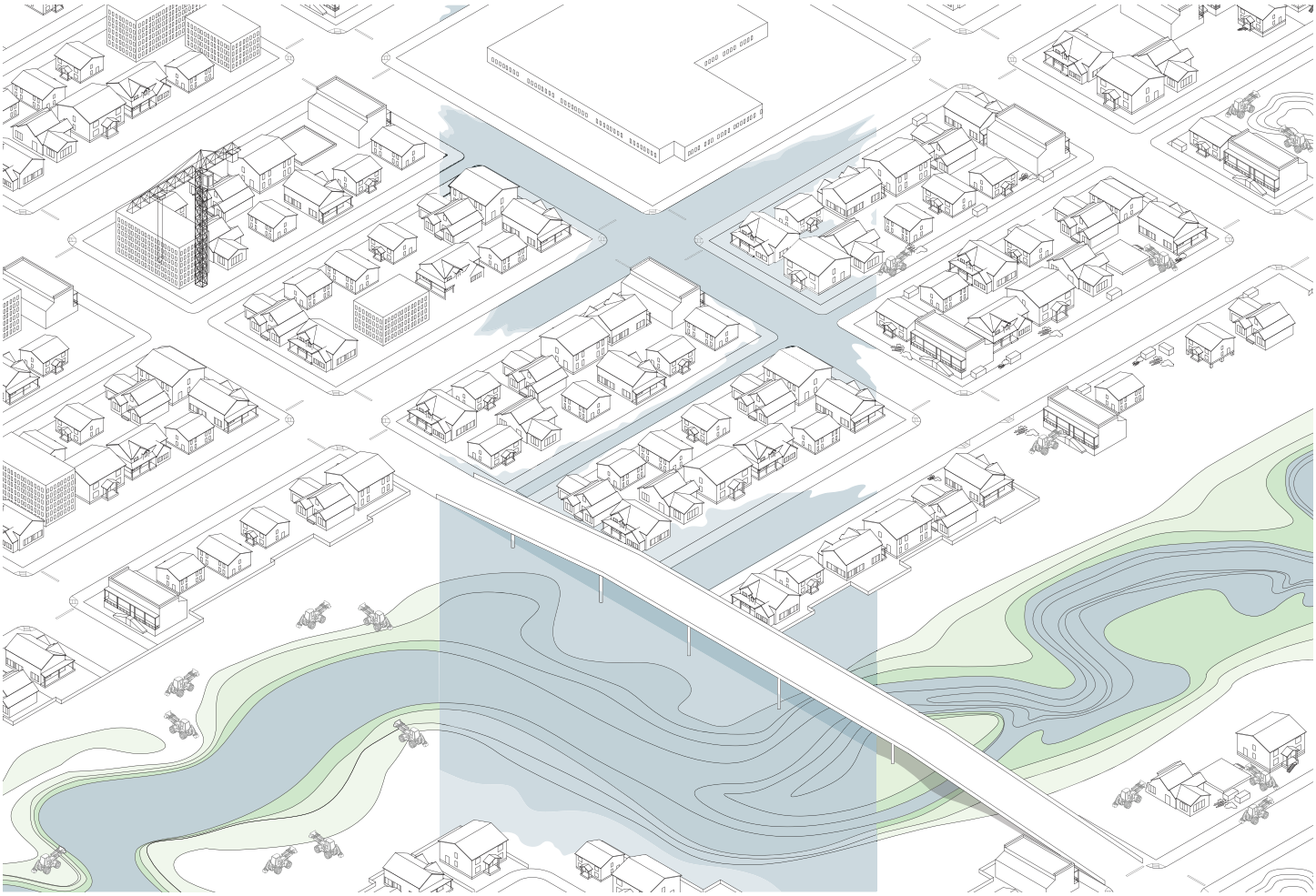
GREATER HOUSTON FLOOD MITIGATION CONSORTIUM

THE FLOOD NEXT TIME
WHAT WE CAN DO NOW



KEEP PEOPLE HIGH AND DRY REMOVE PEOPLE FROM HARM'S WAY RETURN PEOPLE TO NORMALCY

Greater Houston Flood Mitigation Consortium

May 2019

GREATER HOUSTON
FLOOD MITIGATION CONSORTIUM

Since the devastating blow of Hurricane Harvey in the greater Houston region, local jurisdictions have taken a hard look at their flood preparedness, from regulations to structural projects, and regional level projects to site specific solutions. However, significant vulnerabilities remain.

The Greater Houston Flood Mitigation Consortium convened after Hurricane Harvey to advance greater Houston's resiliency and to ensure that all communities benefit from flood mitigation efforts. This independent collaborative of expert researchers and community advocates is committed to compiling, analyzing and sharing a rich array of data about flooding risk and mitigation opportunities; and translating this data into information to engage the public and help guide and support decision-makers at all levels as they direct the Houston region's redevelopment. Consortium members are affiliated with local, regional and statewide universities, research centers and community organizations with deep expertise in hydrology, climate science, engineering, coastal resiliency, energy, community development and urban planning. Houston-based Huitt-Zollars, a planning, engineering and architectural firm, manages the consortium.

The consortium is focusing its work on Harris County's 22 watersheds, several of which extend to surrounding counties. The consortium will complete its work in mid 2019.

Members

Rice University
Kinder Institute for Urban Research

Rice University
SSPEED Center

Texas A&M University
College of Architecture

Texas A&M University-Corpus Christi
Harte Research Institute for Gulf of Mexico Studies

Texas A&M University-Galveston
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Texas Southern University
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University of Houston Hines College of Architecture
Community Design Resource Center

The University of Texas at Austin

Energy Institute, Webber Energy Group

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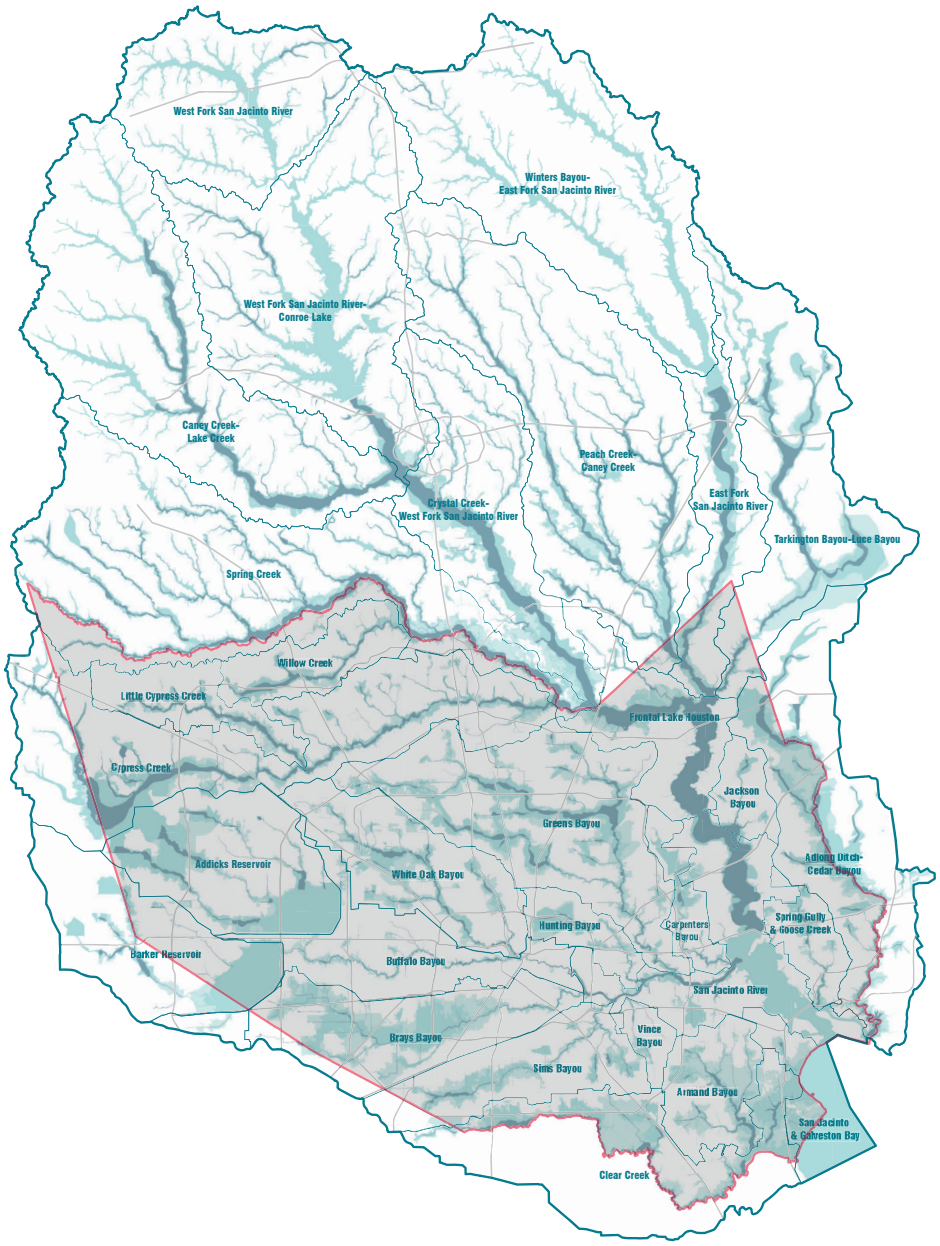
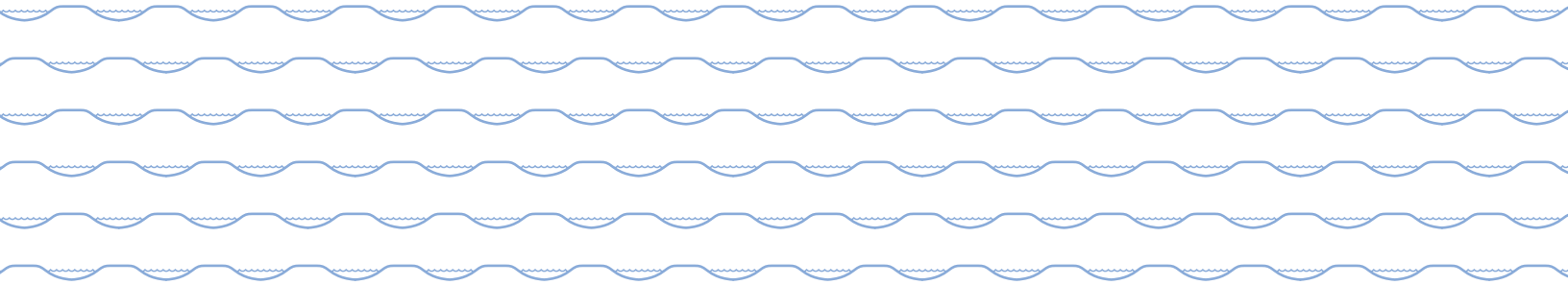
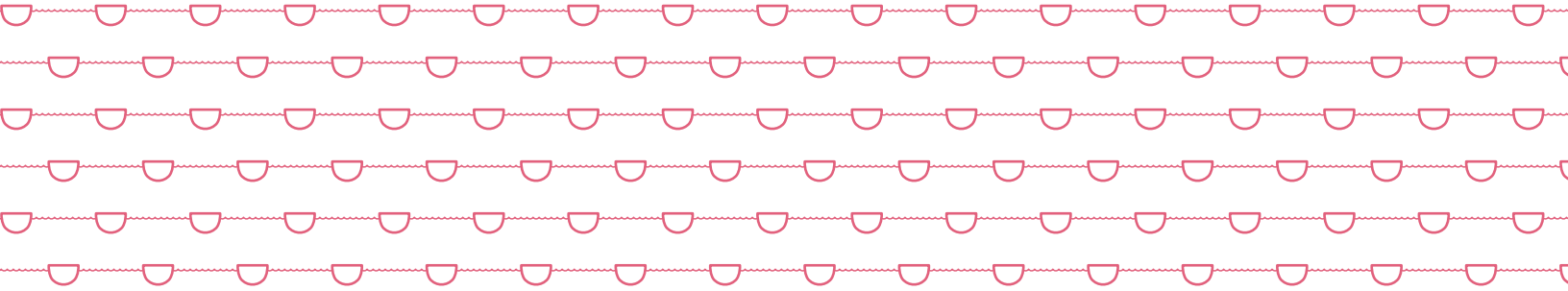
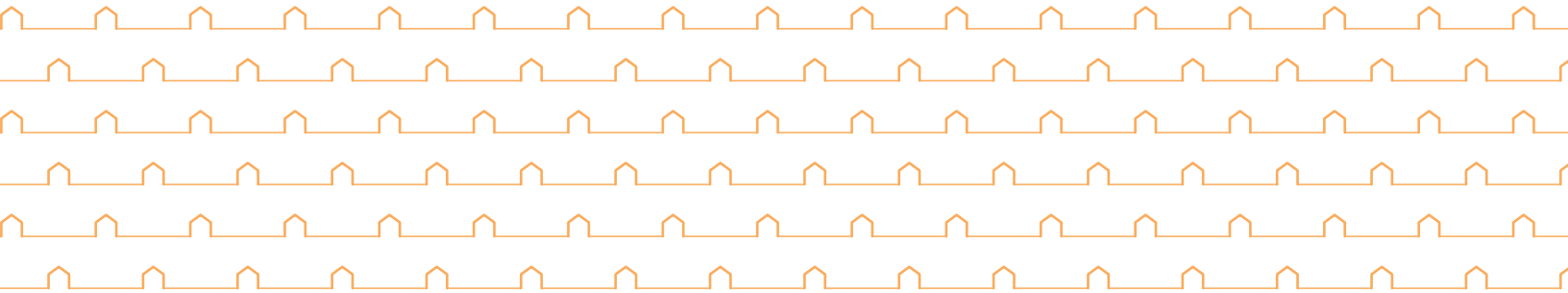
SCOPE OF STUDY AREA









1 KEEP PEOPLE HIGH AND DRY

Resiliency means that when a storm comes, as few homes and businesses as possible are flooded. However, we will never eliminate all flooding.

What can we do now, before the storm, to reduce the extent of flooding and locate homes and businesses where they will not flood?

2 REMOVE PEOPLE FROM HARM'S WAY

Resiliency means that when a storm comes, people who are affected by flooding are safe and their critical belongings are protected. Simply moving someone to safety does not mean their lives are free from loss and disruption.

What can we do now, before the storm, to minimize harm?

3 RETURN PEOPLE TO NORMALCY

Resiliency means that when a storm occurs and resident's homes or businesses have been flooded, they are able to bring their life back to normal - physically, financially, and emotionally - as soon as possible.

What can we do now, before the storm, to prepare a smooth and comprehensive recovery?

Introduction

In its work so far, including "Greater Houston Strategies for Flood Mitigation" and a number of specific research reports, the Greater Houston Flood Mitigation Consortium has gathered information on many aspects of flooding.

We have also reached some key conclusions, based on the professional expertise of our members, our research on Houston, and our investigations of best practices across the world.

We believe that our region needs to view flooding as a human problem. A piece of land being underwater is not a problem; a home, business or vehicle being underwater is. The measure of success in dealing with flooding is in people's lives – their safety, their well-being, their financial stability – not in property.

We believe that flooding exacerbates all of the problems Houston faces. Households that are struggling financially get hit even harder when they are flooded. Inadequate transportation options are even more problematic when people lose their cars. Affordable housing supply contracts, and demand increases, after every flood. Floods spread pollution and increase industrial emissions. Floods worsen existing chronic health issues.

We believe that flooding hits the most vulnerable the hardest. A family that is struggling to make ends meet before the flood, with no savings, with a job that is interrupted after a flood, with a limited social safety net, will have the hardest time recovering.

We believe that rainfall flooding is one of the major issues the Houston region must address. It is not our only resiliency challenge, but it is a critical one. Floods are a regular occurrence here, and the impacts on residents as well as business are severe and long-lasting. Climate change will only make the problem worse.

We believe that flooding cannot be "solved". We as a region should do everything we can to reduce the risk of homes and businesses flooding. We have yet to see a plan, at any price tag, that would ensure that no home or business will flood in the 1% AEP (100 year) storm we have used as a design standard. Even if that were possible there would still be a nearly 1% chance every year of a storm larger than that. For the foreseeable future, homes and business will flood.

We believe that response and recovery are as critical. We need to do everything we can as a region to ensure that when somebody's home floods their life can return to normal – with a secure roof over their heads and a stable household budget – as soon as possible.

We believe that response and recovery needs to be planned before the storm, not after. In order to return people to their livelihood, the systems required for addressing disaster need to be tested, and in place, before the rain starts falling.

We believe that we can address these issues. This region has the expertise, the experience, and the resources to significantly reduce the impact of flooding on Houstonians. We have already made significant progress; we have many good ongoing efforts to build on; and we have many good ideas. In some areas, we are a national model. We know what we need to do; what we need to do it is coordination, communication, resources, and political will.

We believe that it is all our collective responsibility to address flooding. Government is essential – this is not a problem that can be dealt with household by household. Major public investment, regulation and coordination is required. Every Houstonian can play a role by making sure they are as prepared as they can be for the next storm, and by advocating elected officials for continued focus on flooding.

About This Report

This report is a set of strategies compiled by researchers of the Greater Houston Flood Mitigation Consortium, based on science and data, on how the region can better deal with rainfall flooding. The purpose of this report is to provide the region with actionable steps toward better preparing for future floods. This report explores what we can do before the next storm to keep people high and dry, remove people from harm's way, and to return people to normalcy. It provides examples of various possible flood mitigation projects and programs and how they can be implemented.

This report is not a resilience plan. It addresses only rainfall flooding, one of many shocks and stressors this region faces.

This report is not comprehensive. We do not claim to have a complete list of ideas. Not all of these programs need to be adopted to help us prepare, nor are we suggesting that the outlines of possible projects in this report are necessarily the best way to tackle each issue.

This report presents ideas, not recommendations. The ideas here need to be investigated for feasibility, better defined by agencies, reviewed by stakeholders, and shaped by public discussion.

No one agency can implement these ideas. In fact, many require collaboration between multiple agencies, and some require legislation.

We have organized the ideas by how they help – some reduce the magnitude of flooding, some get people out of harm's way during a flood, and some help people recover. This is not a chronological list. All these things are happening at once; even as a flood happens, people are still recovering from the last flood, and projects are underway that will mitigate the next one. Every one of the response and recovery ideas in the report are things that can be implemented now, in advance of the disaster.

These ideas serve as a starting point to considering a wide range of concrete projects and programs that can feasibly be implemented in the Houston region. Almost all of them warrant a closer study and detailed consideration. While some ideas in this report stand alone, others will be most effective if implemented in conjunction with others. Each suggested idea will move us in the direction of mitigating future flood damages.

As the consortium winds down, we hope that Report 2 will serve as a first step towards seeing greater flood resiliency for the Houston region. The ideas highlighted can only be implemented if the political backing, and public demand exists. Every stakeholder of this watershed/region/city must take ownership of the issue. We hope that this document is a practical/serviceable contribution to encourage further exploration, collaboration and implementation.

Fundamentals: Public Education

Providing residents with equitable access to information can empower them with tools and understanding to make decisions that can reduce risks faced by their families and communities. This requires using a variety of media for communication and translations to break language barriers.

An engaged public and good data are essential to all aspects of flood resilience.

Providing residents with equitable access to information can empower them with tools and understanding to make decisions that can reduce risks faced by their families and communities. This requires using a variety of media for communication and translations to break language barriers.

Informed and prepared residents create a stronger and more resilient city, but across the Houston region, access to information, particularly with regard to hazards and emergencies, varies greatly.

One of the primary barriers to access to information is the method by which households receive news, warnings, and information. These methods include the internet, smart phones, texts, telephones, news broadcasts, radio, or by word of mouth. Many households are connected and informed about where to get information, but other households are not. Expanding the type of tools to inform households of their risks before a natural or man made disaster can help to protect lives and property.

Language barriers are also important to overcome. Accessibility to information is not enough; people need to be able to understand, navigate, and engage with the information. Taking the extra step to ensure the information and required actions are understood is important. It may be costly but will eventually save on costs of recovering from preventable impacts of flooding on their lives.

Harris County is a diverse and unique place to live with many different cultures and lifestyles; it is easy to forget about the different communication styles and abilities of residents. In the City of Houston alone there are over 145 languages spoken. In Harris County, 20% of the total population of residents aged 25 years or older do not have a high school diploma. Lastly, 9% of residents in Harris County live with a disability, which the Census Bureau defines a disability as a long-lasting sensory, physical, mental, or emotional condition or conditions that make it difficult for a person to do functional or participatory activities such as seeing, hearing, walking, climbing stairs, learning, remembering, concentrating, dressing, bathing, going outside the home, or working at a job. So it is essential that information is presented to residents in familiar languages and at a comprehensive level that is easy to understand regardless of educational background and ability level.

As we plan for future flooding, providing residents with equitable access to information can empower them with tools and understanding to make decisions that can reduce risks faced by their families and communities. This requires using a variety of media for communication and translations to break language barriers.

Providing the public with information on ways to get help during a disaster can help them take proactive steps to removing themselves from a potentially harmful situation. It is important to provide this information using a variety of methods to make sure everyone has access to it. These methods include internet, smart phones, texts, telephones, news broadcasts, radio, or by word of mouth. Many households are connected and informed about where to get information, other households are not. Expanding the type of tools to inform households of their risks before a natural or man-made disaster can help to protect lives and property.

After a disaster, public education can ensure that people are aware of different programs available to them, know what to do, and get the help they need quickly.

Public education should involve a range of tools:

- Increase the awareness and accessibility of flood risk information, in multiple formats and languages -- for new homeowners, renters, and existing homeowners.
- Increase awareness and use of flood hazard notification systems, create new systems to inform households, in various languages.
- Increase use of 3-1-1 to report drainage problems and other potential risks to flood mitigation, and provide 3-1-1 to all residents, regardless of jurisdiction.
- Inform people about the Community Emergency Response Team (CERT) volunteers and trained

professionals in their neighborhoods.

- Provide guidance on the use of social media for rescue efforts.
- Increase awareness of the National Flood Insurance Program to increase the number of families protected.
- Increase the accessibility of recovery resources, including rebuilding.
- Set up public schools as a place to disseminate education materials and/or deploy case managers and emergency financial assistance. See Schools as "Lily Pads" on p. 59 and Case Managers on p. 91 for complementary ideas.

Websites such as FEMA flood maps (http://www.harriscountyfemt.org/) can be great interactive and informational tools for the public, but for those who do not have online access, other options should be made available. For example, public awareness campaigns through TV commercials, billboards, and flyers (Refer to Information Flyers on p. 11 for more information) with utility bills. Additionally, K-12 curricula could include disaster management options as well as teach students about flood risks.

Fundamentals: Data Collection & Repository

A data repository would provide access to flood-related data that already exists and highlight data that needs to be collected in this region.

A data repository would provide access to flood-related data that already exists and highlight data that needs to be collected in this region.

A data repository could consolidate available flood-related data into a single portal, providing links to the data or to an agency's website that hosts the data. Where warranted and to the extent that resources allow, the portal could become a platform that depicts the data spatially. Researchers, agencies, and the public could use this data to conduct their own analysis and evaluations to better inform projects, programs, and services. Some data listed here can be collected prior to the next disaster and will help rescuers, such as the location of vulnerable and hazardous buildings, however, others would require connecting to social media or other live data collecting websites.

Ideally, as much data as possible would be publicly available; however, some data would be too sensitive and may only be available to a predetermined set of institutions and agencies for research and analysis.

Each agency that collects and provides data in the region would maintain agreements with such a repository for how data would be updated and maintained, how soon after a storm it would become available, and if it is not available, and whether the data may be accessed by the public or limited to certain agencies. These agreements will take time to draft and execute, and post-Harvey experience proves that agencies, service providers, researchers, and residents cannot wait until a storm's aftermath to get them in place. Additionally, while some of this data already exists, other data needs to be collected and made available.

Data sharing and privacy agreements would need to be written and signed by all participants.

Establishing and maintaining such a repository would require an organizational lead, dedicated personnel and other resources. This could be overseen by county or city staff, a collaboration between the two, or a local academic partner.

Relevant datasets might include:

- Past storm inundation levels. Simple low cost sensors installed around the city, not just around bayous, could measure actual inundation levels. Houston Solutions Lab is currently working on a pilot project.
- Past storm damage level estimates or actual counts.
- High water marks on bayous.
- Housing in high/low flood risk areas.
- Risk maps.
- Structural projects, including all flood mitigation projects, built, in-progress, and planned.
- Building slab elevations, collected from elevation certificates or field measurements, to augment LIDAR topographic information.
- Flood warning systems descriptive data -- when and how often they were deployed.
- Underpass shutdowns - where and when they were deployed.
- Evacuations - when and where they were deployed.
- Emergency management descriptive data
- When, where, and how often they were deployed.
- Where CERT teams and leaders are located.
- Locations of hazardous and vulnerable facilities, e.g. hospitals, senior living, etc.
- Social media websites and other avenues for obtaining real-time information on where open shelters are open and rescue efforts are needed.
- Street closures and damages. People may not be able to travel on their normal routes for their daily routines and transportation agencies can reroute to serve neighborhoods and jobs based on impassable streets.
- Public and private services that are open, including grocery stores, pharmacies. This would help the city and non-profits send food into areas with shortages.
- Buyout data. Include who has expressed an interest.
- Insurance data on damages.

- Door-to-door damage assessments done by local jurisdictions but collected in a standardized way so data does not vary across jurisdiction boundaries.

The increased role of social media and crowd-sourcing during crisis and disaster events presents an opportunity to leverage these communication technology tools, not only to disseminate information, but to systematically analyze trends and "nowcast" the spatial and temporal impact of crisis and disaster events.

Social media and crowd-sourced sites are incredibly active during crisis and disaster events. Residents, first responders, and government officials often turn to these sites to share information and make calls for assistance. These sites are increasingly an asset to public officials and residents during and after a disaster. However, the information disseminated on these sites could be more systematically leveraged to provide real-time information and new insight into the spatial and temporal impact of a disaster.

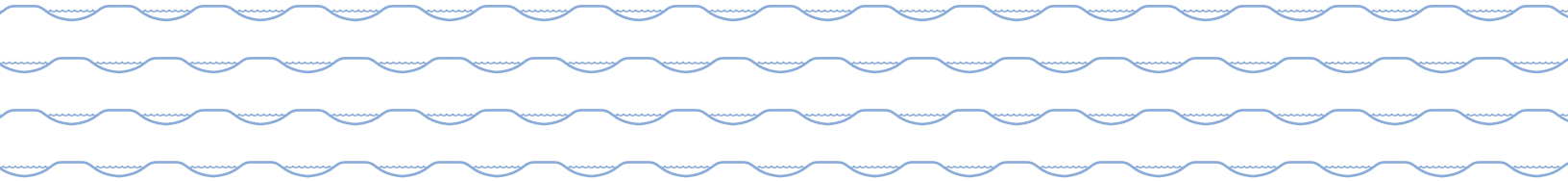
The process is known as crisis informatics, which is simply programming and computer science tools in combination with traditional insight of disasters to "nowcast" the spatial and temporal impact of disasters. The premise of this field is individuals using communication technology and their personal information in innovative ways during a disaster. Individuals respond to social media and crowd-sourced sites differently than they would otherwise; they share information, report on advancements or lack of advancements, signal distress, and in some cases check in as "safe." This provides a unique opportunity to predict the geographical spread of a disaster as it is happening, understand the unique needs of communities as they signal distress, as well as how residents are responding and moving. This is critical information to improve the resiliency of the region.

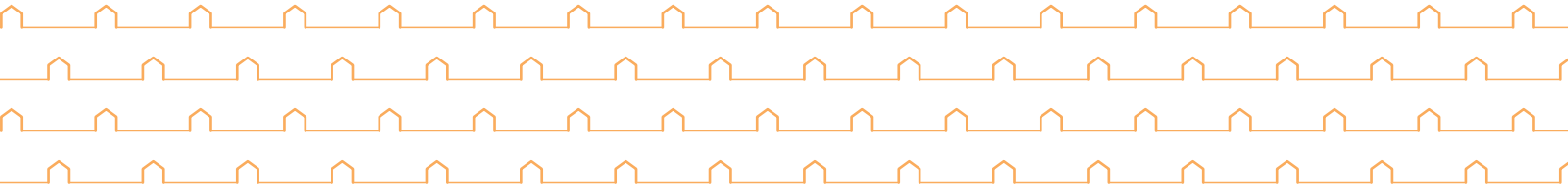
Traditional data sources, such as FEMA damage estimates, can miss key information. Other damage assessments and needs assessments often require substantial human effort and are susceptible to human error and bias. The ubiquity of mobile devices and the internet creates the opportunity for individuals not traditionally part of a conversation to have an equal footing in disseminating information. For example, in the aftermath of Hurricane Harvey, the east side of Houston along Greens Bayou was largely not accounted for in initial damage estimates, despite receiving significant damage. However, social media and crowd-sourced site activity showed the area received substantial damage. Integrating crisis informatics will not replace traditional damage and need assessments, but rather, they can substantively supplement current response and recovery framework.

By developing new protocols to leverage this live information, response and recovery systems can be improved by more accurately assessing damage and the geographical spread of the disaster. While a single social media user is not representative of a community at large, the collection of data from several users is generalizable to a community – throughout the world, Twitter and other social media sites, have been empirically used to evaluate the spatial and temporal aspects of disaster and emergency situations, including terrorist attacks, earthquakes, and flooding events. Indeed, crisis informatics does not assess individuals but larger trends in organic user content during disasters.

This data can be leveraged through a strategic partnership with private communication technology firms. These firms already house the data and are increasingly trying to find ways to use it for a positive impact. At the simplest level, these private firms could package specific data and information during and after a disaster and securely deliver it to government officials in the region.

In a slightly more complicated scenario, the partnership could be broadened to serve metropolitan regions by having regional partnerships with private communication technology firms, research institutes, and municipal governments. In this case, the private technology firms could deliver raw data to research institutes or a collaborative of research groups in the region who then secure and house the data to provide specific analysis for municipal partners. In this partnership, municipal partners would approach the research group with community-specific questions to best allocate resources. This scenario is more favorable than the former, since it provides municipal partners specific information they are seeking, and saves private firms from having to build the infrastructure to support thousands of municipal governments at the national level.





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Resiliency means that when a storm comes, as few homes and businesses as possible are flooded. However, we will never eliminate all flooding.

What can we do now, before the storm, to reduce the extent of flooding and locate homes and businesses where they will not flood?

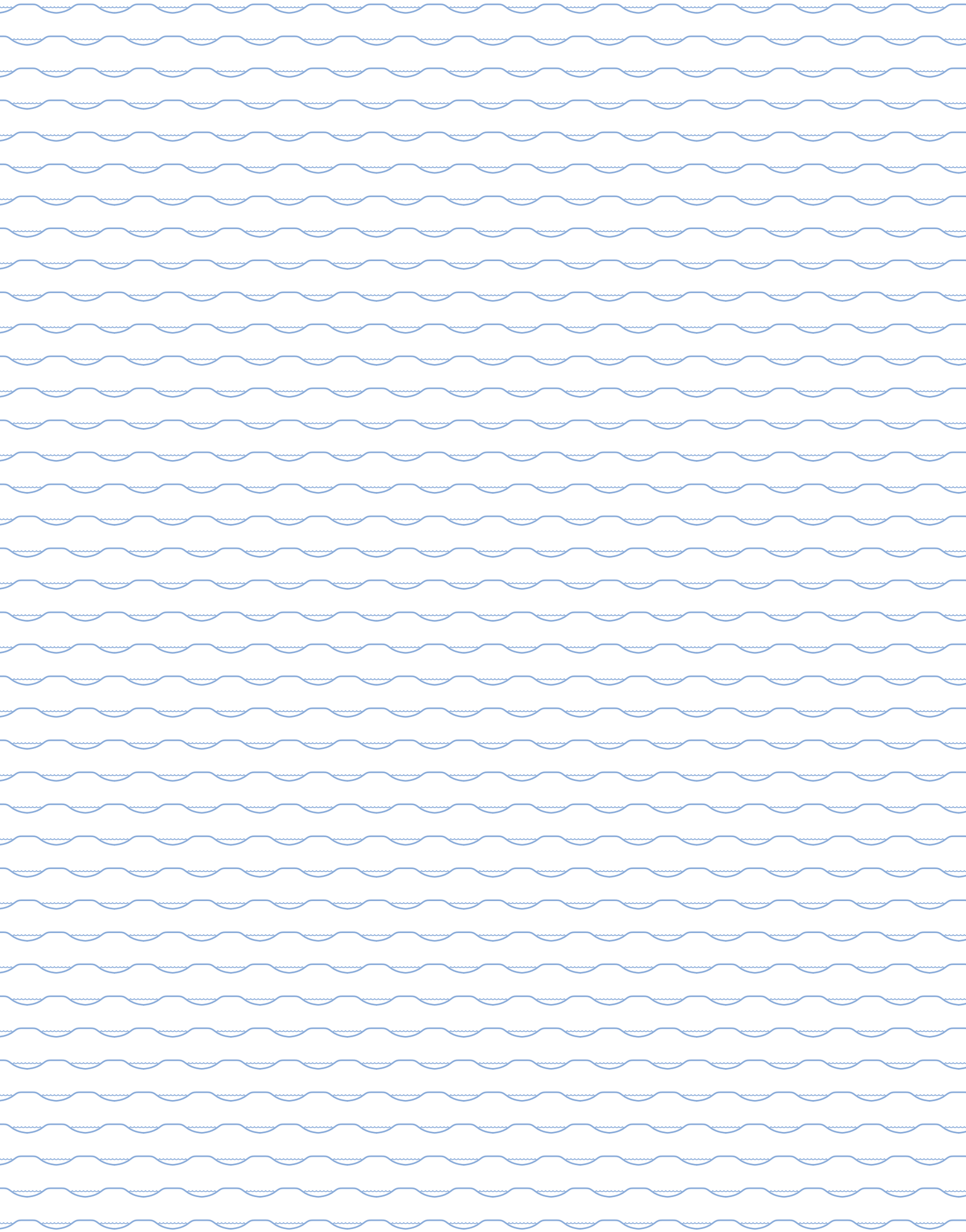
Informed Public

Housing

Infrastructure

Regulations

Other Ideas



Informed Region

Everyone makes decisions that impact our region's vulnerability to flooding, ranging from a resident deciding where to rent an apartment, to elected officials who prioritize how public funds are spent, to voters who put those officials in office. All of these decisions must be informed by a better understanding of how to maximize our chances of remaining high and dry during a flood.

1.1

Probabilistic Risk Maps

Today's flood maps provide limited information on flood risk. Current probabilistic mapping technology can provide information on flooding caused or amplified by local conditions and infrastructure, and show flood depths. The Houston region could benefit from developing such probabilistic risk maps.

Contributors

Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Related Ideas

Fundamentals: Public Education on p. x

Further Reading

Boyd, Jade. "Decade of data shows FEMA flood maps missed 3-in-4 claims." Sept. 11, 2017. Rice University News & Media.

Nance, Earthea. 2009. Responding to Risk: The Making of Hazard Mitigation Strategy in Post-Katrina New Orleans, Journal of Contemporary Water Research and Education 141:21-30.

United Nations Office for Disaster Risk Reduction. 2015. "Understanding Risk: The Evolution of Disaster Risk

What is Disaster Risk?

In terms of evaluating natural disasters, risk is comprised of four factors. Probability is the chance that a disaster will occur. Frequency indicates how often a disaster will occur. Exposure means the number of people and value of property in harm's way. Consequences are the quantifiable impacts of a disaster in terms of the expected lives lost and dollar damages.

Extensive risk is associated with high frequency disasters. This risk is generally understood because of the regularity of exposure. Intensive risk, on the other hand, is associated with high consequence disasters that are infrequent. This risk is often imperceptible because it results from cumulative increasing vulnerability over time. Areas subject to intensive risk experience the most disaster-related deaths. Residual risk—a subtype of intensive risk—is the risk that remains after mitigation measures are in place, such as in areas protected by dams and levees. The tendency to intensify development in such areas only increases residual risk over time. Risk reduction strategies must address all types of risk.

Indicators of Risk

A recent study of Houston area maps found that existing maps were outdated and FEMA flood zones no longer accurately indicated flood risk, and that the biggest challenge was the risk faced by low-lying older homes served by older and under-sized local drainage systems. When Houston's flood maps were updated in 1985 and 2007, the revisions mostly documented flood risk for newly built structures. In the 1999-2009 period, 75% of Houston's flood damage claims occurred outside of the flood zone. More than half of the homes that flooded during Hurricane Harvey were located outside the floodplain. Taken together, these findings show that the current indicators of flood risk are not providing meaningful information about the actual flood risk in Greater Houston.

Risk Assessment

The flood risks in the Greater Houston region are currently communicated through traditional FEMA floodplain mapping, based on historical data. The emerging state-of-the-art approach to flood risk mapping involves a probabilistic approach instead of a deterministic one. This approach takes advantage of advanced hydrodynamic, meteorological, geotechnical, and other models to estimate the probability and impacts of all possible flood scenarios and downstream conditions. These models are mapped as a more realistic gradient of risk rather than the misleading sharp line drawn in traditional floodplain maps that show only the 1% AEP (100 year) or 0.2% AEP (500 year) flood events. Additionally, probabilistic risk maps can account for rainfall flood risk, as well as risk from issues such as over land sheet flow, high water caused by poor drainage systems, and failure or breach of local and regional infrastructure.

A formal assessment of risk is typically undertaken to achieve one or more of the following objectives: 1) to raise awareness; 2) to inform policy decisions; 3) to manage financial investments; and 4) to inform mitigation and preparedness actions. The most common product

for communicating the results of a risk assessment is a risk map. Risk maps create shared criteria for public and private decision making.

The Changing Risk Assessment Paradigm

As computational capabilities have expanded, the sophistication of risk modeling and risk mapping have grown. Consequently, ballpark estimates of risk based on exposure to past disasters (e.g. FEMA's deterministic mapping of 1% AEP (100 year) or 0.2% AEP (500 year) floodplains) can now be combined with mathematical predictions of the hazard and failure analysis of infrastructure (e.g. probabilistic modeling of risk including: probability, frequency, exposure, and consequence) to generate composite risk estimates that account for multiple probabilities. Figures 1 and 2 graphically presents this important difference between deterministic modeling and probabilistic modeling.

The Greater Houston region could benefit from a large-scale effort to model probabilistic flood risk across jurisdictional boundaries. The key difference is that the old "history-based" approach estimated the impacts from a single design storm (e.g., the 1% AEP (100 year) storm), while the modern "prediction-based" approach estimates the risk from numerous possible storms and scenarios.

This could be a state and/or county funded effort led by neighborhoods or smaller cities similar to the 3D Interactive Floodzone Mapping used by Charlotte-Mecklenburg County in North Carolina, can allow the government, communities, and individuals to understand their risk and plan better.

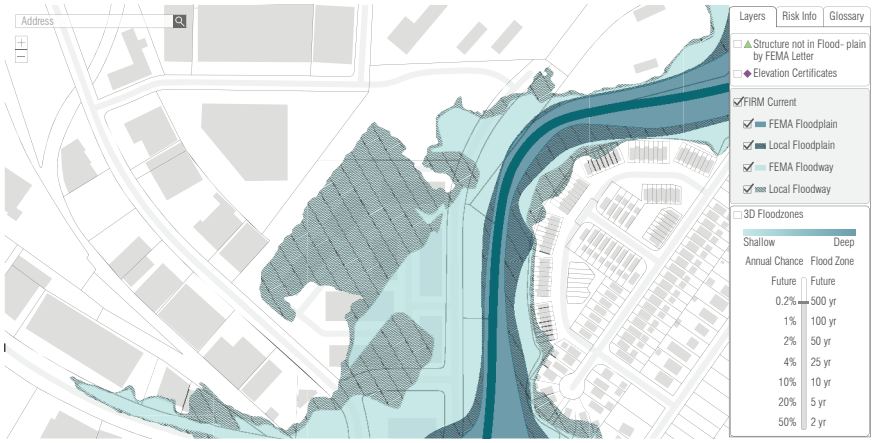


Figure 1: Flood Risk Map base on Deterministic Model

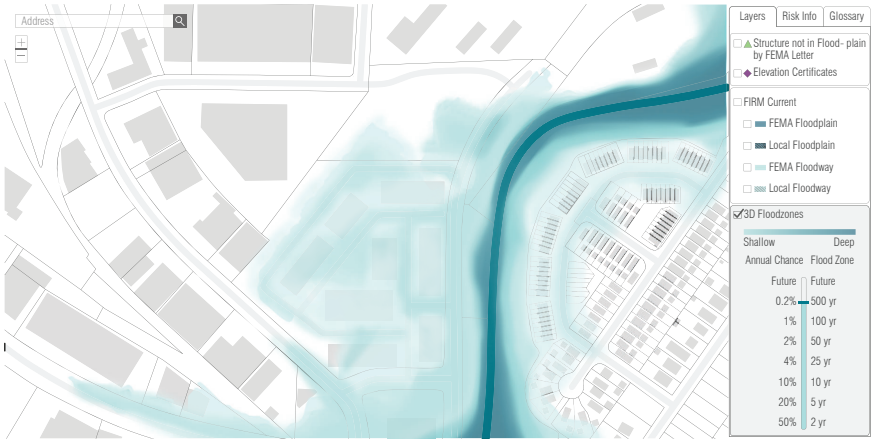


Figure 2: Flood Risk Map based on Probabilistic Model

New flood risk maps would need to be paired with effective dissemination of this information. A commitment to publicly accessible risk information could be required through state law or city ordinances that require landlords to provide this information to buyers and renters. Refer to the Public Education section for more information.

After Hurricane Andrew struck Florida in 1992, the insurance industry switched to the modern approach upon realizing that the historical hurricane record grossly underestimated today's coastal risk. The modern approach more accurately estimated risk that was increasing over time due to the combined effects of increased exposure (i.e., development), undersized and deteriorating infrastructure, increasingly extreme weather events, and climate change. Today's state-of-the-art flood risk assessment tool is a probabilistic multi-hazard risk model.

1.2

Flood Information Plaques

Plaques with flood-related information, installed in a predictable location on every home structure, would provide residents with key information about their home that could help them better prepare for flood events. Additionally, the plaques would serve as a reminder of the ongoing risk of flooding.

Contributors

Huitt-Zollars, Inc.

Related Ideas

Home Reconstruction on p. 19

Watershed Based Development Regulations on p. 37

Building Regulations for Existing Homes on p. 39

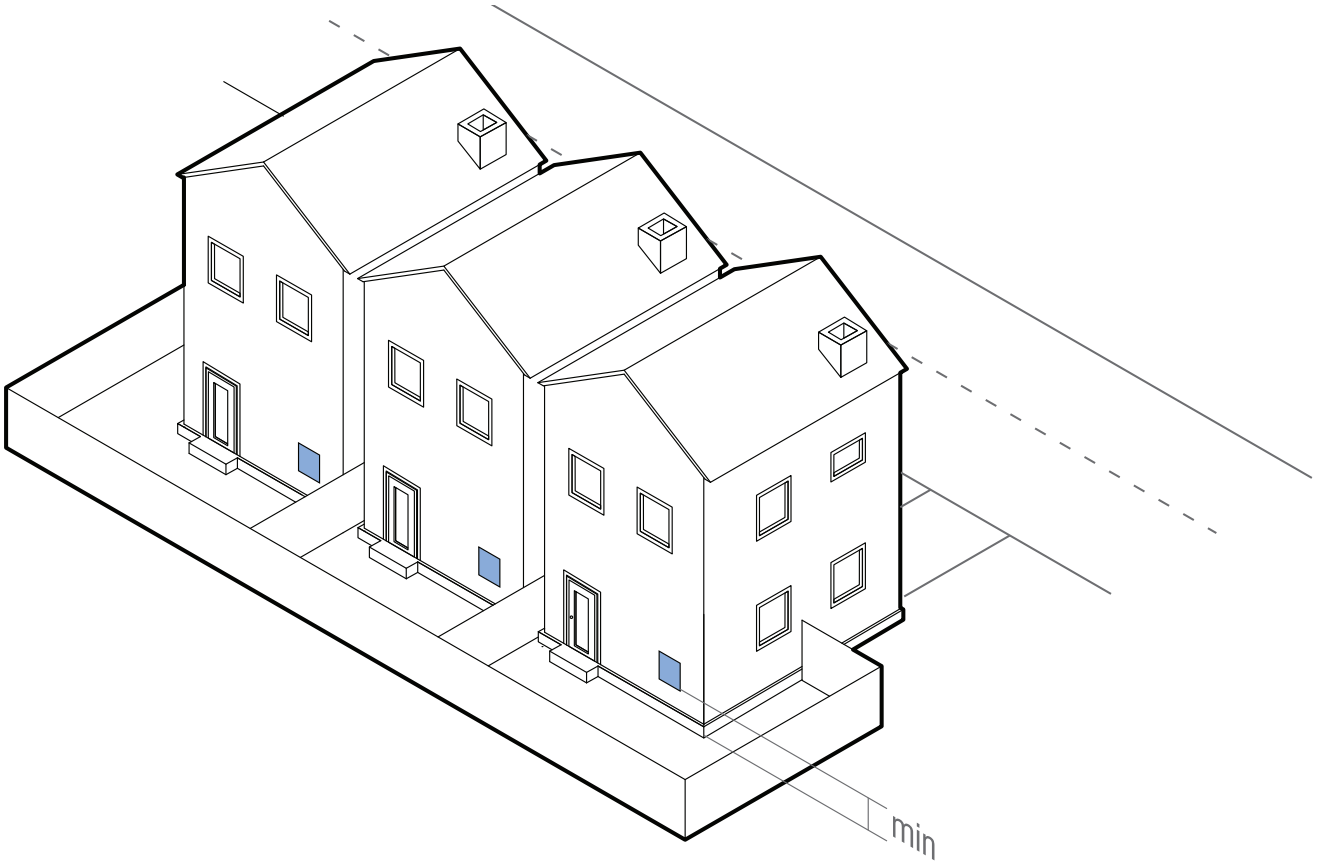
Plaques with key flood information installed on every home structure would not only serve as a reminder of the constant flood risk in the region, but also provide information to residents about their property and neighborhood. These plaques would not be about commemorating an event, rather they would be forward thinking and focus on communication of risk.

Plaques could be installed in the same location on every home structure so they can be found easily by every new occupant. Plaques could have unique identification numbers that are fed into an online system to retrieve the most up to date information or order a plaque renewal.

Plaques could show information as shown in the mock diagrams and could be available in a variety of material options.

There are several implementation options for these plaques:

- Every new house could be required to install one to pass building inspection, along with the existing requirement for a posted address.
- Every home repaired after flood damages could be required to install one.
- Homeowners could pro-actively apply to have one installed.
- Rental property owners could be required to install in any of their rented properties.
- Homeowners could be required to install it when they are selling a home.
- Taxing authorities could offer a monetary incentive on the next property tax payment for installing a plaque.



Disclosure Plaque Location

Glass

Metal

Wood

1.3
Information Flyers

Flood information should be provided to all new residents of every neighborhood to help them prepare for their flood risk.

Contributors

Senchel Matthews | Local Initiatives Support Corporation

Susan Rogers | University of Houston Hines College of Architecture + Design, Community Design Resource Center

Related Ideas

Fundamentals: Public Education on p. x

Probabilistic Risk Maps on p. 7

Whether someone is new to Houston or new to a neighborhood within Houston, it is important for each resident to be fully aware of the surroundings around their new home. An essential first step is to ensure that all residents are acting on the same level of risk information in choosing where to live. This requires policies that include legally required flood risk disclosures. It also points to the need for updated and publicly navigable probabilistic risk maps (Probabilistic Risk Maps on p. 7) that denote risk both inside and outside floodplains. Additionally, knowing their Finished Floor Elevation and their closest stream gage can let them decide when they need to evacuate, before their home is flooded.

Each new resident should be provided with this information upon their move. A flyer of information could be given to every new resident of a community or apartment that would contain targeted information for their specific community.

The same information could be put on a postcard and mailed out to every resident before each year's hurricane season. It could also be circulated door-to-door, at community centers, schools, and libraries prior to hurricane season every year.

State legislators introduced bills during the 86th Texas Legislature that would require such disclosures for homeowners (Huffman SB #339) and renters (Coleman HB #993). Their status was pending at the time of this writing, but these bills represent a very important step toward protecting Texans from flooding.

Lincoln City, Oregon, offers a good example of where the city pro-actively educates new residents on their emergency protocols through a flyer and a buddy system. With every new electricity contract, the resident receives a flyer with the relevant flood information for that property.

Information included on could be as shown in the sample flyer on the right.


Do You Know . . .
Your risk for flooding?
Berry Bayou
Edgebrook Dr
Third St
Frey Rd
Gulf Freeway I45
1. KNOW YOUR RISK: Find out whether you live in a floodplain by going to http://www.harriscountyfemt.org/ or call 832-394-8854 (City of Houston Floodplain Management Office)
2. PROTECT YOUR INVESTMENT: Even if you don't live in a floodplain you could still be at risk of flooding. Flood insurance, available to owners and renters, can protect you from loss. More information is available through your insurance agent or the National Flood Insurance Program at https://www.floodsmart.gov/ or 800-427-4661 (National Flood Insurance Help Center)
3. SPECIAL NEEDS: If you have special health care or transportation needs, make sure you are prepared in case of a hurricane or other disaster by calling 2-1-1 and registering for evacuation assistance
4. SPREAD THE WORD: Share this information with your friends, family and neighbors
Harvey Flooding Facts:
Total estimated flooded homes in . . .
Harris County: 154,700
Berry Bayou: 8,510
Edgebrook Super Neighborhood: 4,853
Sabe usted . . .
riesgo de inundación?
Do You Know . . .
to get involved in your community?
Freeway Manor/ Sun Valley Civic Club
Edgebrook Dr
Old Galveston Rd
Sabe usted . . .
volucrarse en su comunidad?
Arlington Heights Civic Club
Old Galveston Rd

1.4
Flood Totems

Adding flood-focused artwork across the region would memorialize flood events and remind residents of their risks.

Contributor

Huitt Zollars, Inc.

Related Ideas

Fundamentals: Public Education on p. x

Flood Warning and Alert Systems on p. 53

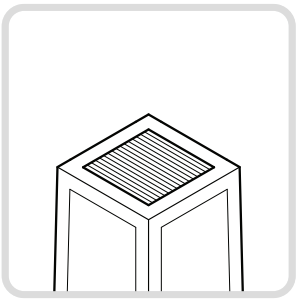
The purpose of artwork implemented across the region that captures various flood events is to retain the memory of each disaster and its impact on human lives and serve as a reminder to residents of the risks they continue to face.

One possible form of such artwork could be flood totems installed in parks and other public spaces that mark major disasters using a light band placed at the level of the flood. These would be visible as bands during the day and could incorporate solar-powered LED fixtures that glow at night. Totems could have more than one band to show more than one flood event. The height of the totems would be a maximum of 8 feet to remain at a human scale while accommodating a marker for over 5 feet of floodwater. While the core materials and design of this monument would remain the same, a customizable screen could help make the monument unique to its neighborhood. This screen could become a new neighborhood-wide art opportunity, like the traffic signal boxes.

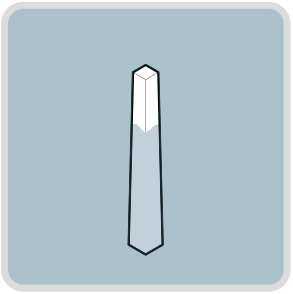
The Houston Arts Alliance, Mayor's Office of Cultural Affairs, City or County Parks Departments, or private property owners could be responsible for the maintenance, although solar panels and LED light fixtures would minimize the required maintenance.

These totems could be located along waterways, public parks, outside schools, or at neighborhood entrances.

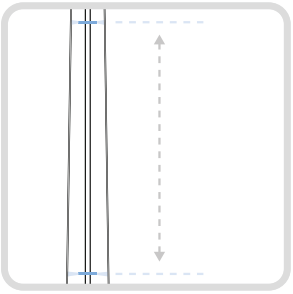
This idea could be expanded beyond art to serve as a warning when a nearby stream approaches a certain flood level. Additionally, it could incorporate an emergency call box.



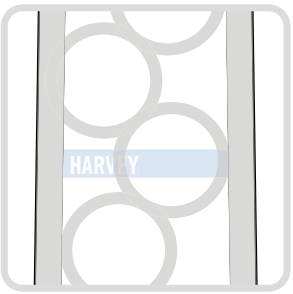
Solar panels used to power lights allow the totem to sustainably operate as a standalone unit



Bands of light would show the high-water datums of various flood events



These bands can be added to the monument if another flood occurs



Totems would standardized but could have customizable elements to make it unique to its neighborhood

Housing Strategies

The issue of older homes in areas that flood remains a challenge. Today, the only options are major infrastructure projects that can take decades to complete, home buyouts, and elevating homes. All of these options are expensive, and often federal funding restrictions mean they can only be effectively employed in wealthier areas. However, there are lower-cost options that can address the very real problems faced by individual homeowners and the communities in which they live.

1.5
Home Exchange

Homeowners who volunteer for buyouts could be offered a choice between the current option, which is to receive a pre-disaster value check for their flooded home, and a new option to swap their flooded home for a new home.

Contributor

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Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Related Ideas

Planning For Buyouts on p. 81

Case Managers on p. 91

Further Reading

HCFCD Home Buyout Program; https://www.hcfcd.org/hurricane-harvey/home-buyout-program/

The nature of the current home buyout process makes participation challenging for homeowners. One of the primary barriers to homeowners volunteering for buyouts, in addition to the required time, knowledge, and logistics, is the uncertainty of relocation. Home buying is a difficult process and often, the pre-disaster value of a resident's flooded home is insufficient to pay for relocation.

The current process begins after a disaster, when jurisdictions apply for federal funding. During this time, the jurisdiction receives applications for buyouts from homeowners. Federal funding typically takes at least 7-9 months to arrive, though often much longer, at which time the actual purchase of homes can begin. According to the HCFCD, the process for a homeowner can take 8-12 months to even get started and then years to complete.

A possible solution is to provide homeowners with keys to a new home built to modern flood standards the day that the buyout purchase is completed. This can be achieved if jurisdictions build a database of information of where priority buyout areas are and where comparable housing for those homeowners can be found in similar communities.

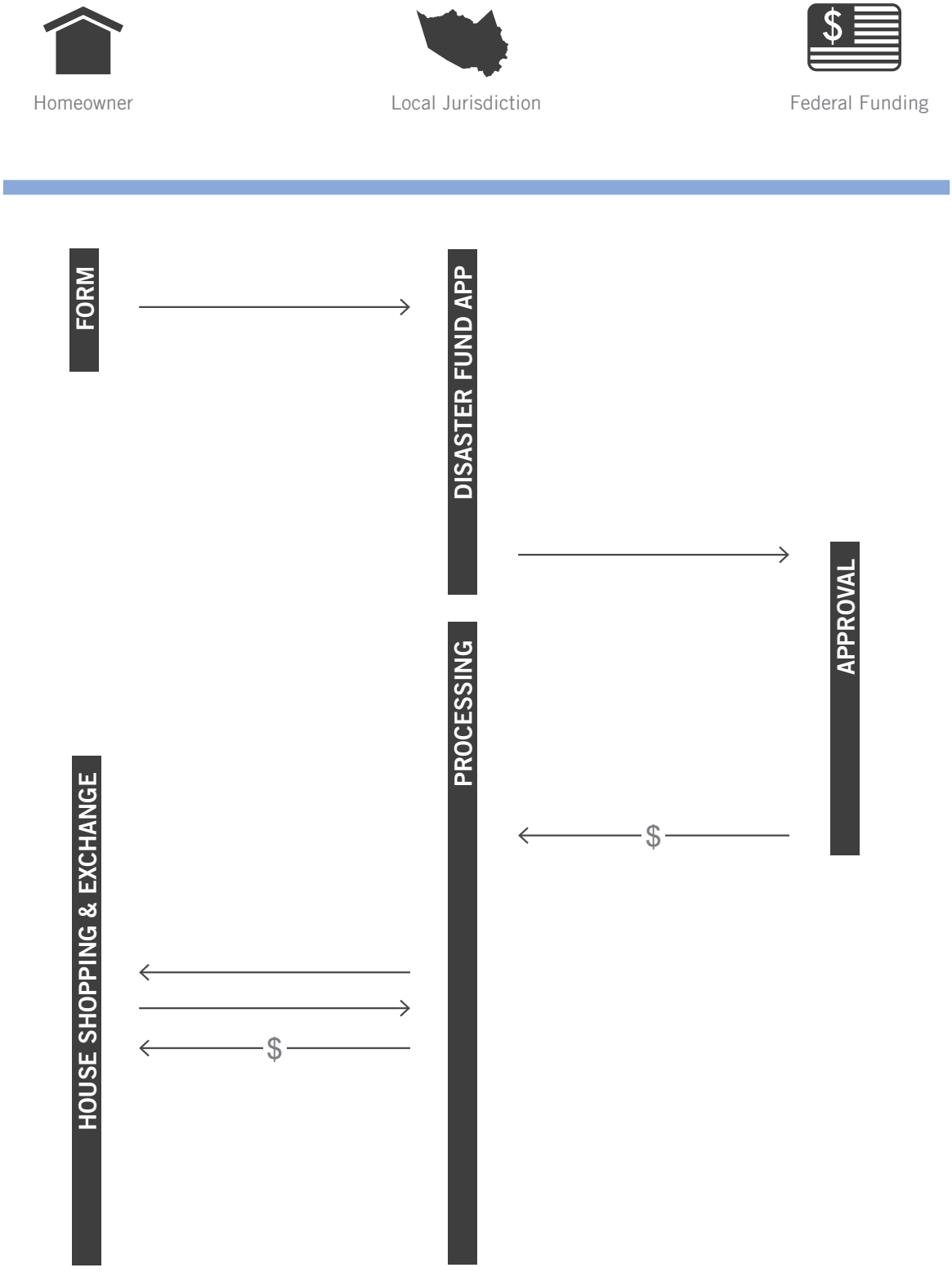
A relocation case manager who works with homeowners and coordinates with real estate professionals, could be trained to handle the financial, legal, and logistical burdens of home buying. They would serve as guides to buyout applicants, leading them through the process and offering insight into real estate data. Jurisdictions can offer homeowners the choice of receiving a check for their home's pre-disaster value or a new home selected from the list of comparable homes in a prepared database. Residents that choose to exchange their homes for a new ones will work with their case manager to select one that meets their needs. If multiple homeowners in a community are being bought out, case managers could offer homes near one another from the database in interest of retaining community and local connections.

The jurisdiction could put out a Request for Proposal to local developers for designs that work with the program. Developers signing up homeowners for an upcoming development could sign up for this.

This program could be implemented in various ways:

- Sometimes, the value of the buyout will cover the cost of a new house and no subsidy is required. However, when the buyout value is insufficient, the resident could be eligible for housing dollars to make up the cost of the new house.
- Partnering with affordable housing and National Flood Insurance Program funding could subsidize the new homes.
- If they choose to, residents could be transitioned to rental or senior living by providing several years of prepaid rent.

All options require additional funds for case management and development coordination.


Homeowner
Local Jurisdiction
Federal Funding
FORM
DISASTER FUND APP
APPROVAL
PROCESSING
HOUSE SHOPPING & EXCHANGE
$
$

1.6

Home Reconstruction

Instead of letting land sit unused after buyouts, it could be redeveloped into a recreational space, used for future flood mitigation, or where appropriate, redeveloped as more flood resilient housing. This last option can be achieved through collaboration with local developers.

Contributor

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Related Ideas

Floodproofing on p. 21

Site Improvements on p. 25

Watershed Based Development Regulations on p. 37

One-Stop Flood Permitting on p. 45

Flood Insurance on p. 85

A major component of the buyout process is determining what to do with the bought-out property. Jurisdictions face a series of challenges in buying out the right number of houses in contiguous locations, and then repurposing the land appropriately.

- Buying out all the houses in a neighborhood can leave the remaining communities sparse and isolated, negatively impacting their quality of life and reducing property values.
- Buying out a critical mass of housing stock from a neighborhood reduces housing units on the market and could lead to a housing shortage.
- There may not be adequate funding to buy out significant portions of a flooded neighborhood.
- Buying scattered homes leaves land unusable for other uses such as parks.

Where deep flooding occurs, buying out a contiguous portion of flooded properties and using it for future flood mitigation projects, such as detention ponds, may protect the remaining houses in a community. In areas where flood depths are shallow enough that future flood mitigation projects may have diminished efficacy, and vacant land is certainly underutilized, building resilient housing may be appropriate. In these areas of shallow flooding, collaborating with local developers to build new housing to a higher flood resilience could be a cost-effective and feasible endeavor while reducing the flood risk residents face. Higher flood resilience could mean building a home with a finished floor elevation informed by probabilistic risk maps and floodproofing that minimizes or prevents much of the damage a flood can inflict.

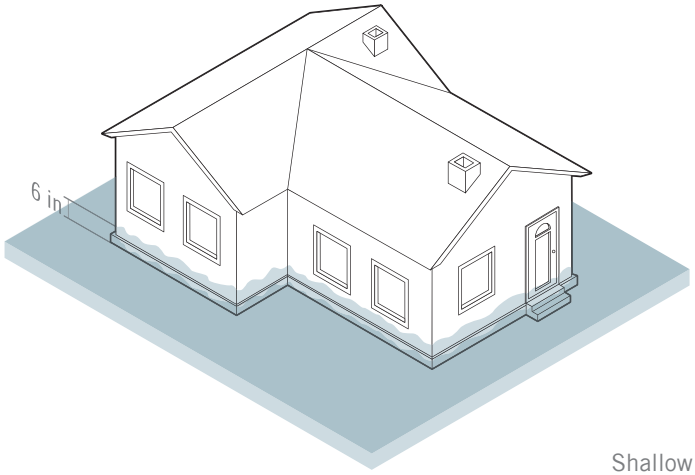
One current technique used in shallow flooding areas is to raise an existing home's finished floor elevation above the flood risk level. However, this is expensive, and does not capitalize on a chance to build a new home that could be more resilient or better suit the homeowner. This idea offers homeowners the option to move into a new home with a higher finished floor elevation rather than waiting for the existing home to be raised and incurring the associated cost.

Once the jurisdiction buys the house from a voluntary seller, the property could then be sold to a local developer to be redeveloped. Rebuilding to this higher standard could be:

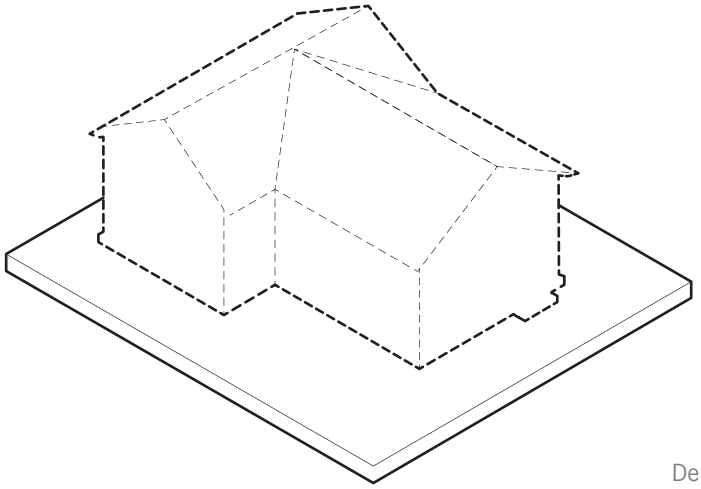
- A condition of the sale,
- Incorporated into building codes, or
- Incentivized through subsidizing property prices or taxes.

Involving local developers to reconstruct a buyout area would benefit the community and adjacent neighborhoods, maintain more housing on the market, and help the jurisdiction recover partial or full cost to allow more buyouts. This approach would also help maintain the tax base.

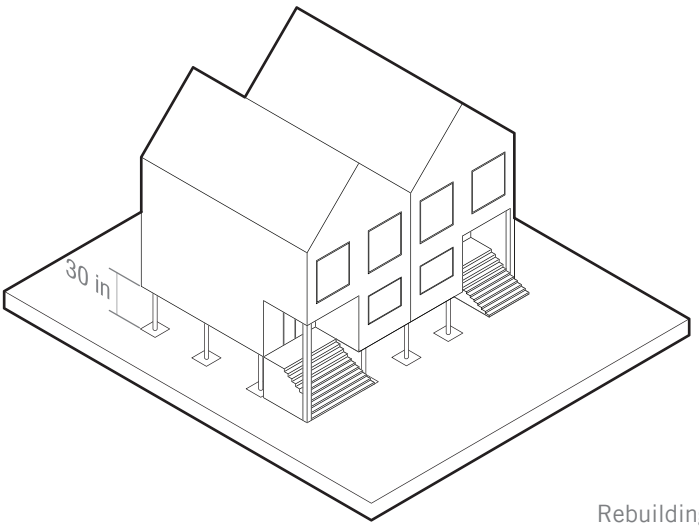
The New York Rising Acquisition for Redevelopment Program allows for voluntary buyouts within the 0.2% AEP (500 year) floodplain, but excluding those in the V Zone defined by FEMA maps to be special flood hazard areas, typically beachfront properties exposed to the additional hazard of wave velocity, to be redeveloped by private developers "in a resilient manner to protect future occupants of this property."



Shallow flooding



Demolition



Rebuilding higher

1.7
Floodproofing

There are several ways to floodproof a home such that future flood damages may be minimized or prevented. Such methods are generally more expensive than simply repairing to a pre-disaster state and may require additional permissions, incentives, and funding from local jurisdictions. Floodproofing strategies include raising home elevations.

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Related Ideas

Home Reconstruction on p. 19

Site Improvements on p. 25

Watershed Based Development Regulations on p. 37

Building Regulations for Existing Homes on p. 39

Flood Insurance on p. 85

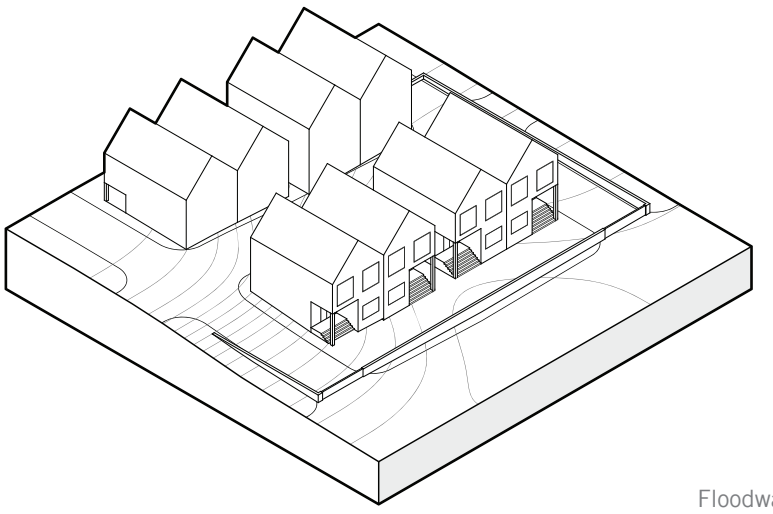
Recovering from a flooded home can be a long, cumbersome, and expensive process. When floodwaters enter a structure, they can cause several types of damage, and these damages can be very costly and difficult to repair.

While the only way to completely avoid future flood damage is to move from a flood-prone area or elevate a home at great expense, floodproofing measures can be taken to reduce the chances and scale of future damages at a lower cost. Some of the strategies outlined here are appropriate for retrofitting existing homes while others may only be economical for new construction.

Floodwalls are physical barriers that hold back floodwaters, such as levees, berms, or concrete and masonry walls. This can be a less expensive option than elevating a structure and does not require occupants to move out during construction. This method avoids structural alterations to a building but makes significant changes to the earth surrounding it. As such, a building permit may be required to build a floodwall, especially if it may alter the flow of water for adjacent properties. Additionally, any loss of water storage should be addressed with cut/fill balancing regulations. There also may be breaks in the wall for pedestrian and vehicular entry points that must be closed in advance of a high water.

The height of the floodwall would need to be at least at the level of the base flood elevation, but a large enough flood event still could overtop the structure. This may cause other issues such as accessibility to the property and increasing division in an urban fabric.

Dry floodproofing means making a building watertight below the flood protection level. Waterproof materials such as impermeable membranes, masonry, or concrete are applied to keep water out and all windows, doors, and other openings must be permanently sealed using flood shields. While dry floodproofing is relatively less expensive compared to elevating or floodwalls, there are



Floodwalls

not many aesthetically pleasing ways to employ this technique when retrofitting a home.

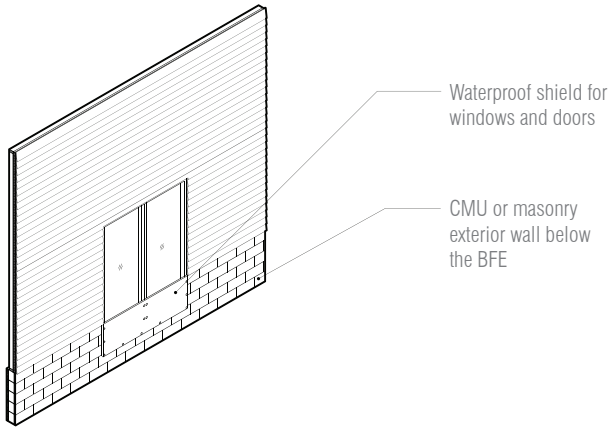
Wet floodproofing uses water-resistant materials below the flood protection level to allow for quick drying and minimal damage. Quick drying materials can prevent mold and mildew from growing and compromising air quality. The following are alternatives to commonly used construction materials that are more water resistant and can significantly reduce damages in the next flood event. Generally, this approach is recommended only when flood waters are projected to be less than XX feet deep.

Gypsum drywall	Cementitious board
Batt insulation	Closed-cell foam insulation
Composite wood sheathing	Plywood sheathing Plaster and lath
Carpet	Polished concrete with movable rugs Tile with movable rugs Floor tile Carpet tile

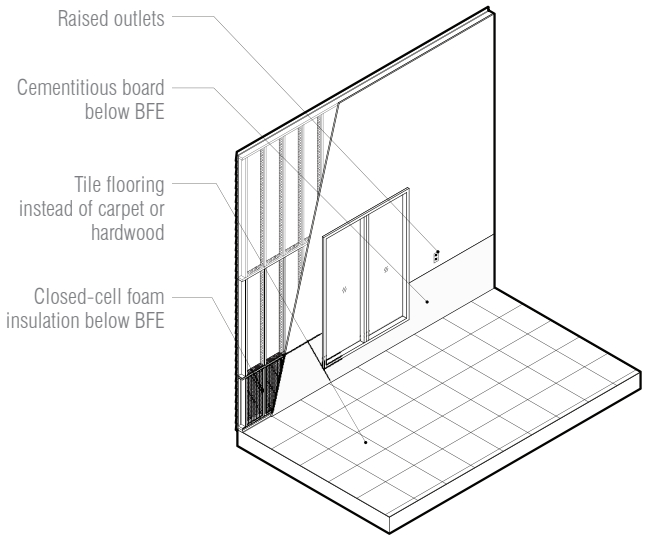
Several of these alternatives may be expensive initially, but can pay off through reduced repair and replacement costs over time. Additional precautions such as higher electrical outlets, movable furniture, and panelized wall and flooring systems can be coupled with wet floodproofing to significantly reduce future damages and repair costs.

FEMA funds and flood insurance can help a family rebuild to the pre-disaster status, but a new program that pays for the additional cost of rebuilding better than before could be implemented. The program could offer technical assistance through which a trained expert could assess damages and propose solutions that would prevent similar damages in a future flood event.

Some of the floodproofing strategies proposed here might be restricted under current building codes. In order for such a program to work, building codes could require or permit certain improvements. Additionally, current building codes require that if repairs cost more than 50% of the home value, the entire house must be brought up to latest code. Improvements geared toward preventing future damages could be exempt from adding to the total repair cost. These regulatory changes would incentivize more people to rebuild safer rather than simply returning to pre-disaster state.



Dry Floodproofing



Wet Floodproofing

Infrastructure

There is no doubt that we must continue to support major investments in large-scale infrastructure as part of our region's strategy to address flooding, but we must remember that a significant amount of the flooding during Harvey was due to local drainage problems rather than rising waters in our bayous. As a result, there must be substantial attention paid to infrastructure investments at a neighborhood and even individual parcel scale.

1.8
Site Improvements

Site improvements can be planned at a neighborhood or watershed scale, and developers and homeowners can be strategically incentivized to implement them.

Contributor

Houston Advanced Research Center

Phil Bedient | Rice University SSPEED Center

Larry Dunbar | Rice University SSPEED Center

Related Ideas

Distributed Neighborhood Detention on p. 27

Local Drainage Improvements on p. 29

Structural Projects on p. 33

Watershed Based Development Regulations on p. 37

Land Preservation on p. 41

There are several site-specific designs improvements a property owner or developer can make, but current regulations neither incentivize these nor address the impact of such improvements on adjacent or downstream sites. Site improvements do not individually have a major impact on flood mitigation, but applied across a neighborhood, the collective impact can be meaningful. Low Impact Development (LID) techniques may not be as effective with infiltration due to the region's clay soils compared to other parts of the country, but employed across sites on a regional scale, they can cumulatively slow down and retain stormwater until evaporation, thereby lessening flooding.

Site improvements may include:

- Bioretention systems
- Bioswales
- Rainwater harvesting
- Permeable pavements
- Green roofs
- Native landscapes
- Pocket prairies
- Rain barrels

Both the City and County use regulation and incentives to improve upon their existing green infrastructure and LID programs. Currently both entities have programs that essentially allow developers to opt in, which has resulted in only a handful of projects using green infrastructure. However, both the City and County are currently considering incentive programs for developers. Conventional gray infrastructure solutions are not adequate to address flood issues on their own. Mixing green and gray elements offers the best chance to mitigate flood across multiple scales. Programs could be tailored to encourage both individual homeowners and large scale developers to pursue a range of practices. Philadelphia and Seattle each offer a range of incentives to residents and developers to encourage the use of green stormwater infrastructure.

Current regulations require new developments to include detention intended to offset the increase in runoff due to the development. Developers could be incentivized, however, to do more than offset but actually improve on current conditions where added detention makes sense in a watershed (generally in the middle and upper reaches). One productive approach to site improvements would be planning them at neighborhood or watershed scales and incentivizing developers with reduced drainage fees or tax rebates. This would identify areas that most need improvements and allow incentives to be targeted there. It would also allow developers to coordinate improvements across multiple sites.


Bioretention Systems
Native Landscapes
Bioswales
Rain Barrels
Permeable Pavements
Distributed Detention

1.9

Distributed Neighborhood Detention

Distributing detention across neighborhoods can help mimic pre-development conditions with the land holding and delaying stormwater, keeping drainage pipes and ditches from being overloaded.

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Larry Dunbar | Rice University SSPEED Center

Related Ideas

Site Improvements on p. 25

Local Drainage Improvements on p. 29

Structural Projects on p. 33

Further Reading

[1] ReBuild Houston: Guidelines for Adjustment of Calculated Impervious Surface Based on Approved Stormwater Management Techniques; https://www.rebuildhouston.org/images/pdf/guidelines_for_adjustment_of_impervious_area_09_19_2011.pdf

Addressing flooding in already developed areas -- many of which predate modern infrastructure standards and development regulations -- will require building new flood control and drainage infrastructure in those existing neighborhoods.

Our flood control networks have been retrofitted at a large scale with new regional detention basins. But there are opportunities for smaller scale detention as well. Detention scattered through a neighborhood can reduce flooding at a watershed scale while also reduce flooding at a local scale by holding water before it reaches storm sewers and drainage ditches to prevent them from overflowing into homes and businesses.

Alongside regional detention basins and channel improvements, HCFCD, the county, MUDs, and cities could create programs to use public dollars to retrofit distributed detention and related drainage improvements into neighborhoods. This can be done in multiple ways:

- Using buyout parcels, and tax delinquent properties that are now in public ownership, and acquiring vacant land. In these cases, the property could be owned and managed for flood control purposes, just as drainage systems, channels, and regional basins are, and also used for secondary parks and greenspace.
- Using land around public buildings. Here, detention could be added to underused portions of these properties through inter-agency agreements where improvements are paid through flood control or drainage funds with a reduction in the drainage fee (as is already allowed in Houston), and the agency that owns the property agrees to preserve and maintain them[1].
- Integrating detention into parks and school playgrounds. The topography created by detention ponds and ditches (and the hills than can be built from the excavated soil) is great for recreation. As with public buildings, these improvements can be funded through flood control and drainage dollars with agreements in place to manage them.
- Integrating new public detention into existing developments. This would require the agreement of private property owners, who would receive payment in exchange for a flood control or drainage easement and a reduced taxable value. The improvements would then be publicly funded and built. The landowners would also benefit from reduced flood risk on their own property due to site improvements that funnel water away from the building to detention. On commercial properties, this could be done in landscaped areas and unused portions for a site. In residential properties, front yards -- which are directly adjacent to drainage ditches and storm sewers -- could be excavated for detention volume.
- These drainage improvements serve the same purpose as bayou improvements and regional detention, and can be funded from the same sources.

Flooding Before the Introduction of Distributed Detention

Distributed Neighborhood Detention and Drainage

1.10

Local Drainage Improvements

A comprehensive model of watersheds showing various sources of water could be created and provided to engineers and developers, so they are able to better design local drainage. Additionally, informing residents about drainage design can help them protect their belongings and minimize damages.

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Related Ideas

Probabilistic Risk Maps on p. 7

Distributed Neighborhood Detention on p. 27

Structural Projects on p. 33

Much of the flooding in Houston is caused by local drainage, not by the major channels and bayous. While the City of Houston and others are investing millions in these systems, improved modeling, additional resources, and new programs could help thousands of homeowners and businesses. The City of Houston already enforces a drainage fee that can be leveraged to partially fund these initiatives, but Harris County does not have such a fee in place.

Comprehensive computer modeling can identify flood prone areas and make it clear what infrastructure can be upgraded. Such modeling has been done in a few neighborhoods, and it showed that flooding is far more widespread than FEMA maps would suggest. A program of doing such models across the region, with a focus on pre-1980s neighborhoods, would allow cities and counties to prioritize local drainage projects.

Old streets can be retrofitted. In the City of Houston, stormwater systems such as pipes and roadside ditches, used to direct water into creeks, bayous, or detention facilities, must be designed to handle a minimum 50% AEP (2 year) flood event. For rain events larger than a 50% AEP (2 year), water should overflow into right-of-ways, which should be designed to handle a minimum 1% AEP (100 year) storm, allowing water to surface flow to a major channel. Before the 1980s, streets were not designed to handle water, and as a result those neighborhoods flood to a greater extent. Much of the existing storm sewer network cannot handle even a 50% AEP (2 year) storm, since they were designed for much smaller rainfall amounts at the time they were built, or may not be maintained to handle that capacity anymore. New curb-and-gutter streets, depressed below the levels of homes, can help. But new street cross sections with less pavement and wider ditches might also help.

Off-street drainage networks can be improved as well. Some older neighborhoods were designed to drain to ditches between houses. Some of these were never formally platted and have not been maintained. Sometimes, they have been interrupted with fences, outbuildings, overgrowth, and other barriers. Working at the neighborhood scale to analyze how the original drainage system worked, properly dedicating easements, then rebuilding the system for more capacity, and regularly maintaining it, could reduce localized flooding.

Building regulations in existing neighborhoods can also address local drainage. In many neighborhoods, overland sheetflow -- from one yard to another -- handles much of the runoff. Developers are required to design new buildings so that they do not block drainage, but that is hard to enforce (and even harder in the case of incremental work by individual homeowners). Creating watershed models to provide developers and engineers with information about upstream conditions, coupled with regulations requiring them to design with comprehensive modeling of sources of water on their site, would help reduce localized flooding away from bayous. In some neighborhoods, it may be appropriate, based on this modeling, to require new buildings to be built on pier-and-beam foundations or to have perimeter drainage ditches.


99¢MAX

1.11

Local Drainage Maintenance

The challenge of keeping up with local drainage maintenance can be addressed with more localized attention, using programs like Houston's Adopt-A-Drain.

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Susan Rogers | University of Houston Hines College of Architecture + Design, Community Design Resource Center

Related Ideas

Fundamentals: Public Education on p. x

While bayous and smaller channels are already well-maintained by Harris County Flood Control District, local drainage systems such as pipes and roadside ditches would benefit from programs that augment the city's Storm Water Maintenance Branch efforts to tackle local drainage at a neighborhood level.

The City of Houston's Adopt-A-Drain program is an innovative attempt to share the load of maintaining drainage systems. This program can be expanded throughout Harris and neighboring counties. Additionally, organizing public education events by neighborhood would help residents understand the hazards of unmaintained drainage systems during a storm event and encourage them to participate. This program could be further incentivized by increasing the drainage fee for individuals not participating in the program. The fee could, in turn, be used by neighborhoods to fund maintenance.

The City of Houston has also adopted new rules on new development on streets with open ditches that require culverts to be increased in size to meet current requirements if they are undersized and replaced if they are damaged.

Public agencies can also play a role. Regular mowing and clearing of ditches in the public right of way, and regular cleaning of storm sewers, could have a significant impact on local flooding.

Additionally, residents are often unaware that roads are intended to act as the secondary short-term storage and/or conveyance systems for water. It is important to communicate this with the public so they can prevent their cars and other personal belongings in the right-of-way from flooding. Removing items from right-of-way will also prevent amplified flooding due to large objects and debris blocking drainage systems.

1.12
Structural Projects

The region has historically used structural solutions for flood mitigation built to withstand the 1% AEP (100 year) storm. We now need to address aging infrastructure, reconsider the design standards for new infrastructure, and better integrate gray infrastructure with green.

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Related Ideas

Probabilistic Risk Maps on p. 7

Site Improvements on p. 25

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Local Drainage Improvements on p. 29

Watershed Based Development Regulations on p. 37

Land Preservation on p. 41

Structural projects such as regional detention basins, channel improvements, and bridge replacements have long been an essential tool for addressing flooding. Since the 1990s, the Harris County Flood Control District has been a national leader in "green," or more natural approaches, to structural projects. Sims Bayou, rebuilt with a grassy channel that provides room for the bayou to spread and detention basins that double as green space, performed very well in Hurricane Harvey. The district's collaboration with Houston Parks Board and Harris County commissioners' parks departments has taken advantage of this infrastructure to create a regional network of greenways. The 2018 Harris County flood control bond dramatically increased the ambition of these projects, taking on watersheds that have gone decades without flood control projects. It also marked a major increase in the level of public outreach around projects, which helped build popular support.

HCFCD and other agencies can build upon this progress:

Watershed studies can consider structural improvements alongside other types of projects, like buyouts and green space preservation, to determine which are the most cost-effective and best for the community in each section of a watershed. The traditional approach assumes structural projects will be most effective, and once those have been implemented, asks what other solutions need to be employed to address whatever is left at risk in a 1% AEP (100 year) storm. This approach proposes an evaluation of all possible solutions simultaneously and with public input.

Flood mitigation projects can be analyzed at the same time as local drainage networks to identify what approaches are most effective. Traditionally, neighborhood scale infrastructure projects have attempted to keep the runoff into the bayou the same, attempting to compensate for any increase in runoff due to better drainage in local drainage networks with local detention basins or oversized pipes. In some cases, though, it may be more efficient to increase runoff locally and compensate by adding more detention elsewhere in the watershed. In other cases it may make sense to integrate detention into neighborhood parks to decrease flow into the bayous. Considering the whole system, rather than treating local drainage networks and bayous as separate, would increase options. Localized low-impact development (LID) projects may also be a part of the solution.

Every major infrastructure project can be used as an opportunity to mitigate flooding. Every road and highway project, for example, should be evaluated for ways to add detention, improve channels, raise bridges over channels, and remove bridges or culverts that obstruct water flow. Rather than simply mitigating the increase in flooding caused by new pavement, these projects can address existing problems and leverage taxpayer dollars to do more. This would require substantial collaboration between transportation and flood control agencies as well as coordination of multiple funding streams.

A comprehensive agreement could be reached with local railroads to address places where railroad

bridges and embankments are restricting water flow. There are many places across Harris County where old railroad bridges are increasing upstream flooding. The railroads, though, do not have the funds to replace all of these. Furthermore, the railroads are at risk of legal liability if they replace a bridge since that could increase flooding downstream. A comprehensive agreement would allow the HCFCD to design new bridges as part of overall watershed plans and remove liability from the railroads. The agreement would also allow public funds to cover the public benefits from flood reduction due to bridge replacement. This may not be easy - the railroads have historically been slow to reach such agreements. It would likely be easier to do a single county-wide agreement rather than pursuing such agreements on a case-by-case basis.

The benefits of structural projects can be explained to the public in terms of reduction in risk, not change in floodplain. The standard federal approach is to calculate the current 1% AEP (100 year) floodplain, then calculate the 1% AEP (100 year) floodplain after a project and count how many homes and business are “removed” from the floodplain. This is a simplistic way to understand a project. Projects do not eliminate flood risk entirely; they reduce it. Homes outside the floodplain are not suddenly safe from all flood risk; in a bigger storm they may still flood. Homes still inside the floodplain after the project still benefit from the project from reduced risk because the flood levels will be lower, and in smaller storms, they may no longer flood at all. This can be expressed by mapping gradients of risk rather than absolute lines. Refer to Probabilistic Risk Maps on p. 7.

Projects could be analyzed for larger storms. Currently in the City of Houston and Harris County, flood mitigation structural projects such as channelized bayous and regional detention basins are built to withstand a 1% AEP (100 year) storm. As our understanding of storm severities and frequencies increases, structural projects need to be upgraded to continue to withstand the new, higher 1% AEP (100 year) storm levels released with the latest NOAA Atlas 14 update. Additionally, considering the increased frequency of severe events, the region may consider regulating gray infrastructure to a higher level storm. The Netherlands, for example, relies on massive gray infrastructure to withstand a .01% AEP (10,000 year) storm while the City of Houston designs its storm sewers for a 50% AEP (2 year) storm. Fortunately, the types of infrastructure that Houston builds will generally help even in a larger storm, unlike levees, which are entirely useless when overtopped.

Flood mitigation planning can be integrated with green space planning. This is already happening; bayous are being transformed into the regional Bayou Greenways network, detention basins are used as parks, and detention has been integrated into existing parks. However, this could be more systematic. Every new piece of flood control infrastructure could be developed as green space. Every park could be evaluated for its flood control potential. That includes neighborhood parks where detention could reduce localized flooding and even school playgrounds. The earthmoving required for detention can make parks better: for example, ponds and hills can serve as playscapes, and improved channels can be beautiful oases in the city.

Regulations

We can be more deliberate about guiding development to low-risk areas and away from areas with high risk by examining whether our current development regulations promote or discourage the development patterns that will keep us high and dry. It is important to remember that most regions use land use policy to reduce the need for costly infrastructure investments as the primary response to flooding.

1.13

Watershed Based Development Regulations

Comprehensive watershed plans would allow for development regulations that more effectively target the specific conditions that contribute to flooding in each watershed.

Contributor

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Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Ryan Bare | Houston Advanced Research Center

Related Ideas

Probabilistic Risk Maps on p. 7

Resilient Senior Living on p. 61

Hazardous Facilities on p. 63

Resilient Power Supplies on p. 65

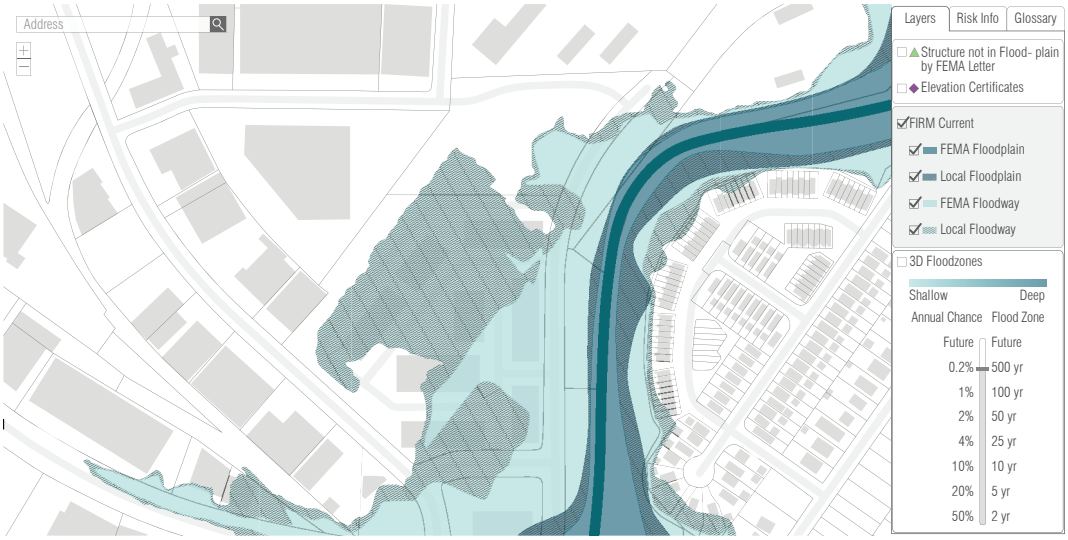
Resilient Wastewater Infrastructure on p. 67

Both the City of Houston and Harris County have taken major steps to strengthen their floodplain development and building regulations. Additional changes to policy and regulation could help reduce the number of people in harm's way and help mitigate future flooding. There is a need to have further attention paid to flood risks outside the existing 0.2% AEP (500 year) flood plain. For example, the majority of the structures damaged by Harvey within the City of Houston rest outside the current 0.2% AEP (500 year) flood plain.

Current regulations, though, are one-size-fits all. Detention requirements for small and medium-sized sites, for example, are the same everywhere, regardless of soil types, topography, and watershed. However, the detention required to truly compensate for the impact of new development is different in different watersheds. Where soils are sandier, undeveloped sites absorb more water, so the impact of new pavement is greater. Development increases runoff from flat, undulating sites more than it does from sloped, well-drained sites. Detention is more useful in the upper and middle reaches of a watershed than it is downstream. Technology has advanced since many of our regulations were adopted, and a more targeted approach is now feasible.

The City, County, and larger region could coordinate land use and development plans and collaboratively simplify processes to minimize future risk and help address existing issues. This requires watershed level planning that can identify flood-vulnerable areas holistically and approach mitigating risk in future developments. This could take the shape of additional restrictions on building inside the floodplains coupled with preservation strategies, flood control infrastructure, and detention requirements that vary based on location in the watershed or require a more conservative standardized detention formula for those who prefer simplicity for their smaller projects.

Watershed planning should be paired with land use regulations that are directly tied to objectives that maximize public safety and minimize flood risks. This does not have to mean traditional zoning, and the Houston region can create a new model that avoids needless interference in the market while more effectively addressing public safety.



Risk Maps and Complete Information

Green Infrastructure Regulations

Comprehensive Land Use and Development Planning

1.14

Building Regulations for Existing Homes

Building regulations could be implemented to address homes built before current codes and standards such that, after a flood, they are rebuilt to be higher flood resilience through materials and design.

Contributor

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Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Ryan Bare | Houston Advanced Research Center

Related Ideas

Home Reconstruction on p. 19

Floodproofing on p. 21

Site Improvements on p. 25

A major challenge that comes to the forefront when considering changes to building and development codes are grandfathered homes. These are buildings that existed before updated standards. The most common issue is that homes have a floor elevation that does not meet current standards for elevation above the floodplain.

If a grandfathered home floods, one of three things happens.

If the cost of the required repairs to bring the home back to pre-flood condition exceeds 50% of the value of the home, the home is considered "substantially damaged" by FEMA definitions and must be brought up to current standards. If the property is valuable enough, the existing structure can be elevated to meet new standards. Many homes, though, cannot economically be elevated, and the only alternative is to demolish the structure and start over.

If the cost of the required repairs does not exceed 50% of the value, building regulations allow it to be rebuilt in its pre-flood form, using the same materials.

In addition to these two legal options for repairing a house, the reality of insurance processing times and difficulty of navigating proper channels leads to some homes not being repaired at all, leaving residents living with mold and other damage, or being illegally repaired without permits.

This system has resulted in many "substantially damaged" homes either being rebuilt in flood-resistant form or demolished, removing residents from a flood zone. However, it has also resulted in some residents living in "repaired" homes that are still at high risk of flooding again, some living in shoddily repaired homes, and others living in homes that have not been repaired at all. In many cases, the owners of these homes may lack the resources needed to bring their homes up to code. This can create a problematic cycle where already vulnerable populations remain at risk of repeated flooding.

Focusing attention on equitable buyouts and relocations, as well as creating funding programs that allow homeowners and multi-family property owners to improve properties and mitigate for flood risk where possible are essential to addressing this issue.

Further, regulations could be added to address homes that fall under the 50% threshold. Regulations could require, for example, that any home rebuilt after a flood be rebuilt with water-resistant wallboard, waterproof flooring materials, and that any utilities that are replaced be elevated or waterproofed. These rebuilt homes would not be floodproofed by any stretch, but they would incur less damage and be cheaper to repair if flooded again. Refer to Floodproofing on p. 21 for more information on flood-resilient materials and design.

1.15
Land Preservation

Vegetated and pervious land provides several natural benefits for flood mitigation such as longer retention of stormwater. There are several tools the Houston region can use to conserve pervious land strategically and thereby reduce potential flooding from new development.

Contributor

Stephanie Glenn | Houston Advanced Research Center

Related Ideas

Planning For Buyouts on p. 81

Further Reading

Texas Coastal Exchange (TCX); https://www.texascoastalexchange.org/who-we-are.html

The protection of open space as a strategy to mitigate the impacts of flooding in our area is vital to the region's resilience. Vegetation and other types of pervious cover – as opposed to impervious surfaces such as concrete and asphalt – provide retention for flood waters. The benefits of preserving pervious cover are numerous, including improved water quality, increased wildlife habitat, and flood mitigation.

Timing is critical – the Houston region has large areas of natural habitat and riparian corridors that absorb large quantities of water and run off slowly, providing natural flood mitigation benefits. As of 2010, more than 2.5 million acres of land in the 11-county region (Brazoria, Chambers, Fort Bend, Galveston, Grimes, Harris, Liberty, Montgomery San Jacinto, Walker and Waller) existed as grasslands, freshwater wetlands and forests; while that number has certainly declined in the following years, there are still many opportunities for land conservation. Conserving vegetated riparian corridors, our region's critical farmland and ranch land, as well as public greenspace and other natural habitats are all important for flood mitigation. Federal and state agencies provide technical and financial assistance or incentives to landowners who wish to improve local water quality, and quantity, or mitigate for flood hazards, often through land conservation. Nonprofit land trusts work with landowners to protect natural landscapes through the establishment of conservation easements.

Conservation easements allow landowners to maintain ownership of their land while permanently protecting the land's conservation value. There are several existing conservation easement programs in Texas. The Texas Farm and Ranch Lands Conservation Program was created to protect the state's productive agricultural lands. Edwards Aquifer Protection Plan in Central Texas protects recharge areas over the Edwards Aquifer through either fee simple acquisition or conservation easements.

Locally, the Texas Commission on Environmental Quality Galveston Bay Estuary Program (TCEQ-GBEP), along with nonprofit conservation land trust organizations, manages the Conservation Assistance Program (CAP). The CAP works with landowners to identify conservation projects, develops funding strategies and assists with purchase and establishment of a conservation easement. Conservation easements allow the private property owner to maintain ownership of their land, while earning tax credits or other incentives. Land acquisition by public entities is used for the purpose of habitat protection, flood mitigation, land conservation and public access to greenspace.

There are a variety of tools that are ready and available to use at the local, county, state, and federal levels to aid in land conservation. These tools can help protect our natural resources and preserve currently undeveloped land, making farming more profitable and less risky.

These are some strategies that could be pursued to help preserve more natural open space:

- Legalities on the transfer of development rights, whereby the City purchases the development rights on private

land from willing landowners and works cooperatively with them to ensure that the land is managed according to the terms and conditions of the agreement. Such easements carry with the title of the land and do not expire regardless of change of ownership.

- Incentivize landowners to steward their lands in a manner that maximizes flood water storage. One proposal that accomplishes this is Rice University SSPEED Center's proposal of forming a Texas Coastal Exchange for willing buyers and sellers of land for ecological services.
- Nonprofit land trusts working with public and private property owners to implement conservation easements.
- Purchase of flood mitigation easements.
- Financial incentives related to regulations for recognition of farmers and ranchers for managing their land in a manner that improves water quality.
- Land use regulations that encourage preservation of hydrologically sensitive land.

1.16
Urban Infill

Incentivizing denser urban infill development reduces development pressure on more natural land in greenfield areas. Urban infill incentives can include reduced infrastructure impact fees, reduced parking requirements, and minimizing setback requirements.

Contributor

Susan Rogers | University of Houston
Hines College of Architecture + Design,
Community Design Resource Center

Amanda Timm | Local Initiatives
Support Corporation

Related Ideas

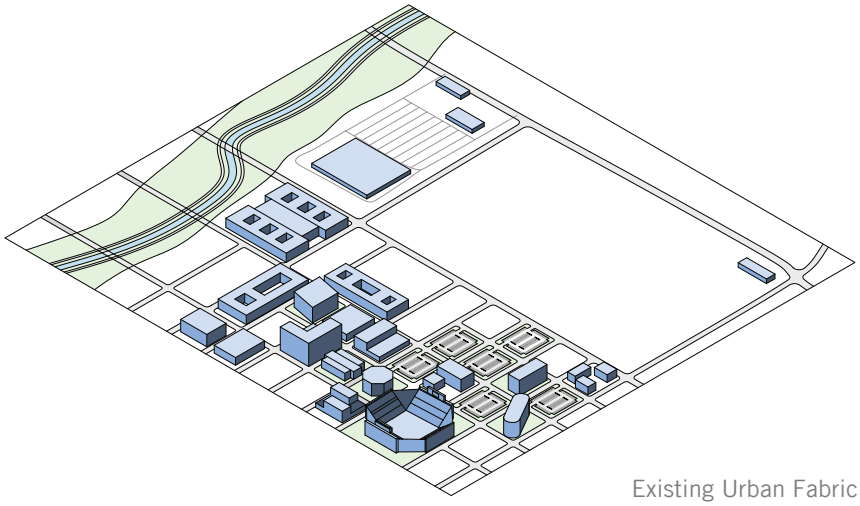
Watershed Based Development
Regulations on p. 37

One method to achieve land preservation is to further incentivize urban infill -- new homes or buildings constructed within the existing footprint of a city, rather than on agricultural or natural land.

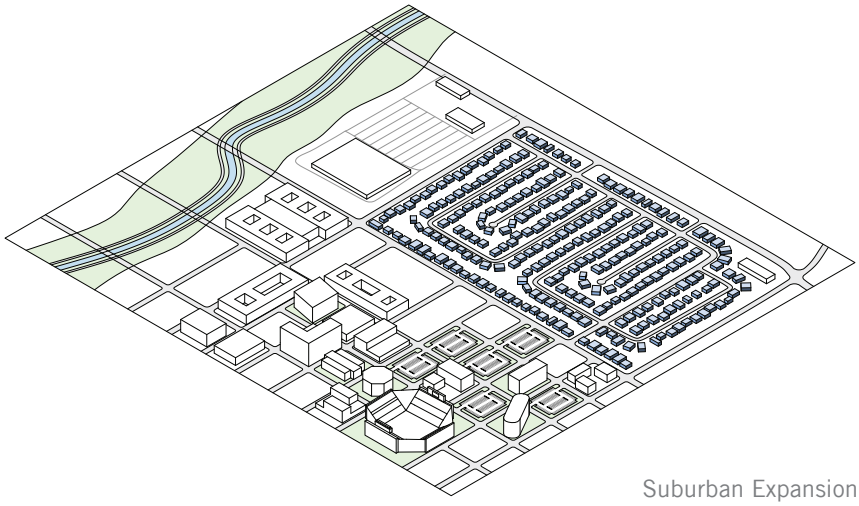
Urban infill puts new homes and business on land that already has storm drainage infrastructure to quickly drain water off a property. The biggest increase in runoff comes not from paving land but from grading it, adding streets, and installing storm sewers. Agricultural or natural land has significantly less runoff than small vacant parcels in developed areas, and a four-story building has exactly the same runoff as a one-story building with the same footprint. While urban development can increase impervious cover (which must be mitigated by ordinance) and can have local drainage impacts (which should be better understood), it does not increase runoff nearly as much as new greenfield development on the edge of a city. As the region grows and more housing units, retail outlets, and office buildings are required, siting as many of those as possible in already developed areas will reduce flooding on a regional scale.

While the market supports urban infill, development regulations can make it difficult. In 2009 the City of Houston adopted the Transit Corridor Ordinance, a code in Chapter 42 intended to encourage dense development adjacent to transit. This ordinance could be expanded to include major bus corridors or bus rapid transit routes, particularly in light of METRO's long-range plans. The program could also be expanded to major thoroughfares, where density is already occurring and could be further incentivized.

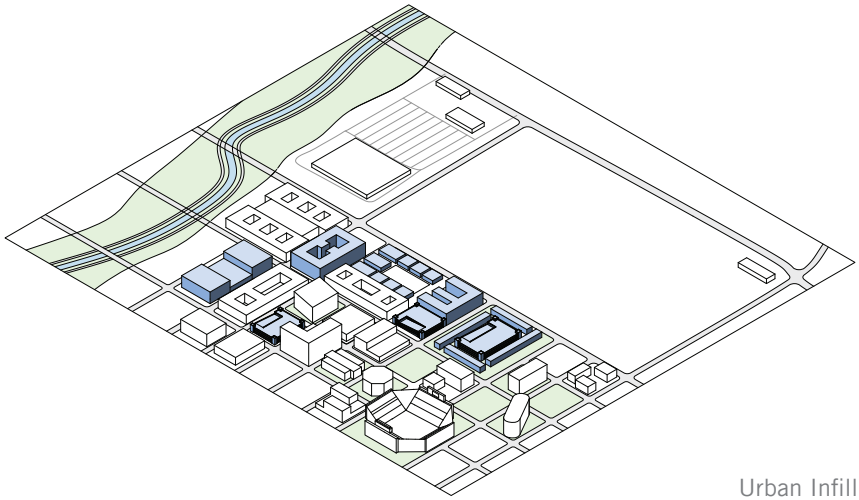
Incentives to promote infill include reduced infrastructure impact fees and costs, reduced parking requirements, and minimizing setback requirements. Other jurisdictions provide property cost write-downs, tax abatements, and other financial incentives. In Houston, this ordinance was used in the development of the Village at Palm Center, which could be a model of urban infill redevelopment that also addresses the need for affordable housing.



Existing Urban Fabric



Suburban Expansion



Urban Infill

1.17

One-Stop Flood Permitting

A single location for issuing flood-related permits across multiple jurisdictions could make the process more streamlined and easy to navigate.

Contributor

Huitt-Zollars, Inc.

Related Items

Home Reconstruction on p. 19

Currently, multiple local jurisdictions enforce building and development regulations that address flooding.

Some regulations are enforced by the authority whose political boundaries contain the project. For example, earth fill projects in floodplains are managed by cities when projects are within their city limits, but are managed by the county outside of them, which means that different cities can have jurisdiction upstream or downstream from each other or on opposite sides of the channel. This is further complicated by the establishment of extraterritorial jurisdictions (ETJs) for cities, which means cities also handle platting for properties that are not inside their boundary.

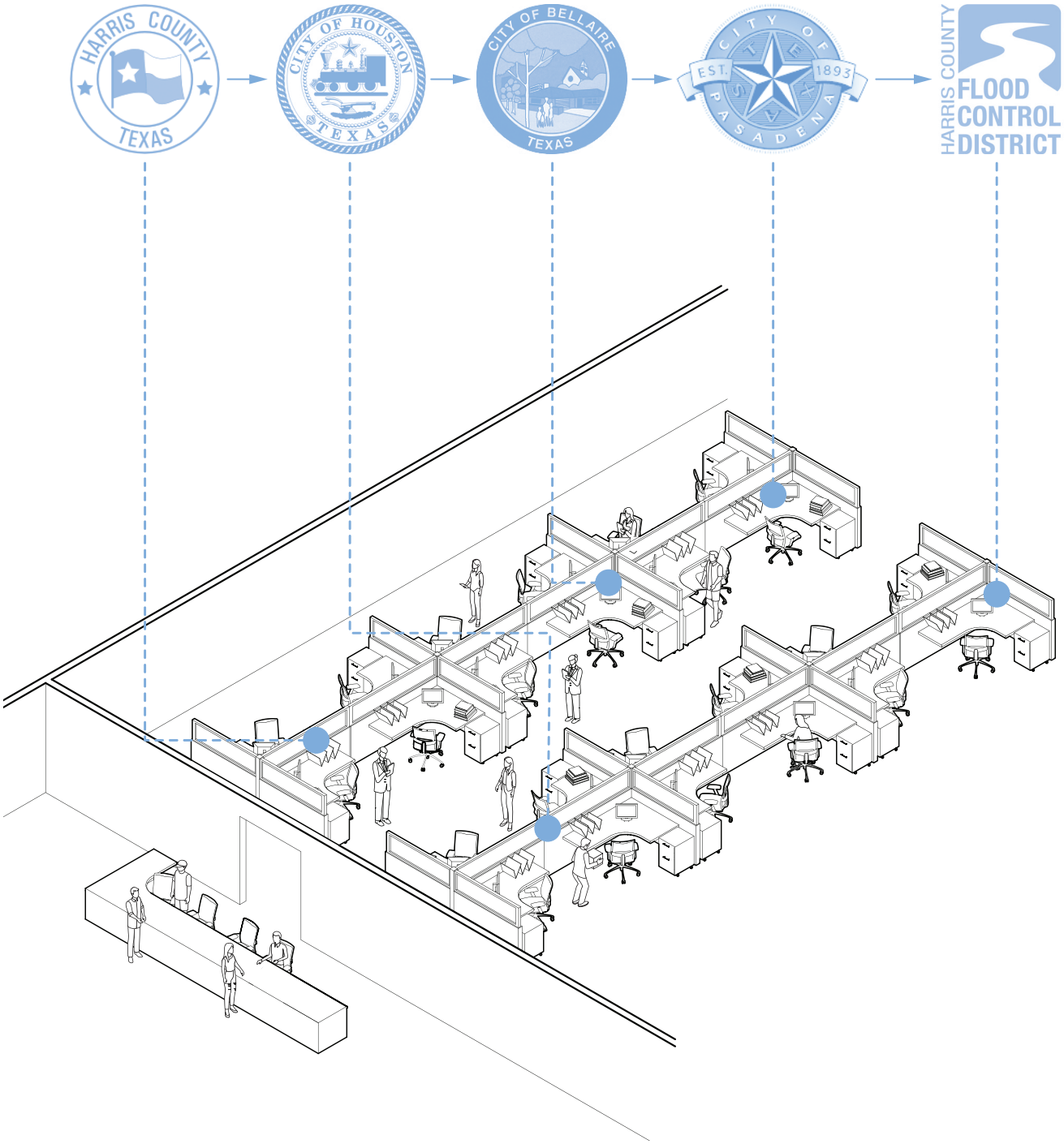
Other controls are not set by political boundaries at all. The governing authority for detention and runoff, for example, is determined by the facility into which the development drains. For example, bayous, drainage channels and storm drains under local streets may be owned and maintained by HCFCD, county precincts, municipal utility districts (MUDs), the Texas Department of Transportation (TxDOT) or a city.

Overlapping regulating authorities can make acquiring permits confusing for property owners and builders. It also means that the staff reviewing one aspect of a development may not be aware of the other permits it has or has not received. For neighborhoods, this can make it difficult to determine whether new construction they see in the floodplain meets the rules.

One solution would be to centralize all flood-related permitting within watersheds. This could be done on a county-wide basis, or, it could include parts of adjacent counties that share the same watersheds. All the relevant jurisdictions could be present within a single office. A property owner submitting for a permit would simply file a single application covering all aspects of flooding, including infrastructure, detention, flood elevation, and fill, at a single flood permitting office., Within that office, the application would be routed to whichever jurisdictions have legal authority, and all the responses could be coordinated before being returned. A development could receive a single permit covering all jurisdictions. To enable this, staff from cities, Harris County, and HCFCD could be co-located in a single building.

An additional benefit from this collaborative approach could be jurisdictions identifying permit applications that fall in gaps left in regulations, where property owners would be unable to receive a permit due non-compliance with a code or ordinance, but left with no reasonable way to satisfy the requirements. These property owners could then reach an agreement with all jurisdictions which satisfies the spirit of the development regulations, and allows them to address the needs of their property.

A single stop regional flood permitting center would be for flood permitting what Houston Transtar is for transportation. Like Transtar, it would not change any entity's jurisdictional, authority, or enforcement powers, and it would not require any state legislation, only inter-agency agreements.


HARRIS COUNTY
TEXAS
CITY OF HOUSTON
TEXAS
CITY OF BELLAIRE
TEXAS
CITY OF PASADENA
EST. 1893
HARRIS COUNTY
FLOOD
CONTROL
DISTRICT

Other Ideas

These concepts emerged from conversations Consortium Members have had among themselves and with external stakeholders. While Consortium members do not have the appropriate expertise to develop conclusions, we felt it was worthwhile to surface them.

Storm Surge Protection

Though storm surge is beyond the scope of this Consortium, it is a significant risk faced by the region. As such, proposals for major storm surge control infrastructure should be closely examined and researched.

The fact that Harvey hit the Houston region primarily with rainfall should not distract us from hurricanes that bring three different hazards: wind, rain, and storm surge. While the center of Houston is out of the coastal storm surge zone, significant parts of Harris County are at high risk of storm surge. In a major hurricane, much of the shore of Galveston Bay could be under 20 feet of water, with pounding waves on top of that. Everything along I-45 from Webster southwards as well as significant areas around the Houston Ship Channel could be under water. Hundreds of thousands of people live in this storm surge zone; the Johnson Space Center and one of the biggest chemical complexes in the world are at risk. Even when storm surge is not too high, it still reduces the capacity for bayous to drain away, which increases flood risk upstream.

There are multiple proposals, at different scales, to build major flood control infrastructure to combat this risk. The risk can also be reduced by hardening individual facilities, preserving natural marshes and wetlands, and limiting construction in risk areas.

Storm surge infrastructure can be expensive, so it is important to understand the cost-benefit analysis and not allow it to take funds away from needed projects for rainfall protection.

2 REMOVE PEOPLE FROM HARM'S WAY

Resiliency means that when a storm comes, people who are affected by flooding are safe and their critical belongings are protected. Simply moving someone to safety does not mean their lives are free from loss and disruption.

What can we do now, before the storm, to minimize harm?

Information

Facilities

Transportation

Other Ideas

Information

During a flood, better information saves lives. Flood warning system can give residents good predictions on what will flood and when, and tell first responders what roadways are open. That kind of information can also guide more sophisticated evacuation plans, getting the people who are most vulnerable to high ground.

2.1

Flood Warning and Alert Systems

Flood warning and alert systems can be implemented across the region that can predict, to surprising accuracy, rainfall amounts several hours ahead of time. These can also be used to provide targeted alerts by geographic area.

Contributor

Phil Bedient | Rice University SSPEED Center

Related Ideas

Fundamentals: Public Education on p. x

Flood Totems on p. 13

Targeted Evacuation on p. 55

Automatic Underpass Shutdowns on p. 73

Currently, Harris County Flood Control District's 171 gages across the county monitor rainfall and water levels in bayous and tributaries. This real-time information is available to the public online and is updated every 15 minutes. However, the system does not predict future water levels only tells the public what is flooded right now.

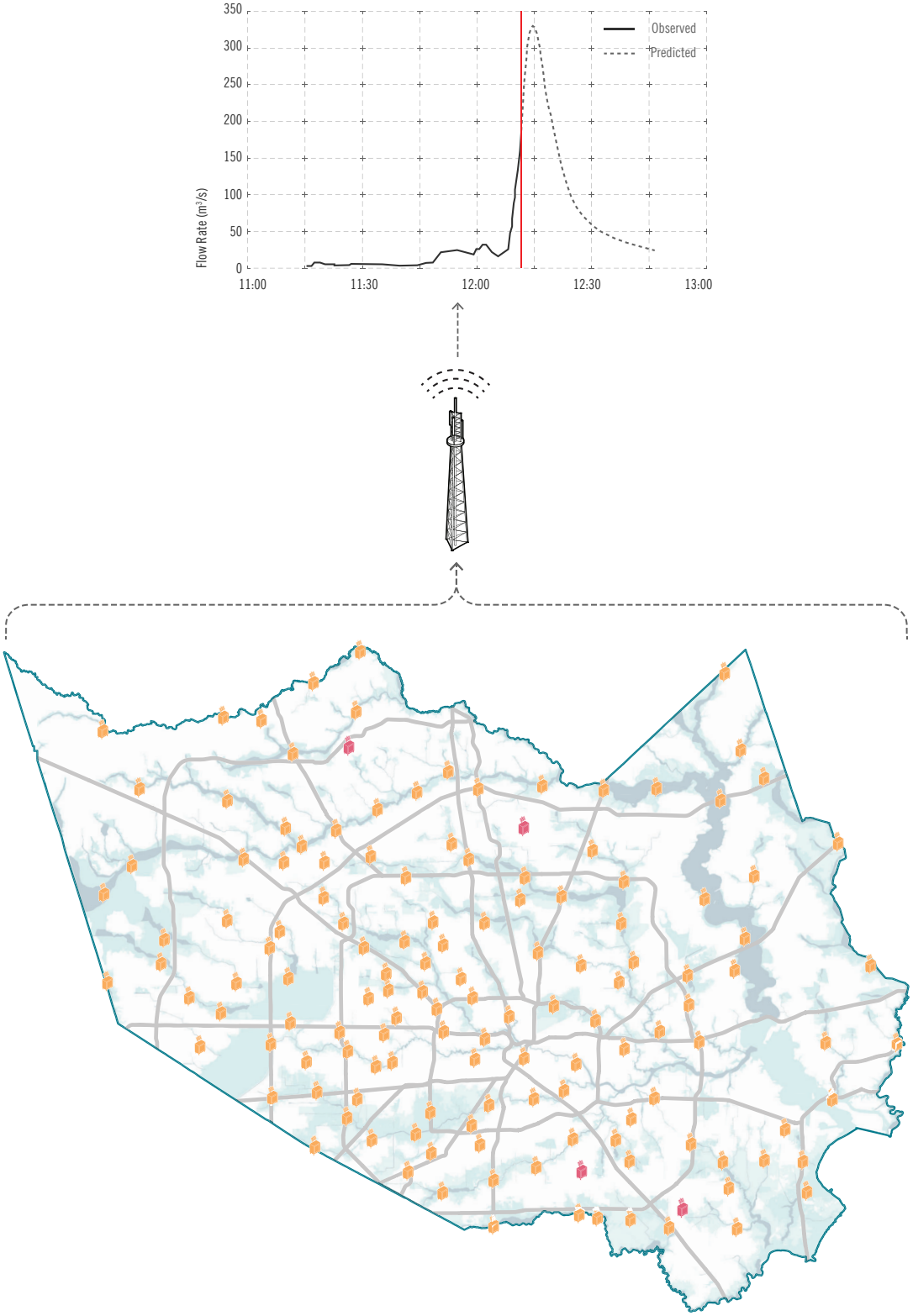
The region's flood alert system relies on notifications from the National Weather Service, which uses only a handful across Harris County to predict water levels and provide flood and other hydrologic warnings every 6 hours. This information is provided to the public in the form of hydrographs, making it difficult to understand. National Weather Service also provides text message and local media alerts, but these are typically for broad, city-wide or regional, weather patterns or large river systems.

Since Hurricane Harvey, the Harris County Flood Control District has continued to improve the flood information available online. During an event, the online flood map shows predictions of currently inundated areas, and HCFD sends out geographically specific alerts about which neighborhoods are flooding.

Flood alert systems can be extended further to predict flood levels hours in advance. Rice University's SSPEED center has developed a flood warning and alert system, FAS4, that can use real-time data to predict future flood conditions several hours in advance to a high level of accuracy. This system's accuracy has been validated over dozens of flood events dating back to 1997. It was most recently tested at the Texas Medical Center (TMC) during Hurricane Harvey. FAS4 allowed the TMC to determine when to implement emergency protocols regarding the placement and/or closing of gates and doors that prevent damages to the TMC from flooding.

Austin's ATX floods is also a flood warning system that allows individuals to sign up online and receive targeted flood alerts via email, text message, and/or phone call. In addition, Austin has placed flashing lights and automated barriers at fifteen low water crossings to prevent motorists from driving into high water. Refer to Automatic Underpass Shutdowns on p. 73 for more information on how these ideas can supplement each other.

Real-time models for all watersheds in the region, servers that can run the models every 15 minutes, and more physical elements such as gages and cameras would produce more accurate results.



Location of HCFCD Flood Gages

2.2
Targeted Evacuation

Large scale evacuations are often not the right approach and can cause more damages than benefits; however, targeted evacuations involving fewer but highly vulnerable people should be considered. As such, we need to identify high risk areas and plan strategic evacuations for various scenarios.

Contributor

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Susan Rogers | University of Houston
Hines College of Architecture + Design,
Community Design Resource Center

Phil Bedient | Rice University SSPEED Center

Related Ideas

Fundamentals: Public Education on p. x

Probabilistic Risk Maps on p. 7

Information Flyers on p. 11

Flood Warning and Alert Systems on p. 53

Further Reading

State of Texas Emergency Assistance Registry (STEAR); https://www.dps.texas.gov/dem/stear/public.htm

Although evacuation can be a life saver, there are many associated risks. For example, approximately three million people attempted to evacuate the Gulf Coast in advance of Hurricane Rita in 2005, and 100 people lost their lives during the evacuation. Further, evacuation comes with significant costs to residents in lost wages, gas, food, and lodging.

To avoid Rita-like scenarios, current regional protocol for evacuations in advance of tropical storms is to advise or require residents in storm surge zones (where staying put would be deadly) to evacuate while asking everyone else to remain home.

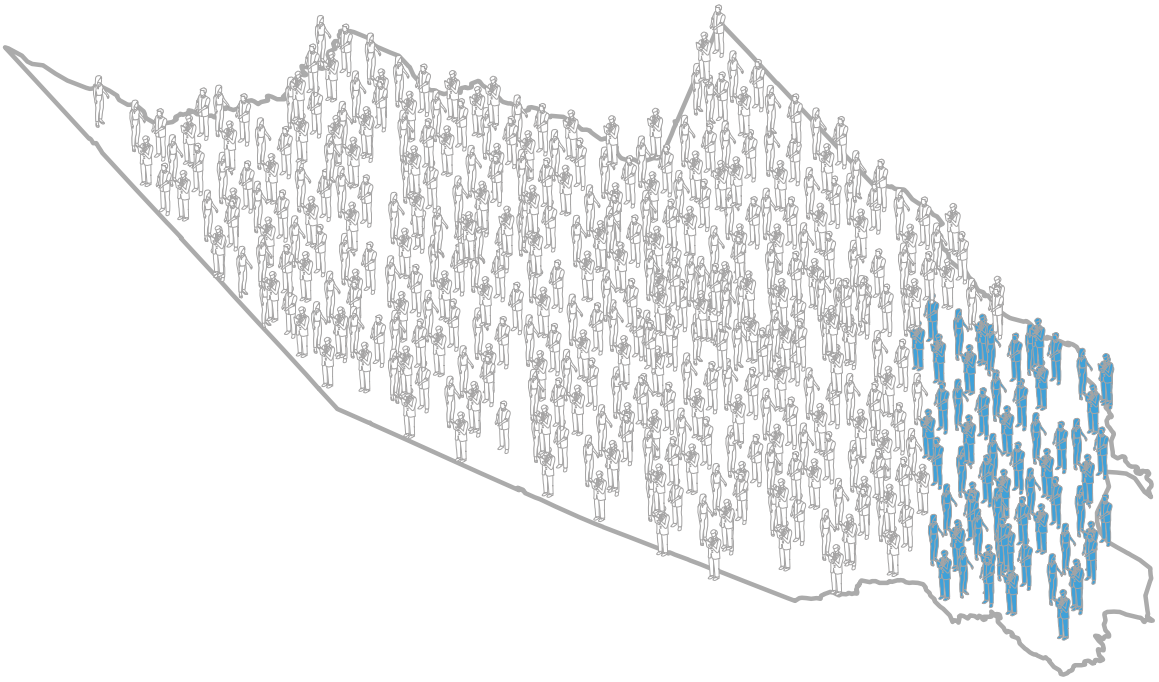
While it does not make sense to try to evacuate everyone in a storm, there are some people who are at high risk by staying in their homes. People who live deep in floodplains are much more likely to be flooded than the average resident. People who live adjacent to chemical plants have the additional risk of spills in a disaster. The elderly or young children are more likely to be injured or sickened by floodwaters or the lack of air conditioning after a storm. People who are dependent on continual medical care like dialysis or oxygen machines could die simply by being stranded or left without electricity.

It may make sense, then, for selected groups of people to evacuate. To reduce strains on the transportation systems, these evacuations could be very local, directing people to shelters on high ground around the Houston region with backup power and other provisions in place.

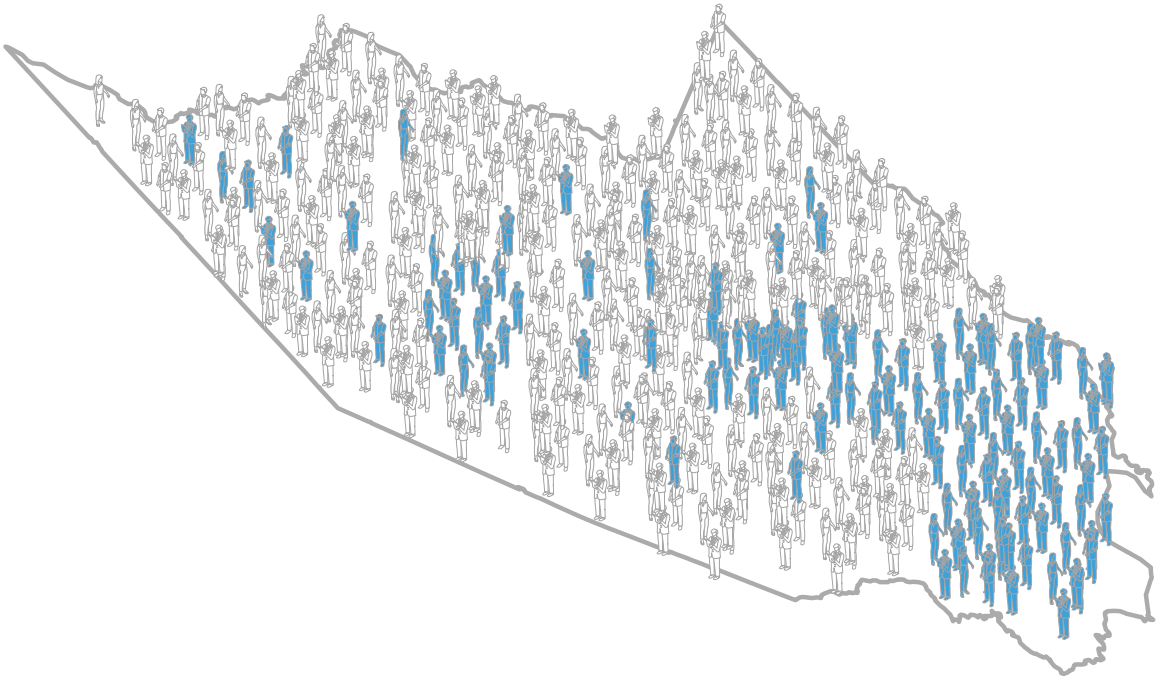
A targeted evacuation plan would require clear criteria. These might include specific geographic areas (like a map of high risk flood areas) as well as age and health criteria. This would need to be planned in advance and well publicized.

Targeted evacuation would also require pre-planned shelters around the region with sufficient capacity to accommodate evacuees.

Finally, targeted evacuation would require a mechanism to evacuate people who cannot evacuate on their own. The State of Texas Emergency Assistance Registry can serve this purpose, with public outreach to encourage people to sign up. With impending flooding, CERT teams could also be used as a way for people to identify which neighbors they have who might be at risk, including those who are not registered. METRO, school districts, and other agencies that have vans or buses could provide transportation to shelters.



Zone-based evacuation from storm surge



Zone-based evacuation from storm surge zones and
targeted evacuation from rainfall flooding

Facilities

Key buildings can be strengthened to protect people who are particularly at risk and provide safe refuges during a storm. Facilities that hold hazardous chemicals pose particular dangers in floods, and better preparation can minimize those. Utilities too, need to be resilient. In hot and humid Houston, electricity can be a lifesaver after storms, and functioning wastewater systems are essential.

2.3

Schools as "Lily Pads"

Elementary schools are evenly distributed geographically and lend themselves to use as shelters for numerous reasons. Equipping existing schools to function as shelters, response hubs, and recovery centers and building new schools on "lily pads" of high ground would allow all inhabitants of that school district a nearby place of refuge.

Contributor

Huitt-Zollars Inc.

Related Ideas

Fundamentals: Public Education on p. x

Information Flyers on p. 11

Watershed Based Development Regulations on p. 37

Resilient Power Supplies on p. 65

Schools serve as an ideal building type for use as a shelter in times of natural disasters, as well as a staging area for relief efforts after a disaster. They are generally evenly distributed across cities and are centrally located within neighborhoods. Schools are familiar to residents and, unlike other common places of refuge, are welcoming of all people within a community, regardless of religion or legal status. Additionally, school districts have staff and infrastructure such as food storage, maintenance, first aid, etc. that make them well suited to stage a refuge and recovery operation, and school buildings are already built to higher standards than typical buildings. While schools have long been used as part of response and recovery, schools that are deliberately designed for such use could be even more effective.

In order to serve as a refuge facility, a building should offer a place for large numbers of people to eat and sleep, functioning restrooms, medical help, communications, and entertainment for children and adults. They should also have office spaces that can be used by response and recovery staff.

The design of school buildings, with facilities like cafeterias and gymnasiums already makes them highly conducive to acting as shelters and relief hubs. Additional rooms and infrastructure could be added to existing and new schools so they are better suited.

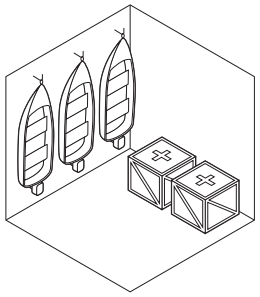
Before storms, schools can be used to store rescue and shelter equipment. During flood events, they can double as shelters, providing helicopter landing facilities, rescue boats, and food. They could even be places where local residents can bring cars to protect them from floodwaters.

Not all schools are suitable for this use. Existing schools should be investigated beforehand to determine their flood risk.

The design of new schools can incorporate additional rooms, resilient power systems, security features, and space for prestaged equipment. Where schools are in floodplains, the buildings and parking lots should be elevated beyond what is required by building codes to ensure that they will remain high and dry.

School districts should not be expected to bear the cost of this secondary function of schools. A statewide program -- equally relevant in parts of the state where the major risks are tornados or wildfires -- could provide funding to cover the increased capital cost

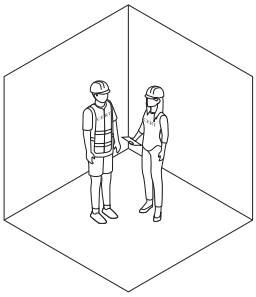
Before



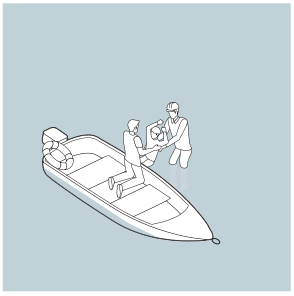
Boats and supplies stored in school

During

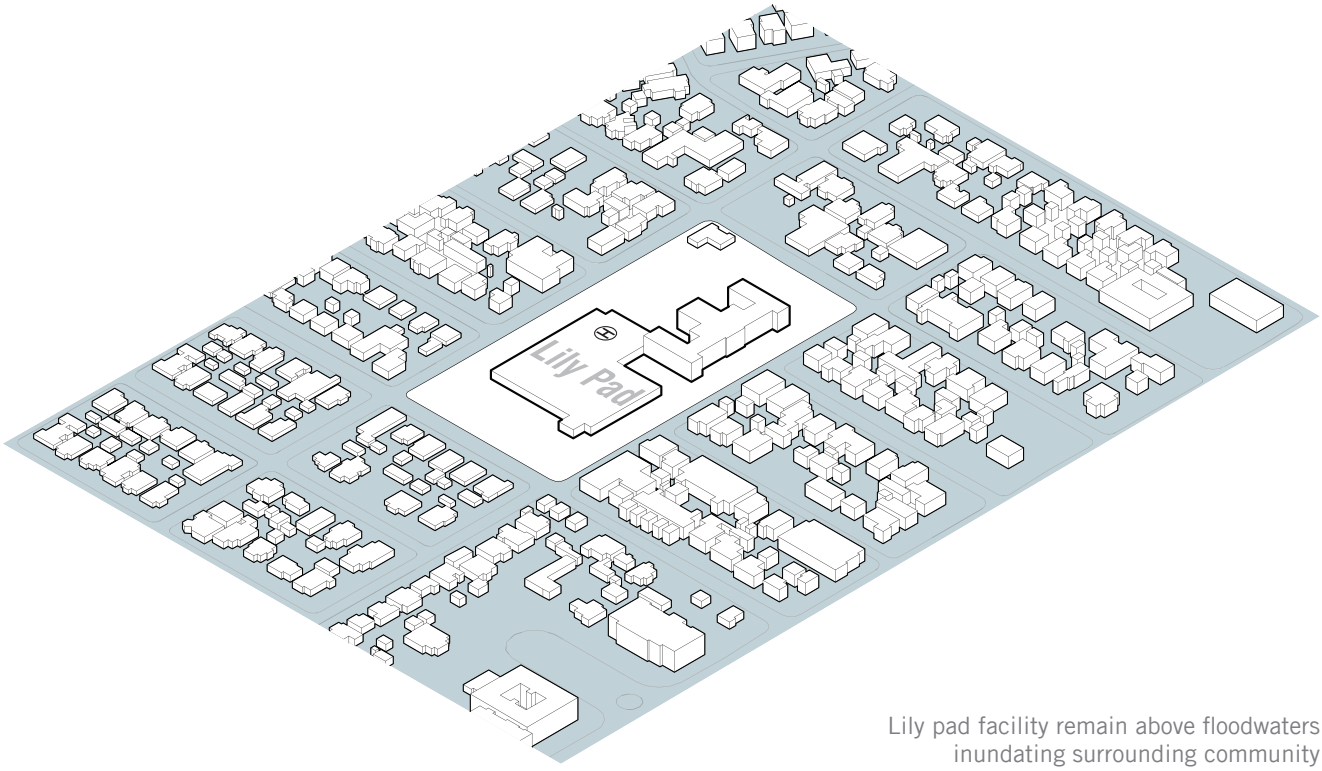
Evacuation of neighborhood prior to storm



CERT uses school as base of operations

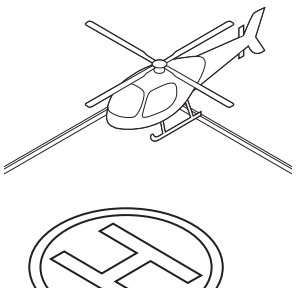


Rescue efforts launched into neighborhood

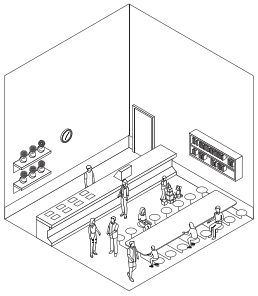


Lily pad facility remain above floodwaters inundating surrounding community

over providing a regular facility and put in place arrangements so that school districts are reimbursed for staff and operational costs after a disaster. This program could begin by taking an inventory of which schools are already located strategically and designed to easily convert into refuge and recovery centers and where new schools are planned.

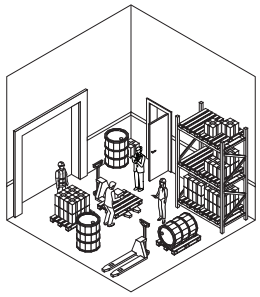


Helicopter landing for emergency response

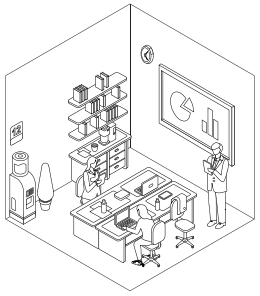


Cafeteria used as shelter

After



Supplies distributed to neighborhood



Case management

2.4

Resilient Senior Living

Senior living facilities need to be designed to minimize risk to inhabitants because evacuation is often not an option for them. This idea outlines some design features that can make senior facilities more resilient.

Contributor

Huitt-Zollars, Inc.

Related Ideas

Watershed Based Development Regulations on p. 37

Resilient Power Supplies on p. 65

One of the indelible images of Harvey was residents of a senior living facility up to their chests in water waiting for help. Senior living facilities are uniquely at risk in disaster; their residents are often mobility impaired and have specific medical and care needs that require staff, running water, and electricity. Furthermore, the residents generally cannot evacuate on their own.

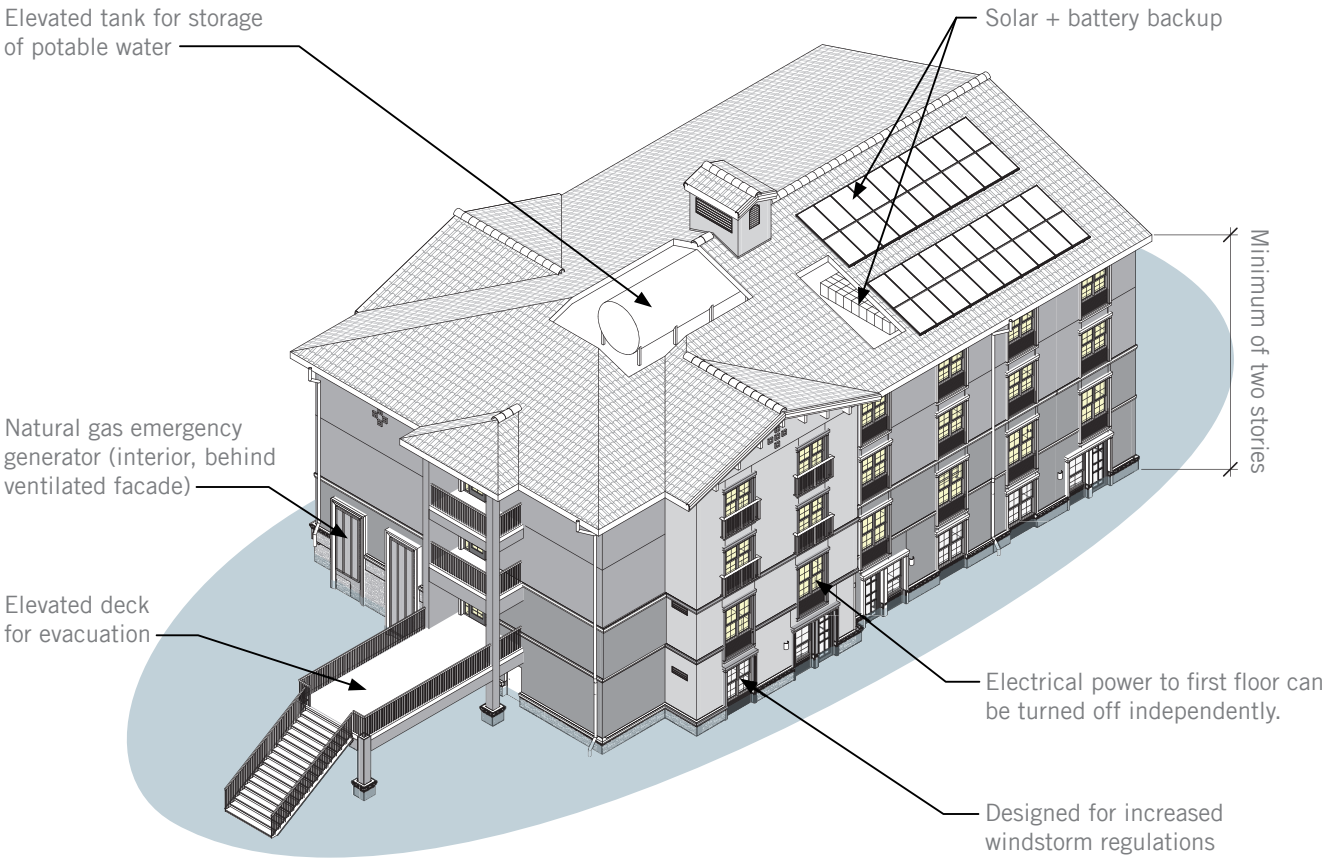
The State of Texas already has specific regulations for senior living facilities in light of these circumstances. These regulations could be expanded to be specific to disasters, and cities and counties could adopt additional rules.

Some regulations to consider include:

- Prohibiting the construction of senior living in 1% AEP (100 year) or 0.2% AEP (500 year) flood zones.
- Requiring all senior living buildings to be 2 stories, with the second floor designed so that all residents can take refuge in it and so that it has access to an elevated deck from which people can be evacuated.
- Requiring an emergency generator, with a main electric panel in an elevated location and the ability to cut off utilities to low-lying parts of the complex. Consider solar + battery installation as discussed in Resilient Power Supplies on p. 65.
- Requiring an elevated tank to store potable water.
- Requiring a reserve food supply of a designated duration.
- Requiring specific emergency equipment to be kept on site.
- Strengthening windstorm regulations.

Evacuation can be risky for senior living residents; they are at risk of health complications from the stress of evacuation, and chartered bus companies have often failed to provide safe and reliable transportation in a storm. An assisted living facility in the right location, with specific provisions to protect its residents in a storm, may be a better solution.

Resources that could be consulted for the further development of this idea include AARP, Baker Ripley's Sheltering Arms, United Way, Area Agency on Aging, Health Departments, and Housing Departments.


Elevated tank for storage of potable water
Solar + battery backup
Minimum of two stories
Natural gas emergency generator (interior, behind ventilated facade)
Elevated deck for evacuation
Electrical power to first floor can be turned off independently.
Designed for increased windstorm regulations

2.5
Hazardous Facilities

Hazardous facilities can add to the flood risk faced by residents, especially already vulnerable populations. To mitigate further potential harm caused by hazardous buildings, they must be located away from flood prone areas and adhere to thorough risk management plans.

Contributor

Bakeyah Williams | Air Alliance Houston

Corey Williams | Air Alliance Houston

Related Ideas

Watershed Based Development Regulations on p. 37

Facilities that store and process hazardous chemicals pose a significant risk to the public in flooding events. Storms can trigger toxic air pollution releases, spill pollutants into floodwater, spread contaminated soils, and even cause catastrophic explosions. All of these risks can be reduced by locating facilities in safer areas, hardening facilities, and ensuring disaster plans are in place.

A comprehensive approach to hazardous facilities would include:

- Land use regulations that prohibit hazardous facilities in flood prone areas, unless there is an unavoidable need for proximity to navigable waterways.
- Building regulations that require facilities to be built to higher resilience to resist floodwaters. During Harvey, the Arkema chemical plant exploded because generators required to maintain power were flooded. Elsewhere, the floating lids of chemical storage tanks flipped over and entire tanks broke loose and floated in the floodwaters.
- A state requirement that all facilities have risk management plans that specifically address flooding, along with regular state review of those plans is needed. Currently, existing hazardous facilities are required to have protocols in place for what to do after an explosion or a chemical release, but no plans are required for prevention of such failures during a storm or required shut-down protocols in advance of predicted severe storms.
- Cleanup plans for Superfund sites that specifically address flooding are also needed

2.6
Resilient Power Supplies

The electric power system is experiencing escalating extreme weather risk. Investment in on-site power generation through combined heat and power, solar + battery and natural gas gensets can significantly decrease this risk.

Contributor

Gavin Dillingham | Houston Advanced Research Center

Related Ideas

Watershed Based Development Regulations on p. 37

Schools as "Lily Pads" on p. 59

Resilient Senior Living on p. 61

Resilient Wastewater Infrastructure on p. 67

Further Reading

[1] nap.edu/catalog/24836/enhancing-the-resilience-of-the-nations-electricity-system

[2] US Blackout Tracker 2017

[3] nap.edu/read/24836/chapter/1

[4] nrel.gov/docs/fy18osti/70679.pdf

[5] energy.gov/sites/prod/files/2013/11/f4/chp_critical_facilities.pdf

[6] betterbuildingssolutioncenter.energy.gov/chp/chp-basics-benefits

[7] doe.icfwebservices.com/chpdb/

[8] nrel.gov/docs/fy18osti/70679.pdf

[9] enchantedrock.com/

[10] Their approach is a significant departure from typical generation approaches where the system is typically sized to provide only power to critical services, thereby limiting a facility's operational capacity.

With increasing intensity and duration of extreme weather events the electric power system is facing greater power outage risks[1]. The grid is susceptible to slow burn, e.g. drought, and fast burn, e.g. hurricanes, weather events.

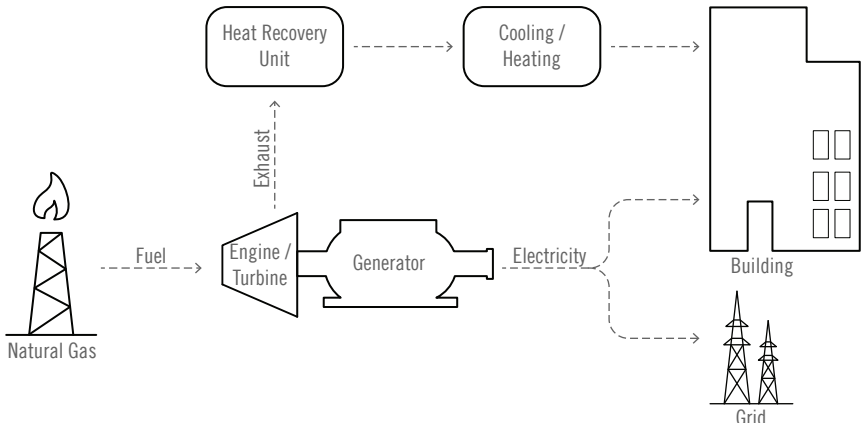
Furthermore, the increasing use of mobile phones, internet, and social media before, during, and after flood events emphasizes the importance of maintaining the functionality of wireless networks. If power to the wireless network had been lost during Hurricane Harvey there would have been major disruptions to the region's ability to communicate and respond. We should not assume the next flood event will not include high winds and the resulting widespread loss of power.

Utilities, public utility commissions and independent system operators understand this risk and are taking steps to harden the grid. A few examples include the roll out of advanced metering infrastructure on the distribution system; building flood walls around and/or elevating electric transformers and substations; and installing dead-end structures on transmission lines[3]. Wireless providers have also installed backup power at many towers to keep the network operating.

Current Solutions

To further alleviate the risk, building owners and operators should consider on-site power systems. Historically, on-site power systems have largely been put in place to meet specific code requirements, such as life-safety codes for hospitals to have back-up generation. In most instances, the systems put in place are the least costly alternative, diesel generators.

The benefit of diesel generators is that they have rapid start-up rates and are relatively inexpensive. The downside is that their reliability can be poor and operational capacity is limited[4], particularly if it is not possible to get additional fuel to the site[5]. A primary issue of a diesel generator is that they may not be tested and maintained properly resulting in poor performance.



A Combined Heat and Power System

New Solutions

Other options do exist that may provide needed resilience. Two options are combined heat and power (CHP) or solar + storage. These systems are able to operate independently from the grid.

Combined Heat and Power (CHP)

CHP operates 24X7 and provides both electricity and thermal services to a facility[6]. The thermal services include heating, domestic hot water, steam, as well as cooling through absorption chillers and steam driven chillers. CHP is widely deployed across the United States and is particularly positioned at critical infrastructure such as hospitals, wastewater treatment plants, university campuses, food processing plants, military bases, data centers, etc. There is also growing use of CHP in the hospitality industry and multi-family complexes.

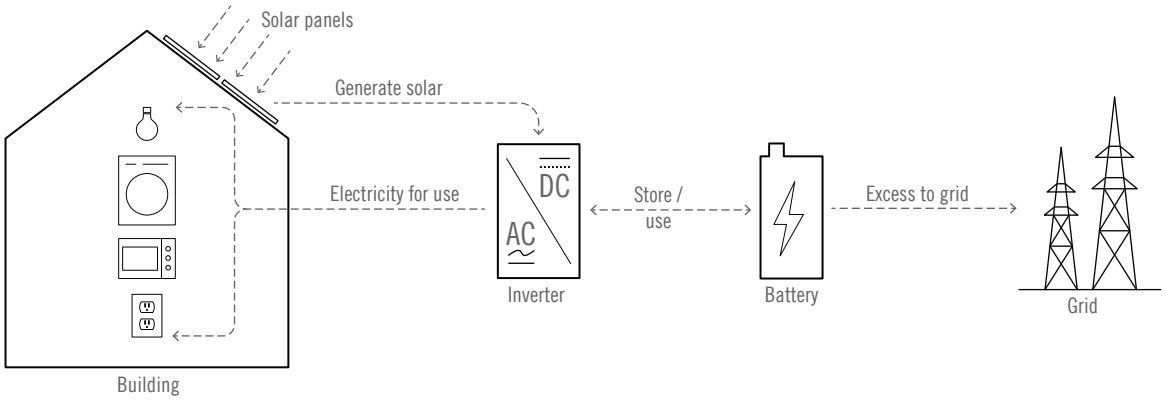
Most CHP plants utilize natural gas as their primary fuel, but there are growing number of plants that use biomass and biogas. The benefit of a natural gas fueled CHP plant is the resilience and reliability of natural gas transmission and distribution. This was demonstrated during Hurricane Harvey where the natural gas system continued to provide fuel to the CHP systems at the University of Texas Medical Branch in Galveston, TECO District Energy, Methodist Hospital in the Texas Medical Center, as well as several other systems along the Gulf Coast[7].

Solar + Battery Storage

Solar photovoltaic (PV) + battery storage work in tandem to provide power to a property. As solar and battery prices continue to decrease, these applications are becoming more common. The benefits of these systems are that they do not require fuel to operate, have no emissions and are relatively easy to maintain. Further, these systems operate 24X7 and can provide power to a property, as well as send power back to the grid, providing a revenue stream for the property and grid services such as frequency regulation[8]. The drawback, although becoming less so, is the cost required to cover all, or at least a significant portion of, the power requirements of a property. A key area of growth for these systems are residential applications. There is a need for solar + battery to be deployed in vulnerable communities that must shelter in place during major power outage events. Solar + battery can significantly increase the passive survivability of a home and allow for the ongoing operation of critical services such as refrigeration and air conditioning.

Potential Business Model

Beyond the two technologies mentioned here, it is important to also point to a successful business model that helps to deploy and maintain resilient power systems, such as that demonstrated by Enchanted Rock[9] at the local HEB grocery stores. One of Enchanted Rock's models is to work with a facility to provide back-up power with a natural gas generator system. Enchanted Rock leases space proximate to the building and installs a natural gas generator that is large enough to provide power to the entire facility[10]. When the power goes off, the site receives power from the Enchanted Rock system. When there is no outage, Enchanted Rock will turn on and off the system to sell power to the grid and provide grid services under certain market conditions. This approach allows for a profitable business model that can provide much needed resiliency to a property and to the grid.



A Solar and Battery Storage System

2.7

Resilient Wastewater Infrastructure

Wastewater infrastructure often needs to be located near waterways by nature, and therefore is at greater risk of flooding. Several precautions can be taken to ensure they pose minimal risk in a flood.

Contributor

Huitt-Zollars, Inc.

Related Ideas

Watershed Based Development Regulations on p. 37

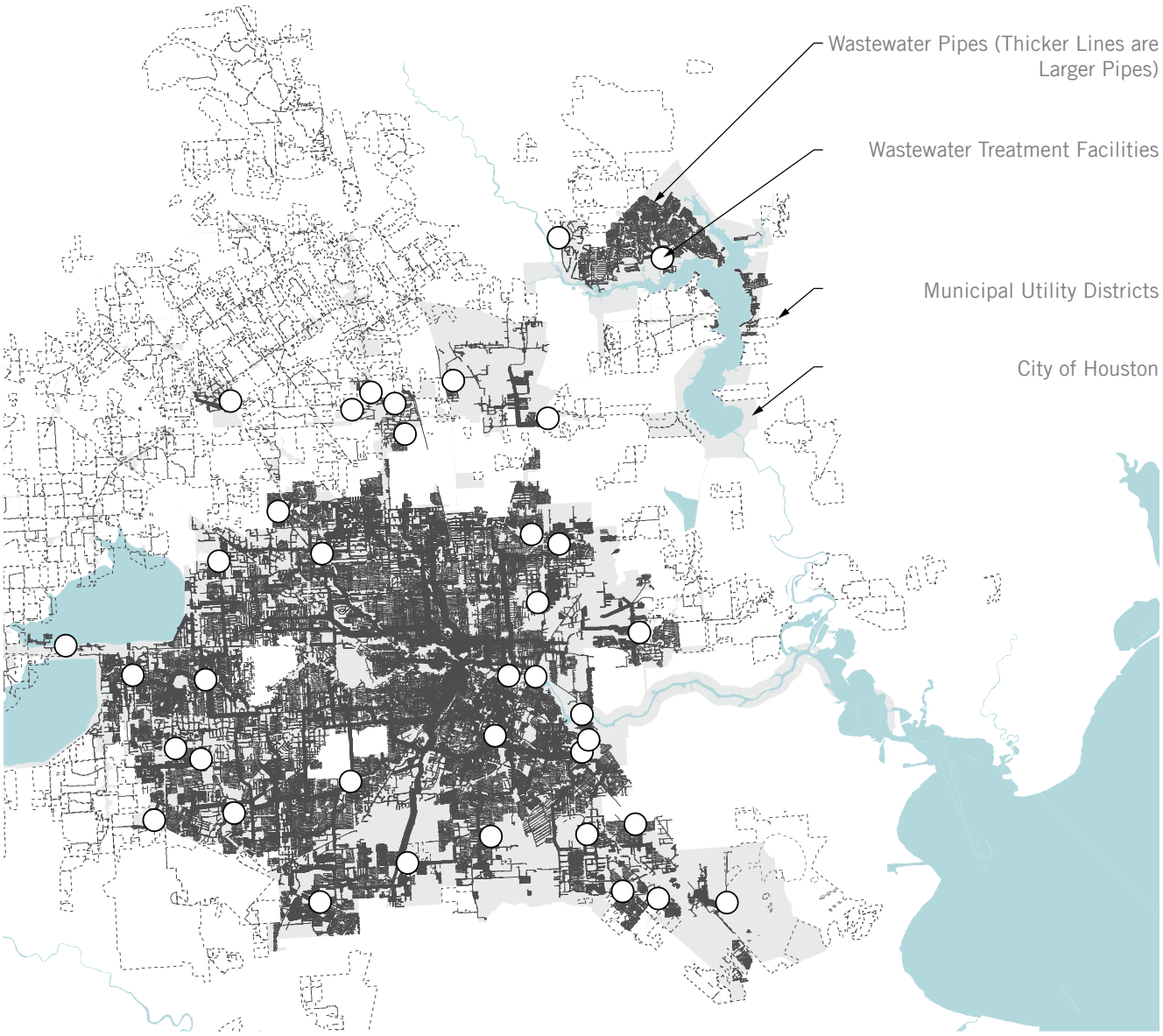
Resilient Power Supplies on p. 65

There are several possible ways wastewater treatment facilities (WWTF) can fail during a flood and endanger residents. Power failure is one of the most common problems, which can cause back ups and overflows. This is often addressed by regulations requiring WWTFs to have backup generators (Refer to Resilient Power Supplies on p. 65). Other types of failures include flooded components, inaccessibility for operating staff, water overflowing from tanks, rainwater overloading wastewater pipes and causing overflows (especially in combined sewer systems, which are not common in Texas), and failed lift stations. Additionally, while cities operate larger WWTFs, several Municipal Utility Districts operate individual smaller ones. While the volume in those is far less, there tends to be worse maintenance and upkeep conditions, increasing risk to proximate neighborhoods.

In Texas, an estimated 61 public-water systems and 40 WWTFs were inoperable or destroyed during Harvey. Thirty-one million gallons of raw sewage spilled across Texas. TCEQ responded swiftly in setting up staff from all over Texas to help in all regions as needed, monitoring and assessing damage and air quality. However, more can be done to reduce damages in a future flood.

WWTFs often need to be close to waterways and are thus located in floodplains, with elevated flood risk. However, there are several strategies that can reduce this risk. The EPA proposes a range of solutions, but solutions need to be catered individually to each region and its unique issues. To this end, the EPA offers a Creating Resilient Water Utilities (CRWU) program that analyzes future risk in a region, conducts planning workshops, and creates targeted long-term strategies. The Houston area could benefit from such an intensive adaptation planning process. Possible strategies include, but are not limited to:

- Back-up power for facilities and pump stations
- Elevating electrical equipment
- Floodproofing doors to protect electrical infrastructure
- Improved watershed management
- Emergency response and recovery plans
- Code changes for things like downspout connections, riparian setbacks, management practices
- Green infrastructure throughout watershed to capture stormwater flows
- Storage for peak flow diversion to increase capacity
- Integrating weather forecast monitoring into operations
- Berms to mitigate storm surge flooding risks
- Dewatering and temporary pumping equipment
- De-centralizing treatment facilities as a long-range option to mitigate the size of the facility and potential impacts from failure



City of Houston and Surrounding Area Wastewater Treatment Network

Transportation

Even during a storm, first responders and other need to get around. We can plan to keep essential transportation links open and minimize the risk of people in cars being killed by floodwaters.

2.8
Key Road Links

Elevating key road links can provide continued access for people whose neighborhoods may not flood but the road infrastructure into and the surrounding neighborhoods do.

Contributor

Huitt Zollars, Inc.

Rice University SSPEED Center

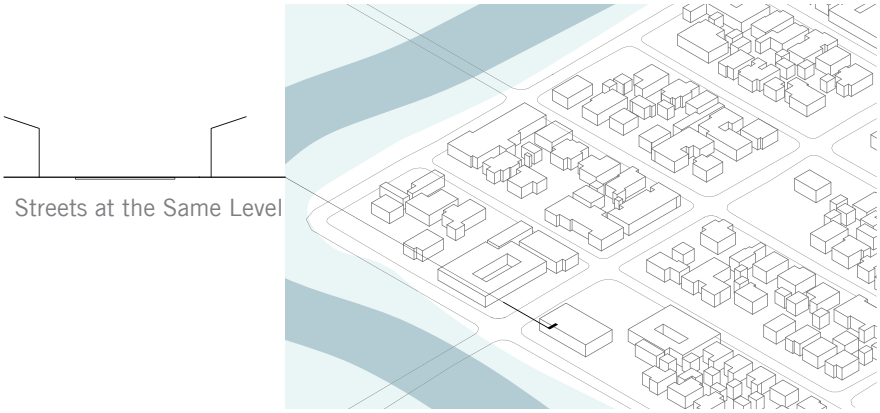
Related Ideas

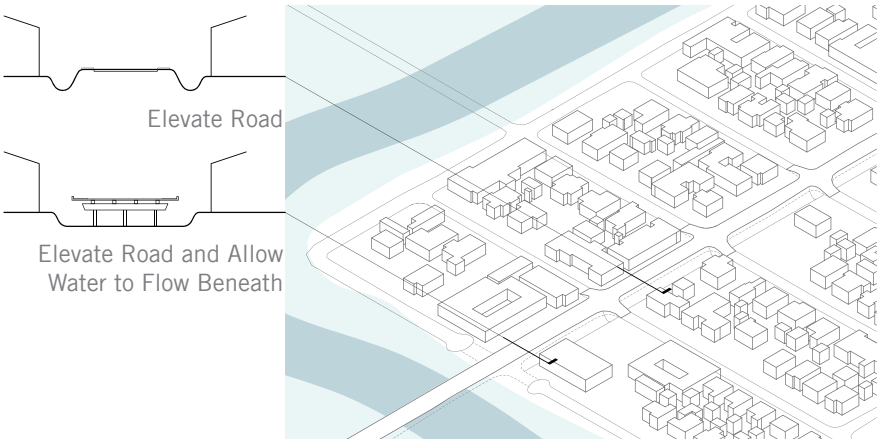
Structural Projects on p. 33

Roadway flooding can cause neighborhoods to become isolated during flood events. Some neighborhoods do not flood but are surrounded by areas that do so residents have no way to get in or out of their neighborhood.

An analysis of which neighborhoods become isolated during flood events can lead to the identification of key roadways that should be elevated. A map of key roadways network could be developed, and these roads can be rebuilt with raised fill or a bridge. Both of these methods, especially fill, will affect drainage across adjacent sites. Any impacts to the floodplain must be studied carefully and mitigated.

Additionally, rebuilding key roadways also presents an opportunity to incorporate drainage improvements, underground and on the surface. To assist with long-term planning, the locations of segments requiring such improvement could be identified on the City of Houston's Major Thoroughfare Plan and similar strategic planning documents for other jurisdictions.





All Streets at the Same Level

Key Road Links Elevated

2.9

Automatic Underpass Shutdowns

Flood sensors can be placed that trigger automatic underpass shutdowns to help people navigate more safely during flood events.

Contributor

Rice University SSPEED Center

Related Ideas

Flood Warning and Alert Systems on p. 53

Two out of three flood-related deaths come from people driving in floodwaters. One way to reduce this risk is to provide better warning at flood-prone underpasses and low bridges.

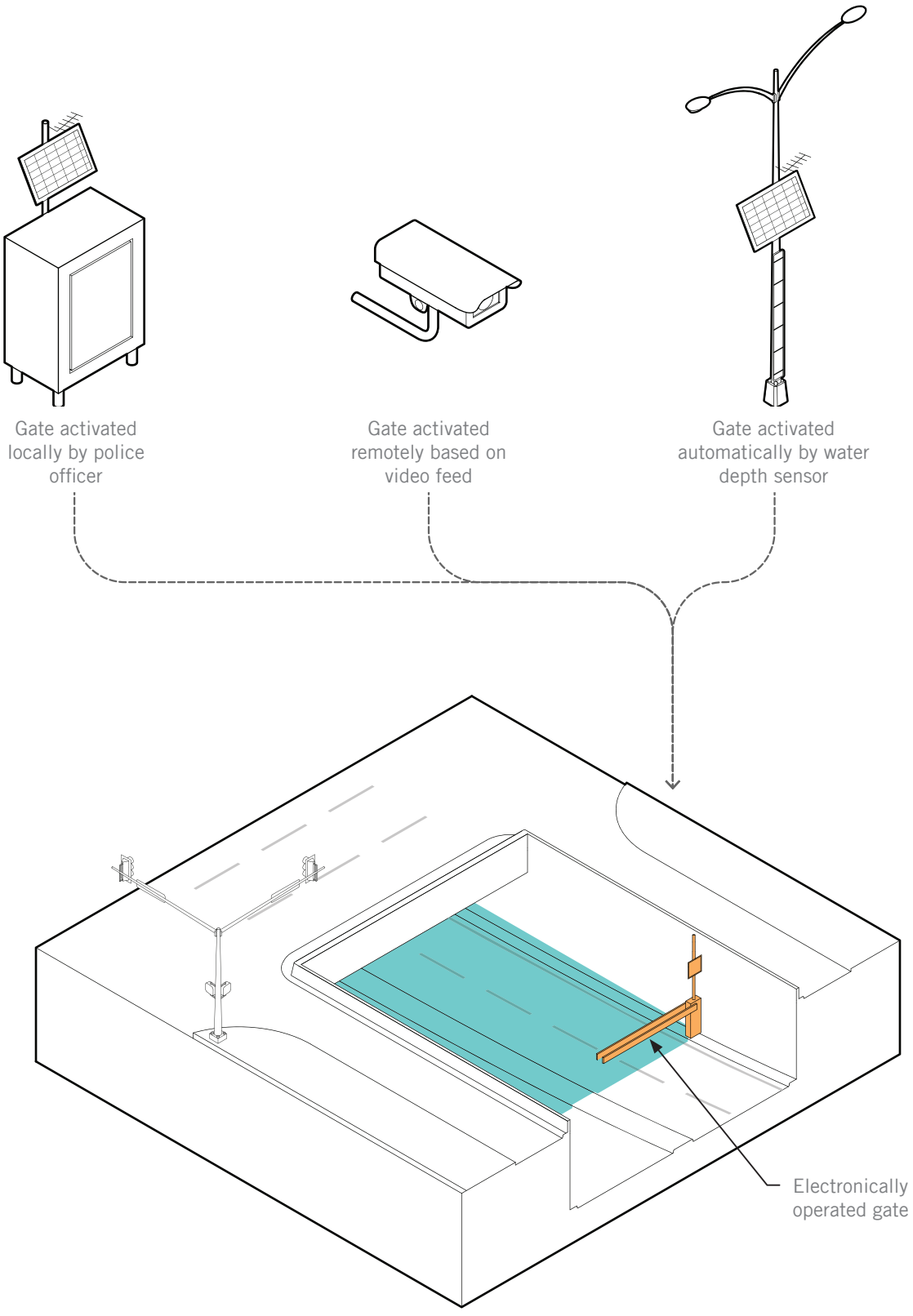
The City of Houston recently partnered with TxDOT and Harris County to win a federal grant to install flood warning systems at 40 locations for a total of $14.4 million. Sensors installed at flood-prone locations will trigger warning lights at the site and send warnings to Transtar so they can be reflected in regional traffic maps. This builds on a previous City of Houston flood underpass flood warning system.

There are many additional locations in the region where such warning systems could help save lives, guide first responders and relief workers to the best paths, and help people navigate through the city during unexpected rainfalls.

This is an area where research and development could bring down costs. A small sealed self-contained sensor, which is solar powered, linked to mobile data networks that could be installed at the base of a streetlight and deployed at hundreds or thousands of locations, could provide better information during a flood event. Cameras like those already used on freeways may be adaptable as flood sensors with image processing software. A sensor installed at existing traffic signals could trigger those signals in a flood event.

In addition to helping during an event, these sensors could help us better understand flooding to better direct flood control and infrastructure funding and adjust the hydrological models that are used to permit new development. There are 171 stream gages along Harris County's bayous and major tributaries; this leaves large gaps along those streams (particularly when some gages fail during a disaster) and no measures of flood depth away from the bayous.

In some locations, it may be wise to supplement flood warning systems with gates. On freeways in particular, cars backing up from flooded areas further increase the danger, adding a risk of collision to the risk of floodwaters. Warning signs and gates located in advance of frequently flooded locations, where there is opportunity to exit, would be valuable.


Gate activated locally by police officer
Gate activated remotely based on video feed
Gate activated automatically by water depth sensor
Electronically operated gate

Other Ideas

These concepts emerged from conversations Consortium Members have had among themselves and with external stakeholders. While Consortium members do not have the appropriate expertise to develop conclusions, we felt it was worthwhile to surface them.

Emergency Contact Management

A database of emergency contacts should be maintained and easily available to the general public.

Emergency contact information is not always easily available to residents; they have to actively search for specific types of emergencies and find the appropriate contact person. Mobile apps can ensure easy access to information for residents who own a cellphone but may not have access to a computer or reliable internet services. Emergency departments can also feed data into existing apps, sending shelter location information to mapping apps, for example, instead of creating their own and hoping people will download and use them. A website could be created where residents are able to type in their home address and are given a list of contacts for various emergencies. This tool can be publicized in community meetings and in public service announcements in advance of known flood events. The list of emergency contacts for each address can also be printed and provided during home sales, rental contract renewals, and during hurricane season. By providing residents with accurate and relevant emergency management resources and contacts; residents are empowered to make the best decisions in a timely fashion that will aide with minimizing loss and maximizing safety.

Safeguarding Key Possessions

We obviously want to keep people safe in a flood, but objects matter, too. Some things are easily replaceable; some are not. Keeping the right things dry can make recovery – emotional, physical, and financial – easier.

Every household has some irreplaceable objects that are more precious than others, like legal papers, important documents, and sentimental items. Even if a house floods, these items can be protected with the right preparation – consolidating them so they are easy to evacuate, or keeping them in a waterproof bag or box. Public agencies could help by encouraging residents to plan or even by making dry bags available through public distribution points or retailers.

Vehicles are also critical – people depend on cars for their daily needs, but cars are often parked in streets and other low areas that are susceptible to flooding. A public-private program to open up elevated parking locations, like garages and lots on higher ground, in advance of a flood could give people a place to evacuate vehicles to. This could also protect tools that people depend on to make a living, which could be loaded into a truck. These can be bulky, and thus hard to protect in place. Such a program would require provisions -- perhaps state legislation -- to protect garage and parking lot owners from liability, and theft looting at these locations would have to be considered.

Predetermined Refuge Shelters

Shelters are a key part of immediate response to a storm. They need to be ready to accept displaced residents as they evacuate before a storm or leave flooded homes after one. Much of this, though, is determined “on the fly” as a storm approaches. Even where the same buildings are used over and over again, decisions and arrangements are made from scratch, or based on individual staff experience rather than procedures.

A region-wide program to identify possible shelters, designate contact people for each, and put financial, logistical, and legal arrangements in place beforehand would make opening shelters much easier. Based on the scale and location of a disaster, emergency management offices would pick which shelters to use and activate the predetermined arrangements. These arrangements will need to extend outside the region to allow for places to evacuate to.

Prestaged Emergency Equipment

Several entities offer a list of tools and equipment, which, when strategically located around the region, can allow emergency response teams to be most effective.

Emergency equipment must be strategically located and well maintained so it is readily available to emergency response teams. Equipment ranges from evenly distributed large vehicles and boats across the region to medical supplies at refuge centers.

While some of the equipment needs to be located at a responder's residence, others must be located at refuge centers. CERT and FEMA provide lists of supplies that can be used for rescue. Shared equipment needs to be restaged in accessible locations so responders know where to find them and how to use them:

- High-clearance vehicles
- Boats
- Generators

Community Emergency Response Teams (CERT)

Community Emergency Response Teams (CERT) is a national program that trains people to respond in various emergencies. Harris County and City of Houston have made significant efforts to carry out trainings in various neighborhoods across the region. CERT efforts can be combined with and build upon Harris County Citizen Corps to ensure every super neighborhood has a response team ready to mobilize. These teams should be identified to community residents so they know who to call and where to find help when needed.

Unifying training efforts at a centralized headquarters with quarterly convenings could ensure that volunteers are equipped with the knowledge and tools they need to be most helpful in their communities. Local buildings of refuge (refer ro Schools as "Lily Pads" on p. 59) can be used as staging centers for practice.

Plugging CERT efforts into 211 and 311 calls for help would mean they have real-time information on where help is needed. Other existing programs should also be tied together to a unified rescue approach, such as State of Texas Emergency Assistance Registry (STEAR). People who may need extra assistance during disasters are able to register with STEAR and this information should be readily available to CERT volunteers. Neighborhood Ready is another program, with a shorter training period that can be offered as an alternative (90-minute training instead of CERT's 8 weeks) for people who want to volunteer but cannot commit to long training times.

Proactive efforts to recruit and train people throughout the county is critical and can be furthered by offering a stipend to attend trainings. This would, of course, require additional funding sources. Creating a human infrastructure within each community will help them deploy resources and aid most efficiently.

Hospitals and Clinics

Smaller clinics are often not nearly as well prepared as major hospitals for flood events, and some clinics are as essential to human life as hospitals. Currently, clinics are not required to have resiliency plans in place. The result of this was most poignant with dialysis services during and after Hurricane Harvey. There are nearly 8,000 dialysis-dependent patients in Harris County and the gap in operations due to flooding left many without access to dialysis services. Clinics closed because they were flooded; staff was unable to reach them, there were no emergency water and power supplies in place; and the private operators simply had no contingency plans. Some operators did much better than others, but any drop in capacity affects patients. There are other similar services that suffer from discontinuity due to flooding.

Strengthened state regulations for clinics that treat chronic diseases could require backup power and water and contingency plans. Even with better facilities, it is likely that in a major disaster some clinics will be inoperable. Addressing this requires a county-wide approach to planning for redistribution of services in extreme weather events. Each patient should have complete knowledge of their options for their needed services by proximity. There should be thoroughly thought-out and clearly communicated plans for what to do at various stages of an emergency and during various types of events.

3 RETURN PEOPLE TO NORMALCY

Resiliency means that when a storm occurs and resident's homes or businesses have been flooded, they are able to bring their life back to normal - physically, financially, and emotionally - as soon as possible.

What can we do now, before the storm, to prepare a smooth and comprehensive recovery?

Housing

Recovery Services

Other Ideas

Housing

People whose homes flood in a storm need repairs or a new place to live quickly so they can get back to normal. Flood insurance helps, but not everyone has it. Buyouts can be a good solution to allowing people to relocate and reducing future risk, but they come too slowly. Better systems can get people in a new home quickly.

3.1
Planning For Buyouts

Thorough planning can result in a buyout process that is more efficient and impactful. Having a single entity in charge, local funding available to spend promptly, probabilistic risk maps, a comprehensive plan, and proactive community meetings to create buy-in can significantly improve the buyout process.

Contributor

Huitt-Zollars, Inc.

Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Susan Rogers | University of Houston Hines College of Architecture + Design, Community Design Resource Center

Kyle Shelton | Rice University Kinder Institute for Urban Research

Related Ideas

Probabilistic Risk Maps on p. 7

Home Exchange on p. 17

Rapid Buyouts on p. 83

The buyout process can be slow and exhausting, and often leads to the "checkerboard effect," whereby some properties in a neighborhood have been brought out, and others have not, which requires continued public services while not being particularly useful for future flood mitigation purposes. Buyouts timed immediately following a flood event would benefit both impacted residents and taxpayers. That is, quick resolution allows buyout volunteers to move on with their lives sooner, while preventing a situation whereby a homeowner repairs the flooded home using public flood insurance, then later accepts a buyout.

A recent analysis of the national FEMA database found that most buyouts happened in neighborhoods that were over 85% white and non-Hispanic (Robert Benincasa, National Public Radio, March 5, 2019). In Greater Houston, buyout programs have failed to thrive in low-income neighborhoods because the lack of affordable housing leaves residents with few options. Solving these and other equity problems will require sustained effort through all phases of mitigation planning and implementation, as the problems exist at all levels.

Substantial prior planning would benefit the buyout process in the Houston area. Taking the time required to plan now will help speed up the buyout process in the long-term. Several steps can be taken to make buyouts more efficient and impactful. Those include:

Single Coordinating Entity

Appoint one regional entity responsible for overseeing all area buyouts to allow a more holistic approach to planning for buyouts. Since floods do not respect jurisdictional boundaries, the regional entity will be able to plan across watersheds. The Milwaukee Metropolitan Sewerage District is an example of a regional entity that plans across 29 municipalities. Already, the City of Houston and HCFCD work together on many buyout efforts.

Local Funding

Implement a tax or a fee to grant this entity greater flexibility and autonomy in spending rather than relying solely on federal funds, which come with strings attached. Having local funds also means that buyouts do not have to happen as a reaction to a disaster, but can be a preventive measure. Charlotte-Mecklenburg County in North Carolina, for example, uses a stormwater fee to match federal buyout funds. Authorization also could be provided for existing tax funds or drainage fees to be used on buyouts. The City of Houston could seek voter approval to allow its drainage fee funds to be used for buyouts.

Risk Maps

Create new maps that build upon FEMA maps with actual risk data to help the continuing process of identifying priority buyout areas. These maps should show depths of flooding and identify high, medium, and low flood risk areas that account for flood mitigation infrastructure. Risk maps should be probabilistic rather than deterministic, derived from hydrodynamic, meteorological, geotechnical, and other available models. Higher risk areas should correspond with higher priority buyout areas. These new maps

should be interactive and available to the public. New Orleans provides a great example of risk maps created after Hurricane Katrina.

Hazard Mitigation Plan

Create a cross-jurisdiction, comprehensive plan across the San Jacinto river and all of Harris County's tributary bayous, that uses appraisal data and FEMA loss data to identify homes in high, medium, and low risk areas. It could also provide risk reduction recommendations for each at-risk property, such as elevations, floodproofing, or buyouts for homes. Jurisdictions could also provide a cost-benefit analysis of the options, and have a plan for the best uses of the acquired land.

Proactive Outreach

Robust community engagement throughout the process is recommended when considering buyouts for a broader community. Early communication and ongoing input from the community members and property owners into the design of the buyout process and how to achieve community, public sector and public safety goals can help to yield better outcomes for all parties. This could entail community meetings to educate the public on the risk levels of their community, offer solutions, and receive community feedback. Strategies for the purchased land would be distributed regularly, including renderings and plans of the proposals. These efforts will motivate some people to volunteer for buyouts before the next storm causes their home to flood, as well as create buy-in for communities who do not wish to see their neighborhood deteriorate due to neglected vacant property.

Buyout Comprehensive Plan for Future of Properties

3.2
Rapid Buyouts

Pre-approvals and planning ahead for funding can significantly reduce the time it takes to process a buyout.

Contributor

Huitt-Zollars, Inc.

Susan Rogers | University of Houston Hines College of Architecture + Design, Community Design Resource Center

Kyle Shelton | Rice University Kinder Institute for Urban Research

Related Ideas

Fundamentals: Public Education on p. x

Home Exchange on p. 17

Planning For Buyouts on p. 81

Rapid Buyouts

Being able to execute buyouts immediately after a flood event benefits both homeowners and taxpayers. People whose homes flooded are able to move on with their lives more quickly, rather than waiting a year or more after the flood.

In addition to allowing people to recover quickly, rapid buyouts reduce costs. If a homeowner has flood insurance, the flood insurance payout could become part of the buyout funding. With the current process, impacted residents receive flood insurance money to repair their home, then are bought out after the repairs are complete, at which point the taxpayers are paying again to buy out the repaired home.

Prompt resolution allows buyout volunteers to move on with their lives. Buying out homes immediately after a disaster may increase participation and decrease the "checkerboard effect."

Substantial planning is necessary to improve the buyout process in the Houston area. Taking the time required to plan prior to a flood event will accelerate the buyout process in the aftermath. Several steps can be taken to make buyouts efficient and impactful beyond removing people from harm's way.

How This Might Work

Local jurisdictions identify target buyout areas and use appraisal data and FEMA loss data to identify homes that would qualify for a buyout if flooded again.

The state or federal government reviews and pre-approves the list, indicating that the listed homes would be eligible for buyouts if flooded again. Thus, much of the paperwork required to document and approve a buyout is in place before the disaster occurs.

The state or local jurisdiction sets aside funds and/or seeks pre-approval of federal funds.

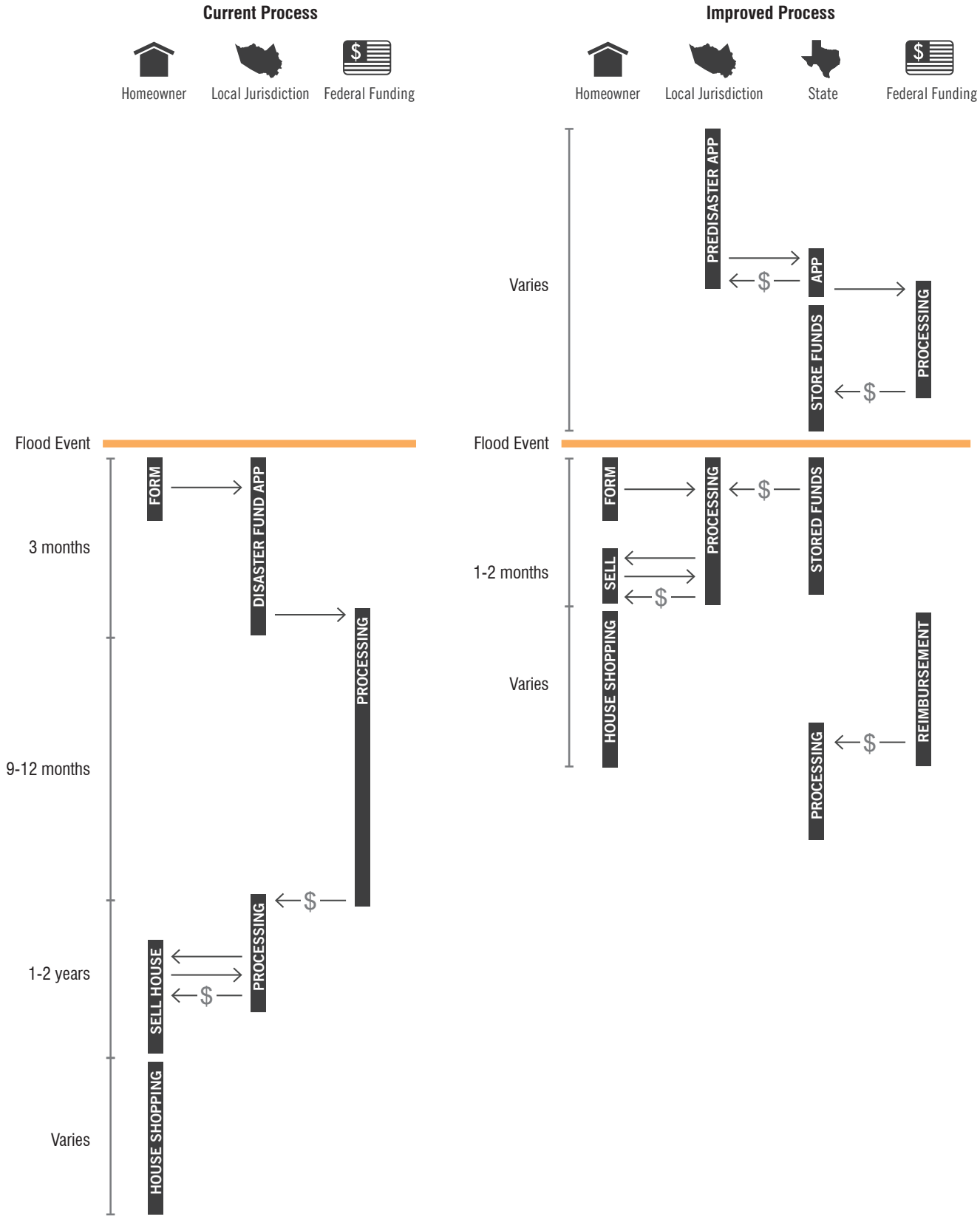
When a disaster occurs, the local agency asks for volunteers for buyouts and homeowners who are interested apply.

The agency responds quickly if that home was on the pre-approved list, eliminating the wait for an approval process.

The state advances the funds, eliminating the wait for federal funds to be appropriated and released.

The home is bought out promptly after the disaster.

The state may be reimbursed with federal or local dollars.


Current Process
Homeowner
Local Jurisdiction
Federal Funding
Flood Event
FORM
DISASTER FUND APP
PROCESSING
SELL HOUSE
PROCESSING
HOUSE SHOPPING
3 months
9-12 months
1-2 years
Varies
Improved Process
Homeowner
Local Jurisdiction
State
Federal Funding
PREDISASTER APP
APP
PROCESSING
STORE FUNDS
Varies
Flood Event
FORM
PROCESSING
STORED FUNDS
SELL
HOUSE SHOPPING
REIMBURSEMENT
PROCESSING
1-2 months
Varies

3.3
Flood Insurance

Purchasing flood insurance will help impacted households protect against financial loss and recover their homes and possessions more quickly.

Contributor

Sam Brody | Texas A&M University-Galveston, Center for Texas Beaches and Shores

Related Ideas

Home Exchange on p. 17

Home Reconstruction on p. 19

Common Intake and Coordination Systems on p. 89

Case Managers on p. 91

Further Reading

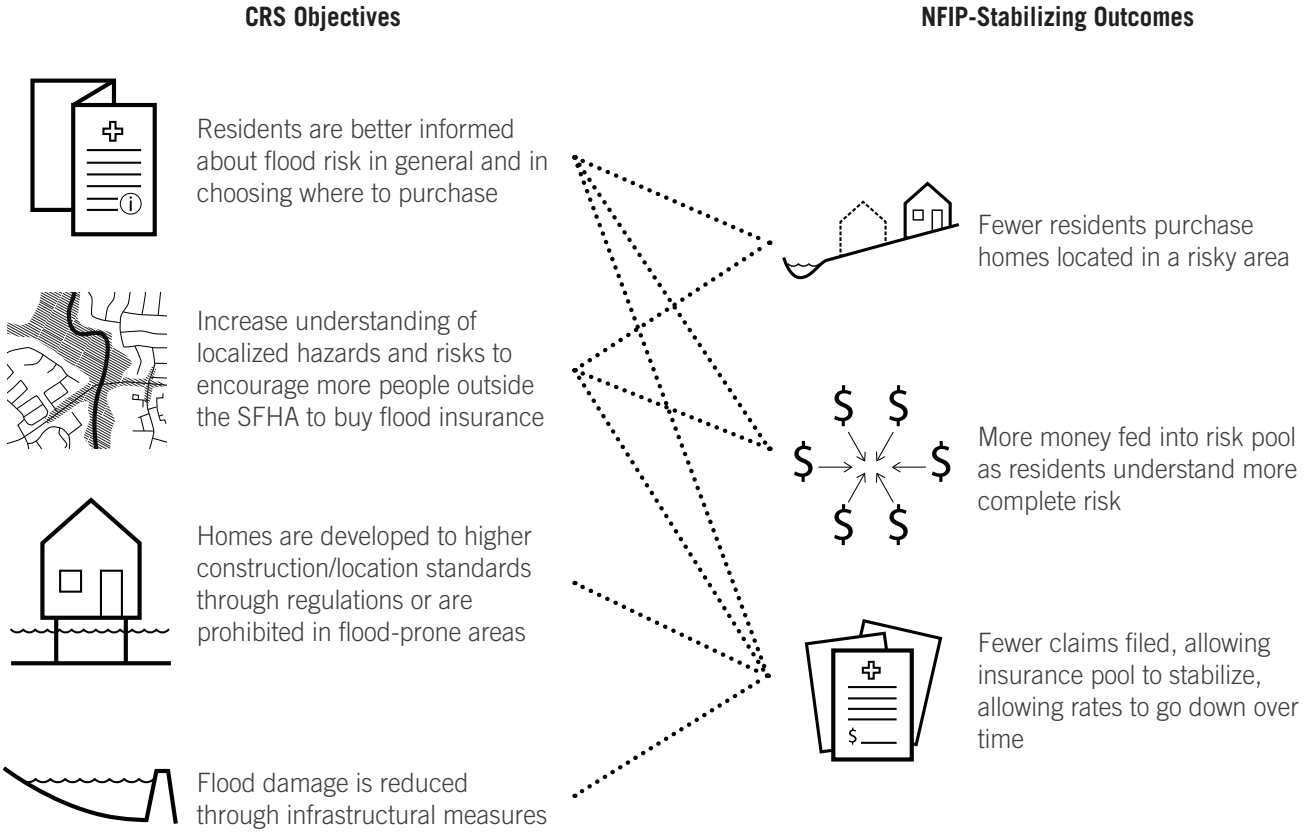
Briefing Document 3: Flood Regulations

While purchasing flood insurance will not prevent loss of property, it will help buffer against adverse financial impacts and speed household recovery after a storm event. The best way to obtain insurance is through the National Flood Insurance Program (NFIP), which provides affordable insurance to property owners, renters, and businesses in participating communities. The maximum coverage for residences is $250,000 for the building and $100,000 for contents. Those with flood insurance consequently experience less impact, while the uninsured take on the full impacts of a flood. Despite ongoing changes and challenges with the National Flood Insurance Program, it remains one of the best options for reducing the personal financial consequences of a flood.

As of March 2018, 682,971 NFIP policies were in force in Texas, insuring $188 billion in assets. Federal flood insurance penetration rates (number of policies divided by the number of structures) are especially low in Texas and the U.S., hovering around 50%.It is important to note that those living outside of the FEMA floodplain can still be at risk. In Harris County, about 38% of flood insurance claims made between 1976 and 2014 were for properties outside the floodplain. This percentage was much higher for structures impacted by Hurricane Harvey.

However, many homeowners who are at risk of flooding do not have coverage. This type of insurance is required for structures located in the FEMA-defined 1% AEP (100 year) floodplain and have federally backed mortgages. Homeowners who do not have a mortgage (such as those who inherited their home, or have paid it off) are not required to have coverage and often do not. Homeowners living outside designated floodplains are not required to buy flood insurance but are strongly encouraged to do so, especially given the affordable rates offered through the NFIP. Local jurisdictions could take steps to promote flood insurance coverage.

- One way to increase coverage is to reduce rates. Harris County and City of Houston already participate in the Community Rating System (CRS), an incentive program that rewards and encourages communities who take substantive steps to limit flood risk by providing discounted insurance rates. Refer to Briefing Document 3: Flood Regulations for more information on CRS. The CRS discounts can incentivize more people to purchase flood insurance. The lower the class number (1-10), the higher the discount rate given to homeowners. Harris County is currently class 7, Houston is 5. As such, taking more measures under the CRS criteria can lower the class each jurisdiction is in and allow residents greater discounts.
- Another way to increase coverage is public awareness. As of Spring 2019, Harris County reports planning a billboard campaign to encourage residents to buy flood insurance. When Hurricane Harvey hit, 83% of Harris County's 1.4 million buildings lacked flood insurance.
- Flood insurance could also be part of the home-buying process. State law could require that homebuyers in flood prone



counties, regardless of the location of their home, be made aware of the benefits of flood insurance.

- At a federal level, rate structures could be changed to make insurance more affordable for those with low risk. This would likely require Congressional action.
- Local elected officials could advocate to make sure the program remains solvent. The recent shift to risk-based actuarial insurance rates under the Biggert-Waters Flood Insurance Reform Act of 2012 and the Grimm-Waters Homeowner Insurance Affordability Act of 2014 will have significant but unquantified impacts on residents. As flood events become stronger and more frequent, FEMA is now required to adjust its flood maps more frequently to reflect increasing risk, and flood insurance rates are scheduled to rise as the risk of flooding increases. Properties below the base flood elevation (BFE), grandfathered properties, properties built before the first map (pre-FIRM), currently subsidized properties, and business properties will see larger increases. Unaddressed in these reforms is the exemption from mandatory flood insurance requirements for structures built behind levees—so-called residual risk structures. The exemption could encourage further shoreline development. Also unaddressed is the requirement that FEMA only use historic flood data to establish flood insurance rates. This practice ignores expected increases in flood risk from climate change.

The impact of flooding, including the recent flooding in Houston, is mediated through flood insurance. Those with flood insurance can have up to $250,000 of flood-related damages covered and consequently experience less impact, while the uninsured take on the full impacts of a flood. Despite ongoing changes and challenges with the National Flood Insurance Program, it remains one of the best options for reducing the personal financial consequences of a flood.

Recovery Services

After the flood, people whose homes, belongs, or businesses were destroyed find themselves confronting a web of different programs and agencies. The process of recording can be daunting for anyone, especially after the trauma of a flood; it is particular daunting for residents with limited resources, limited knowledge of the system, or limited English proficiency. Streamlining the systems, connecting them between agencies, and filling gaps can help people get back to normal. Most importantly, preparing before a storm so that these systems can ramp up quickly can minimize the waiting and backlogs that Harvey victims have experience.

3.4

Common Intake and Coordination Systems

A system which aggregates available social services and nonprofit programs, and uses resident information from a single universal application, could serve to more effectively distribute benefits throughout an affected community and eliminate the burden on residents to navigate multiple services and programs.

Contributor

Huitt-Zollars, Inc.

Amanda Timm | Local Initiatives Support Corporation

Related Ideas

Fundamentals: Public Education on p. x

Case Managers on p. 91

Navigating the wide variety of social services and nonprofit programs can be difficult enough for Houston-area families outside of a disaster. In the aftermath of a disaster, this can be exacerbated by the spike in need and the related increases in funds and new programs. These programs often have differing eligibility requirements, geographic boundaries, and requisite documentation.

Typically, affected individuals and their case managers learn about a few programs within a particular service area and those programs get inundated with requests and applications. There is often no transparency regarding those programs' capacities, which can lead to very long wait lists. Often, other programs, with more funding and capacity than they have clients may be overlooked or under-marketed.

Consolidating intake for particular services into common application and coordination systems can significantly simplify the process for anyone seeking assistance and services post-disaster. The idea is that the system pools together a database of all available services through the local government, nonprofits or other agencies in one location and uses data from the common intake forms to match individuals to services. A specific agency contact would be provided to the individual in need. Web and phone applications could be created to provide multiple access points to this intake system. It could be a one-stop-shop for people in need.

While this proposal would facilitate distribution of benefits and make the process much more convenient for many residents, it must also address the concerns of every resident. Managing privacy and assuring security of information for clients is vitally important. Service providers have found that many immigrants are reluctant to seek services if they know their information will be provided to the government. A well designed system that allows for residents to control how and to whom their information is shared will be critical for this idea's success.

For example, Harvey Home Connect (HHC), created by the Greater Houston Community Foundation and managed by SBP in the wake of Hurricane Harvey, matches eligible homeowners with home repair services after a disaster. HHC has twelve partner agencies operating across Harris County. Through the implementation of this system, HHC and its partner agencies were able to significantly increase customer satisfaction (for both homeowners and disaster case managers), increase throughput (percent of clients starting applications that receive home repairs) from 25% to 52%, and decrease the time it takes for a client to receive home repairs. HHC and its partners are on track to repair over 1000 homes. In addition, a system-level view allowed HHC and its partners to create new processes and interventions to help homeowners with ownership and mortgage delinquency issues, to ensure home repair and preservation.

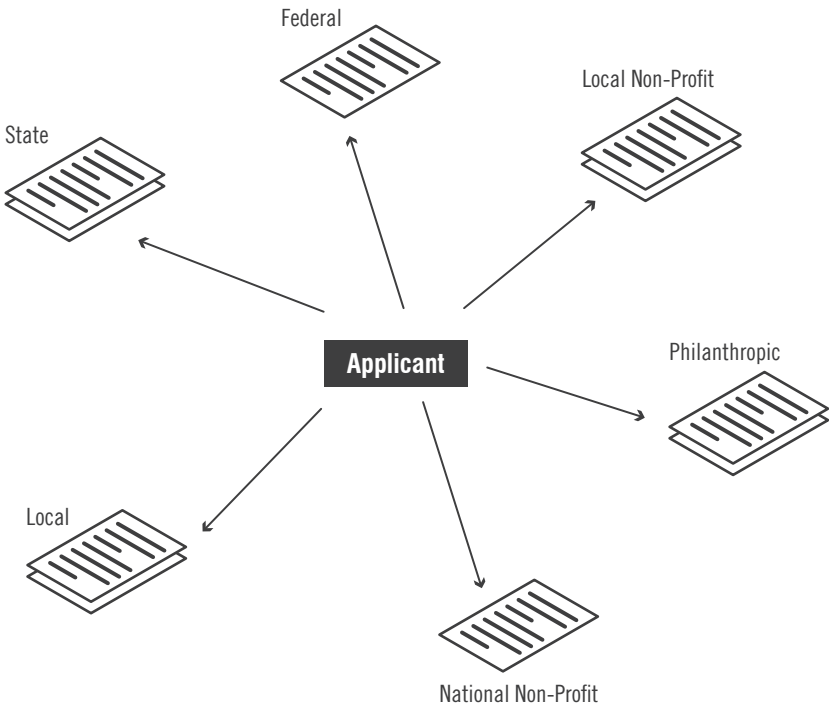
Common applications or intake forms could similarly serve survivors with any type of need, beyond home repair, by connecting them to any required service. Ensuring that the formats allow for maximum transferability between agencies

helps improve the customer experience and efficiency. Additionally, maintaining the system in between disasters helps to ensure preparedness and a faster launch to serve households and people seeking services after a disaster.

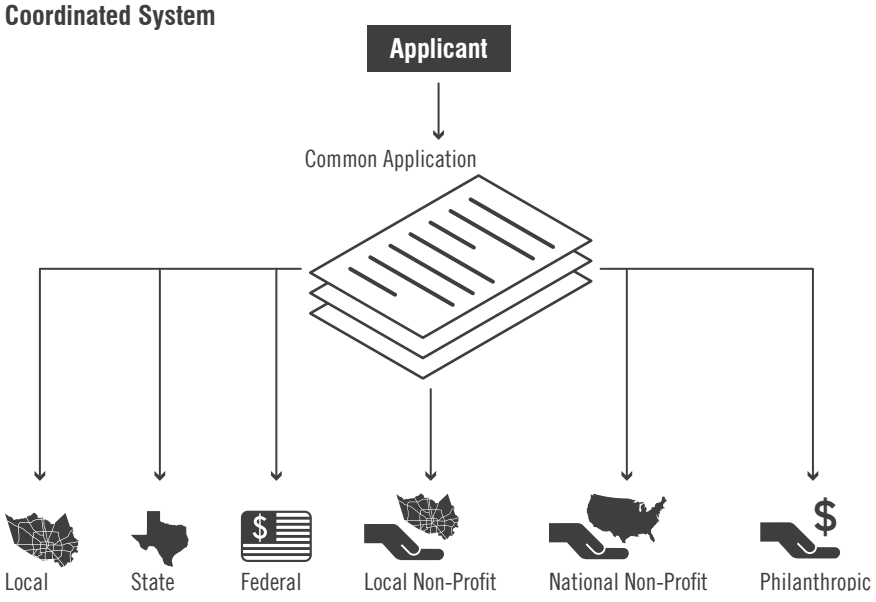
The Homeless Management Information Services (HMIS) is another example of an information technology system that uses client data to match at-risk or homeless individuals and families with housing services targeted to their specific needs.

Setting up and maintaining such a common intake and coordination system would take significant funding, collaboration and change management within partner organizations. Forging partnerships with ISDs, nonprofits, and other agencies; creating a database of services; maintaining an updated list of point-of-contacts; and managing new data and keeping existing data up-to-date would be a significant undertaking. But the pay-off, especially for vulnerable populations, would be unparalleled, especially if it is available from the very beginning of the recovery process.

Uncoordinated System



Coordinated System



3.5
Case Managers

Setting up a network of case managers before the next disaster is a critical way to return people to normalcy quickly and smoothly. Case managers can be organized to be the single point of contact for impacted residents with various needs and serve as a coordinator to help people navigate various systems to secure assistance.

Contributor

Huitt-Zollars, Inc.

Amanda Timm | Local Initiatives Support Corporation

Related Ideas

Common Intake and Coordination Systems on p. 89

In order for people impacted by a disaster to return to normalcy, they must be able to access the assistance and financial aid programs available to them. In the hectic and challenging post-disaster period, many public, private, and philanthropic initiatives are set in motion that are implemented through numerous local, state, and federal agencies as well as local and national nonprofit organizations. The landscape of the recovery effort quickly becomes complex, even for those who are charged with managing it. It is an even bigger challenge for individuals who have lost their homes, jobs and other underpinnings of their daily lives to navigate this complex system while struggling to return to normalcy.

In this confusing environment case managers are the critical link between the impacted residents of a disaster and the resources that can help them. They engage with an impacted resident to (i) quickly assess their immediate and long-term needs, (ii) help them navigate the complex recovery system and its attendant applications, documentation requirements, and restrictions on funding and (iii) direct them to available resources, often from multiple sources. A key element of the process is also creating a recovery plan for the client. Ideally, the same case manager remains with an impacted resident throughout an often long process as they get to know their particular needs and challenges. This work requires patience, social work skills, in-depth knowledge of what resources are available (along with where and with what restrictions, such as income limitations, prohibitions against assisting undocumented individuals, and programs targeted for specific geographies or demographic groups). It also requires an ongoing effort and a system to stay abreast of the changing resources available. Case managers also act as an advocate and liaison on behalf of the residents to various agencies. Based on past experience, the value of local disaster case managers is considerable. Ensuring that contracted firms are hiring local staff and partnering with locally based agencies for case management reduces the amount of time needed to become familiar with the various entities, systems, and community cultural norms.

In the months after Hurricane Harvey, effective systems were put in place to coordinate efforts among organizations. Through hard work and dedication, case managers and those they worked with also excelled at helping impacted residents find the help they needed. The challenge is less about fixing the system as it evolved and more about quickly ramping up the system's capacity in the immediate aftermath of a disaster when residents are most in need. There are several strategies that could help:

Pre-designate front-line organizations. Government and nonprofit agencies can be identified in advance with a requirement for annual training of their staff to ensure prompt post-disaster recovery operations. Both large organizations with broad capabilities along with smaller organizations that can address special needs in vulnerable populations should be included. Local partnerships and hiring local case managers can help address this. In addition, prioritizing cultural competency and sensitivity

as an individual and organizational requirement for providing services can provide better outcomes to support people during times when it may be difficult to communicate every detail regarding providing support.

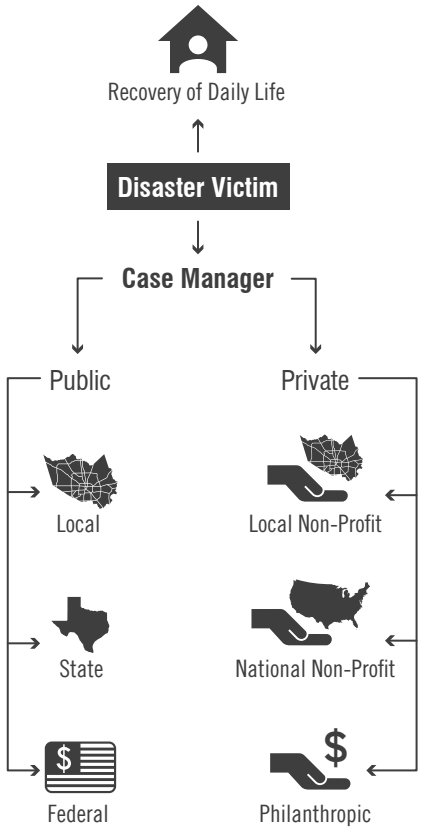
Tap into a new state-wide response network. Refer to Other Ideas on p. 95 for more information regarding a Statewide Response Network.

Expand and institutionalize setting aside funds for the immediate response in advance. The government and public responses to disasters are often generous, but it takes time for money to begin flowing. Until that happens, the aid to impacted residents is hobbled. A modest amount of money could be set aside in a trusted community organization, such as the United Way or Greater Houston Community Foundation. In addition to pre-approved case management funding, it could be restricted to two tasks, (i) annual training of the designated interim case manager work force and pre-designated front-line organizations, and (ii) annual review of anticipated post-disaster response needs and confirmation of plans to activate in the case of a disaster. The plans would include hiring of case managers, which would give pre-designated front-line and community-based organizations of various sizes the assurance they need to begin hiring long-term case managers and providing immediate supports.

Additional considerations include remaining aware of the need to coordinate services beyond home repair (mental health, child care, legal issues, unmet needs) and creating a space to engage ad hoc groups that are great connectors in some communities and among organizations. Finally, finding ways to launch services so that people can begin connecting to case management services immediately, e.g. at shelters and emergency response areas, can help reduce the amount of time to full recovery.

Recovery without Case Manager

Recovery with Case Manager



3.6

Public Transportation Links

Public transportation can be organized during a storm event to serve areas in need and temporarily compensate for the loss of cars by connecting people to the places they need to go.

Contributor

Huitt-Zollars, Inc.

Amanda Timm | Local Initiatives Support Corporation

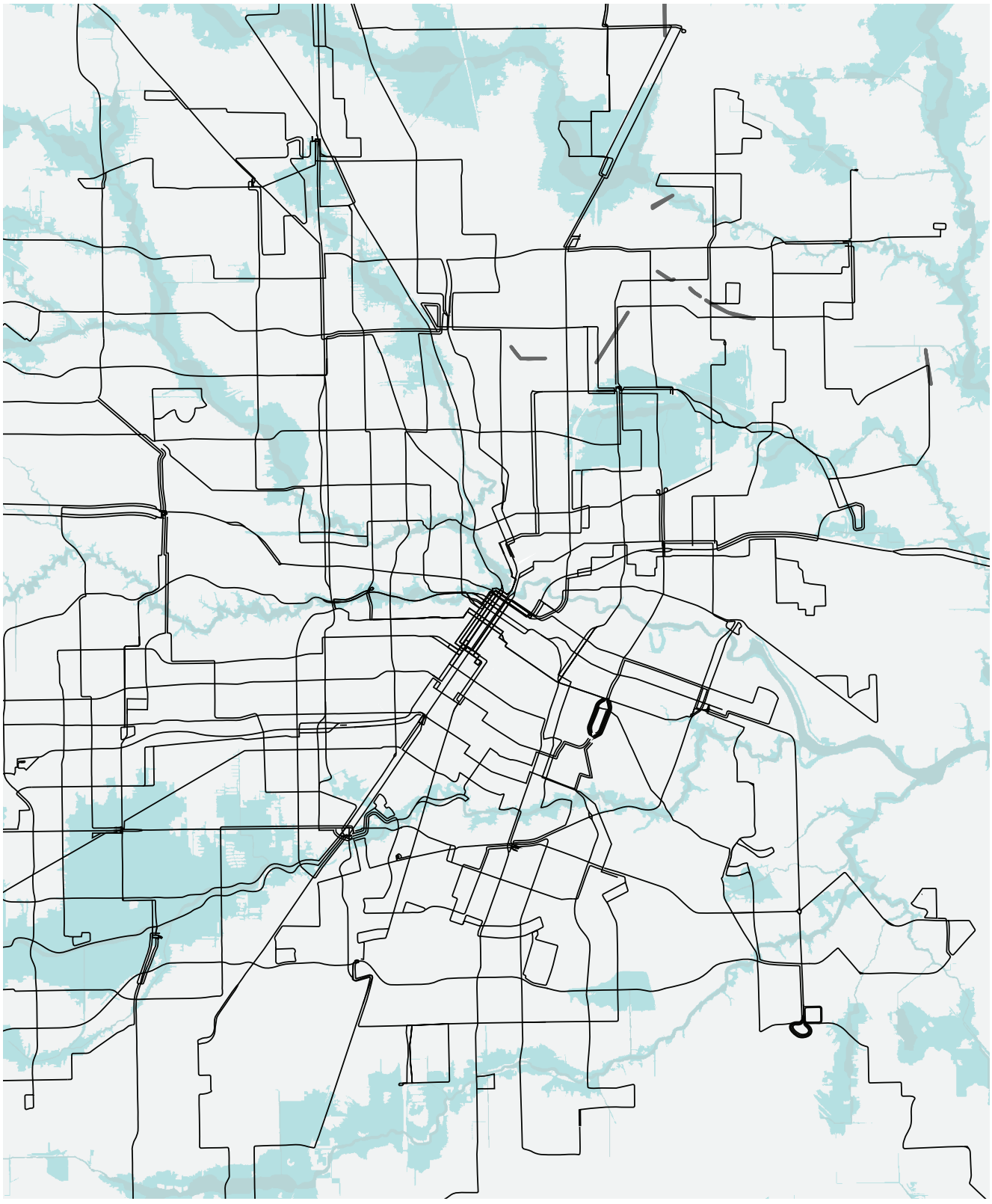
Related Ideas

Key Road Links on p. 71

One of the major impacts of flooding is the destruction of cars. Because streets, parking lots, and driveways are often lower than homes, many people whose homes do not flood will lose their cars. For some, this is a temporary inconvenience; they will get an insurance check and buy a new car. For others, though, it can be devastating. Residents with low income and no comprehensive car insurance may not be able to afford to replace the car, and if they do not replace the car, they will need another way to get to work, school or basic services, such as food.

Integrating transit into disaster response can address this issue. This can take several forms:

- Provide information about public transportation services available and transit fare cards to those staying in temporary shelters. This took place after Harvey, where METRO had a table in the George R. Brown Convention center, integrated with the tables that offered other services, that handed out farecards and helped people plan trips.
- Case managers and neighborhood leaders can have information about existing public transportation services available and distribute transit fare cards, provided by METRO, to residents who have lost their cars. In many cases, existing bus and rail routes may be an option for residents that they may not be aware of.
- Emergency taxi and ride-share contracts can be put in place through pre-negotiated contracts with METRO to provide on demand shared rides in areas that are known to have flooded and that are not within walking distance of transit.
- Public transit agencies can use data about flooding, reports from recovery workers, and demographic data to identify neighborhoods that likely had a large number of residents lose their cars and provide new temporary transit routes. This might include either fixed route bus service or on-demand “community connectors,” in these areas.



Other Ideas

These concepts emerged from conversations Consortium Members have had among themselves and with external stakeholders. While Consortium members do not have the appropriate expertise to develop conclusions, we felt it was worthwhile to surface them.

Staffing and Operating Recovery Centers

The City of Houston partnered with local nonprofits after Hurricane Harvey to open up Neighborhood Recovery Centers (NRCs) in various locations. NRCs and city staff served residents with information and resources for recovery as well as helped neighborhoods establish plans for future resiliency. According to the Greater Houston Community Foundation (GHCF), the NRC effort faced capacity challenges, which led to delayed launches of additional centers. In addition to pre-staging recovery centers, the nonprofits that will support their staffing can be pre-identified. This could be tied to pre-storm agreements with funders to ensure funds to support staffing.

Business Continuity Planning

Small businesses can minimize losses during and after disasters by business continuity plans. Being unable to resume operations quickly after a disaster can be catastrophic for a small business, and preparation can reduce that risk. To help small businesses prepare, local agencies could work with the Small Business Administration to hold workshops or one-on-one consultations to help businesses prepare continuity plans. Local agencies can also recommend locally relevant best practices. It is in the region's interest for some post-disaster practices to be coordinated.

Income Protection

The temporary loss of income during a disaster can have a major impact on low income households. While salaried employees are generally paid during a disaster whether their workplace is open or not, hourly employees are not. FEMA provides Disaster Unemployment Assistance for people who lose their jobs due to a natural disaster, either because their employer has closed or because they are unable to make it to work. However, this does not cover lost wages due to reduced shifts or short closures. A state program to provide immediate payments to people who have lost income as the result of a disaster would help many households. It would also give employers, especially small businesses, the peace of mind to know that not opening for the business day when the city is shut down will not hurt their employees. Large employers could also do this on their own, by paying employees even if workplaces are closed.

Mold Remediation

Mold remediation must be deployed quickly in order to prevent mold growth that can contribute to significant health issues and increased remediation costs. A potential solution is for local jurisdictions to establish pre-developed contracts for mold remediation services for vulnerable neighborhoods or communities, and to negotiate an agreement with FEMA to reimburse these rapidly-deployed mold remediation services

Pro-Bono Legal Services

Pro-bono legal services are often underutilized in the wake of a disaster, when unlawful evictions and other legal violations are common place and property owners without clear title due to past inheritances have trouble getting rebuilding assistance. Public awareness campaigns could help residents know their rights and prevent contractor fraud. Community meetings to link people with resources such as nonprofits that provide free or low-cost legal aid. Nonprofits could provide early access to legal services for FEMA appeals (ions). Legal services could be integrated within other organizations providing disaster recovery services to increase awareness of how legal services can address consumer issues (tenant/landlord, wage theft, etc.) Public agencies could keep an up-to-date list of volunteer lawyers for disaster recovery.

Coordination of Public Benefits

Often the public is not aware of what post-disaster benefits are available or how to navigate the process to receive them. Centralized communication of benefits, as well as common application and coordination systems can be used to consolidate information on public benefits and assist people in utilizing their benefits after a disaster. Gathering information regarding public benefits and then consistently distributing them throughout affected communities could also

reduce the confusion residents experience when navigating the myriad of programs and nonprofit services available to them in the aftermath of a disaster.

Support For Nonprofit Collaboration

Building capacity among nonprofit organizations can lead to increased effectiveness in the deployment of public benefits. Ensuring strong nonprofits will in turn ensure their ability to serve their communities. Continuing periodic convenings of nonprofits through the Long-Term Recovery Committee (LTRC) or other gatherings can facilitate relationship building and coordination of services. Investing in the collaborations among nonprofit providers to coordinate data, services, resources and strategy can provide better outcomes. Investing in the infrastructure and systems that facilitate collaboration and efficiency can also help. Nonprofit collaborations that have the support and engagement with public sector agencies hold even more promise for better outcomes. LTRCs use this collaborative and coordinate approach, but could benefit from enhanced capacity and approaches that are responsive to the scale of the disaster.

Continuous Identification and Monitoring of Gaps

As large relief funds are dispersed and nonprofit programs are available to serve the community, a continuous assessment of gaps is necessary to determine how to direct and redirect resources. For example, a certain geography or population may not be receiving the support it requires to recover. In those cases, funders and public partners should work together to close the gap.

Using a systematic approach to map services, agencies, and resources, gaps can be responded to in a strategic manner to help coordinate benefits.

For example, according to Greater Houston Community Foundation (GHCF) Houston Harvey Relief Fund (HHRF) found gaps in the capacity and number of organizations serving the Northeast and Southeast regions. Similarly, there were gaps in services provided to undocumented and LGBT-identifying individuals. This assessment identified the need for targeting certain geographies in future rounds of funding and providing additional grantee training to ensure that all affected individuals felt welcome accessing services.

Yearly Convening/Recovery Drill

Drills are held regionally for disaster response. A similar drill could focus on the recovery process. An annual convening of government agencies, school districts, and nonprofit agencies would provide a platform to come together and rehearse how they would work together and how they would plug into the recovery efforts. These convenings can also be used to identify gaps in organizations' needs and ensure that they are capable of fulfilling their roles during a disaster. This level of planning and preparedness also allows the local leaders to maximize the resources and service offered by Volunteer Organizations Aiding Disaster (VOAD) groups that descend on a disaster area in the days and months after a storm. If a local community is ready, they can be of greater help by plugging into an existing well organized system.

Statewide Response Network

After Harvey, it took the Houston region months to build capacity in critical areas like case management, home repair programs, and to coordinate between various types of disaster response services seeking to assist each impacted resident. In the meantime, these residents suffered for longer than they would have otherwise. We have come to understand that there is in fact a "new normal" that means the Houston region and much of Texas should plan for floods, fires and other disasters associated with changing climate and weather patterns on a much more regular basis. Given the increasing frequency of these events, it is worth considering a state-wide response network that is trained in post-disaster response. It could replicate similar networks for fighting fires and restoring electric utility grids. This network could be deployed throughout the state in response to a variety of disasters, with its primary mission being to quickly train local government and nonprofit personnel in the details of meeting residents' needs during post-disaster response, regularly update written protocols to keep abreast of changing federal guidelines and best practices, to provide support services like an established online platform, and to obtain pre-identified and ready-to-secure warehouse locations for relief supplies and building materials. To elevate the importance of this work, an annual conference could be held that would give a wider audience.

Appendix A: Contributor Biographies

Kyle Shelton | Rice University Kinder Institute

Kyle Shelton is the director of strategic partnerships at Rice University's Kinder Institute for Urban Research, where he leads research on urban development, transportation, resilience and placemaking, as well as on urban and metropolitan governance. Shelton has a Ph.D. in American history from The University of Texas at Austin. His research focuses on how the intersections of transportation, urban development and policy shape the built and natural environments of cities in the past and today. He is the author of Power Moves: Transportation, Politics and Development in Houston.

Phil Bedient | Rice University SSPEED Center

Dr. Philip B. Bedient is the Herman Brown Professor of Engineering in the Department of Civil and Environmental Engineering at Rice University. He teaches and performs research in surface water hydrology and flood prediction systems, and radar based flood alert. He has directed 60 research projects over the past 35 years, has written over 180 articles in journals and conference proceedings. He has worked on hydrologic problems including major floodplain studies, water quality assessments, and hydrologic modeling for a number of watersheds in Texas, Florida, and Louisiana. He has been actively involved in the area of hydrologic analysis for flood prediction and warning, and has developed a real-time flood alert system for the Texas Medical Center, based on the use of NEXRAD radar data. Dr. Bedient directs the SSPEED Center at Rice for Severe Storm Prediction, consisting of several universities in the Gulf Coast area, which has funding to address the impacts of Hurricane Ike in the Houston area. Both storm surge prediction, inland flooding, and long-term mitigation strategies are being studied with funding from the Houston Endowment. Dr. Bedient also is evaluating low impact development schemes with funding from the City of Houston.

Larry Dunbar | Rice University SSPEED Center

Lawrence G. Dunbar, P.E. is a licensed professional engineer and a licensed attorney here in Texas. He has been practicing as a Water Resources & Environmental Engineer for over 30 years, and as a Water and Drainage attorney for over 20 years.

Mr. Dunbar has been a consultant to both the public and private sector, such as drainage districts, counties, water authorities, developers, engineers, landowners and lawyers. He has served as an expert witness in various administrative proceedings, as well as in both state and federal litigation matters. He has also been a frequent speaker at numerous legal and engineering seminars, and has taught college engineering students as a part-time teacher and lecturer.

Sam Brody | Texas A&M University-Galveston, Center for Texas Beaches and Shores

Samuel D. Brody is a Regents Professor and holder of the George P. Mitchell '40 Chair in Sustainable Coasts in the Departments of Marine Sciences and Landscape Architecture and Urban Planning at Texas A&M University. He is the Director of Center for Texas Beaches and Shores and the Lead Technical Expert for the Governor's Commission to Rebuild Texas.

Dr. Brody's research focuses on coastal environmental planning, spatial analysis, flood mitigation, climate change policy, and natural hazards mitigation. He has published numerous scientific articles on flood risk and mitigation, and recently authored the book, Rising Waters: The causes and consequences of flooding in the United States published by Cambridge University Press.

Dr. Brody teaches graduate courses in environmental planning, flood mitigation, and coastal resiliency. He has also worked in both the public and private sectors to help local coastal communities adopt flood mitigation plans. For more information, please visit www.tamug.edu/ctbs.

Earthea Nance | Texas Southern University, Barbara Jordan-Mickey Leland School of Public Affairs

Earthea Nance, PhD, PE, CFM is an associate professor of environmental planning and a registered professional civil engineer. Her current research addresses two core dilemmas of environmental management facing communities and public agencies: How should vulnerable communities hold public agencies accountable for environmental injustice? How should public agencies—specifically engineering and planning agencies—incorporate the demands of vulnerable stakeholders? These questions are addressed in her book, "Engineers and Communities: Transforming Sanitation in Contemporary Brazil," (Lexington Books/Rowman & Littlefield, 2012). Dr. Nance directed hazard mitigation and environmental planning for the City of New Orleans after Hurricane Katrina, which under her direction produced the city's first sustainability action plan, its first FEMA-approved hazard mitigation plan, its first carbon report, and its first citizen guide to soil remediation. She presently serves on the City of Houston's Climate Action Advisory Board and the non-profit Coalition for Environment, Equity, and Resilience. She previously served on advisory committees for the Water Institute of the Gulf, as well as EPA's Science Advisory Board, Board of Scientific Counselors, and National Environmental Justice Advisory Council. Earthea teaches a variety of environmental courses and has mentored dozens of graduate students. Prior to joining Texas Southern University, she served on the urban planning faculty at the University of New Orleans, Massachusetts Institute of Technology, and Virginia Tech. Professor Nance received her doctorate degree from Stanford University.

Susan Rogers | University of Houston Hines College of Architecture + Design, Community Design Resource Center

Susan Rogers is a designer, educator and activist. Her work is based on the disciplinary foundations of architecture and city planning with an expanded lens to directly engage questions of justice and equity. One part demographer, one part cartographer, one part community developer, one part designer, one part educator—she believes in thinking big and acting locally.

Rogers is an Associate Professor of Architecture at the Hines College of Architecture and Design at the University of Houston and the Director of the Community Design Resource Center (CDRC). The CDRC's mission is to apply design thinking to the broad spectrum of challenges that face our cities and communities—with a focus on equity and resiliency. Under her direction, the CDRC has completed over three dozen projects in partnership with communities across the region ranging in scale from temporary public art interventions to large-scale community visions. She has presented her work across the globe and her writing has appeared in Urban Design International, Urban Infill, INT/AR: Interventions and Adaptive Reuse, ii the International Journal of Interior Architecture + Spatial Design, Places Journal, Cite: The Architecture and Design Review of Houston, and ArtLies, A Texas Art Journal. She is the coauthor of "An Architecture of Change," the Introduction to Expanding Architecture: Design as Activism. In 2017, the CDRC received an Excellence Award for Advancing Diversity and Social Change in Honor of Paul Davidoff from the American Planning Association. In May 2014, her work "The World in the City" was part of the Banlieue is Beautiful exhibit at the Palais de Tokyo in Paris France. She has designed and installed two major exhibits at the University of Houston: Flood[Zone] and Thick Infrastructure.

Professor Rogers holds a Masters of City Planning and a Masters of Architecture from the University of California at Berkeley and a Bachelors of Architecture from the University of Houston.

Stephanie Glenn | Houston Advanced Research Center

Dr. Stephanie Glenn is Program Director for Hydrology and Watersheds at HARC. Dr. Glenn joined HARC in 2003 where she leads research and program efforts specializing in ecology and hydrology. She is responsible for the development and supervision of projects to improve the sustainable management of water and ecological resources. Dr. Glenn has worked in the water resources sector for over twenty-five years. Current research includes coastal groundwater quality & quantity, watershed protection & surface water quality, and developing ecological tools for management. Dr. Glenn received her Ph.D. in Environmental Science and Engineering from Rice University in Houston, Texas. Previous degrees include a M.S. in Environmental Science from Indiana University and a B.A. in Mathematics from Northwestern University.

Gavin Dillingham | Houston Advanced Research Center

Dr. Gavin Dillingham is Program Director for Clean Energy Policy at HARC. Dr. Dillingham joined HARC in 2012 where he leads research and program efforts focusing on improving the climate resilience of the electric power infrastructure and built environment. Dr. Dillingham has worked in the clean energy industry for the last twenty years in both the private and public sector. Much of this work focused on climate action planning, greenhouse gas mitigation strategies and strategic energy management for large institutions and cities. Dr. Dillingham's programmatic activity includes directing the Department of Energy's Southcentral Combined Heat and Power Technical Assistance Partnership which is tasked with improving community resilience and reducing energy waste. Dr. Dillingham received his PhD in Political Science from Rice University in 2008 where he studied policy diffusion and adoption of natural resources policies across U.S. states.

Ryan Bare | Houston Advanced Research Center

Ryan Bare is a Research Associate at HARC under the Hydrology and Watersheds program and is a PhD candidate in the Water Management and Hydrological Science doctoral program at Texas A&M University. He holds a M.S. in Marine Resource Management from Texas A&M University at Galveston where he studied temporal and spatial trends of a water quality indicator bacterium in the Coastal Health and Estuarine Microbiology lab. He received his B.S. in Environmental Science with a concentration in Marine and Coastal Resources from Texas A&M University - Corpus Christi. At HARC, he focuses on sustainable water management, natural resource and ecosystem management, and the water quality impacts of developing coastal communities. He is a Certified Associate in Project Management (CAPM) designated by the Project Management Institute.

Amanda Timm | Local Initiatives Support Corporation, Houston

Amanda Timm is the Executive Director of the Local Initiatives Support Corporation's Houston office. LISC works with residents and partners to forge resilient and inclusive communities of opportunity across America that are great places to live, work, visit, do business and raise families. It does that by providing capital, partnerships and support to community-based nonprofits and leaders. During its 30 years of working in Houston, LISC and its affiliates have invested more than $363 million and leveraged more than $887 million in projects for housing, real estate development, and other community revitalization efforts. The investments have helped to develop more than 9,200 affordable homes and nearly two million square feet of commercial and community space. Houston LISC is an affiliate agency of the United Way of Greater Houston.

Amanda began her tenure at LISC as a program officer in 2001 working on capacity building with community partners. After taking the leadership role at Houston LISC in 2007, Amanda orchestrated the program's strategic shift to a comprehensive approach for community development. The implementation of this strategy has included the launch of Great Opportunities (GO) Neighborhoods, Houston LISC's targeted neighborhood approach to comprehensive community development, and the Financial Opportunity Center program, an evidence based model to help families reach financial stability.

Prior to her work with LISC, Amanda served the City of Houston as a Senior Planner with the Planning and Development Department.

Amanda serves on the board of directors for LINK Houston, a group focused on transportation equity and access to opportunity as well as the Executive Committee for UpSkill Houston, a region wide collective impact efforts to address workforce and the middle skills gap. Amanda serves on the Complete Communities Advisory Committee for the City of Houston and is a graduate of the Center for Houston's Future Business and Civic Leadership Forum. She also participates on the community advisory boards for several banking institutions and worked with the leadership team that launched the Houston Housing Collaborative.

Amanda holds a Bachelor of Arts degree from Southwestern University and a Master of Public Affairs degree from the LBJ School of Public Affairs at the University of Texas at Austin.

Senchel Mathews | Local Initiatives Support Corporation, Houston

Senchel supports Houston LISC's data management and evaluation systems and Go Neighborhoods work. She has experience in regional planning, social enterprise development, mental health services, and community engagement. Previously, she worked with the Achievement School District in Memphis, TN by creating a program that connected families with community resources and holistic support to help their students achieve academic success. She also worked at Heifer International with the Seeds of Change program that equipped producers & entrepreneurs with tools to grow and source sustainable crops, develop viable value chains, and increase profits in the AR-MS-TN Delta. Over the years, she has worked on numerous planning projects that had a strong focus on collective impact, community development, and wrap-around services for families.

Senchel holds a Bachelors of Arts in History/Geography from Tennessee State University in Nashville, TN and a Master's degree in City & Regional Planning from the University of Memphis. In her free time she enjoys traveling, cooking, hosting book clubs & social chats, archery, camping, and volunteering at the local crisis hotline center.

HUITT-ZOLLARS

ADVANCEDESIGN℠

Huitt-Zollars, Inc.

Huitt-Zollars is an award-winning, full-service design practice providing comprehensive architecture, engineering, interior design, urban design and planning services in 20 offices across the United States. AdvancedDESIGN is a company-wide philosophy the firm practices every day. It is an approach that explores design from all sides, meeting challenges from new angles and helping to uncover perspectives often overlooked. This innovative approach to design coupled with technical expertise have earned worldwide recognition. The Houston-based planning group's recent work includes greenways and park planning in Houston, transit planning in the Twin Cities and South Carolina, strategy for national and regional foundations funding mobility projects, new street design manuals for the City of Dallas, and a community-based vision for Galveston. The Dallas-based hydrology group's work includes a new drainage manual for the City of Dallas and new assessments of how to assess hurricane risk. Huitt-Zollars contributors to this report include Christof Spieler, Mandi Chapa, Tanvi Sharma, David Copeland, Alex Stitt, Corey Phelps, Kyle Byrne, Rob Armstrong, and Allison Wood.

Bakeyah Nelson | Air Alliance Houston

Bakeyah Nelson, PhD, has served as the Executive Director of Air Alliance Houston for two years. Prior to working as Executive Director, she led a consulting firm focused on advancing health equity. She previously served in the Office of Policy and Planning for Harris County Public Health where she was responsible for leading community health initiatives to reduce environmental inequities where people live, work, learn, and play.

Dr. Nelson has served on a number of committees aimed at improving community and environmental health including but not limited to the Executive Committee of the Houston-Galveston Area Council's Regional Air Quality Planning Advisory Committee, the African American Health Coalition, and the National Association of County and City Health Officials (NACCHO) Environmental Health Committee.

She is the co-founder and serves as co-chair of the Coalition for Environment, Equity, and Resilience (CEER) - a coalition of 24 organizations focused on raising awareness between people, place, pollution, and public health. She is also one of the founding members of the New Giving Collective, a giving circle established in 2017 to serve as a vehicle to support and respond to the needs of the Black community.

Dr. Nelson was recently honored as one of the Texas Organizing Project's 2018 Community Champions. She is a current Fellow of Class XLVI of the American Leadership Forum and has been selected as one of the Aspen Institute's Health Scholars for the 2019 Aspen Ideas Festival.

In 2012, she was selected for the University of California, San Francisco's Program on Reproductive Health and the Environment Reach the Decision Makers Fellowship, which trains scientists, community members, clinicians and public health professionals to effectively promote science and health-based policies. Later in 2012, she was a recipient of the National Association of County & City Health Officials (NACCHO) Model Practice Award for demonstrating exemplary leadership to advance environmental justice and public health.

Dr. Nelson's doctorate in public policy, master's in applied sociology and bachelor's degree in psychology all come from the University of Maryland, Baltimore County.

Corey Williams | Air Alliance Houston

After nearly a decade of work as an environmental compliance contractor in Houston-area industries, Corey became increasingly concerned about the efficacy of efforts to improve the culture of environmental responsibility within industry. He has since turned his efforts outside the fenceline and has found a home as the Policy and Research Director for Air Alliance Houston. Since joining AAH, Corey has worked to better understand and communicate the unique environmental conditions affecting Houston-area communities and to advocate for the creation of equitable and sustainable environmental policy solutions. He holds a BS in Geography and Minor in Environmental Science from the University of Houston – Clear Lake and is currently a graduate student in the school's Environmental Management program.

Appendix B: Abbreviations & Acronyms

AEP Annual Exceedance Probability - “A 0.2 AEP flood has a 20% chance of occurring in any given year, and this corresponds to a 5 year recurrence-interval flood... AEP terminology reminds the observer that a rare flood does not reduce the chances of another rare flood within a short time period.” - USGS (https://www.usgs.gov/special-topic/water-science-school/science/100-year-flood?qt-science_center_objects=0#qt-science_center_objects)

ATX Austin, Texas

BFE Base Flood Elevation - "The BFE is the computed elevation to which flood waters are anticipated to rise during the base (1%-annual-chance) flood event... The BFE is the regulatory requirement for the elevation or flood proofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium." - FEMA https://www.fema.gov/faq-details/Base-Flood-Elevation-BFE/

CAP Conservation Assistance Program - a program "to support regional efforts to preserve wetlands and coastal habitats that protect the long-term health and productivity of Galveston Bay." - https://gbep.texas.gov/partnerships/

CDRC Community Design Resource Center - http://cdrchouston.org/about/

CERT Community Emergency Response Team

CHP Combined Heat and Power

CMU Concrete Masonry Unit

CRS Community Rating System - a system that "recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards." - https://www.fema.gov/community-rating-system

CRWU Creating Resilient Water Utilities - An "initiative provides drinking water, wastewater and stormwater utilities with practical tools, training and technical assistance needed to increase resilience to extreme weather events." - https://www.epa.gov/crwu

EPA Environmental Protection Agency - "Established on December 2, 1970 to consolidate in one agency a variety of federal research, monitoring, standard-setting and enforcement activities to ensure environmental protection." - https://www.epa.gov

ETJs Extraterritorial Jurisdictions

FAS4 Flood Alert System - "The Rice University and Texas Medical Center Flood Alert System is an integrated system utilizing radar, rain gage information, bayou stage data, and hydrologic modeling for the purpose of issuing flood warnings and forecasts for the Rice University / TMC Complex." - FAS4 Website http://fas4.flood-alert.org/#Home:Home

FEMA Federal Emergency Management Agency - "The... Agency coordinates the federal government's role in preparing for, preventing, mitigating the effects of, responding to, and recovering from all domestic disasters, whether natural or man-made." - https://www.fema.gov/

FIRM Flood Insurance Rate Map - "The official map of a community on which FEMA has delineated both the special hazard areas and the risk premium zones applicable to the community." - https://www.fema.gov/flood-insurance-rate-map-firm

GHCF Greater Houston Community Foundation - The "Foundation is dedicated to expanding philanthropic impact with our donors." - https://ghcf.org/

HARC Houston Advanced Research Center - "A 501(c)(3) organization incorporated as Houston Advanced Research Center, is a research hub providing independent analysis on energy, air, and water issues to people seeking scientific answers." - https://www.harcresearch.org/

HCFCD Harris County Flood Control District - "The mission... is to: Provide flood damage reduction projects that work, with appropriate regard for community and natural values." - https://www.hcfcd.org/

HHC Harvey Home Connect - "A new common application and coordination system that will assist eligible, low-to-moderate income seekers of home repair services in the City of Houston and/or Harris County affected by Hurricane Harvey." - https://harveyhomeconnect.tfaforms.net/22

HHRF Houston Harvey Relief Fund - "Set up by Houston's Mayor Turner and Harris County Judge Emmett, is focused on immediate and long-term relief efforts in Harris County and Houston" - https://ghcf.org/learn/

HMIS Homeless Management Information Services - "A computerized data collection tool specifically designed to capture client-level, system-wide information over time on the characteristics and services needs of men, women and children experiencing homelessness." - http://www.homelesshouston.org/hmis/

LED Light Emitting Diode

LGBT Lesbian, Gay, Bisexual, and Transgender

LID Low Impact Development - "A design principle that seeks to decrease the "ecological footprint" of development." - https://tcwp.tamu.edu/land-use/low-impact-development/

LIDAR Light Detection and Ranging - "A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses- combined with other data recorded by the airborne system- generate precise, three-dimensional information about the shape of the Earth." - NOAA https://oceanservice.noaa.gov/facts/lidar.html

LISC Local Initiatives Support Corporation - "With residents and partners, LISC forges resilient and inclusive communities of opportunity across America – great places to live, work, visit, do business and raise families." - http://www.lisc.org/houston/

LTRC Long-Term Recovery Committee

MUDs Municipal Utility Districts

NFIP National Flood Insurance Program - A program that "aims to reduce the impact of flooding on private and public structures. It does so by providing affordable insurance to property owners, renters and businesses and by encouraging communities to adopt and enforce floodplain management regulations." - https://www.fema.gov/national-flood-insurance-program

NOAA National Oceanic and Atmospheric Administration - "An agency that enriches life through science. Our reach goes from the surface of the sun to the depths of the ocean floor as we work to keep the public informed of the changing environment around them." - https://oceanservice.noaa.gov/welcome.html

NRCs Neighborhood Recovery Centers

PV Photovoltaic

SBP Formerly the St. Bernard Project, SBP is a nonprofit disaster relief organization. - http://sbpusa.org/

SSPEED Severe Storm Prediction, Education and Evacuation from Disasters - "Led by Rice University, the SSPEED Center organizes leading Gulf Coast universities, researchers, emergency managers, industry leaders and private and public entities to better address severe storm prediction and its impact on the region." - https://www.sspeed.rice.edu/

STEAR State of Texas Emergency Assistance Registry - "A free registry that provides local emergency planners and emergency responders with additional information on the needs in their community." - https://www.dps.texas.gov/dem/stear/public.htm

TCEQ Texas Commission on Environmental Quality - "The Texas Commission on Environmental Quality is the environmental agency for the state." - https://www.tceq.texas.gov/

GBEP Texas Commission on Environmental Quality Galveston Bay Estuary Program - An "Estuary programs in Texas... (whose mission is) to preserve Galveston Bay for generations to come." - https://gbep.texas.gov/

TECO Thermal Energy Corporation - "the only organization in the Texas Medical Center authorized to supply multi-user thermal services." - https://tecothermalenergy.com/

TMC Texas Medical Center

TSU Texas State University - https://www.txstate.edu/

TxDOT Texas Department of Transportation - https://www.txdot.gov/

WWTF Wastewater Treatment Facilities