency irrigation system and native and drought-tolerant plants, which reduce the amount of water needed by an estimated 62 percent.[44]

Innovative Water Management Features

- **Green roofs.** An extensive 8,000-square-foot green roof is spread equally across the office and residential buildings. This green roof system comprises a water retention layer, a drainage layer, filter fabric, engineered soil, and succulent plantings. On the residential roof, more than 300 linear feet of raised planters with tall evergreen hedges shield the pool and terraces from sight and wind.
- **Stormwater treatment and reuse system.** Water is absorbed by the green roofs and then sent through interior piping into the stormwater filter, which includes two sand filters, an ultraviolet sterilizer, and an ionizer that kills algae, bacteria, and viruses without the use of extra chemicals. This system allows plants to grow directly in the water feature and requires less maintenance than a standard infiltration system.[45] Water is then recirculated into the 7,500-gallon cistern, which is located underneath the courtyard, within the five-level parking garage below. Irrigation water is pumped directly from the cistern, and all other stored rainwater is continuously pumped through the courtyard water feature and treatment system.

  The development's robust stormwater management system for collecting, treating, and reusing rainwater in an inviting courtyard is able to manage an estimated 76,000 gallons of stormwater.[46]
- **Courtyard water feature.** The attractive water feature doubles as a stormwater container, holding roughly 15,000 gallons of water that has been recirculated through the cistern and treatment system. The courtyard's water feature is 100 percent supplied by reclaimed stormwater. The water feature includes aquatic vegetation in perforated planters that allow the roots to provide supplemental filtration.

Value Proposition

The Avenue has been a resounding commercial success. It achieved the highest residential rents in the city for a project of its size and had a relatively fast lease-up: 11 months for 335 apartments. The commercial space also attracted tenants quickly. "By every metric, the project has exceeded expectations," says Richard Ellis of Boston Properties. Ellis attributes this success to a variety of factors, including the location, the quality of construction, and the design of the courtyard space.

Beyond serving as an attractive public space, the courtyard has enhanced views throughout the development. "There's no such thing as a bad or back view," explains Ellis. "Some people look at a green courtyard; some look at a busy commercial corridor."

LESSONS LEARNED

- **The courtyard water feature has provided residents with significant amenity value.** The courtyard is an extremely popular amenity for residents, office workers, and members of the public. Beyond improving public spaces, the courtyard also enhances views for residences and offices, thereby contributing to the desirability of the project and the real estate value.
- **Innovative design can create additional water storage capacity.** The design team was interested in creating more water storage than was available in the 7,500-gallon cistern. "We were constrained by the size of the cistern because of the premium for parking," explains designer Matt Langan of Sasaki. Instead of proposing a larger cistern in the parking structure, the landscape architects designed the water feature to be unusually deep, with water circulating in and out from the cistern and infiltration system.

The Rose

QUICK FACTS

Location: Minneapolis, Minnesota

Project type: Mixed-income multifamily redevelopment

Status: Completed in 2015

Project cost: $36.2 million

Site size: 1.65 acres

Development program: 145,000 square feet; 90 units (43 market rate and 48 affordable)

Development team: Aeon, Hope Community

Design team: MSR Design (lead), Emmons O'Rourke and Associates, Karges-Faulconbridge, Meyer Borgman Johnson, Elert and Associates

Water management features: Efficient fixtures, filtration systems, native plants or trees, rain gardens, rainwater cistern, reuse systems, stormwater vault

The Rose is a 145,000-square-foot mixed-income redevelopment in the final phase of Minneapolis's South Quarter. Stormwater management was a key strategy to remediate contamination present in one of most ethnically diverse neighborhoods in Minneapolis. The development features 33 percent green space and is designed with rain gardens that infiltrate and reuse about 90 percent of rainwater for community gardens. In 2013, the Rose became one of the first affordable housing developments in the nation to be selected as a Living Building Challenge™ pilot for its stringent commitment to sustainable design and its achievement of nearly net-zero water, waste, and energy.

Context

Creative partnerships were the cornerstone to achieving high sustainability standards while preserving affordability at the Rose, located in one of Minneapolis's lowest-income and most ethnically diverse neighborhoods. The Rose created 90 units of market-rate housing, affordable housing, and supportive housing for the long-term homeless as part of the final phase of the South Quarter district's redevelopment. The complex is located on a 1.65-acre former brownfield site surrounded by freeways, spanning nearly a block of South Minneapolis.

Lead developer Aeon partnered with another nonprofit developer, Hope Community, whose strong ties to the neighborhood ensured the development

Children enjoy a landscape feature in one of the Rose's courtyards. *(Aeon/MSR Design)*

"We focused on finding the highest return on investment for each design strategy. For example, every design element had a goal to provide more than one benefit; it also had to bolster the performance of another system or component. Thus, we were able to evaluate on a building-wide basis the right balance of life-cycle cost, first cost, durability, and energy and water savings." | LESLIE ROERING, PROJECT MANAGER IN HOUSING DEVELOPMENT, AEON

Built on a previously contaminated site surrounded by freeways, the Rose has integrated stormwater management mechanisms to cleanse and reuse 90 percent of captured rainwater. *(Don Wong/ MSR Design)*

process was both inclusive and on target to meet local needs.[47] In 2013, the Rose became one of the first affordable housing developments to be selected as a pilot project for the Living Building Challenge, a rigorous certification standard for sustainable construction and design.[48]

While aspirationally pursuing the Living Building Challenge, the development team complied with the Enterprise Green Communities Criteria, a point and checklist system with mandatory considerations for sustainability, required by the Minnesota Housing Finance Agency as a condition for public funding.[49] At the project's inception, the general contractor and the design team entered into an informal Integrated Design and Delivery process, a contract from American Institute of Architects that jointly establishes energy budgets, bidding cycles, and life-cycle costs of product alternatives.[50]

Innovative Water Management Features

- **Rain gardens.** Up to 26,000 gallons flowing from the east quarter of the building roofs can be filtered through three rain gardens on site.[51]
- **Underground retention system.** A 48,500-gallon-capacity underground retention system captures the stormwater runoff from roofs that the rain gardens cannot capture.
- **Water quality unit.** Before runoff reaches the Mississippi River, oil, trash, and sediment are removed from stormwater runoff on site.
- **Rainwater cisterns.** Rainwater is captured in cisterns and reused in a 5,000-square-foot community garden that offers food-production programming on site.
- **Solar water-heating system.** On-site solar panels heat 35 percent of the water used in the project.
- **Water-efficient fixtures.** To reduce potable water use, the Rose installed 1.5-gallon-per-minute (gpm) maximum-flow showerheads, 1.5 gpm maximum-flow kitchen faucets, 0.5 gpm bathroom faucets, and 0.8-gallon-per-flush toilets.[52]

Value Proposition

An independent third party, the Weidt Group, estimates the payback period for the Rose's sustainable features is 11.4 years.[53] Potable water use at the Rose has decreased by an estimated 47 percent since water-conserving features were installed.[54] By design, the Rose exceeds the city's water consumption standards nearly by half, with a system that uses up to 35.6 gallons of water per capita per day. After these sustainability and water management features were implemented and over half the units were set aside for low-income and formerly homeless tenants, construction costs still came to only $156 per square foot.[55]

Leslie Roering, project manager in housing development at Aeon, notes, "Our goal was to transform the blighted, contaminated site into a place of refuge. We incorporated 33 percent green space, fully accessible tree-lined walkways, and gathering spaces that serve as buffers to streets. Underground parking frees up space for use by people instead of cars, and a band of rain gardens infiltrates 90 percent of rainwater collected on the roof and site and feeds it into cisterns for reuse in the community garden."

The Rose's commitment to sustainable, healthy, and affordable housing has earned it numerous awards and accolades, including the ULI Jack Kemp Excellence in Affordable and Workforce Housing Award, the AIA Minnesota Honor Award, and the Environmental Initiatives Award, Energy & Climate category.

LESSONS LEARNED

- **On-site contamination can be remediated when stormwater capture is integrated at different levels of design.** The Rose, developed on a former brownfield site surrounded by freeways, cleans stormwater runoff and conserves potable water through rainwater harvesting systems and water-efficient fixtures.
- **Affordable and supportive housing can be preserved while achieving a high level of sustainability.** The Rose's sustainability features have an estimated payback period of just over 11 years. This investment was viable for the project, although over half the units are for low-income families and formerly homeless people.
- **Creative partnerships between design and construction teams are essential to forecast and mitigate costs at the inception of a development.** The general contractor was informally integrated into the design team at the inception of the Rose's development, containing costs for construction to $156 per square foot.

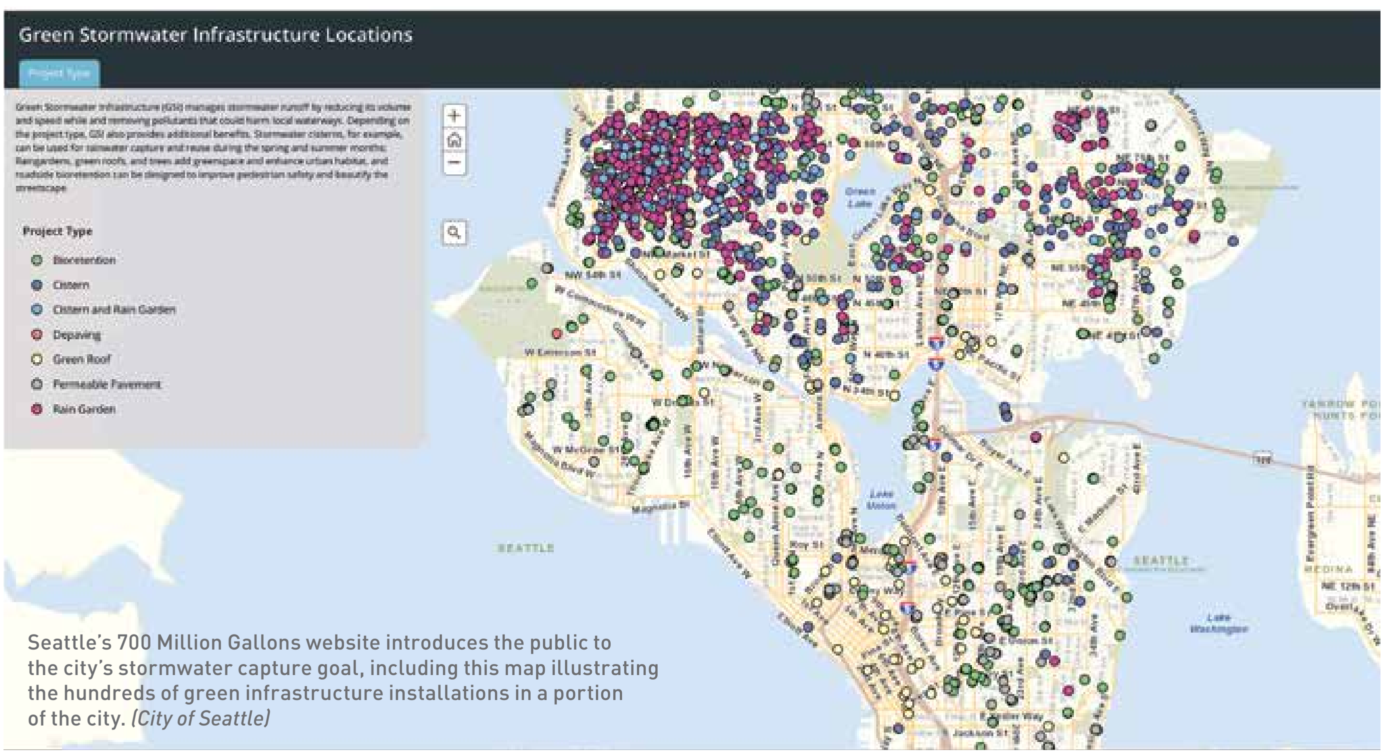
CHAPTER 6

The Stormwater Policy Landscape

In cities across the United States, investments in green infrastructure are growing through both public sector programs and private sector involvement. New York City has committed to spending $1.6 billion on green infrastructure in 20 years,[1] while Philadelphia has estimated that public investment in stormwater retrofits over the next 25 years will total $1.2 billion.[2] Smaller but still substantial green infrastructure targets are also in place in Los Angeles; Detroit; Portland, Oregon; and Kansas City, Missouri.[3] Along with these public investments, government policies often encourage or require private real estate sector participation.

"The goal [of a holistic green infrastructure strategy] is for all sectors and residents of cities to see the benefit to themselves personally and to their cities as a whole," explains Mami Hara, general manager/chief executive officer of Seattle Public Utilities and former deputy commissioner of the Philadelphia Water Department. "These strategies should make the best use of every infrastructure dollar spent, to achieve the multiple ends that we need to in order to have a more sustainable society."

Municipalities encourage private sector participation in green infrastructure development in multiple ways. Some cities have focused on putting new requirements in place, whereas others have focused primarily on development incentives. "While developing and paying for additional stormwater management systems is still an option [for cities], using existing tools to share risk with citizens and landowners in a way that achieves many



Seattle's 700 Million Gallons website introduces the public to the city's stormwater capture goal, including this map illustrating the hundreds of green infrastructure installations in a portion of the city. *(City of Seattle)*

STORMWATER POLICY TOOLS

On-site water retention requirements	These policies require developments over a certain size threshold to capture a specific minimum volume of water on site, typically measured by inches of rain or percentage of a certain type of rain event.
Credit-trading schemes	Credit-trading schemes, such as the innovative new policy in Washington, D.C., offer real estate developers the opportunity to adhere to on-site mitigation policies or purchase credits from other sites that have voluntarily complied with the requirements.
Green area ratios	Green area ratios encourage the layered use of different stormwater mechanisms through the use of a score-based tool that requires a certain percentage of a site to be covered by green infrastructure, with different points awarded to different interventions.
Frameworks and design guidelines for low impact development	This largely bottom-up, market-driven approach offers developers the tools to use the LID approach for their projects, providing resources such as guidebooks, development incentives, and expedited permitting. LID refers to systems that mimic natural processes to manage water and protect water quality.
Stormwater fees	Stormwater fees are charged based on the amount or percentage of impervious surface on a site, encouraging the incorporation of impermeable or green surfaces. Sites that put larger burdens on the public drainage systems are required to contribute more.
Development incentives	Development incentives for green infrastructure have included FAR bonuses, tax abatements, and rebates.
Implementation of total maximum daily loads (TMDLs)	Calculated in watersheds discharging too much pollution, TMDL refers to the maximum amount of a pollutant that a body of water can receive while adhering to water quality standards. Reducing the volume of runoff from a development directly reduces the pollutant load and can help achieve the required pollutant load reduction.
Community grant programs and design competitions	Cities have sought to generate new ideas about green infrastructure and to inspire innovation through ideas competitions aimed at the design community. Community grant programs have supported citizen-led stormwater management and community greening projects.
Monitoring and open data programs	Green infrastructure is one of the many topics that can be analyzed through open data platforms, with cities releasing green infrastructure data to gain insights on effectiveness and performance.
Toolkits for households	Beyond policies affecting large-scale residential, mixed-use, commercial, and office development, cities have introduced policies, toolkits, and incentives to encourage private homeowners to make small-scale, low-cost alterations to their properties to reduce impervious surfaces.
Demonstration projects	Numerous municipalities have shown their commitment to green infrastructure by initiating demonstration projects in the public realm intended to spark discussion and inspire private sector action.

STORMWATER POLICY STRATEGIES: EXAMPLES FROM SIX CITIES

STRATEGIES	**New York** Capture rainfall on 10% of impervious surfaces by 2030	**Chicago** Capture up to 250 million gallons/year by 2020	**Philadelphia** Capture rainfall on 34% of impervious surfaces by 2035	**Seattle** Capture up to 700 million gallons/year by 2025	**Baltimore** Capture rainfall on 20% of impervious surfaces by 2018	**Washington, D.C.** Capture rainfall on 75% of all surfaces by 2035
On-site water retention requirements	•	•	•	•	•	•
Credit-trading schemes						•
Green area ratios				•		•
Fee structures	•	•	•	•	•	•
Development incentives	•	•	•	•		•
Community grant programs	•		•	•	•	•
Open data and monitoring programs	•	•	•		•	•
Design and idea competitions	•		•		•	•
Household toolkits	•	•	•	•	•	•
Demonstration projects	•		•	•	•	
Greening vacant land	•		•		•	
CONTEXT						
EPA consent decree	•	•				•
EPA settlement agreement	•			•	•	
EPA partnership agreement			•		•	•
Average rainfall	50" average rainfall/year	37" average rainfall/year	43" average rainfall/year	39" average rainfall/year	42" average rainfall/year	40" average rainfall/year
Public commitment	$2.4 billion	$50 million	$1.6 billion	$57.7 million	$77.5 million	$2.6 billion
Municipal plan	*2010 New York City Green Infrastructure Plan*	*2014 Chicago Green Stormwater Infrastructure Strategy*	*2009 Green City, Clean Waters: A Long Term Control Plan Update*	*2015 Seattle Green Stormwater Infrastructure, Implementation Strategy*	*2013 Baltimore City Watershed Implementation Plan*	*2012 Sustainable DC Plan*

Principal sources: EPA Statute Enforcement Database; 2010 New York City Green Infrastructure Plan; 2014 Chicago Green Stormwater Infrastructure Strategy; 2009 Green City, Clean Waters: A Long Term Control Plan Update; 2015 Seattle Green Stormwater Infrastructure, Implementation Strategy; 2015 Baltimore City MS4 and TMDL Watershed Implementation Plan; 2016 District of Columbia, Water Quality Assessment Integrated Report to the US Environmental Protection Agency and Congress Pursuant to Sections 305(B) and 303(D) Clean Water Act (P.L. 97-117); NOAA Online Weather Data.

Note: See appendix on page 64 for complete citations.

additional benefits is a resilient approach—and one cities around the world should consider trying," explains Amy Armstrong, vice president for knowledge and impact at 100 Resilient Cities, a project of the Rockefeller Foundation.

Philadelphia and Washington, D.C., currently have particularly broad stormwater management programs, which are likely to inspire other cities if successful development outcomes are achieved. Both include on-site water retention requirements alongside a range of other programs and policies that have been mixed and matched by other cities establishing green infrastructure programs.

Some cities are increasingly looking to green infrastructure to address climate change–related issues, particularly concerns about flooding. Jeff Hebert, chief resilience officer, chief administrative officer, and deputy mayor for the city of New Orleans, notes that the city has found neighborhood-scale green infrastructure to be more effective at reducing flooding vulnerability than investments on individual properties. He explains: "The city of New Orleans did an analysis and decided that it was more advantageous for us to invest in green infrastructure with our hazard mitigation and severe repetitive loss area funds. The model showed that investing in even smaller green infrastructure in parks and other places actually reduced the risk across the board." Today, the city has revised its approach to its repetitive loss funds and the Comprehensive Zoning Ordinance for the city of New Orleans requires on-site stormwater management.

Cities have also sought new strategies to track the success of their investments, considering costs in comparison to both gray infrastructure and the potential costs related to property damage from flooding. "For cities and property owners to make effective investments in sustainable stormwater management, they need to be able to evaluate its performance," explains Steve Fifita, executive director of City Digital in Chicago, which recently launched a green infrastructure monitoring project.

The following section of this report introduces a range of approaches to stormwater management policy and explores their relevance to real estate.

On-Site Stormwater Retention Requirements

On-site mitigation policies require real estate projects to retain a certain volume of water on site. In 2013, 18 states and the District of Columbia had on-site standards for stormwater infiltration or evapotranspiration—the process by which moisture is carried from plant roots to tips for release into the atmosphere.[4] Typically, these standards are measured in terms of volume of stormwater that must be captured (for instance, the first inch of stormwater) or percentage of stormwater from a certain type of rain event that must be captured.

Developers achieve these goals by incorporating into their projects green infrastructure, such as green roofs, cisterns, rain

Los Angeles's LID Road Map offers residents and developers clear guidance on how to navigate LID requirements. *(City of Los Angeles)* gardens, bioswales, or other design approaches. The goal is to keep stormwater out of drainage and sewer systems by minimizing impervious surfaces on the site as well as between the site and adjacent sites.

The following cities currently have such standards:

- **Philadelphia:** Among the most progressive in the country, Philadelphia's stormwater requirements are likely to set a standard for other cities seeking new approaches to managing runoff. One of the most stringent requirements is for new development to capture the first 1.5 inches of stormwater from all directly connected impervious areas using green infrastructure.[5] If infiltration is not possible or is environmentally harmful for any reason, the method of compliance is then derived from the sewershed where the project is located.[6]
- **Washington, D.C.:** The District of Columbia requires new development to retain on site the first 1.2 inches of rainfall from a 24-hour storm for all projects over 5,000 square feet, with evapotranspiration, retention, or rainwater harvesting occurring during the following 72 hours, if no additional rain occurs.[7] Building retrofits that cost more than half the structure's prerenovation value are required to capture 0.8 inches of rainfall.[8] The organization Clean Water Action heralded this permit standard as an opportunity to improve water quality in the District.
- **New Orleans:** Following recommendations from the post-Katrina recovery blueprint, *The Unified New Orleans Plan*, the city of New Orleans updated its Comprehensive Zoning Ordinance (CZO), adopting a new CZO in 2015. A place-based development code, the CZO advocates for a denser urban pattern and addresses stormwater management by focusing on landscape, stormwater management, and screening. The CZO requires that new development detain and filter the first 1.25 inches of water using stormwater best management practices.[9] Stormwater management plans must be prepared by a registered landscape architect and analyze pre- and postdevelopment runoff rates.[10]
- **Los Angeles:** Los Angeles introduced an LID ordinance in 2012 that requires projects of a range of sizes, including small-scale developments, to capture stormwater at the source.[11] The ordinance describes these stormwater management requirements as critical to achieving the city's revitalization plans for the Los Angeles River.[12] The ordinance aims to apply "an integrated approach to incorporate wastewater, stormwater and runoff, and recycled water management," citing an increase in impervious area, which has increased runoff and decreased water quality because of the transport of pollutants downstream.[13] The city's LID ordinance was particularly innovative in its inclusion of smaller properties, including housing developments of ten or more units, single-family hillside residential developments, commercial or industrial developments with one acre or more of impervious area, and others. Nearby Santa Monica also requires that all new development or retrofitted development capture runoff from impervious surfaces for a storm dropping 0.75 inch of rain.[14]

Credit-Trading Programs

Washington, D.C.'s new stormwater policies introduced a credit-trading program for stormwater volume, a first-of-its-kind concept in the United States and internationally.[15] Washington's program offers developers the choice of either capturing the required volume of stormwater on site by implementing green infrastructure or purchasing stormwater volume credits from other sites that have voluntarily exceeded the volume capture requirements and have additional stormwater volume credits to sell. The city of Los Angeles is considering adopting a similar program, as are a number of other cities across the country.[16]

A credit-trading program can be particularly attractive to real estate developers leading high-density downtown development projects. For example, the developer of a high-rise building with limited green space may choose to purchase credits rather than forgo rooftop amenities to make way for green infrastructure, or forgo some of the underground parking or space for utilities to make space for cisterns. Conversely, developers with larger sites and more flexibility regarding green infrastructure implementation may retain a higher volume of stormwater by using additional green infrastructure and sell the credits at a profit.

Credit-trading systems also create a role for suppliers and aggregators who can build green infrastructure and sell the capacity to developers, such as District Stormwater LLC, a startup launched in 2016 through the Nature Conservancy's impact investment arm, NatureVest, drawing a $1.7 million investment from Prudential Financial.[17] "We are a large-scale aggregator in the market," explains managing director Craig Holland. "We will continue to build credits on behalf of the development community in D.C. that would offer a long-term compliance alternative."

In Washington, one stormwater retention credit is equal to one gallon of retention capacity for one year, meaning that a project developer can purchase one credit instead of implementing one gallon of the stormwater retention requirements. Developers are eligible to use credits to achieve up to half of their stormwater capture requirements.[18] The D.C. Department of Energy & Environment is administering the credit scheme and sought to accelerate adoption through a $12.75 million Purchase Agreement Program launched in May 2016, which created the option of selling the credits to the department to create a price floor in the early days of the program.

USING THE D.C. STORMWATER CREDIT MARKET

The former Shaed Elementary School is located on a small site in northeast Washington, D.C. In 2014, the nonprofit Building Hope leased the school, which had closed because of low enrollment, and an extensive renovation of the building began. This improvement project triggered the city's stormwater regulations and led to the first Stormwater Retention Credit (SRC) trade in Washington, D.C., when the District Department of Energy & Environment approved the transfer of 11,013 SRCs for a value of approximately $25,000.

"It was a tradeoff," Tom Porter of Building Hope explains, "between carrying out a complex and expensive green infrastructure project and buying credits." The school's modest size and structural limitations made it difficult for Building Hope to meet the required 11,013 credits on site. Almost 31,000 square feet of this 39,413-square-foot lot is composed of impervious surfaces, and the foundational work required for a green roof or bioswale would increase the initial costs of green infrastructure to over $100,000.

The Shaed Elementary School bought credits from the Westchester, a co-op apartment complex located in northwest Washington. A person involved in the trade says the initial cost of installing rain gardens on the property, including engineering plans, was close to $75,000. Thus far, the Westchester has generated more than $70,000 in income by selling SRCs. "Revenue from this trade will help cover the costs of designing, installing, and maintaining the rain gardens that generated the SRCs," the seller of the credits says. "Now we're looking at other ways to install practices on our property to generate additional SRCs." In addition, the Westchester is entitled to receive a discount for the stormwater portion of its monthly water bill, which is quite a significant savings for a property of 11 acres.[i]

Ecologically, the trade fits nicely into the city's plan to encourage more green infrastructure where it is most needed. The Westchester is located in an area served by a municipal separate storm sewer system, or MS4, where stormwater runs directly into the city's waterways without any filtration or treatment. Green infrastructure is especially important for water quality in these areas. The Shaed Elementary School, by contrast, is served by a combined sewer system that brings both sewage and rainwater to the city's Blue Plains Advanced Water Treatment Plant. The SRC trade between the Shaed Elementary School and the Westchester, therefore, is a successful example of the main purpose of the SRC program: to shift investment in green infrastructure to MS4 areas of the District.

Transfer Date	Watershed where SRCs are generated	Sewershed where SRCs are generated	Purchase price per SRC	Number of SRCs (tot)	Total value of transfer (tot)
10-13-2016	Potomac	MS4	$1.90	11,013	$20,925
09-26-2016	Rock Creek	CSS	$1.70	4,648	$7,902
09-08-2016	Rock Creek	CSS	$2.00	2,142	$4,284
08-10-2016	Rock Creek	CSS	$1.80	108	$194
08-08-2016	Potomac	MS4	$1.90	2,115	$4,019
08-03-2016	Rock Creek	CSS	$1.80	3,105	$5,589
07-08-2016	Rock Creek	CSS	$1.90	584	$1,110
07-08-2016	Rock Creek	CSS	$1.80	1,257	$2,263
10-02-2015	Potomac	MS4	$1.90	11,013	$20,925
09-18-2014	Potomac	MS4	$2.27	11,013	$25,000
Totals (10 groups)				46,998	$92,209

Washington, D.C.'s stormwater credit market database website includes data on recent sales and purchase prices. *(D.C. Department of Energy & Environment)*

i. J. Strong, "D.C. Introduces Cap and Trade System to Keep Dirty Water out of Local Streams," WAMU 88.5 American University, June 19, 2015, http://wamu.org/programs/metro_connection/15/06/19/dc_introduces_cap_and_trade_system_to_keep_dirty_water_out_of_local_streams.

To function well, stormwater credit-trading systems must create different markets for different watersheds and ensure that the volume of stormwater captured through credit trades is all within a single watershed. The optimal outcome occurs when more properties are managing stormwater, including projects in full compliance and other projects in partial compliance, covering a broader geographic area. Having a high number of runoff management systems allows communities to capture more water over time than they might have with fewer systems designed for larger rain events.

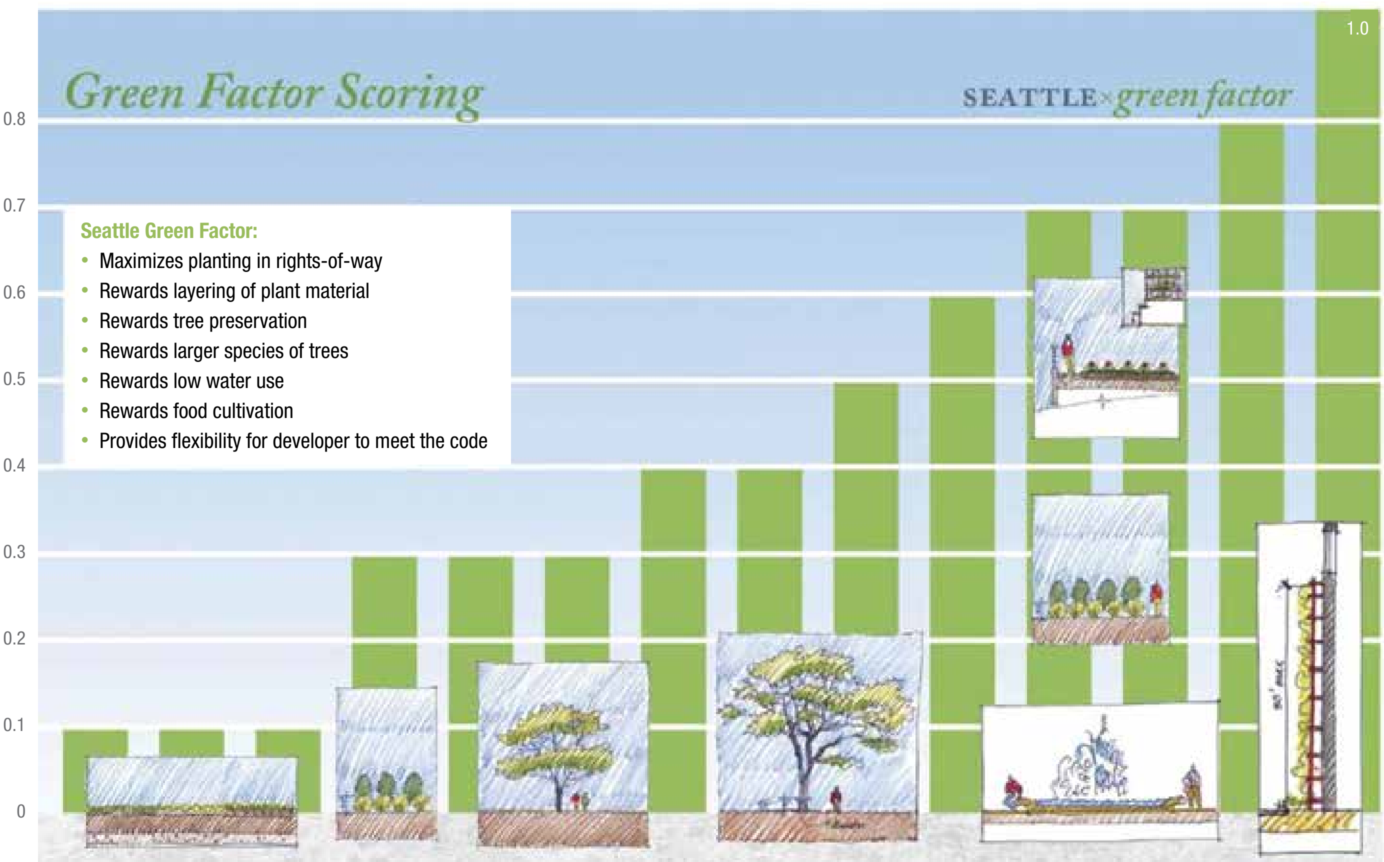
Ideally, the system will not only offer alternative means of compliance for the real estate community, but also encourage development of environmental infrastructure in underinvested parts of the watershed. According to Craig Holland, managing principal of District Stormwater LLC, "The places where you are most likely to want to build stormwater management credit supply are often areas where not a lot of development is occurring. These also happen to be places where oftentimes there is a lack of public infrastructure investment. Credit-trading systems incentivize suppliers to go out and build in places where the investment is most needed."

On a statewide scale, Oregon's Department of Environmental Quality runs a Water Quality Trading system that is designed to allow facilities that discharge wastewater to streams and rivers to address regulatory requirements by buying pollution reduction credits from other sources or by participating in wetland and riparian area restorations.[19]

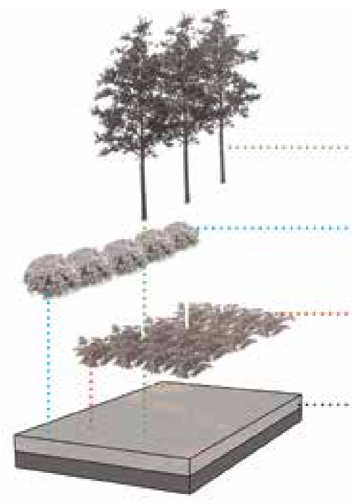
Green Area Ratio

The green area ratio, an alternative metric to on-site mitigation requirements, encourages the layered use of a range of stormwater capture mechanisms. The tool is intended to provide real

Seattle's Green Factor establishes a score for different types of green infrastructure; properties must then meet a minimum score tied to a lot's zoning. *(City of Seattle)*



Bonus +0.1: Drought-tolerant or native plants, rainwater harvesting, features visible to the public, and food cultivation.



Washington, D.C.'s Green Area Ratio includes a range of landscape elements with different multipliers. *(D.C. Department of Energy & Environment)*

estate developers with a menu of options for compliance with green infrastructure and stormwater capture requirements.

Pioneered in Berlin, Germany, in 1997 as the "biotope area factor," the green area ratio awards points for different types of green infrastructure, creating a score that considers the design interventions in the context of a site.[20] Malmö, Sweden, has used a similar system, as has Hamburg, Germany.[21]

Seattle was the first U.S. city to adopt a green area ratio, known there as the Seattle Green Factor (SGF). The city describes the SGF as a "score-based code requirement that increases the amount and improves the quality of landscaping in new development," aiming to manage stormwater runoff as well as improve habitat and aesthetically enhance a neighborhood.[22] Seattle adopted the SGF in 2006 and expanded the program in 2009, with the priorities being livability, ecosystem services, and climate change adaptation.[23] Fife, Washington, a suburb of Tacoma near Seattle, also adopted a Green Factor as part of an LID ordinance in 2009.[24]

Development projects must achieve a minimum SGF score indicated by zoning, with different standards set for commercial and residential properties. To achieve the score, developers can choose from a menu of options that provide credits, including rain gardens, native landscaping, vegetated walls, green roofs, and food gardens. Each provides a number of points weighted by green infrastructure size, functionality, and aesthetics,[25] with the total then divided by the parcel size to create the SGF score.[26]

The system encourages the layered use of different stormwater mechanisms to increase absorption capacity and create rich and varied aesthetics. Landscaping in the public right-of-way is considered with landscaping on the site itself, and bonus points are awarded for landscape aspects visible to the public.[27]

According to the American Society of Landscape Architects, "because SGF significantly raises the bar for landscaping in affected zones, landscape design now starts in the initial stages of site planning, allowing more collaboration between design professionals; the resulting landscapes are more attractive and better integrated into site programs and amenity areas."[28]

Washington, D.C.'s Green Area Ratio (GAR) is a system very similar to the Seattle SGF. The GAR applies to all new buildings that require certificates of occupancy as well as to any additions or renovations with construction costs that exceed 100 percent of the building value within a one-year period.[29] Different GARs are required for different zone districts within the city, with the specific ratios determined in line with land use expectations.[30] Single-family residences, some designated historic properties, some properties with historic roofs, and wastewater treatment plants are exempt.[31]

Development Incentives

Development incentives offer another strategy for encouraging the development of green infrastructure on sites controlled by the private sector. The following cities are among those that offer development incentives correlated with stormwater management strategies:

- **Austin, Texas:** In 2009, the Austin City Council established a stakeholder group, including the renowned Lady Bird Johnson Wildflower Center,[32] to study green infrastructure incentive programs elsewhere in the country, including San Diego, Chicago, and Portland.[33] Today, the city offers developers additional square feet of floor area for each square foot of planted bed on a vegetated roof, measuring the percentage of vegetated roof cover as a ratio of planted bed divided by total roof area.[34] The program also offers additional square feet of floor area if the green roof is publicly accessible and if it achieves the city's "downtown public plaza standards."[35]
- **Portland, Oregon:** Portland offers developers an ecoroof FAR bonus for properties within the Central City Plan District.[36] The program allows developers of large-scale projects, such as commercial, industrial, and multifamily units, to create additional floor area beyond what is allowed

Percentage vegetated roof cover	Bonus area granted	Bonus area granted for publicly accessible green roofs	Bonus area granted for green roofs meeting the downtown public plaza standards
30%–49%	2 bonus square feet	2 additional bonus square feet	2 additional bonus square feet
50% or greater	3 bonus square feet		

Austin's green roof density program is an example of a development incentive tied to green infrastructure. *(City of Austin, Green Roof Existing Credit Fact Sheet)* by zoning codes if they include a green roof that adheres to specific requirements.[37]

- **New York, New York:** In 2008, New York City and New York state passed legislation creating a one-year tax abatement for property owners who incorporate green roofs.[38] The program, which was amended in 2013, offers tax relief of $4.50 per square foot of green roof, or up to $100,000 of the building's tax liability.[39] Participating property owners must certify their green roof projects, ensuring that the green roof's vegetation layer offers 80 percent coverage.[40] The abatement is currently in place through March 2018.[41]
- **Nashville, Tennessee:** In response to a 2009 EPA consent decree acknowledging the 765 million gallons of combined sewer overflow sent into the Cumberland River in 2007,[42] the city of Nashville initiated a range of stormwater management projects and policies, including a citywide Green Infrastructure Master Plan and development incentives such as Green Roof Credit Program. The Green Roof Credit program is for private properties within the combined sewer system area and offers a maximum credit of $10 per square foot of green roof, applied to the monthly sewer charges for the property for up to 60 months.[43]
- **Chicago, Illinois:** In Chicago, permit applications for projects with stormwater management BMPs, such as rainwater harvesting and green roofs, as well as other green technologies, such as wind turbines, photovoltaic panels, and geothermal systems, are processed through the Green Permits program.[44] Eligible buildings must also achieve LEED or Green Globes certification, or LEED for Homes for residential properties. Qualifying projects receive expedited permitting and potential for reduced permit fees.

LID Frameworks and Design Guidelines

LID frameworks and design guidelines offer the real estate community the tools to implement green infrastructure systems with market-based application. In general, low-impact development refers to practices that use natural processes for filtration and evapotranspiration, which typically preserve natural landscape features and minimize impervious surfaces. Cities with LID frameworks, guidelines, and programs often offer expedited permitting, reduced permitting fees, and other incentives to those that participate. LID toolkits are now popular across the United States and have been developed for the state, county, and city levels. In many cases, LID approaches are not mandated but are encouraged and incentivized.

Harris County, which surrounds and includes the city of Houston, was the first in Texas to offer an LID framework. John Blount, Harris County's engineer, says interest in the Houston region is largely driven by consumer interest in low-impact-style amenities. "People use [LID] to be successful," he explains.

THE PHILADELPHIA STORY: THE *GREEN CITY, CLEAN WATERS* PLAN

Philadelphia's *Green City, Clean Waters* plan has been lauded for its pioneering approach to using sustainable landscaping and green technologies to collectively retrofit its over-100-year-old stormwater and sewage system at a neighborhood scale and at a low incremental cost.[i] The plan features many of the policy tools profiled in this report, promoting green infrastructure at the citywide level and actively involving the private sector.

Green City, Clean Waters represents a holistic approach to incorporating green infrastructure across the city at a cost affordable to taxpayers. Mami Hara, former deputy commissioner of the Philadelphia Water Department, who initially pioneered the project with design firm WRT, explains that the plan did not emerge "with a wide-eyed perspective that we should use this stuff to make things pretty. It's really from a perspective of trying to make the very best use of all of our investments. In certain places, green infrastructure is the best value, and I think that holds true for developers as well."

In the 1990s, the evaporation of the federal Construction Grants Program and the threat of lawsuits over contaminated stormwater runoff spurred the Philadelphia Water Department to completely overhaul the city's aging network of underground pipes, pumps, and treatment facilities.[ii] In 2012, Philadelphia reached a consent agreement with the U.S. EPA to finalize a series of decentralized investments over a period of 25 years.[iii] These investments and the related policies are outlined in *Green City, Clean Waters*.

Green City, Clean Waters is estimated to cost $1.6 billion over the lifetime of the project. An independent economic analysis of this plan estimates that, without the Green City, Clean Waters program, the city of Philadelphia would have needed $8 billion to $10 billion and several decades to upgrade and expand its conventional combined sewer overflow system.[iv]

Today, the Philadelphia Water Department displays the progress of its stormwater management strategies, spanning 45 percent of city land, on an online interactive map, which includes 409 privately constructed and 474 publicly constructed features to date.[v]

Currently, the following projects are under design or construction:

- 742 stormwater tree trenches;
- 195 stormwater planters;
- 49 stormwater bump outs;
- 179 rain gardens;
- 6 stormwater basins;
- 268 infiltration/storage trenches;

- 63 porous paving projects;
- 48 bioswales;
- 2 stormwater wetlands;
- 33 downspout planters; and
- 25 other projects.

Environmental Benefits

The Philadelphia Water Department is tracking environmental outcomes of its stormwater management services, particularly as they relate to air quality, soil erosion, the cost avoidance of sick days, and health care costs associated with asthma and heart attacks.[vi]

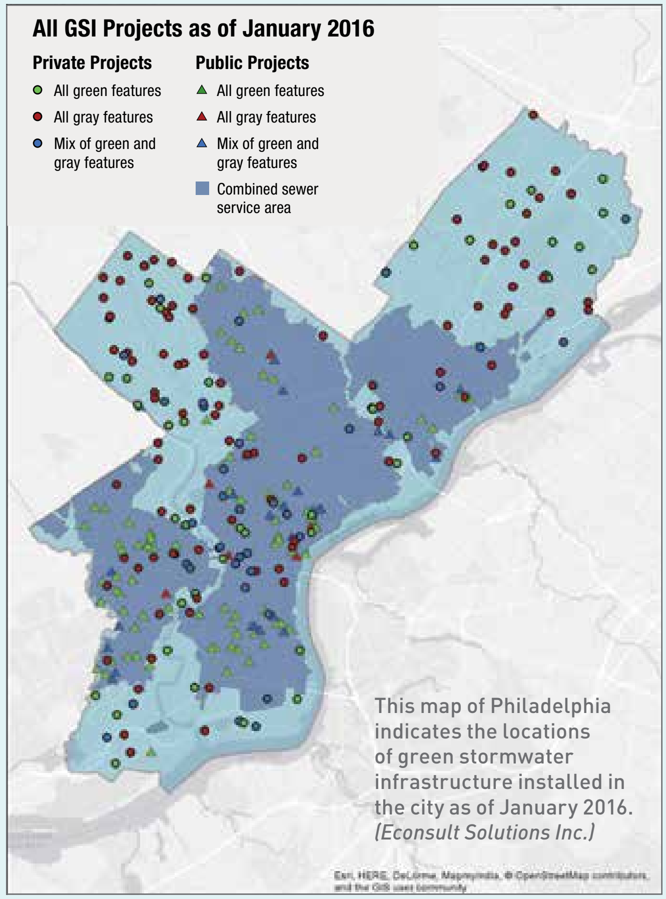
A 2011 report estimated Philadelphia waterways will have up to 85 percent fewer pollutants and 1.5 billion pounds of avoided or sequestered greenhouse gases through the plants and trees distributed throughout the city.[vii] The program has also catalyzed up to $8.5 million in investments over the next 40 years to restore habitats and support biodiversity in targeted locations, including the preservation of 45 acres of existing wetlands, the creation of 148 acres of new wetlands, and the restoration of 7.7 miles of streams in the Cobbs Creek watershed and 3.4 miles of streams in the Tookany/Tacony Frankford watershed.[viii]

Economic Benefits

Conservatively, Philadelphia's sustainable stormwater practices are estimated to have a nearly $60 million economic impact, sustaining 430 local jobs and generating $1 million in local tax revenue.[ix] Local firms in the fields of architecture, engineering, and landscaping have been able to export their innovative stormwater management technologies and services to other cities, such as Washington, D.C., and New York City, which seek to emulate Philadelphia's model policies.[x] From 2013 to 2014, public and private firms related to stormwater management grew 14 percent, with revenues totaling more than $146 million.[xi]

Social Equity Benefits

Philadelphia's Green City, Clean Waters program has concentrated the majority of public and private stormwater management amenities and services in low-income communities to improve environmental and physical health.[xii] The stormwater management programs completed in the first five years of the program alone are estimated to have resulted in a total of $9.9 million invested in local schools and $8.1 million invested in city services through property tax revenue.[xiii]



This map of Philadelphia indicates the locations of green stormwater infrastructure installed in the city as of January 2016. *(Econsult Solutions Inc.)*

i. Philadelphia Water Department, *Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control, Program Summary, Amended* (Philadelphia, 2011), www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf.

ii. Sarah Madden, "Choosing Green over Gray: Philadelphia's Innovative Stormwater Infrastructure Plan" (master's thesis, Massachusetts Institute of Technology, 2010), 24, http://web.mit.edu/cron/Backup/project/urban-sustainability/Stormwater_Sarah%20Madden/sarahmadden_thesis_MIT.pdf.

iii. Philadelphia Water, *Green City, Clean Waters*.

iv. Econsult Solutions, *The Economic Impact of Green City, Clean Waters: The First Five Years* (Philadelphia: Sustainable Business Network of Greater Philadelphia, 2016), www.sbnphiladelphia.org/images/uploads/Green%20City,%20Clean%20Waters-The%20First%20Five%20Years(1).pdf.

v. Philadelphia Water, Green Stormwater Infrastructure Project Map, www.phillywatersheds.org/BigGreenMap.

vi. Econsult Solutions, *The Economic Impact of Green City, Clean Waters*.

vii. Philadelphia Water, *Green City, Clean Waters*.

viii. Ibid.

ix. Econsult Solutions, *The Economic Impact of Green City, Clean Waters*.

x. Ibid.

xi. Ibid.

xii. Ibid.

xiii. Ibid.

A low-impact-development approach, as seen here in Stonebrook Estates outside Houston, can create space for parks and trail access. *(Terra Visions LLC)*

"Whether that means gaining residential lots for development or having space for park use . . . the suburban market really wants to have access to parks and trails within the neighborhood."

Different approaches to LID frameworks include the following:

- **Harris County, Texas:** Harris County's LID criteria address swales, permeable pavement, stormwater planters, green roofs, rainwater harvesting, soil amendments, and other stormwater management practices. The LID manual was developed after a low-impact development design competition in the region piqued the interest of the real estate development and design community. Projects that follow LID criteria often can provide a lower volume of detention because LID techniques slow down stormwater runoff and reduce downstream impacts.
- **Nashville–Davidson County, Tennessee:** Nashville–Davidson County introduced its LID manual in response to the requirements of its municipal stormwater quality permit, which required the use of green infrastructure. The manual details the design approaches of LID and confirms which incentives are available at the county level, including green roof credits, reduced detention credits, and stormwater user fee credits, for sites designed using the approach detailed in the manual.

Stormwater Fees

Stormwater fees are a stormwater management approach likely to be familiar to any member of the real estate development community. Although not particularly innovative, stormwater fees are becoming increasingly commonplace, particularly as the cost of improving and maintaining aging infrastructure rises.

These fees typically encourage the implementation of permeable surfaces by assessing fees based on percentage of impervious area on a site, which is directly related to the amount of stormwater runoff the site discharges to the public drainage system.

More than 1,400 local jurisdictions assess stormwater user fees (proportional to each site's burden on the public drainage system), applied toward the capital and operating expenses for public stormwater infrastructure.[45] These programs often offer credits for those incorporating green infrastructure, which reduces the site's burden on the public system.

Models for stormwater user fees and credits can be found in the following cities:

- **Portland, Maine:** Portland has a stormwater service charge, applied to all properties with rooftops or paved areas on site.[46] However, property owners can earn credits, applied to the relevant portion of the site's impervious area, if green infrastructure elements are incorporated.[47]

CITY STORMWATER MANAGEMENT RESOURCE: NACTO'S *URBAN STREET STORMWATER GUIDE*

Following in the footsteps of the National Association of City Transportation Officials (NACTO) *Urban Street Design Guide*, the forthcoming *Urban Street Stormwater Guide* is a collaboration between city transportation, public works, and water departments to advance the discussion about how to design and construct sustainable streets that responsibly manage stormwater. Across North America, cities are meeting the dual mission of providing safe and vibrant streets for people while leveraging streets and public rights-of-way to develop resilient infrastructure.

The *Urban Street Stormwater Guide* provides cities with national best practices for sustainable stormwater management in the public right-of-way, including core principles about the purpose of streets, strategies for building interdepartmental partnerships around sustainable infrastructure, technical design details for siting and building bioretention facilities, and a visual language for communicating the benefits of such projects. The guide sheds light on effective policy and programmatic approaches to starting and scaling up green infrastructure, provides insight on innovative street design strategies, and proposes a framework for measuring performance of streets comprehensively.

Green stormwater infrastructure can be a bridge between environmental and mobility goals. Rain gardens can be integrated in curb bulbs, enabling shorter and safer street crossings while beautifying the sidewalk. Bioswales can line bikeway and transitway buffers, making active travel modes more attractive to use and effective in function. The guide highlights case studies at many scales to give cities practical examples of success, like the Metro Green Line project in the Twin Cities, a large capital transit project serving a million transit riders each month that has catalyzed $3 billion in commercial and residential development and uses green infrastructure to manage half the stormwater on the 11-mile corridor. On a smaller scale, a retrofit project on Newcomb Avenue in San Francisco is lowering the burden on aging stormwater infrastructure by reducing the peak stormwater flow from the street into the existing drainage system by nearly 80 percent while calming vehicle traffic and making a safer environment for residents and families.

The *Urban Street Stormwater Guide* illustrates a vision of how cities can use one of their best assets—streets—to address resiliency and climate change while creating public spaces that are truly public and nurturing streets that deliver social and economic value while protecting resources and reconnecting natural ecological processes.

Green infrastructure runs alongside Minneapolis's Metro Green Line corridor. *(Metro Transit)*

- **Minneapolis, Minnesota:** Minneapolis's Stormwater Credit Program encourages developers to implement stormwater management practices through an incentive program, with separate credits available for stormwater quality and quantity.[48] Building owners can reduce their stormwater fees by up to 50 percent for stormwater quality interventions and by 50 to 100 percent with interventions that address the quantity of stormwater absorbed.[49]
- **Charlottesville, Virginia:** In 2013, Charlottesville implemented a Water Resources Protection program to "comply with federal and state stormwater regulations, rehabilitate the city's aging stormwater system, address drainage and flooding programs, and pursue environmental stewardship."[50] A stormwater utility fee provides a funding source for the program and is levied according to the amount of impervious surface on each property.[51] Property owners can reduce their utility fees by either reducing impervious surfaces on site or operating and maintaining stormwater management facilities.[52]

Monitoring and Open Data Programs

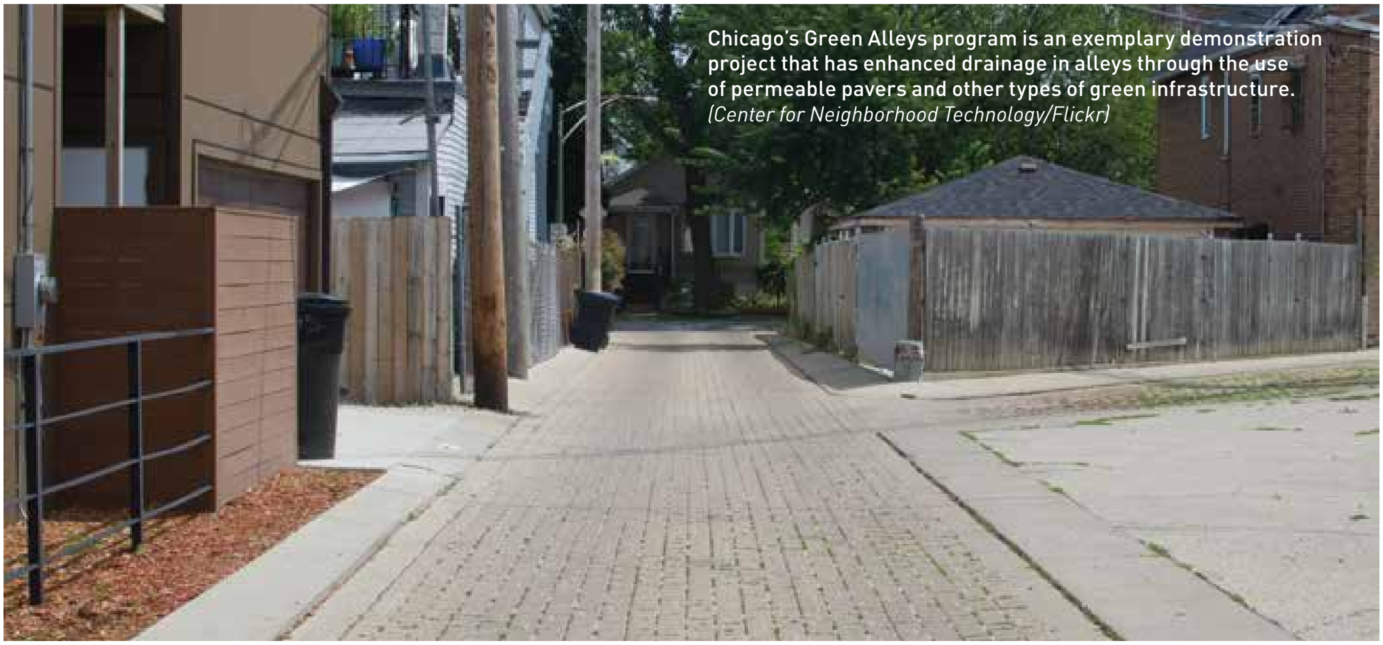
As more cities encourage data sharing and civic hacking initiatives to evaluate municipal services, green infrastructure is likely to become one of the areas analyzed. Green infrastructure is one of many topics that has been and can be studied through open data platforms. Accordingly, cities are likely to use open data as a strategy to measure the effectiveness of city investments and policies encouraging green infrastructure.

Cities using open data for analysis of green infrastructure programs include the following:

- **New York:** Open data was a key strategic initiative for the Bloomberg administration. Bloomberg initiated a citywide open data policy in 2012, which led to an Open Data Portal intended to share information on city services. The de Blasio administration has since built on these initial policies, including a 2015 initiative called Open Data for All, intended to make data sets more user-friendly and accessible.[53]

  Today, New York City's Open Data Portal features a data set from the New York City Department of Environmental Protection on the location of sites within the NYC Green

Underground sensors at the UI LABS bioswale in Chicago collect data on soil moisture and groundwater levels, while an aboveground weather station collects data on precipitation, wind, humidity, solar radiation, and temperature. *(© 2017 by UI LABS)*



Chicago's Green Alleys program is an exemplary demonstration project that has enhanced drainage in alleys through the use of permeable pavers and other types of green infrastructure. *(Center for Neighborhood Technology/Flickr)*

Infrastructure initiative, including green roofs and bioswales. Between September 2014 and late 2016, the data set was downloaded more than 1,350 times and viewed 2,400 times.[54]

- **Chicago:** Smart Green Infrastructure Monitoring, a project launched in late 2016 by Chicago-based consortium UI LABS, is using sensors and cloud computing to study the impact of green infrastructure projects. Sensors on a bioswale and a green street featuring permeable pavement and native plants are tracking soil moisture, humidity, precipitation, air pressure, and chemical absorption.[55] The project will ultimately include six green infrastructure sites, with sensors monitoring over 20,000 data streams.[56]

  Steve Fifita, the executive director of City Digital, explains, "The Smart Green Infrastructure Monitoring pilot combines our partners' technology into a new product—a platform that will help us make smarter decisions about stormwater management and water infrastructure maintenance, and ultimately reduce property damage caused by urban flooding."

  City officials are seeking to both understand where green infrastructure has been the most effective and explore different models for data transmission, analysis, and modeling. The data will then be available on the city's open data portal in 2017. A goal is to have data on different types of green infrastructure performance in different locations and data points about which investments have been the most effective.[57]

Demonstration Projects

Beyond implementing new regulations, taxes, and incentives, U.S. municipalities are also showing their commitment to green infrastructure by investing in demonstration stormwater management projects. Although the private sector is not responsible for these costs, the projects often involve prominent sites in the public realm that can set new expectations for stormwater management. Well-designed demonstration projects can also showcase the aesthetic and community-building opportunities that green infrastructure can bring. Notable demonstration projects include the following:

- **Green Alleys, Chicago:** With 1,900 miles of alleys, Chicago has more miles of alleyways than anywhere else in the world, totaling about 3,500 acres,[58] or the paved equivalent of five medium-sized airports.[59] Initially unpaved,[60] many of these public streetscapes lack a connection to the city's combined sewer and stormwater system, making flooding a frequent problem.[61]

  Chicago's Green Alley program, launched in 2006, promotes the incorporation of green infrastructure to avoid flooding, including permeable pavement, open-bottom catch basins, and high-albedo pavement.[62] The city describes the cost of the program as competitive with traditional alleyway design when the decreased long-term maintenance costs are taken into account.[63]
- **Greenstreets program, New York City:** PlaNYC, New York City's ambitious 30-year plan from 2007, committed the city to green infrastructure, including through tree plantings, stormwater management "bluebelts" (natural drainage corridors), and its Greenstreets program.[64] The subsequent *NYC Green Infrastructure Plan* provided further detail on implementation, seeking combined sewer overflow reductions and cleaner

waterways.[65] Although these long-term plans proposed a variety of new green infrastructure policies, Greenstreets was one of the smaller-scale investments that became particularly visible across the city.

Launched in 1996 by the New York City Department of Parks and Recreation as a citywide beautification project, the Greenstreets program was a popular initiative that also had tremendous potential for stormwater management.[66] The program, which is now funded by the city's Department of Environmental Protection, transforms paved medians and vacant traffic islands into green spaces designed to capture stormwater.[67]

PlaNYC committed to the creation of an additional 80 green streets each year, including a $15 million funding commitment for street design and implementation of the Greenstreets program between 2007 and 2017.[68] Researchers estimate that a 1,500-square-foot green street captures nearly 1,900 gallons of stormwater per year, with the total capturing more than 9.4 million gallons annually.[69]

Community Grant Programs and Design Competitions

Design and idea competitions are an increasingly popular means of engaging the design community in solving complex environmental and community problems. Rebuild by Design, the design competition to increase resilience in the New York metropolitan area post-Sandy, is arguably the highest-profile example, particularly given that the U.S. Department of Housing and Urban Development (HUD) released $920 million to fund the winning designs.[70] At a more local level, several cities have initiated competitions to encourage local designers and community groups to develop holistic design and land use concepts that address water management.

Numerous cities have used design and idea competitions to address critical stormwater needs and seek multidisciplinary approaches to project delivery. Community grant competitions also address a different need by encouraging local community groups to develop and initiate innovative stormwater projects. Both idea competitions aimed at the design community and grant competitions aimed at community groups raise local awareness and create opportunities to identify more efficient ways of designing and implementing green infrastructure.

- **Philadelphia, Pennsylvania:** Philadelphia's *Green City, Clean Waters* plan is one of the most ambitious in the country and uses many policy tools to advance the city's goals of reducing impervious surfaces. In June 2016, the city added an idea competition sponsored by the Philadelphia Water Department and the city's Office of the Chief Administrative Officer to the mix. The Green Stormwater Infrastructure Innovation Challenge sought to find ways to increase the effectiveness of the *Green City, Clean Waters* plan by reducing the cost of green stormwater infrastructure projects.[71] The competition sought a new strategy for assessing the subsurface conditions at potential green infrastructure sites, seeking new approaches for studying soil conditions, analyzing subsurface data, and mapping locations.[72]
- **Portland, Oregon:** Portland's Community Watershed Stewardship Program is a community-focused stormwater grant program that offers grants of up to $10,000 for civic groups.[73] Projects may address topics such as community gardens, pavement replacements, stream and park restorations, environmental education, youth leadership, and job training.[74] A recent winner of the Jimmy and Rosalynn Carter Foundation Campus Community Partnership Award, the program has been celebrated as an example of best practice in community engagement, university-city partnerships, and initiatives to advance social equity.[75] Washington, D.C., launched its own Riversmart Innovation Grant award in 2016, modeling the program after Portland's example.
- **Baltimore, Maryland:** Partnering with the Chesapeake Bay Trust and the U.S. EPA, the city of Baltimore encouraged its design community to think green through the Growing Green Design Competition in 2014. The competition focused on designs for vacant lot transformations following the guidelines in the city's *Green Pattern Book*. Seven winning projects won a total of approximately $300,000 to design and construct the concepts.[76] The winning proposals, submitted by community groups, nonprofits, and design firms, included pocket parks, a fruit recovery garden, native plant restoration, and an urban cut flower farm.[77]

Toolkits for Households

Stormwater policies focusing on larger developments, including commercial, mixed-use, and institutional projects, are often complemented with policies and tools aimed at homeowners. These programs typically offer a combination of grants, tax subsidies, and educational programming aimed at reducing impervious cover in residential properties. Cities with notable or innovative household stormwater management programs include the following:

- **Seattle, Washington:** Seattle seeks to manage 700 million gallons of annual runoff through green infrastructure by 2025, up from a current 100 million gallons.[78] Seattle's RainWise Program, which is run by Seattle Public Utilities, offers tools to encourage residents to manage stormwater at home by planting trees, composting, reducing the paved areas on their properties, and installing water management tools such as cisterns, rain gardens, and rock trenches.[79] RainWise resources include rebates for contractors, how-to booklets and videos, and lists of local suppliers.

Many cities have adopted policies encouraging homeowners to install rain barrels and other easy-to-assemble stormwater management techniques. *(© Barb Howe/Flickr)*

- **Washington, D.C.:** D.C.'s Department of Energy & Environment's RiverSmart Homes program provides incentives for on-site stormwater mitigation by homeowners. Homeowners are eligible to receive up to $2,400 worth of improvements, including incorporation of rain barrels, rain gardens, shade trees, or permeable pavers.[80]

  The department also runs the RiverSmart Schools program to promote schoolyard greening, including educational materials, and the RiverSmart Communities program, which provides incentives for apartments, condominiums, co-ops, locally owned businesses, and places of worship. Participants in RiverSmart Communities are eligible for rebates or for design/build LID projects in high-priority watersheds.
- **Norfolk, Virginia:** In addition to Norfolk's stormwater management planning and policies, a recent initiative sought to encourage homeowners to implement short-term, "tactical" projects to manage stormwater. The Retain Your Rain project, sponsored by the city of Norfolk, Downtown Norfolk Council, and the Rockefeller Foundation's 100 Resilient Cities program, encourages homeowners to address flooding by using rain barrels, planter boxes, and rain gardens. The workshop hosted homeowners and taught them how to build and install these facilities at a low cost, encouraging small-scale flood mitigation because "Norfolk's resilience depends on all of us."[81]

Conclusion

Considered together, this wide range of policies, requirements, and incentives offers cities a variety of ways to work with the private development community on the implementation of green infrastructure. Examples of real estate development projects that have responded to the requirements innovatively, exhibiting best practices in stormwater management while offering successful development outcomes, are provided in the Case Studies section of this report.

GLOSSARY

Aquifer
An underground surface or geological formation that holds or conducts groundwater.

Baffle box
A concrete or fiberglass structure used to removal pollutants from stormwater by slowing the flow velocity through sediment settling chambers. It also contains a screen that skims the top, capturing floating materials and trash.[1]

Basin
A landform or area draining to a point of interest. A stormwater basin collects water to reduce the risk of flooding.

Berm
A constructed area of compacted earth, designed to direct water or restrict flow.

Best management practices (BMPs)
Methods that have proven to be the most effective, practical means of preventing or reducing pollution from a source that needs to be controlled, such as stormwater runoff.[2] BMPs provide a basis for estimating the performance, costs, and economic impacts of achieving management quotas or policies.

Bioinfiltration
A stormwater management practice that uses vegetative land cover to filter and cleanse stormwater runoff into an aquifer.[3]

Bioretention
The process by which water is collected in a treatment area to advance infiltration and remove sediment.

Bioswale
A green infrastructure technique that captures stormwater runoff from a large impervious surface in a sloped vegetated area. Slopes usually use native species and allow the water to infiltrate into the ground slowly.[4]

Breathe Easy Home
Construction standards that use particular features to decrease risk factors that cause asthma and other respiratory illnesses.[5]

Carbon sequestration
The uptake of atmospheric carbon by plants and soils.

Cistern
A large storage facility, often built below ground, at ground level, or on rooftops, that stores stormwater.

Clean Water Act
An act passed by the U.S. Congress and enforced by the EPA that established the structure for regulating pollutant discharge into U.S. bodies of water. The act implements pollution control programs and water quality standards.

Combined sewer overflow (CSO)
During rain or snow events, drainage systems in a combined sewer system exceed the capacity of the collection system, discharging untreated sewage and stormwater into designated lakes, streams, and other bodies of water.[6]

Combined sewer system
Wastewater collection system that is designated to carry both sanitary sewage and stormwater in a single piping system to a treatment facility.[7]

Consent decree
A legal document used to formalize an agreement reached between the U.S. EPA and another party to correct or halt certain actions that violate the Clean Water Act or other EPA-initiated regulations; it also outlines financial penalties.[8]

Credit-trading scheme
A program policy that offers real estate developers the opportunity to purchase or sell credits for stormwater compliance in an open market. Those who own credits have met regulatory requirements for retaining stormwater.

Curb cut
A part of a street curb removed to connect the street level with another surface, often a stormwater management or green infrastructure mechanism that can absorb water in place of the traditional drainage system.

Daylighting
The process of uncovering a waterflow that was previously piped, covered, or buried to create an open channel, which improves aesthetics and allows biological activity and infiltration.

Detention pond/basin
A low-lying, porous, sometimes vegetated, area that is designed to hold water for a temporary amount of time after a weather event. Although effective at holding stormwater, detention basins do not traditionally offer water quality treatment.

Evapotranspiration
The process by which moisture is carried from the plant roots to tips for release into the atmosphere.[9]

Fee structure
A program that requires financial payments based on the amount of impervious surface on a site, encouraging investment in permeable surfaces or green infrastructure methods.

Filter medium
A material, often consisting of sand and organic matter, that removes pollutants through filtration.

Green area ratio
A score-based tool that encourages including multiple stormwater management techniques by awarding points for different mechanisms.

Green Globes
An online rating system and certification tool that also provides guidance on green building design, operations, and management. Three modules include new construction/significant renovations, commercial interiors, and existing buildings.[10]

Green infrastructure
Mechanisms that enable natural systems to capture stormwater runoff, enhance water and air quality, and create green space. Some examples are bioswales, green roofs, permeable pavement, rainwater harvesting, rain gardens, and tree pits.

Green roof
A green infrastructure technique that uses rooftop vegetative plantings to absorb rainwater and heat, in addition to improving air quality and decreasing energy needs for the building below.

Groundwater
Water flowing beneath the earth's surface, between rock, sand, and soil. Groundwater is the source of water for wells and springs.

Impervious surface
A hard surface that prevents or impedes the flow of water to the soil mantle, such as concrete.[11]

Infiltration
The process by which water percolates from the land's surface into the ground.

Leadership in Energy and Environmental Design (LEED)
A rating system administered by the U.S. Green Building Council that provides the development and building industry with quantitative standards for sustainable design. The system takes into consideration five key areas: sustainable site development, water savings, energy efficiency, material selection, and indoor environmental quality.[12]

Low-impact development (LID)
A land planning and design approach that emphasizes mimicking natural system processes to store, infiltrate, retain, and detain precipitation and rainfall as close to its source as possible.

Makeup
The amount of water necessary to replenish losses caused by evaporation, leaks, or discharge in a cooling tower system.[13]

Municipal Separate Storm Sewer System (MS4) Permit
A permit required to develop stormwater management programs to prevent harmful contamination to the watershed, required for publicly owned conveyance that discharges into federal or state waters.

National Pollutant Discharge Elimination System (NPDES)
Provision of the Clean Water Act that forbids pollutant discharge into U.S. water systems by regulating point sources.

Natural drainage system
A quality of many green infrastructure mechanisms; systems that mimic the natural flow of water to create attractive open spaces while channeling stormwater.

Nonpoint-source pollution
Pollution that occurs when water runs over land, development, or through the ground and picks up pollutants that are ultimately carried into lakes, rivers, coastal waters, or groundwater.

Nonpotable water
Water that is not of drinking quality but that still may be used for other purposes, such as toilet flushing and clothes washing.

On-site mitigation requirements
Policies that require a development to capture a specific minimum volume of water, usually measured by inches of rain or a percentage of type of rain event, to deter stormwater from entering drainage or sewer systems.

Peak runoff rate
Maximum speed or flow rate of water during a storm event.

Percolation
Process by which water passes through a filter.

Permeable
Allowing liquid or gas to filter through.

Permeable pavement or pavers
Engineered porous paver, concrete, or asphalt that allows runoff to filter through strata and into a drainage system or directly into the aquifer.

Potable water
Water that is of drinking quality.

Rain barrel
A container or storage device that collects water, often from a roof.

Rain garden
A small vegetated area designed to be located where stormwater naturally flows, which captures and infiltrates runoff into the ground. It is a commonly used green infrastructure technique in landscape and streetscape designs.[14]

Rainwater harvesting
A green infrastructure technique that collects and stores rainwater for future use.

Retention pond/basin
A low-lying, sometimes concrete, area that is designed to hold water from a weather event for an indefinite amount of time. Retention basins hold harvested water or are connected to the sewer system for slow release.

Retrofit
A best management practice installed into a previously developed area to improve stormwater quality or reduce stormwater quantity when compared to current conditions.

Riparian
Related to a stream, river, or bank of a waterway.

SITES
A rating system administered by Green Business Certification Inc. that measures performance and value of sustainable landscaping. SITES certification projects include developments with or without buildings and range from parks to corporate campuses, streetscape, and residential homes.[15]

Stormwater management
Structural and nonstructural mechanisms used to control and prevent stormwater runoff over impervious surfaces into sewer systems.

Stormwater runoff
Portion of precipitation that flows over impervious surfaces and carries pollutants in quantities unmanageable by sewer and natural water systems.

Stormwater vault
A type of detention basin, this subsurface facility commonly made of concrete, steel, or fiberglass, manages stormwater in an urban setting because of its ability to capture large quantities of water.

Total maximum daily load (TMDL)
A regulatory term used within the U.S. Clean Water Act that describes the calculated maximum amount of a pollutant that a body of water can assume while maintaining designated water quality standards.

Tree pit
A commonly used green infrastructure technique that collects stormwater runoff, particularly in urbanized areas where space is limited, and diverts stormwater into the sewer system or subsoil.

Urbanization
An increase in human concentrations within dense urban areas and outer suburban periphery, which leads to the replacement of natural landscape with impervious surfaces.[16]

Watershed
An area of land, which is often regional, that drains to a single place, such as a river, stream, bay, or ocean.

Wetland
An area of land saturated by ground or surface water for all or part of the year. Wetland habitats typically support both aquatic and terrestrial species.

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APPENDIX

STORMWATER POLICY STRATEGIES: EXAMPLES FROM SIX CITIES (ANNOTATED)

STRATEGIES	**New York** Capture rainfall on 10% of impervious surfaces by 2030	**Chicago** Capture up to 250 million gallons/ year by 2020	**Philadelphia** Capture rainfall on 34% of impervious surfaces by 2035	**Seattle** Capture up to 700 million gallons/ year by 2025	**Baltimore** Capture rainfall on 20% of impervious surfaces by 2018	**Washington, D.C.** Capture rainfall on 75% of all surfaces by 2035
On-site water retention requirements	• [1]	• [2]	• [3]	• [4]	• [5]	• [6]
Credit-trading schemes						• [7]
Green area ratios				• [8]		• [9]
Fee structures	• [10]	• [11]	• [12]	• [13]	• [14]	• [15]
Development incentives	• [16]	• [17]	• [18]	• [19]		• [20]
Community grant programs	• [21]		• [22]	• [23]	• [24]	• [25]
Open data and monitoring programs	• [26]	• [27]	• [28]		• [29]	• [30]
Design and idea competitions	• [31]		• [32]		• [33]	• [34]
Household toolkits	• [35]	• [36]	• [37]	• [38]	• [39]	• [40]
Demonstration projects	• [41]		• [42]	• [43]	• [44]	
Greening vacant land	• [45]		• [46]		• [47]	
CONTEXT						
EPA consent decree	• [48]	• [49]				• [50]
EPA settlement agreement	• [51]			• [52]	• [53]	
EPA partnership agreement			• [54]		• [55]	• [56]
Average rainfall	50" average rainfall/year[57]	37" average rainfall/year[58]	43" average rainfall/year[59]	39" average rainfall/year[60]	42" average rainfall/year[61]	40" average rainfall/year[62]
Public commitment	$2.4 billion[63]	$50 million[64]	$1.6 billion[65]	$57.7 million[66]	$77.5 million[67]	$2.6 billion[68]
Municipal plan	*2010 New York City Green Infrastructure Plan*	*2014 Chicago Green Stormwater Infrastructure Strategy*	*2009 Green City, Clean Waters: A Long Term Control Plan Update*	*2015 Seattle Green Stormwater Infrastructure, Implementation Strategy*	*2013 Baltimore City Watershed Implementation Plan*	*2012 Sustainable DC Plan*

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On the back cover: Green infrastructure can be used to manage water in arid climates, as pictured here at San Jacinto Plaza in El Paso, Texas. *(ULI)*

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