CITY OF HOUSTON, TX
NEIGHBORHOOD RESILIENCE
PLANNING SERVICES

WATERSHED PLANNING BEST PRACTICES REPORT

One Architecture & Urbanism

with
Climate Adaptation Partners
Community Lattice
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CONTENTS

SUMMARY

Neighborhood Resilience Plans are a crucial step forward in realizing the vision established in the citywide resilience plan, Resilient Houston. The Neighborhood Resilience Plans are a key component of achieving Goal 4 of Resilient Houston: We will ensure that all neighborhoods have equitably resourced plans.

The Watershed Planning Best Practices Report (WPBP) is one of the initial actions to catalyze the creation of the Neighborhood Resilience Plans. The following best practices for watershed planning will help inform the watershed management at the region, city and community levels and help reduce the flooding and damage caused by extreme weather events.

GOALS OF WPBP

The WPBP encompasses four goals:

1. The lessons learned from national and international best practices will help inform the process and decisions made in Houston Neighborhood Resilience Planning for the three pilot neighborhoods and future neighborhoods. The lessons encompass measures (what's done), governance (who's involved), process (how it's done), funding (how it's paid), and innovation (what is new).
2. This report provides a reference for experts, such as representatives of other departments within the City of Houston, to understand what measures are taken elsewhere and what can be done in Houston and Harris County.
3. The report can help communities imagine what they might do and offers examples for community-led advocacy in local decision-making. These examples highlight what to be aware of, what to advocate for, and what actions communities might be able to take when planning for resilience.
4. This report offers a framework for comparison that the City of Houston can update as necessary when new best practices emerge. A scheduled refresh every three years can ensure that future Neighborhood Resilience Plans benefit from the latest examples of watershed planning.

NATIONAL AND INTERNATIONAL BEST PRACTICES

In recent years, many cities and regions have introduced new watershed management practices for regional and urban watersheds. This report looks at a range of national and international best practices that stand out in their approach to community involvement, large-scale collaboration between agencies, and management of large volumes of water. Each practice is presented in a summary description and a deeper look at the scale of implementation (region/city/neighborhood), which water concerns are managed, how the community and stakeholders are involved, the implementation strategy, how funding is arranged, and what key lessons Houston can draw from the specific example.

LOCAL CONTEXT

To contextualize the example best practices within a local framework, this report looks at the current responsibilities, policies, and threats relating to the watershed management of Houston's region, city, and neighborhoods. It considers issues regarding stormwater flooding (pluvial or heavy rainfall), riverine flooding (or fluvial, which occurs when lakes, bayous, or rivers overflow), coastal flooding (caused by tides, storm surge, and sea level rise), compound flooding (combinations of pluvial, fluvial, and/or coastal flooding), groundwater supply (rising or receding groundwater and its relation to drought and fresh water supply), and water quality.

KEY LESSONS FOR HOUSTON

We have identified 5 key lessons for Houston. Please refer to the report for a full description and actions.

1. Make every investment stormwater proof:
Each day, Houstonians and the City invest in the physical transformation of the built environment. Houstonians upgrade gardens, yards, roofs, and driveways and build houses. The City maintains streets, constructs new infrastructure, and refurbishes parks. Every small- or large-scale investment decision by community members and the City alike can consider how each action incorporates mitigation strategies for reducing future risks associated with climate change. Over time, these daily practices help build resilience at the city level.

2. Creating room for the bayous and surface stormwater in the neighborhoods:
Harris County Flood Control District and the Army Corps of Engineers are constructing more detention areas, such as Buffalo Bayou Park and the Reservoirs, to create room for stormwater. Additionally, the City of Houston and Harris County Flood Control District can collaborate to create even more space for stormwater detention by establishing an integrated, flexible program focused on the dual goals of ensuring water safety and improving spatial quality.

3. Clear communication for community outreach:
Setting up a social network approach to connect all residents and stakeholders who are involved in the physical transformation of neighborhoods can help facilitate stormwater-proof investments. Producing clear communication materials that are easy to understand helps community members become more aware of what is going on, connect ideas to their own apartments, houses, streets, parks, and neighborhoods, and inform them of what they can do to build resilience (from implementing measures to purchasing flood insurance).

4. Online data and shared information between agencies:
As water flows across juridical boundaries, providing real-time data on a shared, online platform helps with collaboration between agencies, so that Houston can maintain daily operations as long as possible and avoid upstream actions that may cause downstream flooding. It can also help to warn people of impending hazards such as flooding due to extreme rainfall or storm surge. The City of Houston could invest in an online platform for stormwater flooding in the neighborhoods to link with the existing online platform from Harris County Flood Control.

5. Modeling stormwater street runoff:
Accelerating the building of a stormwater model showing street runoff during various storm events is a prerequisite for calculating type of best watershed management measures (BMPs), for creating cloudburst management plans, for creating an online shared data platform, and for assigning an economic value per gallon rainwater detention to remove runoff from stormwater sewers.

Tom Wussow Park
Image Credit: Dalia Munenzon,
One Architecture, 2021

1. INTRODUCTION

INTRODUCTION

1.1 PROJECT SUMMARY - HOUSTON NEIGHBORHOOD RESILIENCE PLANS

Neighborhood Resilience Plans are a crucial step forward in realizing the vision established in the citywide resilience plan, Resilient Houston. Beginning in 2022, the Planning and Development Department will work with the Mayor's Office of Resilience and the ONE team to guide three communities still recovering from Hurricane Harvey in creating their own plans for Resilience Districts as outlined as a task in Resilient Houston. This effort will generate a Neighborhood Resilience Plan for each of the three pilot neighborhoods and establish a replicable framework for other neighborhoods to follow in creating their own resilience plans.

Resilience Districts weave together climate adaptation and risk reduction, economic development, infrastructure modernization, and social empowerment into a neighborhood-specific strategy. The Neighborhood Resilience plans will be community and data driven with input from relevant City departments and collaborating organizations. They will help each neighborhood to direct future investments to reduce flooding, address vulnerability to hazards, improve quality of life, and drive economic opportunity. See also https://www.letstalkhouston.org/nrp.

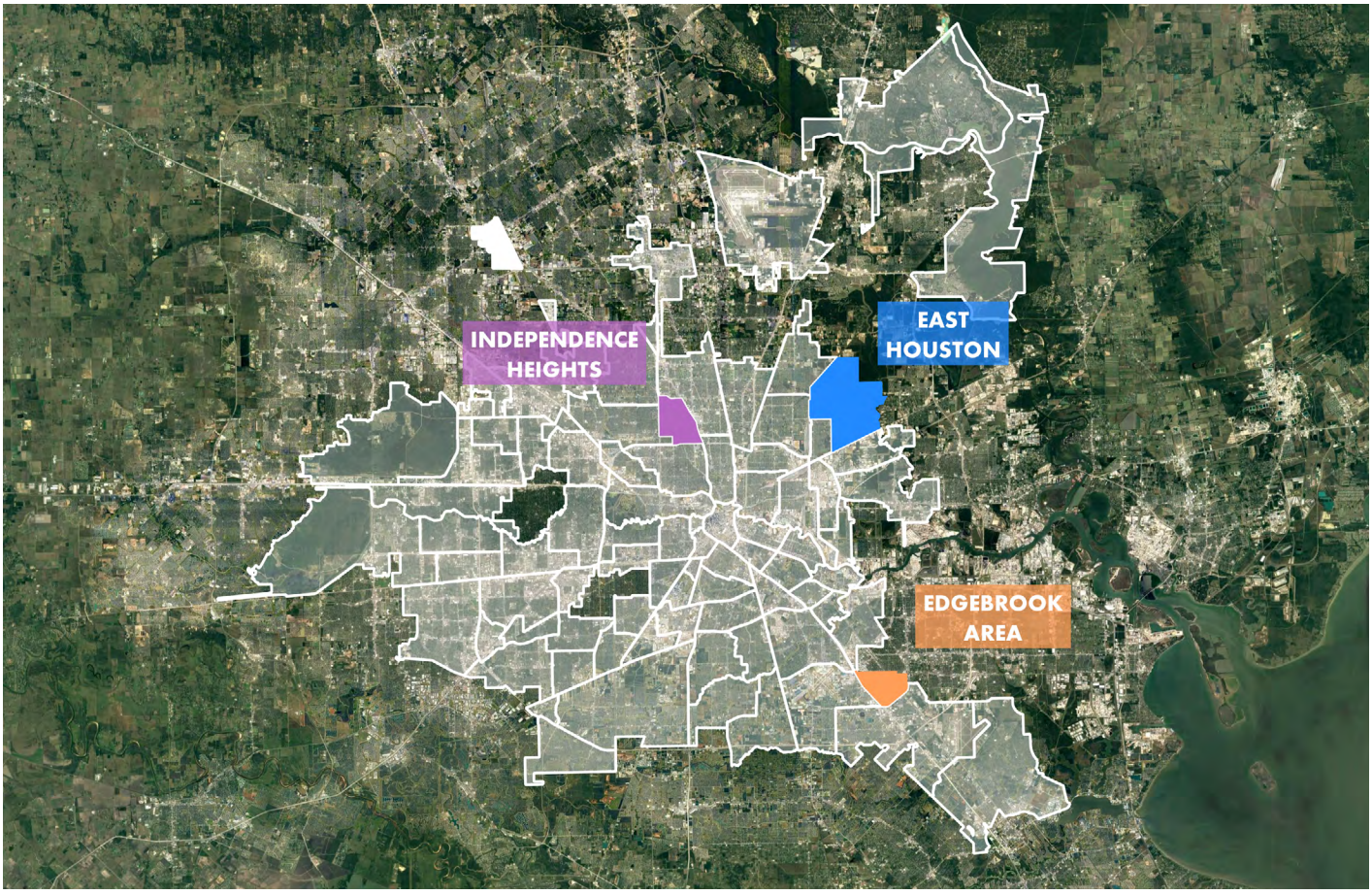
Initiation and Replication
The team will initially work with the neighborhoods of Independence Heights, East Houston, and Edgebrook to develop neighborhood-specific resilience plans through a replicable process. Subsequently, other neighborhoods may follow the same process to create their own neighborhood-specific plans, resulting in increased resilience across all of Houston.

Participation
In developing each neighborhood resilience plan, The Planning & Development Department, the ONE Team, and the community will work together in three distinct but related venues:

- Public Meetings
- Neighborhood Support Teams (NST)
- Technical Advisory Committee (TAC)

WATERSHED PLANNING BEST PRACTICE REPORT

The Watershed Planning Best Practices Report (WPBP) is part of the actions creating the Neighborhood Resilience Plans. The watershed best practices will help to inform the watershed management from region, city and community and hereby help to reduce the flooding and damage caused by extreme weather events.



1.2 ONE TEAM APPROACH FOR NEIGHBORHOOD RESILIENCE PLANS

The ONE Team understands the importance of linking this effort to the substantial work already developed in Complete Communities, Resilient Houston, Houston Climate Action Plan, the many community health programs, and the various Harvey recovery projects. With thoughtful outreach, in collaboration with local community organizations, ONE Team identifies compound risks, offer multi-benefit strategies to address flooding, moderate extreme heat, improve economic development, integrat¬e transportation, and strengthen public health. By addressing historical and prevailing inequities we will collectively build capacity to advance neighborhood priorities, attract investment, and encourage equitable growth. This effort seeks to transfer agency to neighborhood advocates and community members to steward resilience efforts at the local level, while considering initiatives and impacts at the City and Regional levels.

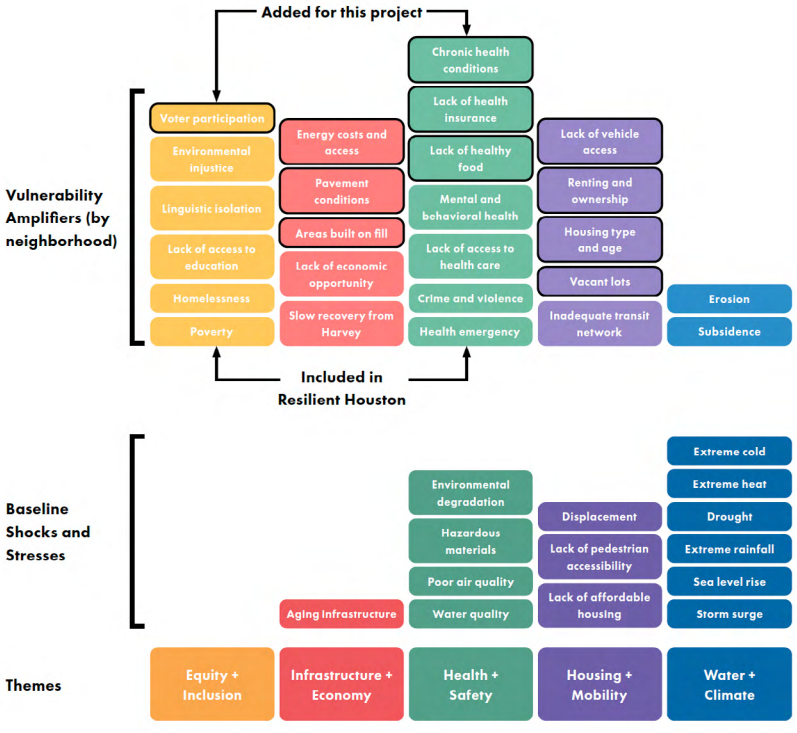
The bayous are one of the linking elements between the different levels, regional, citywide, neighborhood specific and individual plots. Watershed management is therefore also encompassing the different scales and jurisdictions

CONCEPTUAL FRAMEWORK

Building on the priority shocks and stresses identified in Resilient Houston, the Neighborhood Resilience Planning effort will assess key baseline stresses expected to affect the City of Houston at large as well as vulnerability amplifiers specific to each neighborhood. This framework acknowledges the disparities in the ways Houstonians experience climate events and provides a pathway for each neighborhood to highlight the opportunities and challenges that are of highest priority to them.

For looking at watershed management best practices a subset of the categories of Resilient Houston have been taken into account. Please refer to page 5 Chapter 1 – Our approach to WPBP for details.

Framing Houston's resilience-building by theme and scale.
Image from Resilient Houston



Priority shocks and stresses based on those identified by Resilient Houston

1.3 GOALS OF THE WATERSHED PLANNING BEST PRACTICES REPORT

The Watershed Planning Best Practices Report (WPBP) encompasses four goals:

1. The lessons learned from national and international best practices will help to inform the process and decisions made in Houston Neighborhood Resilience Planning for the current three neighborhoods and future neighborhoods. The lessons encompass measures (what's done), governance (who's involved), process (how it's done), funding (how it's paid), and innovation (what is new).

2. This report will inform experts, such other departments of the City and County who's priority might not be working on Neighborhood Resilience Planning, about what is done elsewhere and what can be done in Houston and Harris County.

3. The report helps communities to imagine what they might do and gives language and examples for their advocacy in local decision-making. These examples highlight what to be aware of, what to advocate for, and what actions communities might be able to take themselves when planning for resilience.

4. This report will provide a framework for comparison that the City of Houston can update as necessary when new best practices emerge with a scheduled refresh every three years to ensure that future Neighborhood Resilience Plans can benefit from the latest examples of watershed planning.

1.4 OUR APPROACH FOR THE WATERSHED PLANNING BEST PRACTICES REPORT

The ONE Team has used the Resilient Houston Framework for looking at the best practices in watershed management. These have been collected from a wide range of sources, including desktop research and interviews with local experts. Each best practice example has been examined at the scale of the region, city, neighborhood, and parcel and will be viewed through multiple lenses of the Resilient Houston framework:

- Equity and Inclusion: How has the community been involved and how does the community benefit?
- Water and Climate: Which issues and threats are mitigated by each best practice example?

Several categories identified in Resilient Houston are beyond the scope of the WPBP report and have not been evaluated relative to each example. These include: infrastructure and economy, health and safety, and housing and mobility. Please refer to page 4 for all the categories. Also, the amplifying factors specific to individual neighborhoods identified by the ONE team are not considered in this report.

Each practice is summarized by looking at the following: what it entails, what scale of implementation (region/city/neighborhood) is used, what water concerns are managed, how the community and stakeholders are involved, what the implementation strategy is, how the funding is arranged and what the key lessons for Houston are from this specific example.

BUILD-UP OF REPORT

Chapter 2 of the report will look at an overview of the watersheds, its management, what the concerning issues are and who is responsible. Chapter 3 and 4 will look at the national and international practices respectively. Chapter 5 looks at the overall key lessons for Houston that come out of the best practices.

Tom Wussow Park - Greens Bayou
Image Credit: Dalia Munenzon,
One Architecture, 2021

2. OVERVIEW OF WATERSHEDS

2. OVERVIEW OF WATERSHEDS

2.1 WATERSHED MANAGEMENT AND PLANNING

What is a watershed, what is watershed management, and why is it relevant to Houston?

WATERSHEDS

A watershed is an area of land that is drained by creeks, rivers, or river systems into a common outlet or waterbody. A watershed includes the land over which water flows and the rivers and streams that naturally convey the water to a common outlet. The edges of watersheds are defined by ridges or high points in the landscape.

WATERSHEDS MANAGEMENT

Watershed management is the comprehensive management of a watershed's natural resources to preserve or improve the quality of those resources while reducing negative downstream impacts (like flooding) and enhancing their productive capacity and benefit to local populations.

In Houston the common watershed outlets are the regional surface water channels consisting mainly of bayous that fall under the jurisdiction of Harris County Flood Control District, which has statutory responsibility for their management and maintenance. Though they are managed at the County level, Houston's bayous are an interconnected drainage network intertwined with the local drainage systems of the neighborhoods through which they pass. For this reason, the Neighborhood Resilience Planning process assumes a multi-scaled watershed management approach to evaluate regional-to-local issues within a single, comprehensive framework. As watershed management requires an understanding of stresses across multiple jurisdictions, this framework also considers other water-based threats related to both the watersheds, the neighborhood water - infrastructure, the stormwater sewer sheds, the groundwater, and the water quality.

DIFFERENT SCALES OF WATERSHEDS

Watersheds presents themselves differently on the three scales that affect the neighborhood: The regional scale, the city scale, and the neighborhood scale.

Regional scale
Harris County is serviced by 23 independent watersheds, which consist of an extensive network of open- channel system (bayous) and regional detention ponds. The bayous in Harris County are fed predominately by rain that falls within the county boundaries. Minor exceptions are in Addicks and Barker Bayous, Spring Creek, Clear Creek, and Cedar Bayou, which are also fed from drainage outside of the county. The bayous are dry or contain small amounts of water most of the time. The San Jacinto River watershed is the only major watershed with more area outside of Harris County than within. Harris County Flood Control District is the entity responsible for maintaining most of the bayous.
City scale
Multi-scaled Watershed management relating to the City consists of the stormwater drainage system, drinking water system, sewage and the waste water treatment system.

The City stormwater drainage system consists of roadside ditches, storm sewers, and treatment plants that outfall downstream into the regional, County-managed bayou system. The City is responsible for this detention and flow drainage system, which also includes a few of the bayou channels that were converted and merged into the City's drainage system.

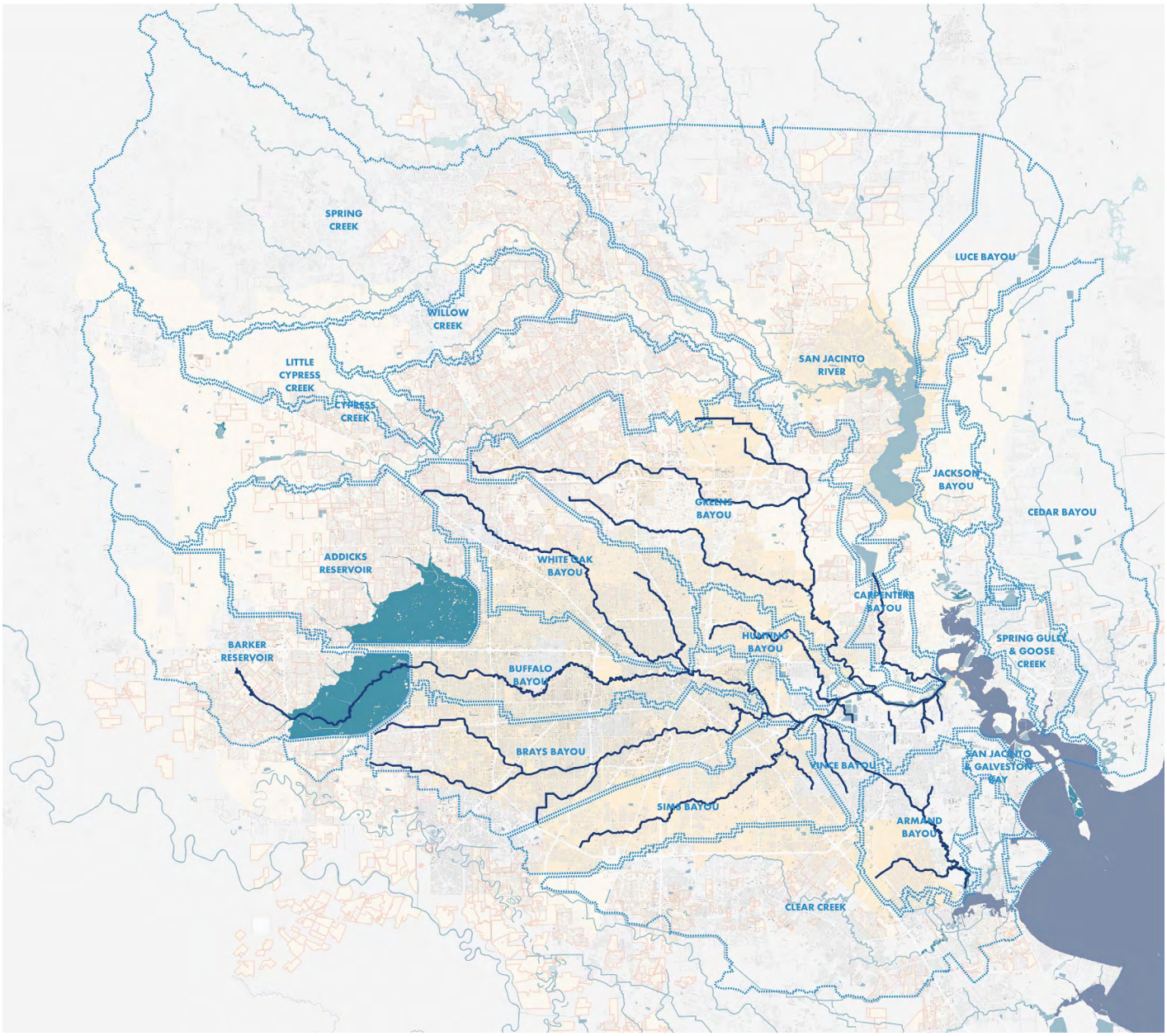
Today, approximately 2.2 million citizens receive high-quality drinking water at sufficient pressure to meet their daily needs from three surface water treatment plants and several groundwater systems. Houston's water system spans over 600 square miles, serving four counties.

The City treats over 250 million gallons of wastewater a day by operating 39 wastewater treatment plants, 381 lift stations, and approximately 6,200 miles of sewer mains (gravity & force mains). Most of the City wastewater treatment plants discharge treated water directly to local bayous and lakes that eventually find their way to the Houston Ship Channel and Galveston Bay. The City of Houston wastewater system has consistently been awarded gold and silver awards from the National Association of Clean Water Agencies.

Neighborhood scale
The neighborhoods are nested in the regional watersheds of the bayous and the citywide stormwater drainage systems, citywide drinking water systems, and citywide sewage systems. The neighborhood infrastructure is the City's infrastructure. Most of the times multiple neighborhoods are part of one urban drainage watershed. In some cases, multiple neighborhoods outfall into a major thoroughfare storm sewer system, which then outfalls to the regional bayous.

HOUSTON RELEVANCE

Watershed management is relevant to Houston because good watershed management practices can help reduce the flooding and damages caused by extreme weather events. Also, public awareness of the range of water management issues at stake help to inform advocacy, decision making and actions.



Houston's bayous and watersheds

HOUSTON'S CLIMATE IMPACT ASSESSMENT

While the City of Houston's flooding issues are well documented and understood, the climate impact assessment for Resilient Houston (2020) shows that in the future even greater variability in day-to-day precipitation will occur. The precipitation will increase during extreme events, such as the wettest three-day period each year, with a risk of more flooding caused by extreme rain events, tropical storms, and hurricanes. Experts have stated Houston is at greater risk of flooding due to extreme rain events than flooding caused by sea level rise.

2.2 THREATS AND ISSUES RELATING TO WATER IN HOUSTON

Houston Watershed Management considers stormwater flooding (pluvial), flooding that occurs when the water level in a lake, bayou or river rises and overflows onto the surrounding land (fluvial), coastal flooding from the sea (caused by tidal, storm surge, sea level rise), compound flooding (combinations of pluvial, fluvial, and/or coastal flooding), groundwater issues (rising or receding rising or receding groundwater and its relation to drought and fresh water supply), and water quality.

Each neighborhood vulnerability assessment provides details on how specific water issues and threats relate to the neighborhoods. Please refer to the map atlas and the vulnerability assessment per neighborhood for details.

STORMWATER FLOODING (PLUVIAL)

Stormwater flooding is flooding from rainwater runoff from buildings, yards, streets, squares, and parks when it rains harder than the stormwater sewer can handle resulting in sheet flow flooding from direct rain or back up flooding from the stormwater sewer. Stormwater flooding is caused by extreme precipitation events, tropical storms and hurricanes. This is also called pluvial flooding.

Direct rain: When it rains harder than what the stormwater sewer has been designed for rainwater cannot enter the storm sewer and will create sheet flows on streets, yards, and other hard surfaces. Flooding risks to adjacent or downstream properties and especially to low lying areas will then occur when the surfaces do not have enough space for the sheet flow. In addition to the challenge that, due to climate change, extreme rain events, hurricanes and tropical storms will increase in amount of rain, challenges further include the need to incorporate sheet flows from offsite areas and the lack of capacity in the receiving bayous.

DESIGN CRITERIA FOR THE DIRECT RAIN RUNOFF:
Within the City, the entire street Right of Way conveys 100-year flows to the bayous. The design criteria for the direct runoff within the service area must be sized to convey the 100-year storm (18 inches/24 hours) and a velocity of 3 feet/sec through a combination of street cascading and storm sewer systems with no adverse impact to adjacent or downstream properties. The size of the underground storm sewer system is a challenge. Ranging from a current minimum of 24 inches in diameter of conveyance pipes to very large 15 feet x 15 feet, the system requires significant sub-surface space. Finally, Hurricanes like Harvey far exceed the current 100-year flood events with a total rainfall of 42 inches – 60 inches.

Stormwater sewers backup and overflows: Houston has a separated sewer system segregating rainwater and sanitary sewer flows. An overflow in the rainwater sewer system will not create a back-up in the sanitary sewer system. The underground rainwater sewer system, however, can be blocked. This would create sheet flow as well as possible exploding manhole covers downstream.

A sanitary sewer overflow is a backup and discharge of raw wastewater that can contaminate water, cause property damage, and threaten public health. The most common causes of sanitary sewer overflows are blockages (caused by grease & wipes), wastewater line breaks, and flooding (stormwater overloads the wastewater system by fluvial flooding).

RIVERINE/BAYOU (FLUVIAL) FLOODING

Riverine/bayou flooding is flooding that occurs when the water level in the bayou rises and overflows onto the surrounding land. This is also called fluvial flooding.

Upstream precipitation: Flooding of the bayous occur when upstream rainfall volume exceeds bayou capacity. The standard capacity of the bayou is less than a 10-year rain event—in other words, each year there is a 10% chance that a 1 in 10 year rain event will occur. However, a 10-year event may occur once, twice, several times, or not at all during a 10-year period. When bayous exceed capacity, this poses a challenge for draining any specific system resulting in flooding of floodplains and potential backup flooding in the neighborhood sewer systems.

Upstream release: The Addicks and Barker Reservoirs, located upstream of Buffalo Bayou, and managed by the US Army Corps of Engineers (USACE) protect downtown Houston from flooding. With increasing intensity of rainfall, these reservoirs near critical capacity and require the USACE to release water during extreme precipitation events in order to avoid structural failure. Such release can create downstream flash-floods threatening critical infrastructure such as wastewater treatment plants. Other reservoirs, such as Lake Houston and Lake Conroe, primarily drinking water reservoirs with some flood control benefits, can cause similar downstream flooding if extreme precipitation events require releases.

Floodplains: Approximately 34% of Harris County is in a FEMA-designated Special Flood Hazard Zone for riverine flooding:

- 7% in a floodway +
- 16% in the 100-year floodplain +
- 11% in the 500-year floodplain.

These delineated floodplains reflect the flood risk associated with channel capacity within the County.

COASTAL FLOODING

Coastal flooding is flooding coming from the sea. Coastal flooding includes flooding caused by storm surges, tidal inundation and sea level rise.

Storm surge: The City of Houston is susceptible to storm surge in the Clear Lake area and along the Ship Channel.

Flood zones: Approximately 2% of Harris County is in a FEMA-designated Special Flood Hazard Zone for coastal or surge flooding.

Sea level rise (SLR): The City of Houston is susceptible to a combination of global sea level rise and land subsidence of the coastline which results in that the relative rate of SLS is among the highest in North America. (See maps on page 20 of the Climate Impact Assessment.)

Tidal inundation: Tidal inundation is not widespread in the City of Houston and only routinely impacts the bottom portion of the channels close to the bay and the Houston Ship Channel.

COMPOUND FLOODING

Compound flooding is flooding caused by simultaneously occurring various types of flooding.

A significant portion of the City of Houston experiences compound flooding from stormwater and fluvial flooding, which is due to insufficient local infrastructure (undersized or crumbling storm sewer systems, including pipes and inlets) and poor receiving bayou capacity.

GROUNDWATER

Groundwater is the water found underground in the tiny spaces (pores) between rocks and particles of soil. If you dig into the ground and find water welling in the hole, you have reached the groundwater table. The depth of the groundwater table varies through Houston with areas with high ground water and low ground water occurring. Groundwatertable fluctuates through the year, but climate change and peoples actions can create rising ground water or receding groundwater. Receding groundwater is a major cause for subsidence.

Drought: City of Houston is prone to both a slight increases in number of dry days and increasing risk of drought due to soil moisture decreases resulting from higher temperatures. The clay-rich soils swell when wet and shrink when soil moisture evaporates. During the drought of 2011 this shrinking resulted in damage to infrastructure, foundations, roads, water- and sewer infrastructure.

Subsidence due to groundwater extraction for potable water: Over the 20th Century, the City of Houston leaders explored other long term water sources and initiated construction of Lake Houston and the East Water Purification Plant (1954), including purchases of water rights to Lake Livingston (constructed in 1969) and Lake Conroe (constructed in 1973) and eventually Trinity River water rights. Although these additional water sources supported Houston's growth, continued use of the local groundwater created land subsidence problems through the metroplex area. Recognizing this issue, by 2030, Houston water can only source 20 percent of its potable water from groundwater, the remaining coming from the surface sources mentioned previously.

WATER QUALITY

Water quality is a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. Water quality is among others effected by temperature, erosion, contaminants (such as pesticides but also medicines) and decaying organic materials. The water quality is important for use of drinking water, for the health risks relating to ground water and or surface water from the bayous and Ship Channel.

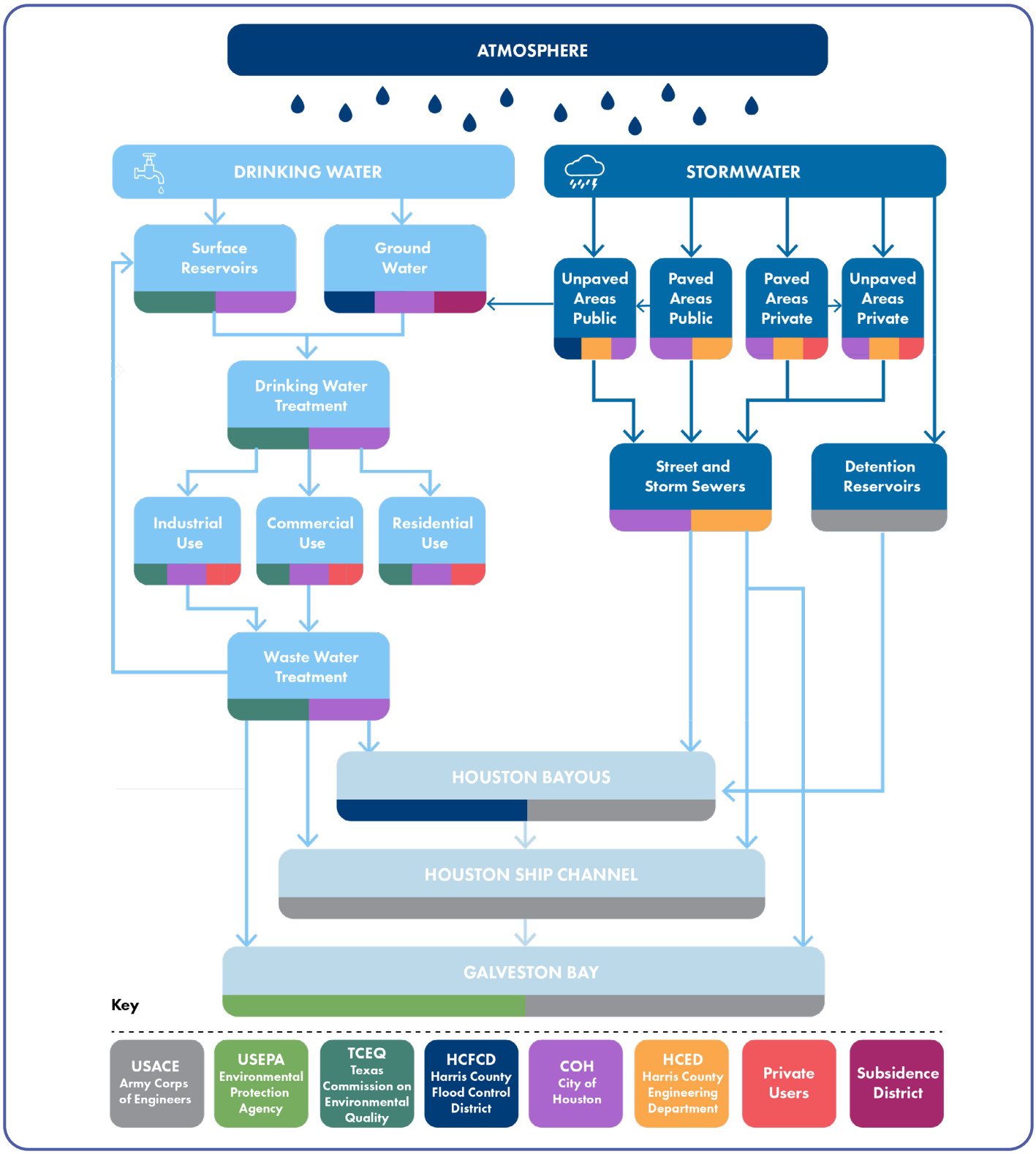
Bayous and Ship Channel: The Ship Channel has issues with water quality due to industrial runoff. The less developed watersheds have water quality issues largely related to agricultural runoff. The San Jacinto watershed, including Spring and Cypress Creeks, has a water quality issue related to sediment runoff. All of the bayous mainly have trash and debris problems that also result in reduce capacity of the channels and tributaries.

Groundwater quality: We are checking the current understanding that there is no water quality issues on the groundwater.

Other water quality concerns: The City of Houston has had challenges with drinking water quality related to mixing water sources (groundwater and surface water), types of disinfection and water age (when drinking water stays in the pipes too long) due to the size of the distribution system. The North East Water Treatment Plant has also experienced challenges treating water due to turbidity and low alkalinity in Lake Houston which is partially attributable to sediment in the upstream areas.

2.3 WHO IS CURRENTLY RESPONSIBLE FOR WATER MANAGEMENT AND ADDRESSING WATER ISSUES?

The City of Houston is responsible for management of storm sewer systems with the City, including enclosed storm sewers and roadways.



Water management jurisdictions for the City of Houston

2.4 WHAT POLICIES, AND FINANCING SOURCES CURRENTLY ADDRESS WATER ISSUES?

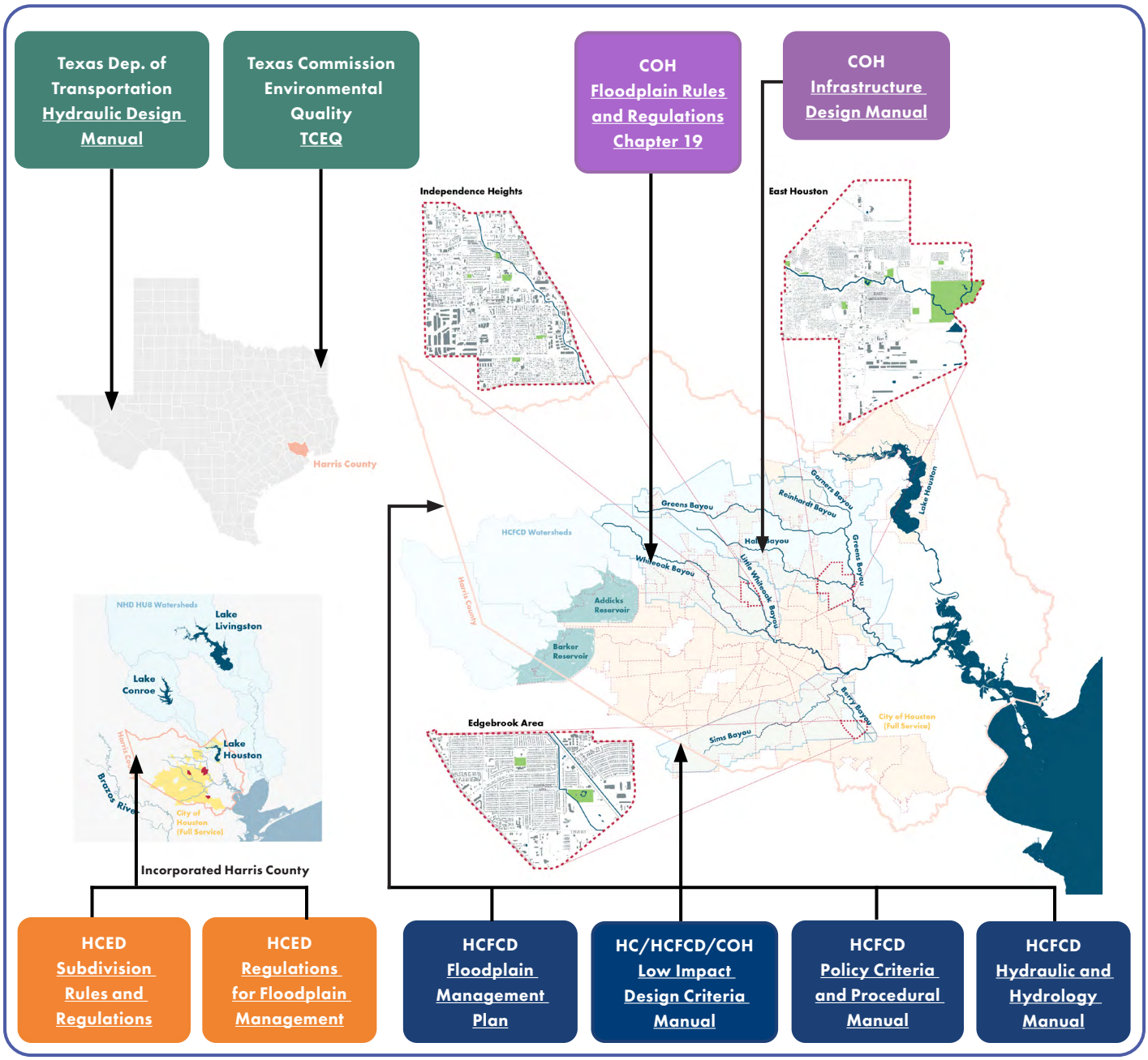
City of Houston infrastructure is funded through revenues from water bills, the drainage fee, property taxes and sales taxes. Special districts controlled by the City also have dedicated revenue sources, such as TIRZs.

EPA Consent Decree

In 2021, the U.S. District Court for the Southern District of Texas approved a consent decree between the City of Houston, the U.S. Environmental Protection Agency (EPA), and the State of Texas to improve Houston's wastewater system. The consent decree will provide an estimated $2 billion of additional work in improvements to upgrade Houston's aging wastewater system and keep up with Houston's rapidly-growing population. The goal of the consent decree is to protect the environment and human health and improve the wastewater system for generations to come.

The consent decree with the EPA is part of a national program to reduce sanitary sewer overflows, which the Clean Water Act prohibits.

Low-income communities with higher numbers of sanitary sewer overflows and aging infrastructure will be among the first priorities under the consent decree.



Policies relating to watershed management at various scales are nested within the City of Houston, Harris County, and the State of Texas.

Brock Adventure Par, City of Houston Parks and Recreation Department
Image: Anthony Rathbun Photography via Houston-Galveston Area Council

3. NATIONAL BEST PRACTICES

3. NATIONAL BEST PRACTICES

In recent years, many cities and regions have introduced new watershed management practices for regional and urban watersheds. Though the geographic locations and environmental conditions addressed by these practices differ, elements of these strategies are directly applicable to watershed management in Houston. The criteria for selecting the range of national and international best practices are: different aspects of community involvement, large-scale collaboration between agencies, practices relating to managing large amount of water. Each practice is summarized by giving a description and looking specific at the scale of implementation (region/city/neighborhood), what water concerns are managed, how the community and stakeholders are involved, what the implementation strategy is, how the funding is arranged and what the key lessons for Houston are from this specific example.

The following national examples are reviewed: Portland, New Orleans, Charleston and Hoboken. This report also includes a summary of the City of Houston's flood control practices and Harris County Flood Control practices, which may provide a useful example for other areas. As all these examples have only looked at specific water concerns and not taken all water concerns into an integrated water management effort, One Water approach is also reviewed.

3.1 ONE WATER (NATION WIDE)

The US Water Alliance is leading an initiative known as One Water. This initiative encourages all water sources and uses to be valued comprehensively.

One Water is the integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs. It is an emerging term in the United States for what is commonly known as integrated urban water management.

"One Water promotes the management of all water within a specific geographic region. Drinking water, wastewater, stormwater, and greywater are a single resource that must be managed holistically, viably, and sustainably. Under the current system of water management, within any given community, different streams of water are compartmentalized, managed in almost complete isolation from one another. Collaboration across these silos is a critical ingredient, and an absolute necessity, if decisions are to be made that are truly in the best interest of the community and water resources. These practices, however, don't come easily. Collaboration, often times between disparate audiences, requires committed leadership, common sense, political capital, a diversity of participants and institutions, as well as the right supporting tools and techniques.

Using a One Water approach requires thinking of water as a single system and recognizing that all urban water flows—including stormwater, rainwater, and wastewater—are potentially useful resources. For professionals, identifying water as a single system requires a shift in mindset to think beyond one's individual area of expertise (e.g., water conservation, drinking water quality, or groundwater management) to how this area is connected to the wider system of water management. It involves exploring the connections between water supply, groundwater, stormwater and rainwater, wastewater, and the overall impact of managing these water sources on flooding, water quality, wetlands, watercourses, estuaries and coastal waters" (Source: Advancing One Water in Texas, Feb 2018).

ONE WATER SF (SAN FRANCISCO)

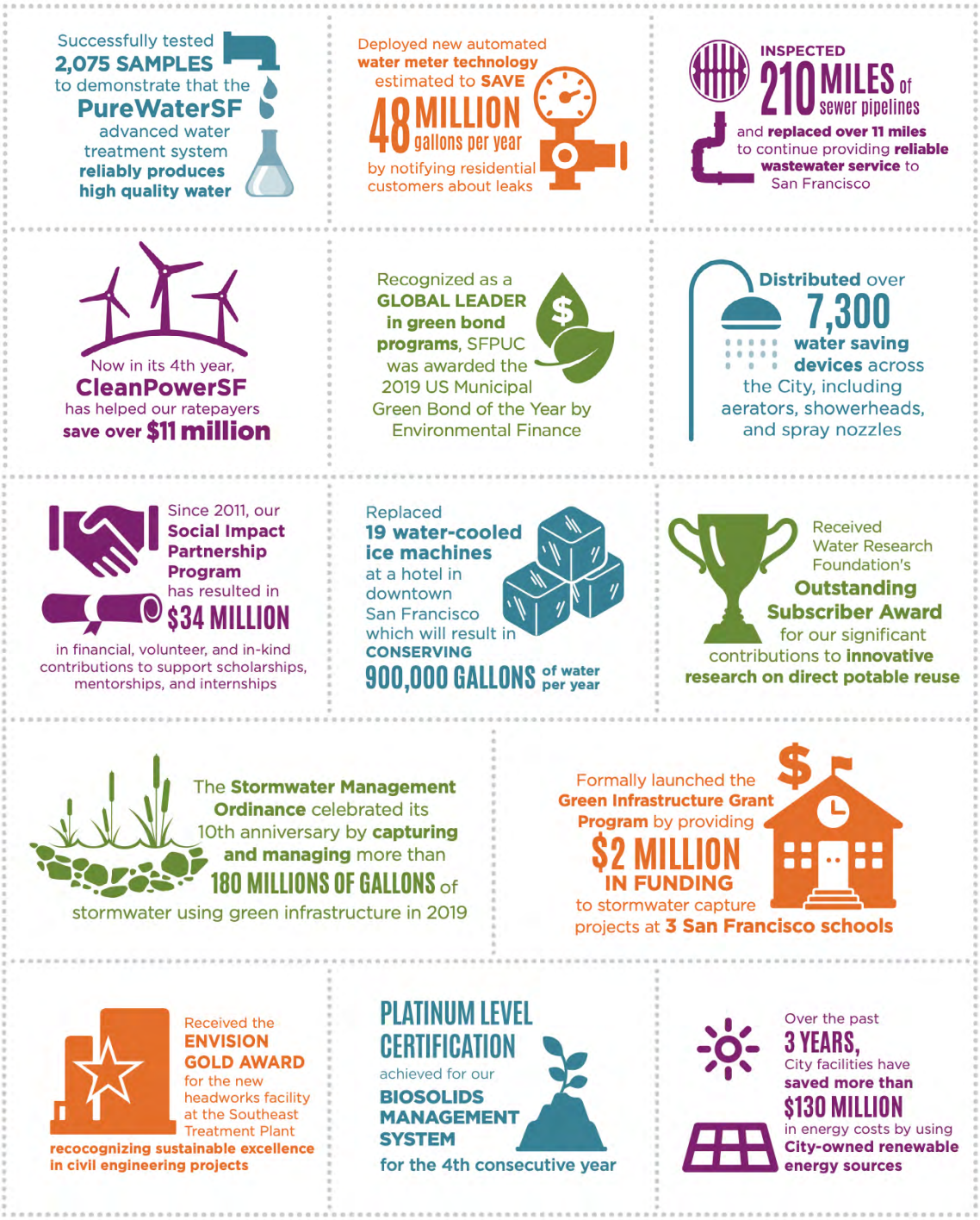
San Francisco has implemented One Water at a local level and includes energy in the approach. OneWater SF merged an existing Regional Water System that provides high quality water and electricity at a low energy cost, with a strong Local Water Program that includes groundwater, recycled water and conservation.
The accomplishments include:

- Deployed new automated water meter technology estimated to save 48 million gallons per year by notifying residential customers about leaks.
- Inspected 210 miles of sewer pipelines and replaced over 11 miles
- CleanPowersSF has helped ratepayers save over $11 million
- Distributed over 7,300 water savings devices across the City

FURTHER INFORMATION

One Water: http://uswateralliance.org/one-water
One Water SF: https://sfpuc.org/about-us/policies-plans/onewatersf

KEY LESSONS FOR HOUSTON
The City of Houston expedite similar devices notifying customers about water leaks, starting in areas of oldest infrastructure.



Resilience goals accomplished by OneWaterSF. Image credit: OneWaterSF

The OneWaterSF vision is to optimize the use of finite water and energy resources to balance community and ecosystem needs, creating a more resilient and reliable future. Image credit: OneWaterSF

3.2 PORTLAND GREEN INFRASTRUCTURE

The City of Portland has several resiliency-focused green infrastructure programs including: a tree program, the Green Street Steward Program; Portland Ecoroofs and an Innovative Wet Weather Program in addition to monitoring and tours.

- The Environmental Services Tree Program works with community partners to plant trees where they will contribute to human and watershed health.
- As part of the Green Street Steward program, the City implements National Pollutant Discharge Elimination System (NPDES) inlet markings, and an Adopt A Storm Drain program. Both of the programs already exist at some scale in the Houston area, with inlets having stamps and with an adopt an inlet program.
- The Portland Ecoroofs program includes information about planning, resources, and a do it yourself guide. The online literature also includes case studies and incentive cost analysis.
- The City of Portland also has an innovative wet weather program that is funded (in part) by the EPA. The program is environmentally focused but has some components that are related to stormwater quantity as well. The project categories include water quality-friendly street and parking lots, downspout disconnections, Eco-roofs, monitoring and feasibility studies, educational efforts, and grant and project management.

WATER CONCERNS MANAGED

Stormwater flooding  Water quality 

Portland uses a variety of green infrastructure to improve watershed quality. The Green Street approach reduces polluted stormwater entering Portland's rivers and streams, diverts stormwater from the sewer system and reduce basement flooding, sewer backups and combined sewer overflows (CSOs) to the Willamette River; reduces impervious surface so stormwater can infiltrate to recharge groundwater and surface water and reduces demand on the city's sewer collection system and the cost of constructing expensive pipe systems. The Green Street approach was passed by City Council in April 2007.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The city offers opportunities for community and stakeholder involvement through volunteer programs such as tree planting and green street steward program. Partners include park and recreation, department of transportation, school districts, and other neighborhood associations and local environmental groups.

The City also has a series of tours including Green Infrastructure at Portland State University, the Hosford-Abernathy neighborhood tour, and Portland State University walking tour of innovative storm water management projects. A southeast cycling tour is posted to the website. The 13-mile tour includes various projects such as ecoroofs, naturescaping, street trees, green streets, planters, swales and rain gardens, and stormwater management projects. These types of tours are great for engagement and education.

SCALE OF IMPLEMENTATION

City

FUNDING MECHANISM

The City has employed various funding mechanisms for their green infrastructure programs. Between 2002 and 2009 the U.S. EPA granted the City of Portland $3.4 Million to fund innovative public and private projects that demonstrate storm water management solutions. Green Street program also has leveraged funding from the Portland Bureau of Transportation's Affordable Transportation Fund. Project costs for street improvements were also provided by local improvement districts.

IMPLEMENTATION STRATEGY

The best management practices are implemented both through executing green public projects and by partnering with stakeholders. The City showcases projects in order to encourage future green infrastructure projects.

FURTHER INFORMATION

Green Streets: https://www.portlandoregon.gov/bes/45386

Wet Weather Program: https://www.portlandoregon.gov/bes/35941#:~:text=The%20City%20of%20Portland's%20Innovative,environment%20contributes%20to%20healthy%20watersheds.

KEY LESSONS FOR HOUSTON

Although Houston's flat landscape and intense rainfall events operate differently from Portland's steeper landscape, Houston may still benefit from implementation of similar BMPs. To determine which ones would be most worth pursing, some analysis should be considered. The City of Houston has invested in green infrastructure in City limits, particularly along Bagby in Midtown. These programs could be expanded..

Green infrastructure is integrated into Portland's street design and includes bioswales, rain gardens, and tree planting, contributing to improved human and watershed health. Image credits: City of Portland

Images from top to bottom left to right:
Ankeny Green Street
Tabor to the River
Capital Highway and 34th
Albina Triangle

3.3 NEW ORLEANS READY FOR RAIN PROGRAM

New Orleans has implemented two programs for dealing with stormwater flooding: the New Orleans Community Adaptation Program and the NOLA Ready program. The New Orleans Community Adaptation Program is the residential component of the City of New Orleans National Competition Grant managed by New Orleans Redevelopment Authority. It focusses on low-income households in owner-occupied single-family homes.

The NOLA Ready program is the City's Emergency Preparedness Campaign managed in the City's Office of Homeland Security and Emergency Preparedness (NOHSEP). Ready for Rain is a component of the NOLA Ready program. The program Ready for Rain has a community education component through their website. It describes the reasons that the community should be "ready" and purchase flood insurance, lists community non-profits that can assist residents and provides information on green infrastructure. The green infrastructure components included in this program could be used as best practices in creating a more resilient community. The infrastructure included in the program is focused on small scale owner implementable infrastructure and includes the following Best Management Practices (BMPs): rain gardens, detention basins, storm water planter boxes, infiltration trenches, pervious pavers, rain barrels, and tree plantings.

WATER CONCERNS MANAGED

Stormwater flooding 

New Orleans' climate and topology mean that the City experiences frequent flooding. The low-lying City averages 62 inches of rain annually which is a bit more than Houston. The NOLA Ready for Rain program encourages the use of green infrastructure to reduce the volume of stormwater..

COMMUNITY & STAKEHOLDER INVOLVEMENT

NOLA Ready partners with a large list of community non-profit organizations including Advocacy and Coastal Restoration groups, K-12, Tree planting groups and Community education groups. In addition, the Community Adaptation Program (CAP) provides homeowners in the Gentilly neighborhood the opportunity to apply for grant funds to install green infrastructure.

FURTHER INFORMATION

https://ready.nola.gov/rain/
https://ready.nola.gov/green-infrastructure/

SCALE OF IMPLEMENTATION

City/Neighborhood/Parcel

FUNDING MECHANISM

NOLA Ready is implementing $300 million resiliency projects through the Hazard Mitigation Office, the Office of Resiliency, and the Department of Capital Projects for flood reduction and environmental awareness. Additionally, the City and Sewerage Water Board have combined local and federal funds to create $2.4 billion to restore damaged infrastructure. The New Orleans Redevelopment Authority is a subrecipient to the City on a National Disaster Resiliency Competition grant awarded by the US Department of Housing and Urban Development, which funds the CAP.

A large number of the highlighted projects are private projects located on private property and appear to be privately funded.

IMPLEMENTATION STRATEGY

The program is implemented through Capital projects and community members. An application for funding is available for certain neighborhoods.

KEY LESSONS FOR HOUSTON

New Orleans and Houston have similar topography and rainfall events. Because of these similarities, it's possible Houston could benefit from similar Best Management Practices (BMP). Information from the City of New Orleans on the effectiveness of storm water management BMPs on flooding, water quality, etc. would be useful.

The community outreach provided, including information about the terrain, building requirements and benefits of flood insurance is easy for a resident to read and digest. Houstonians could benefit from this type of clear-cut outreach and information.

The New Orleans Ready for Rain program and the New Orleans Community Adaptation program help low-income households with prepare for heavy rain. Images credit: NOLA

3.4 CHARLESTON RAINPROOF

The Charleston Rainproof program is focused on utilizing both public and private spaces to capture rainwater. It is inspired by the Dutch Amsterdam Rainproof program (see international examples for further details). The program includes raingardens and rain barrels and cisterns. Highlighted projects include several community garden projects and private projects that have implemented these Best Management Practices (BMPs).

WATER CONCERNS MANAGED

Stormwater flooding  Water quality 

The program's goal is to address the increasingly frequent and heavy rainfall that Charleston experiences while managing water quality.

COMMUNITY & STAKEHOLDER INVOLVEMENT

Charleston Rainproof partners with a local nursery to provide guidance to residents interested in installing rain gardens. The Master Rain Gardener program is managed by the Clemson Extension Carolina Clear. The program also offers workshops that provide rain garden and rainwater harvesting demonstrations.

SCALE OF IMPLEMENTATION

City/Neighborhood

FUNDING MECHANISM

A large number of the highlighted projects are private projects located on private property and appear to be privately funded.

IMPLEMENTATION STRATEGY

As the majority of these projects are on private property, implementation focuses on developing property owner awareness of the program and workshops to build skills for implementation.

The program also created an online platform for showing implemented projects on a website in order to stimulate others to construct green infrastructure measures too.

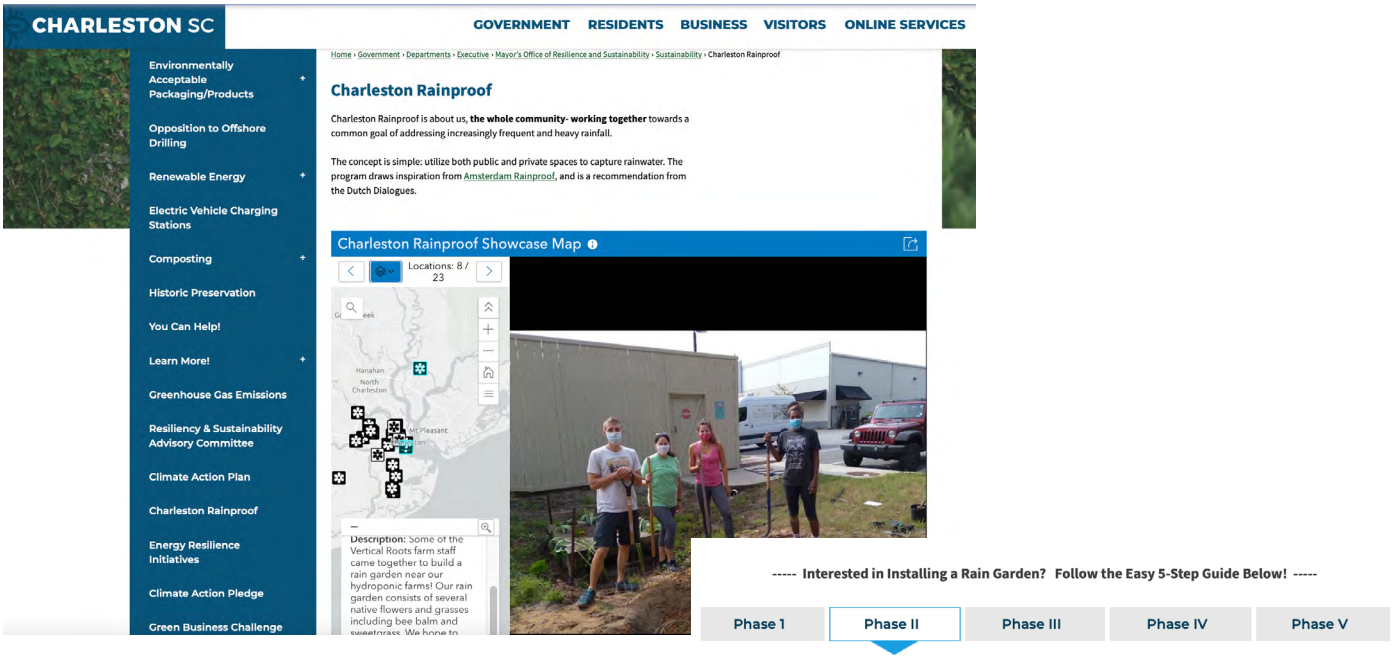
KEY LESSONS FOR HOUSTON

As the volume of these BMPs is small compared to Houston's statistical rainfall volumes, these BMPs would have to be installed on a large scale in order to provide a measurable change to runoff volume.

The key lesson is in the link to empowering community activism through community engagement with local businesses such as nurseries and professional gardeners.

FURTHER INFORMATION

https://www.charleston-sc.gov/rainproof



Screenshots of a Charleston-based website showcasing completed projects and providing simple instructions for how to install green infrastructure

Corine Jones Community Garden with rain garden and rainwater harvesting system installed by the Master Rain Gardener course through Clemson Cooperative Extension
Image credit: Charleston Rainproof

3.5 THE CITY OF HOBOKEN GREEN INFRASTRUCTURE

The City of Hoboken's Green Infrastructure Strategic Plan was published in 2013. The intent was to "create a framework for city-wide green infrastructure investments as a mechanism for improving stormwater management, controlling flooding, and preparing for future climate change. It also encourages policy changes, such as zoning requirements and incentives, pilot projects, and plans for public lands and rights-of-way." The plan identifies sewersheds and assess the total amount of stormwater that can be captured using green infrastructure.

- Best Management Practices in this program included constructed wetlands, permeable pavements, stormwater street trees, vegetated bioswales, rainwater harvest and reuse, stormwater basins or ponds, rain gardens, stormwater infiltration planters, subsurface storage, and green roofs.

WATER CONCERNS MANAGED

Stormwater flooding  Coastal flooding 

The City of Hoboken's Green Infrastructure Strategic plan is a mechanism to improvement stormwater management, control flooding, and prepare for climate change. The City's challenges also include Sea level rise, aging infrastructure and CSOs.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The City hosted a public outreach meeting, held in a central location. An online survey was also available on the City's website for two weeks, as well as available in person in certain City buildings.

SCALE OF IMPLEMENTATION

City/Neighborhood

FUNDING MECHANISM

This plan also includes a funding component and an implementation plan. The funding component includes in-lieu-of payments to a Stormwater Trust Fund as a means of generating revenue.

Total program cost: $150 million.

Funding sources:

- $18 million municipal bond
- $7.5 million municipal Open Space Trust Fund
- $3 million Hudson County Open Space Trust Fund
- $15 million in federal grants
- $73 million in State Revolving Fund loans
- $35 million in leveraged funds from project partners, such as North Hudson Sewerage Authority

IMPLEMENTATION STRATEGY

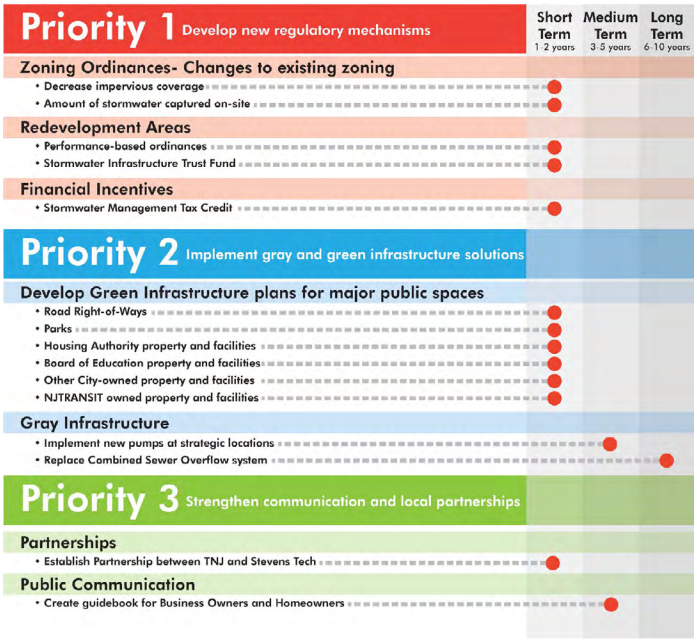
The plan identifies neighborhoods and even smaller areas for green infrastructure pilot projects. These areas include demonstration projects in public housing projects, and low-income areas that have potentially more vulnerable populations. The implementation planning also analyzes sewersheds and assesses the total amount of stormwater that can be captured using green infrastructure. Prioritization included the immediacy of implementation and issues that were within the jursidictions control.

KEY LESSONS FOR HOUSTON

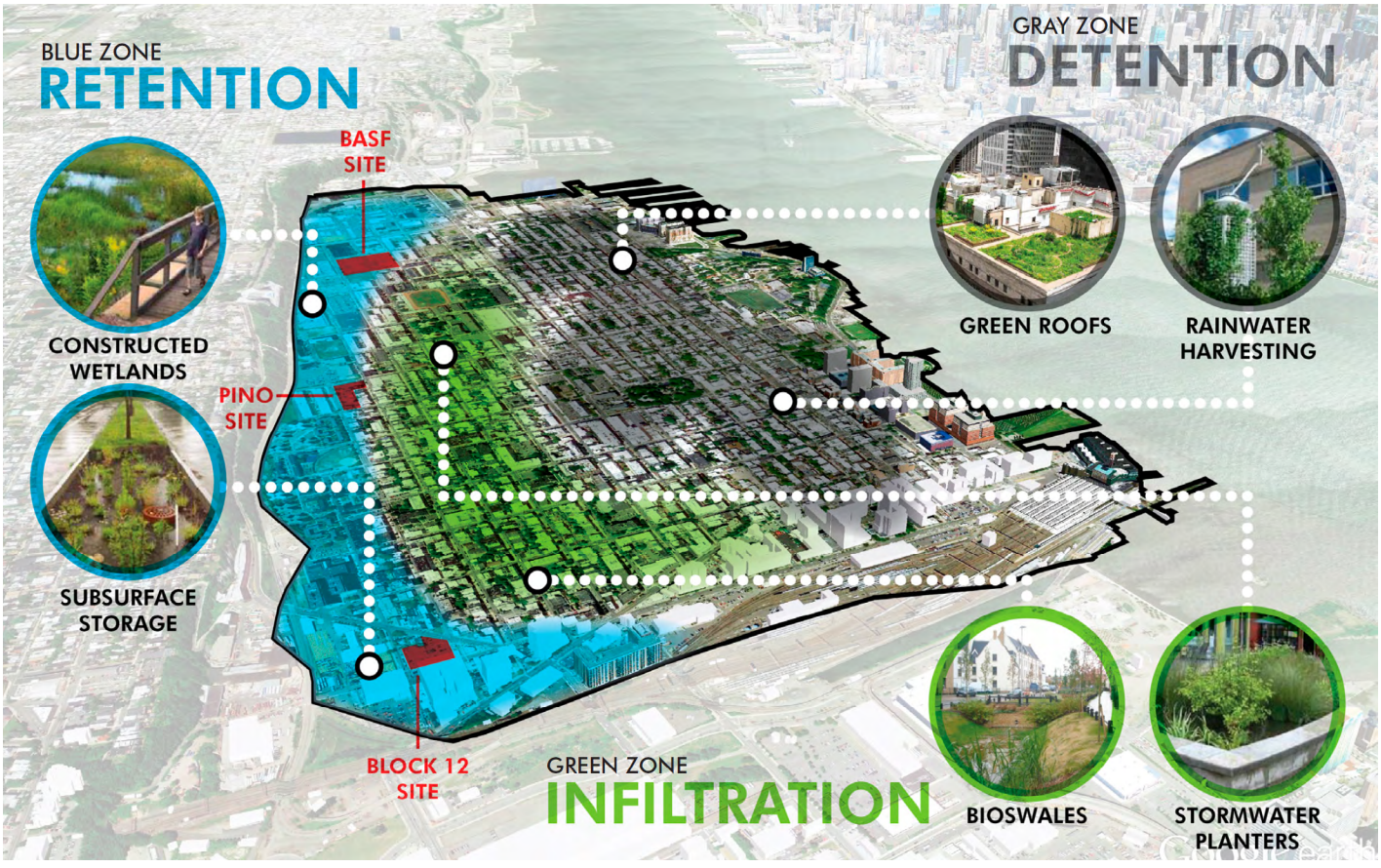
The City of Hoboken is very small in comparison with the overall City of Houston. However, the implementation planning that was completed within the City of Hoboken may be applicable to the City of Houston neighborhoods. The City of Houston's Master Drainage Plan will also identify sewersheds within its scope of services. There may be an opportunity to use the data to look into how various BMPs can affect total surface runoff volume (sheet flow) in various neighborhoods once the existing sewersheds and peak flows are established across the entire community, however this would require a large city wide study in combination with existing studies from Harris County Flood Control District.

FURTHER INFORMATION

https://www.jerseywaterworks.org/resources/hoboken-green-infrastructure-strategic-plan-6/ (Green Infrastructure Strategic Plan)



Set of priorities created together with the communities for the City of Hoboken Green Infrastructure Strategic Plan. Image credit: City of Hoboken



Green infrastructure strategy for the City of Hoboken. Image credit: Perkins Eastman

3.6 CITY OF HOUSTON

The City of Houston is a participant in the National Flood Insurance Program (NFIP) and has a Class 5 rating as part of the Community Rating System (CRS). The goals of the CRS are to reduce flood losses, facilitate accurate insurance rating, and promote awareness of flood insurance. This is done through requirements relating to floor elevations, detention areas, and analysis showing no impact. Those requirements help with mitigating stormwater flood risks.

WATER CONCERNS MANAGED

Stormwater flooding  Drought 

All of these requirements are aimed at reducing flooding for all new private construction and the City's own Capital Improvement Projects.

The City of Houston also has a water conservation plan, which includes a drought management plan.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The City hosted community engagement workshops involving Super Neighborhoods, developers, engineers, and real estate professionals to discuss the desired requirements, as well as understand the implications for such changes for future housing costs.

SCALE OF IMPLEMENTATION

City

FUNDING MECHANISM

The City's resources to fund public projects include revenues from property taxes, sales taxes, revenues from the water bills and also revenues from the Rebuild Houston drainage fee.

IMPLEMENTATION STRATEGY

- The City requires newly permitted structures within a flood zone to have a finished floor elevation 1.5 feet above the Base Flood Elevation (BFE). In areas without a BFE, one must be established prior to determining the finished floor elevation.
- The City requires a detention rate of 0.75 acre-feet/acre for increased imperviousness by building e.g. roads and buildings in both private and public development.
- The City requires an analysis demonstrating no impact to adjacent properties, including an analysis and plan for managing sheet flow.
- The City of Houston has a water main replacement program to reduce regulatory compliance issues, improve customer service and reduce water loss.
- The City of Houston has a plan to reduce water loss through metering to detect leaks, reduce water usage by City facilities and other non-revenue users, reducing water theft, expediting shutoff of water meter with no account owner.
- The City of Houston completed it's first phase of the consumption awareness program to notify users in real time how much water is being used.
- The City of Houston revised its plumbing and building codes in 2011 to reduce water usage.

KEY LESSONS FOR OTHERS

Be strict about the finished floor elevation, the offset of increased imperviousness, mitigation for fill in the floodplain and the process that is required to demonstrate no impact on adjacent properties.

FURTHER INFORMATION

https://library.municode.com/tx/houston/codes/code_of_ordinances?nodeId=COOR_CH19FL

3.7 HARRIS COUNTY FLOOD CONTROL

Harris County Flood Control District (HCFCD) has regulatory authority over the open channel system throughout Harris County. The entity is a special district created by the state of Texas and its primary purpose is to reduce flooding within the entire county. This is done through requirements for specific analyses done that shows no adverse impacts for the 2-, 10- and 100-year events; by developing an extensive flood warning system and by implementing measures such as wet bottom detention basins.

WATER CONCERNS MANAGED

Stormwater flooding  Riverine flooding 

All requirements, warning systems and measures are aimed at reducing flooding for all new private construction, as well as reducing riverine flooding throughout the County.

COMMUNITY & STAKEHOLDER INVOLVEMENT

All projects funded as part of the 2018 Flood Control Bond include public outreach through public meetings at the end of the feasibility analysis to convey to the public what proposed projects will entail.

SCALE OF IMPLEMENTATION

Region

FUNDING MECHANISM

HCFCD is funded through property taxes and the 2018 Flood Control Bond.

IMPLEMENTATION STRATEGY

- Harris County Flood Control District requires all analyses to be completed using the latest FEMA-effective models, and the best available data, if new models are pending FEMA-approval. HCFCD created a Model and Map Management System with the FEMA-effective models, which includes every approved Letter of Map Revision (LOMR) to date. This is practical due to the LOMR delegation agreement HCFCD has reached with FEMA. HCFCD also has strict guidelines for which analyses will require a Conditional Letter of Map Revision (CLOMR) submittal prior to issuance of a construction permits and the LOMR must be approved prior to issuance of the final permit (issued by Harris County). HCFCD requires all analyses demonstrate no adverse impact for the 2-, 10- and 100-year events.
- HCFCD has also implemented wet bottom detention basins, with storm water quality features under the static water surface elevation, for all new regional flood reduction basins. The storm water runoff is routed through the pond, allowing opportunities for sediment to drop out prior to discharging to the channel. HCFCD is only authorized to fund flood reduction measures, but regularly partners with funding partners to include other facilities such as walking trails or other park facilities.
- HCFCD has developed an extensive Flood Warning System for real time monitoring of the streams and bayous throughout Harris County and even some gages beyond the county limits. The system measures real time rainfall and water levels, along with a layer indicating channel status. The channel status layer was added post-Harvey for clearer communication with the public. The site is used frequently by the local meteorological reports on the local news.

KEY LESSONS FOR OTHERS

Maximize the detention required to offset the increased imperviousness within the rules of the Texas Water Code, mitigation for impacting the floodplain, and the process that is required to demonstrate no impact on adjacent properties.

FURTHER INFORMATION

https://www.hcfcd.org
https://www.harriscountyfws.org

3.8 INNOVATIVE FUNDING MECHANISM - ENVIRONMENTAL IMPACT BONDS

In addition to these national watershed management practices new funding mechanisms for water related concerns have been implemented in at least three cities in the US which could be useful for Houston.

A relatively new form of raising funds for infrastructure projects is to issue an Environmental Impact Bond (EIB). EIBs are a form of performance-based financing, where repayment is based on how successfully the projects achieve environmental, social and/or economic outcomes for local communities. These are a type of municipal bond that require issuers to predict, measure, and report on the environmental or social outcomes generated by the funded projects. Some EIBs also connect bond buyers' financial returns directly to the performance of the funded projects, which allows risk-sharing between the issuer and investors. The requirement for impact measurement and disclosure differentiates EIBs from traditional Green Bonds, which support specific environmental and climate-related projects, but do not require the same level of rigor in outcome prediction, measurement and disclosure. In many cases, there are large investment firms looking to invest in projects with environmental, social or economic goals but also provide a financial return. EIBs provide a way to meet these goals while also improving the community.

ATLANTA

In 2002, the Department of Watershed Management (DWM) was formed to manage the City of Atlanta's essential utility operations: drinking water, wastewater and stormwater systems. Their CIP is one of the largest in the country with a budget of approximately $4 billion. DWM created the first-ever publicly offered EIB. The $14 million bond is financing six green infrastructure projects in the Proctor Creek watershed to manage stormwater, reduce local flooding, alleviate water quality impacts, increase access to green space and create local green jobs.

WATER ISSUES MANAGED IN ATLANTA

Stormwater flooding  Water quality 

The Proctor Creek watershed in recent years has become fraught with flooding, water quality and other environmental and economic challenges. Proctor Creek's headwaters now originate from runoff due to the increase in impervious surfaces (parking lots, buildings, highways, etc.) in downtown Atlanta. This urbanization, combined with increasing rainfall, has put growing pressure on the area's outdated stormwater and wastewater infrastructure.

IMPLEMENTATION STRATEGY IN ATLANTA

The EIB had a two-tiered performance structure. The high performance threshold was set at 6.52 million gallons of capacity for stormwater capture. The cost-effective methodology validates the total capacity of the projects to capture stormwater through as-built surveys and aerial imagery once the projects are complete.

DWM estimates the green infrastructure projects have the capacity to absorb 55 million gallons of stormwater annually from flowing into the watershed. Additional co-benefits include hundreds of homes protected from future flooding, dozens of local sustainable jobs created, and increased access to green space with 100% of the green infrastructure implemented in economically distressed neighborhoods.

FUNDING MECHANISM IN ATLANTA

Funding for this program is obtained from several different sources:

- Low interest loans from Georgia Environmental Finance Authority (GEFA)
- Environmental Impact Bond (EIB) – The EIB issuance was supported by a grant from The Rockefeller Foundation with additional underwriting support provided by KeyBanc Capital Markets and Siebert Cisneros Shank. The $14 million Atlanta EIB tied the amount the City paid out on the bond directly to benefits related to the volume of stormwater the projects successfully manage.
- State and federal funding sources including Water Infrastructure Finance and Innovation Act (WIFIA) and US Army Corps of Engineers
- Philanthropic funding and grants
- Water and sewer charges

DC WATER

In 1996, DC Water was formed as an independent authority of the District of Columbia to provide water and sewer service to the region. DC Water's finances were no longer tied to the District's overall budget which meant every dollar collected by DC Water can be reinvested into operations and capital improvements. Their CIP is one of the largest in the country with a budget of approximately $5 billion. In 2016, DC Water executed a $25 million EIB in partnership with two private investors. This bond will fund a pilot program to create 20 acres of green infrastructure that will mimic nature over time.

WATER ISSUES MANAGED IN DC WATER

Stormwater flooding  Water quality 

Washington DC's combined sewer overflows were dumping an average of 2.5 billion gallons of combined sewer water annually into three rivers including the Rock Creek tributary that ultimately flows into the Chesapeake Bay. This polluted water overflow contained bacteria, trash, and heavy metals which contaminated Washington DC's

watershed and disrupted the entire ecosystem. In response, local residents and community organizations demanded change, resulting in legal actions which ultimately concluded with the EPA issuing a consent decree in 2005 that required DC Water to address the sewer overflow issue.

IMPLEMENTATION STRATEGY IN DC WATER

If the DC Water green infrastructure performs as planned, with the ability to capture approximately 650,000 gallons of water annually, DC Water will build out its green infrastructure acreage further to include 345 acres, allowing it to avoid costs associated with the construction of a third pipeline. If it over-performs, it means the green infrastructure is more efficient and effective than expected, and DC Water can scale accordingly to achieve the desired effect.

The EIB reduced the flow of runoff and sewage into the Chesapeake Bay as well as delivering access to new green spaces which has been well documented to improve health outcomes. The green infrastructure implementation created jobs, sparked the creation of a green infrastructure workforce certification, and produced green spaces for the community to enjoy. The green infrastructure projects financed though the EIB achieved the goals set in 2016, reducing runoff into Rock Creek by nearly 20 percent over 5 years.

FUNDING MECHANISM IN DC WATER

Funding for DC Water is obtained from water and sewer charges in addition to several innovative financing sources:

- Green Bonds – DC Water issued the first "certified" green bond in the US debt capital markets; the green certification is based upon the DC Clean Rivers Project's environmental benefits
- 100 Year Century Bond (2014) - $350 million taxable issuance to fund the Federally-mandated Clean Rivers Project; bonds will be paid back over 100 years which is the useful life of the Clean Rivers tunnels
- Environmental Impact Bond (EIB) – The EIB issuance was in partnership with two private investors (Calvert Social and Goldman Sachs). The $25million DC EIB tied the amount the City paid out on the bond directly to how much reduction the green infrastructure could achieve in stormwater and combined sewer overflows.
- Forward Purchase Agreement – These are refunded Series 2012 A and C bonds for lower interest cost which saved $64 million
- Commercial Paper – these are short-term notes issued by DC Water to bridge the gap between capital expenditures and the issuance of long-term debt
- Use of Solar Energy at Treatment Plants
- Water Infrastructure Finance and Innovation Act (WIFIA) loan

DC Water was the first municipality to issue an EIB privately.

HAMPTON, VIRGINIA

Water, sewer, and stormwater services is handled by the City of Hampton Department of Public Works. They issued a $12 million EIB in 2020 to finance the construction of three nature-based projects that will help slow, store, filter, and redirect stormwater in low- to moderate-income communities in Hampton. These projects are among the first prototypes in a multi-stage decades-long pipeline of resilience work, built through nearly two years of public engagement, regional partnerships, and consultation with national and international experts. The City's strategy is coordinated through Resilient Hampton, a city-wide initiative to alleviate chronic stresses and enable recovery from extreme events and shocks such as hurricanes.

WATER ISSUES MANAGED IN HAMPTON

Stormwater flooding 
Coastal flooding 
Riverine flooding 
Land subsidence 

Hampton, located on the mouth of the Chesapeake Bay, has experienced increased flooding frequency and severity in recent years due to increased rainfall, higher concentrations of impervious surfaces, a creek that winds through the city and swells with the tides, rapid land subsidence, and the highest rate of relative sea level rise on the Atlantic Coast. Hampton is one of the oldest cities in America as well as one of the fastest growing cities in the region and is highly exposed to climate change risk.

IMPLEMENTATION STRATEGY IN HAMPTON

Through the EIB, Hampton will predict, measure, and report on the stormwater volume storage capacity added by these projects. The gathered data will inform future public investments in resiliency projects that seek to improve quality of life, economic viability, and environmental health for residents.

Hampton's three critical nature-based projects are expected to add more than 8.6 million gallons of storage capacity for stormwater that would otherwise contribute to flooding and polluted runoff in the Newmarket Creek watershed, a key environmental, economic, and transportation corridor. Water equity in Hampton will be enhanced as low- to moderate-income communities that have been impacted the most from chronic flooding will see improved conditions.

FURTHER INFORMATION

https://www.quantifiedventures.com/atlanta-eib
https://www.quantifiedventures.com/dc-water
https://www.quantifiedventures.com/hampton-eib

Watersquare Benthem Plein, Rotterdam
Image credit: Urbanisten/ Ossip van Duivenbode

4. INTERNATIONAL BEST PRACTICES

4. INTERNATIONAL BEST PRACTICES

Lessons on best watershed management practices can also be learned from abroad, especially from countries located in deltas, who have dealt with water for many years.

4.1 ROOM FOR THE RIVER (THE NETHERLANDS)

Room for the River is a national program designed to increase resilience against riverine flooding caused by peak rainfall and meltwater in the Dutch delta while improving the spatial quality of the river landscape.

Room for the River created more space for water along branches of the Rhine by moving dikes back from the water's edge, deepening floodplains, removing obstacles in riverbeds and floodplains, creating high-water side channels, and giving polders back to the water. The short-term solutions for lowering water levels were chosen to avoid preventing long term solutions for creating a safer river delta accounting for climate predictions to 2100.

From 2006 – 2015, 34 projects were collaboratively implemented by the national government, regional waterboards, provinces, municipalities, local inhabitants, and businesses.

WATER CONCERNS MANAGED

Riverine flooding 

Room for the River was the result of a paradigm shift following the high water and related flooding in the winters of 1993 and 1995 that nearly breached dikes, flooded villages outside the levees, and caused 250,000 people and 1 million animals to be evacuated out of precaution. The Netherlands changed its river management from channeling rivers and raising levees to creating space for rivers. The primary goal was to immediately increase the peak flow rate to the sea and Ijsselmeer without raising water levels.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The measures were designed and chosen in collaboration with stakeholders, including municipalities, water boards, provinces, local inhabitants, and businesses. The final measures were selected from an initial 700 proposed measures with the help of a nationally designed tool called Block-Set. Local stakeholders could choose various measures from the block-set in their area and see the resulting reduction in water levels, what they would look like in terms of spatial quality, and the total costs, helping to choose the preferred package of measures. Other selection criteria for the final measures included the available local support. The block-set also helped with wider communication and creating a bridge between national knowledge and local information. During construction, communities could observe the process and results during open days and tours.

SCALE OF IMPLEMENTATION

Country/Region

FUNDING MECHANISM

The total budget and final costs for the implementation of the Room for the River program was € 2,3 billion. This was paid by the national government. Costs included implementation of measures as well as property buyouts, mitigating inundation costs, and some unforeseen costs for found ammunition and archeology. Various regional and local governments leveraged the national money for Room for the River with their own budgets to achieve additional spatial quality for the Room for the River projects.

IMPLEMENTATION STRATEGY

A national planning decision in 2000 made Room for the River possible, but the idea to establish more natural and spacious river runs existed before the 1995 floods. The structure of national responsibility for overall program and approvals with regional and local responsibilities per river branch, including implementation of final local measures, allowed Room for the River to be realized on time and within budget. The programmatic funneling process of possibilities and measures and working with agreed adaptive models helped to deliver the ambitious goals while accounting for changes in knowledge and local landscapes during the 20-year process.

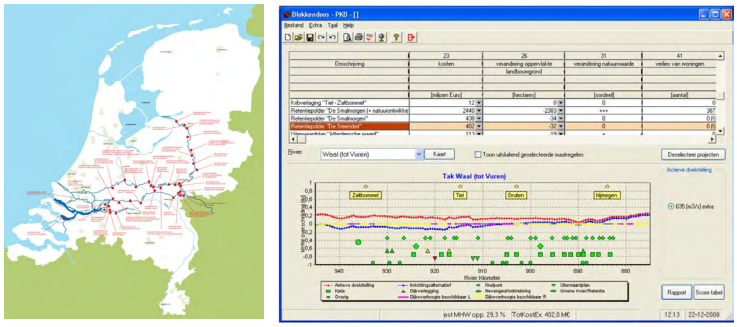
FURTHER INFORMATION

https://www.rijkswaterstaat.nl/en/about-us/gems-of-rijkswaterstaat/room-for-the-river

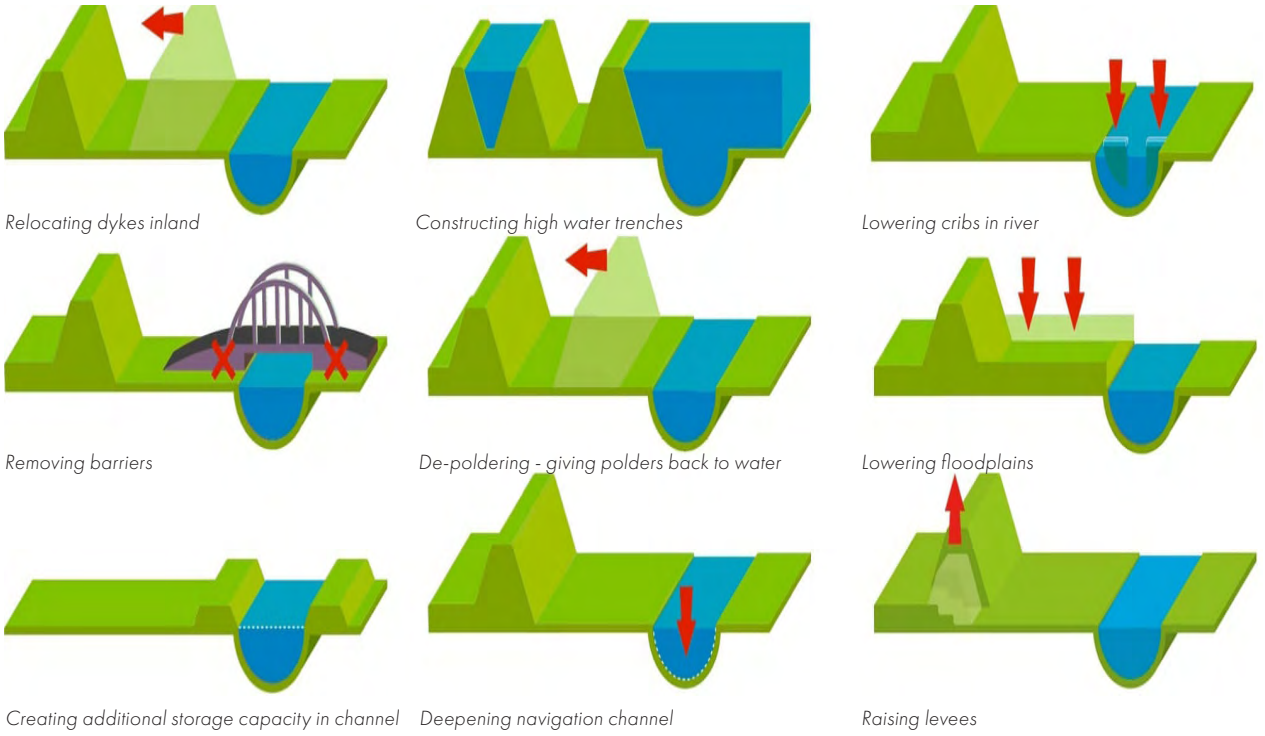
KEY LESSONS FOR HOUSTON

The combined goal of water safety and spatial quality creates possibilities for inclusion of regional and local demands.

The flexibility of a programmatic approach, creating a set of tools, and designing a selection process can facilitate effective collaboration between national government and regional and local stakeholders



An example of a "Block-Set" showing measure, costs, change in area agriculture, change in natural value and amount of houses that need to bought out. Image credit: Rijkswaterstaat



Room for the River Measures. Image credit: Rijkswaterstaat

Flooded park with meandering water trenches next to Dalfsen, NL during winter 2022. Most of the time, the park is dry and used for recreation. Image credit: Thomas Klomp

4.2 SLIM WATERMANAGEMENT (THE NETHERLANDS)

Slim (Smart) Water Management is a collaboration between the various regional water boards, provinces, and national water authority to divide the surface water across these borders of responsibility as optimally as possible. The goals are to delay flooding and water scarcity and maintain normal operations instead of crisis management as long as possible.

The tools to accomplish these goals per region are: Failure probability analyses, an online information platform for all members with real-time visual data describing water levels, regional water-balances including flow-rates and water quality, lines of reasoning of what to do when for the various topics, daily projections, and an applied game giving players the experience of the complex water management.

The benefits are in daily operations by understanding each other's systems and requirements and avoiding crisis management and therefore costs.

WATER CONCERNS MANAGED

Freshwater management  Riverine flooding 

Stormwater flooding  Water quality 

The regional collaborations surrounding Smart water management started as an action of the National Detlaprogramme Fresh Watersupply to be able to divide scarce fresh water as efficiently across the regions as possible. However, the regions incorporated topics of too much water and water quality (specifically salinity) to the collaborations.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The first step of Smart Water Management was to establish collaboration between the various organizations responsible. With help of the applied game, Smart water management is now reaching out to other organizations responsible for managing water flowing into and exiting the system, including municipalities, and communicating with the wider public.

SCALE OF IMPLEMENTATION

Country or Region

FUNDING MECHANISM

The Deltaprogramme Fresh Watersupply (2014) funded € 4,6 million for all 6 regions for the first 7 years and funded the creation of the tools described above. The regional partners contributed labor and sometimes further funding for regionally-specific analyses and tools. The various partners saved significant amounts of money in operations by avoiding disasters and crises. In the coming 7 years the regional platforms will be combined into a national information platform.

IMPLEMENTATION STRATEGY

The experts divided the Netherlands into 6 Smart Water management regions organized around watersheds of larger rivers, canals, or former inland seas. The regional teams of civil servants worked part-time in-house in their partner's organizations to develop the tools and analyses. Through this understanding, the daily operations have improved with shorter lines of communication on the information platform and through using WhatsApp to request redirection of water flow to areas that might better handle or even require the water.

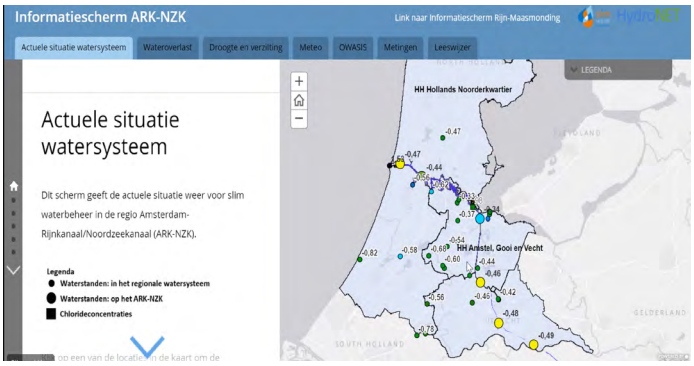
KEY LESSONS FOR HOUSTON

As water flows across jurisdictional boundaries, a shared online information platform with real-time data helps with collaboration, allowing partners to remain in daily operations as long as possible.

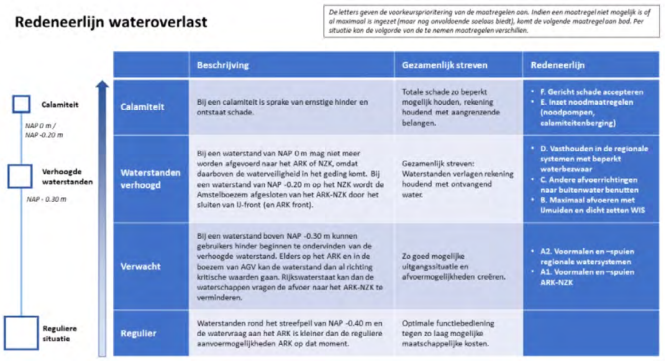
Creating lines of reasoning for which actions to take in conjunction with neighboring partners helps avoid miscommunication during times leading up to a crisis.

FURTHER INFORMATION

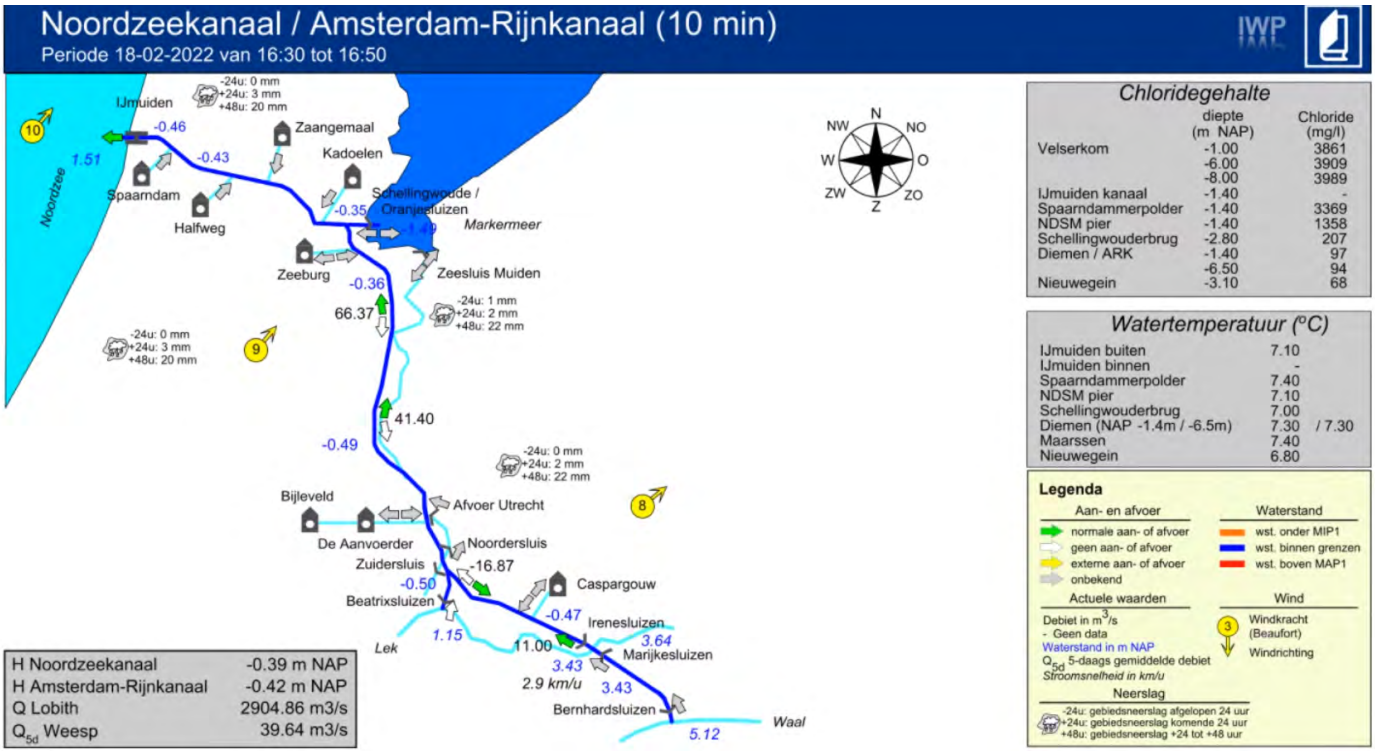
https://www.slimwatermanagement.nl



Screenshot of online information platform with real-time water levels



Screenshot of established lines of reasoning across organizations in case of flooding (from maintenance actions to emergency)



Screenshot of online information platform with real-time data on water quality provided by different organizations.

Different organizations playing the applied game of Smart Water Management to understand each other's concerns and technical challenges. Image credit: Waternet

4.3 AMSTERDAM RAINPROOF (THE NETHERLANDS)

Amsterdam Rainproof is a semi-independent program initiated by the public water-cycle company, Waternet, to make the capital of the Netherlands 'cloudburst resilient' by 2050. Amsterdam reduces damage from heavy rainfall while creating a healthier and greener city by investing in infrastructure that captures, detains, infiltrates, or transports stormwater, and in projects that "harvest" rain for reuse or waterproof vulnerable assets such as basement and metro entrances on public and private land.

Rainproof was initiated in 2014 as a social network with the aim to involve all stakeholders in rainproofing Amsterdam and to incorporate rainproofing into all policies and actions of those stakeholders to ensure more of the public and private land transformation is done in a rainproof way. It connects and activates all parties that can contribute to rainproofing Amsterdam, including the municipality and water authority along with businesses, property owners, residents, consultants, and educational institutions.

WATER CONCERNS MANAGED

Stormwater flooding 

Riverine flooding 

Drought 

Amsterdam Rainproof began with a focus on how to protect the city against the impact of extreme rainfall, as the risks of rainfall are visible to all and therefore more relatable. Over time, it widened its scope to include other climate and water impacts: drought, heat, and fluvial flood risks. Measures that benefit other resiliency aims, health, biodiversity, and social equity are preferred over grey technological measures.

COMMUNITY & STAKEHOLDER INVOLVEMENT

As a social network, Amsterdam Rainproof started with involving all stakeholders able to contribute to the physical transformation of the city. Combined with a vulnerability analysis of the various neighborhoods most at risk, a stakeholder analysis informed the actions of the program towards people and communities. It incentivized private parties such as insurers, garden retail centers, and housing corporations to act as intermediaries to reach larger groups, particularly homeowners. Additionally, it collaborated with existing government and non-government initiatives with aligned interests to work together. This broadened their reach and helped with inter-organizational capacity building. The program also worked with vulnerable local communities, physically helping to green their gardens and public spaces, and supporting their actions for creating social networks surrounding greening their neighborhoods.

SCALE OF IMPLEMENTATION

City and neighborhood

FUNDING MECHANISM

The program and network of Amsterdam Rainproof is funded by the sewage tax. This includes funds for staff, for online and offline communication, for the online social platform, for creating tools and supporting innovation and for small scale support to private stakeholders. The total spend budget in 8 years is €4 million. The physical implementation of measures is funded out of the capital investments of the public and private organizations involved and is calculated as the additional costs required to change a standard measure to a rainproof measure, so they continue doing what they're doing, but in a rainproof way.

To make the city rainproof by 2050, Rainproof Amsterdam calculated that it will cost €130 per household/year.

IMPLEMENTATION STRATEGY

Rainproofing Amsterdam is implemented by mainstreaming resiliency for extreme rainfall in all policies and actions of public and private stakeholders in the city. It started with creating awareness on all levels, and encouraging via positive communication public and private actions, including rainproof in all guidelines and policies, Rainproof to become the new normal. Now e.g. whenever a street is opened for work, the street bed is designed and built back rainproof. Regulatory changes have only been taken when policy and funding barriers required it, such as the now regulatory requirement for detaining a certain amount of rain/hour (60mm/hour) on private property.

FURTHER INFORMATION

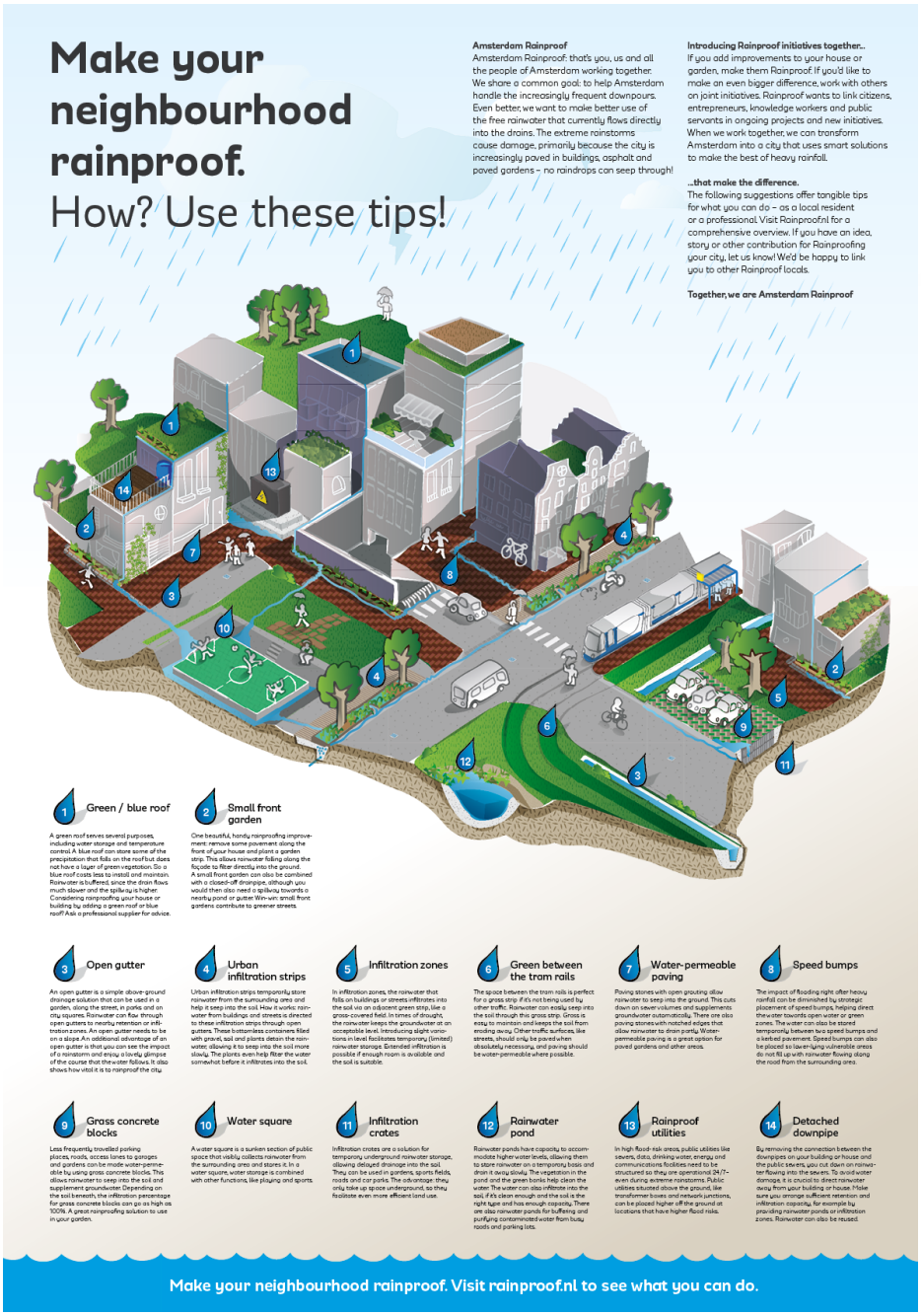
https://www.rainproof.nl
https://www.rainproof.nl/communication-material-in-english

KEY LESSONS FOR HOUSTON

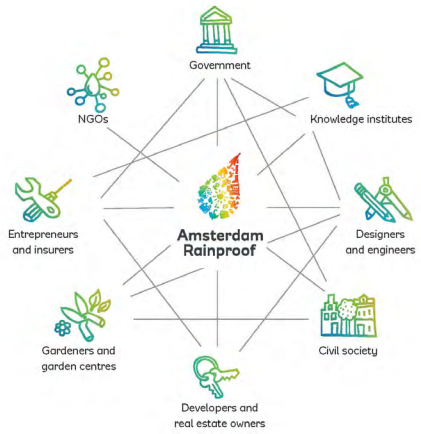
Houston can become more resilient by making sure that climate change is taken into account in every investment decision made by anyone, from how to plant your garden to how to organize and maintain your street, to how to build a new building. These measures in aggregation, taken over a period of time, and during their natural investment cycles, will make communities rainproof. Every action counts, every step counts, every drop counts.

To achieve a rainproof Houston:

- An integrated social network approach is key
- Clear communication helps
- Capacity building is required



Clear communication to all stakeholders. Image Amsterdam Rainproof



Amsterdam Rainproof connects and activates all stakeholders involved.
Credit for all images: Amsterdam Rainproof

Example gardens in garden retail centers

Small- and large-scale implemented measures

Stormwater management to transform a city street is integrated in policies, strategies, instruments, guidelines and key personnel.

4.4 ROTTERDAM APPROACH (THE NETHERLANDS)

The city of Rotterdam, located on the delta of the River Maas, has been coping with too much, too little, and too low a quality of water for the last few decades. The city has invested in innovative ways of integrating large-scale rainwater detention areas in the dense and complex urban fabric by utilizing water squares, sub-surface parking garages (below the entrance ramp and/or integrated in the construction of the roof of the garage), and in multi-use of public space as floodplains.

WATER CONCERNS MANAGED

Stormwater flooding 

Riverine flooding 

Water quality 

Rotterdam's main concern in establishing its large-scale detention areas is creating resiliency for extreme rainfall events. Depending on whether the neighborhood has a combined or separate sewer system, the detention areas help tackle water quality issues and reduce health-related risks. The water squares are only implemented when a separate sewer system is in place detaining rainwater from surrounding surfaces and connected to rainwater sewer. The integrated detention with sub-surface parking garages is also used for combined sewer overflow or may be linked to overflows of the urban canals.

COMMUNITY & STAKEHOLDER INVOLVEMENT

Rotterdam learned the hard way that community involvement is key for implementing water squares. The first proposed water square was rejected by the surrounding community, who perceived the additional risks to small children as too high to justify implementation. For subsequent proposals, the city made a list of criteria to better understand the possibility of implementing water squares in each neighborhood. One of the new criteria was to avoid locating detention areas in socially-vulnerable areas with many children and another was to involve the surrounding community from the beginning of the process in order to create the necessary stewardship.

SCALE OF IMPLEMENTATION

City and neighborhood

FUNDING MECHANISM

Rotterdam's physical measures were funded through various means. The first water square was constructed in 2014 and partially (33%) funded through European subsidies. Current water squares are funded through a combination of capital investments by city departments, including: sewage investments, open space investments, public works, and a small amount of funding from the relevant waterboard, which helps put public pressure on the City to deliver. The above ground and below surface water detention is 40 – 50% of the budget for most water squares. The Water Department of Rotterdam assigned an amount they are willing to pay for the detainment of 1 cubic meter of water and its removal from the sewer and wider water system. Depending on the vulnerability to flooding of the neighborhood, the Water Department pays 500 - 1000 euro/cubic meter for detaining rainwater. This number helps to make water detention a standard part of many large-scale investments in public space.

IMPLEMENTATION STRATEGY

Rotterdam has analyzed each neighborhood's vulnerability to extreme rainfall by using rainwater flooding maps to estimate the amount of rainwater that must be detained in each area. With the defined cost of detained rainwater per cubic meter, Rotterdam has an indication of the investment required to create a stormwater resilient city by neighborhood by the year 2050. The phasing depends on opportunities to couple investments in rainwater detainment with other large municipal investments.

KEY LESSONS FOR HOUSTON

Setting an economic number per gallon water detained helps to make rainwater detention the new normal.

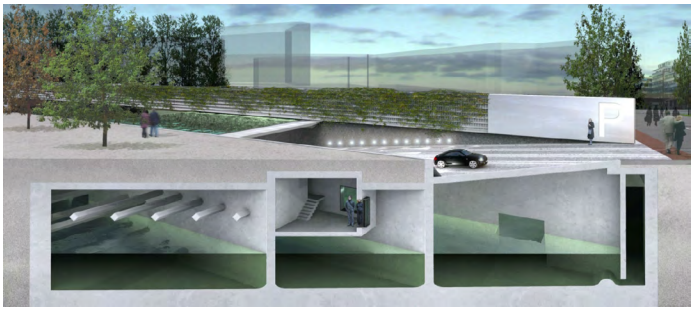
Adding water detention standard to large scale investments in public space or infrastructure (parking garages).

Sharing capital costs from various departments and organizations helps to create integrated climate adaptive solutions.

FURTHER INFORMATION

https://www.urbanisten.nl/work/benthemplein
https://www.rotterdam.nl/wonen-leven/waterberging-museumparkgarage/

Waterwall on the Benthemplein designed by the Urbanisten,
Image credit: Jurgen Bals



Water detention in underground parking. Images credit: Municipality Rotterdam
Above: Detention in roof construction of Kruisplein garage
Below: Detention in left-over spaces in parking garage museum square

First Water Square Benthemplein designed by the Urbanisten. Image credit: Ossip van Duivenbode

4.5 COPENHAGEN CLOUDBURST MANAGEMENT (DANMARK)

Copenhagen established the Cloudburst management plan for the entire city following the 1 in1000 year storm event of 2011. This event of 150 mm rainfall in 1,5 hours resulted one meter of contaminated rainwater at some places and 1 billion euros of claimed damage by stormwater entering underground buildings and services.

The Cloudburst Management Plan consisted of the following actions that have been implemented over the last years:

- Data collection and investigation of areas with cloudburst risk indicators to understand potential investments, assess property values, and create a ranking for actions
- Large-scale hydrological modeling and mapping of stormwater catchment areas, including above- and below-ground infrastructure, and landscape characteristics showed that Copenhagen can't be made cloudburst proof with underground piping solutions alone
- Calculating the cost of doing nothing for comparison
- Identifying hotspots and working with a cloudburst toolkit for various streets and spaces to form cloudburst plans
- Involvement of many city agencies
- Socio-economic cost benefit analyses on two options

These actions aimed to ensure future damages due to cloudbursts are limited and blue-green infrastructure solutions contribute to cloudburst management and to the spatial and social requirements of the city.

WATER CONCERNS MANAGED

Stormwater flooding  Water quality 

The primary concern of the Cloudburst Management Plan is to manage stormwater, but water quality is also taken into account due to the combined sewer system.

COMMUNITY & STAKEHOLDER INVOLVEMENT

The cloudburst plans and the 300 identified projects were developed through an interdisciplinary approach involving engineers, hydraulic experts, GIS and information technologists, architects, planners, biologists, economists, communication specialists, and landscape architects. Initial discussions began with the public utility company, Hofor, and the cross-agency collaboration of the City. Lately, private developers, investors, and homeowners have become more involved in order to contribute their pieces of the larger cloudburst management puzzle.

FURTHER INFORMATION

https://iwa-network.org/city/copenhagen/

SCALE OF IMPLEMENTATION

City and neighborhood

FUNDING MECHANISM

A combination of various extreme cloudburst events (The 2011cloudburst and two events in 2014 of 1 in 400 years events and 1 in 100 year) helped to garner the public funding for developing the Cloudburst Management Plan. Implementation of the 300 projects identified is supported by the analysis of what it would cost to do nothing (€55-80 million per year by 2110), and the socio-economic cost benefit analyses showing a potential savings of 50% more for blue-green solutions compared to conventional piped solutions.

IMPLEMENTATION STRATEGY

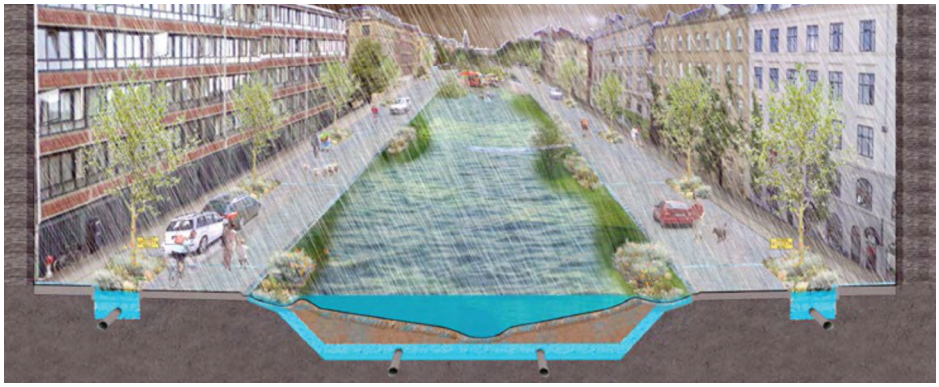
Copenhagen is divided into 8 catchment areas. Cloudburst plans are created for each catchment area to establish which streets are retention streets, which are discharge streets, and which are green streets. These plans provide a roadmap for building cloudburst resilience into public spaces through their physical transformation over time.

KEY LESSONS FOR HOUSTON

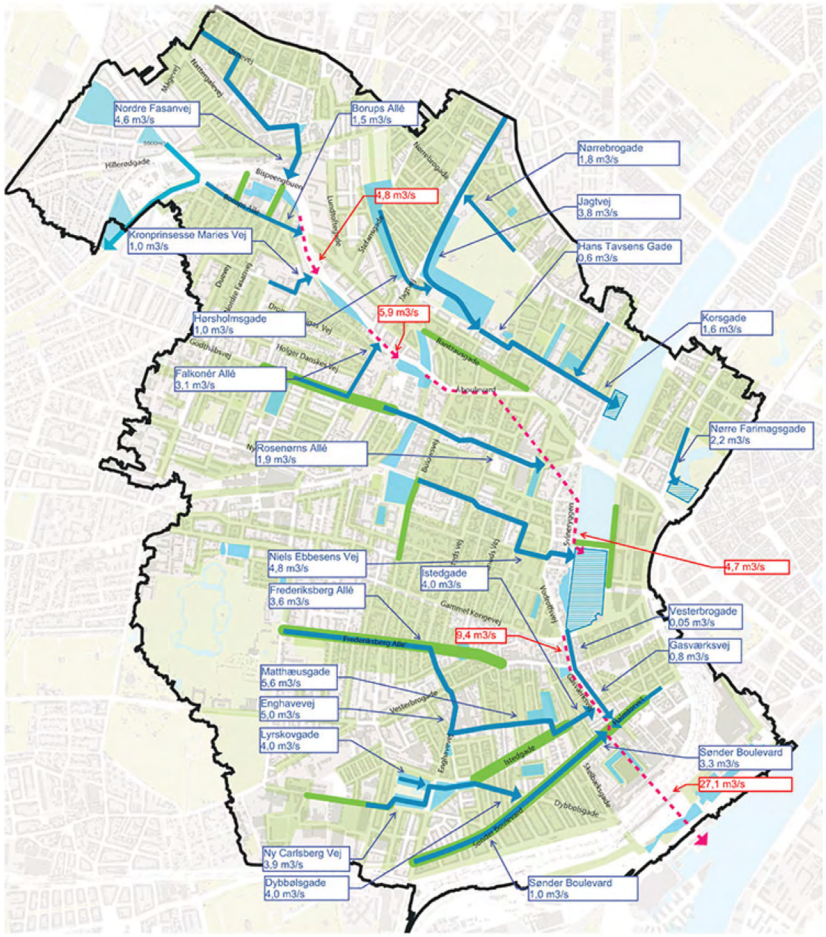
Creating and integrated below- and above-ground GIS model helps to understand the risks and benefits of an approach combining grey infrastructure and blue-green measures.

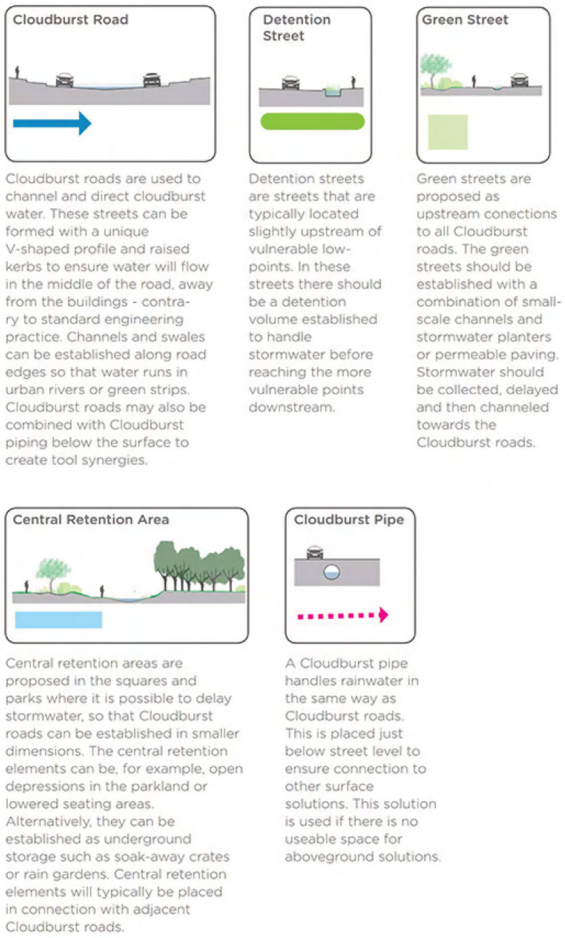
Creating cloudburst management plans per catchment area that show the benefit of upstream measures help to ensure every investment contributes to a more cloudburst proof city.

Calculating the economic quantities of what it will cost to do nothing and understanding the added value of blue-green infrastructure helps to attract investors and create measures with multiple benefits.



Cloudburst Boulevard Copenhagen on dry days (top) and during cloudburst events (bottom). Images credit: Ramboll





Cloudburst Plan Copenhagen. Image credit: Ramboll

4.7 CITY OF 1000 TANKS CHENNAI (INDIA)

The project 'City of 1000 Tanks' was commissioned to develop transformative urban solutions for the city of Chennai under the 'Water as Leverage for Resilient Cities: Asia' initiative. Chennai experiences heavy rains, flooding, water scarcity, and pollution. The project uses decentralized nature-based solutions to create a unique Water Balance Model. The restoration of 53 water tanks in the city's historic temples has a groundwater recharge potential of 50 million liters a day. It seeks to achieve a flood-proof system by linking overflowing tanks during heavy monsoons and aims to transform the perception of water from that of scarcity to one of abundance.

WATER CONCERNS MANAGED

Stormwater flooding  Water quality  Freshwater supply 

The project offers a holistic solution to the problems of water management and water pollution by identifying the interrelationships between urbanization and natural resources. Although Chennai receives more water via rainfall than it consumes each year, the city risks running out of water in the next decade. The project employs nature-based solutions at a community level and devises a network of blue-green infrastructure to prevent climate-change-induced droughts and mitigate the risks associated with high-frequency floods and sewage pollution. Collecting rainwater, treating wastewater and runoff pollution, and recharging them to the underground aquifer increases groundwater reserves and prevents saline intrusion from sea level rise. The project intends to improve supply shortages by creating water retention and supply capacities of 200-250 MLD (Million Liters per Day) in the first two phases (current urban demand is 1,580 MLD).

COMMUNITY & STAKEHOLDER INVOLVEMENT

The City of 1,000 Tanks team, led by OOZE Architects, brought together international and Indian experts from the fields of urban design, water management, social and cultural engagement, policy, and finance to create inclusive and robust solutions. The project team conducted several workshops in Chennai with experts, government officials, vulnerable communities, and other stakeholders to collectively devise solutions and explore the economic opportunities created in maintaining these nature-based solutions. They provided transparency, established ownership, and helped build trust among communities. Local leaders disseminated information, increased awareness, and enhanced capacity. The guidelines are built on extensive interaction and participatory planning exercises with the residents, especially women and children.

FURTHER INFORMATION

https://www.cityof1000tanks.org

SCALE OF IMPLEMENTATION

Regional, city and neighborhood

FUNDING MECHANISM

The project 'City of 1000 Tanks' was commissioned by the Dutch Special Envoy for International Water Affairs, Henk Ovink and the Dutch Government (Ministry of Foreign Affairs and Netherlands Enterprise agency RVO.nl). Resilient Cities, the Dutch Ministry of Infrastructure and Water Management, the Global Centre of Excellence on Climate Adaptation, and the UN/World Bank High-Level Panel on Water are the commissioners for research. Funding for the ongoing research and the flagship projects happen in incremental phases. Presentations, conferences and discussions were organized with the Water as Leverage advisory board and the representatives of various International Financing Institutions and monetary funds to discuss the prospects of long term financing. This innovative process of bringing potential financiers onboard in the gestation period of the project became a crucial way to ensure long-term bankability. The project's implementation is funded by Multilateral Development Banks, certain European and South Asian governments, along with national and local administrative bodies. Public sector financing through CSR initiatives also plays a pivotal role. The team is currently in the process of developing funding proposals for individual flagship projects.

IMPLEMENTATION STRATEGY

The project is implemented in an incremental fashion, which allows for flexibility during and following implementation. Instead of short term and reactive approaches, this approach allows comprehensive, integrative, long-term, and nature-inclusive plans that are contextually sensitive and create room for innovations to occur. The project implementation heavily relies on culture and awareness programs, civic and social engagement, and micro economy and upcycling. Flagship projects are introduced in diverse contexts while others gestate. Currently, the pilot at Little Flower Convent in Mambalam is creating septic tanks, constructed wetlands, bioswales and detention parks. The Water Balance Pilot will set a precedent for scalable Water Balance Model.

KEY LESSONS FOR HOUSTON

- Identifying context-specific solutions through community engagement that can facilitate resilience at a regional and city scale.
- Making the local communities the main stakeholders to create a sense of ownership by facilitating Guerilla urbanism practices.
- Funding through innovative practices to ensure long term aid.
- Developing feedback mechanisms to study the outcomes of pilot projects at the local scale.

Workshops and participation with context specific design solutions.
Image credits from top counter clockwise:

- Cynthia van Elk / Water as Leverage
- Ooze Architects
- Ooze Architects

Delegates at the second regional workshop for funding proposals in Singapore. Image credit: Cynthia van Elk/Water as Leverage

Plantage Lab
Image credit: Amsterdam Rainproof/ Merlijn Michon

5. OVERVIEW OF ALL BEST PRACTICES

5. OVERVIEW OF ALL BEST PRACTICES

NAME	INITIATOR	WATER CONCERNS MANAGED	COMMUNITY ENGAGEMENT
Portland Green Infrastructure	City of Portland		Government, Schools, NGOs Volunteering program + Tours
New Orleans Ready for Rain	City's office for homeland security and emergency preparedness		Community non-profit organizations program + tours
Charleston Rainproof	City of Charleston		Local nurseries and gardeners Workshops on installations
The City of Hoboken Green infrastructure	City of Hoboken		Outreach meetings + online survey
Room for the River (The Netherlands)	The Dutch State		Measures chosen with local and regional stakeholders 'block-set' tool + tours
Smart water management (The Netherlands)	Deltaprogram fresh water (combined program of national, regional and local public sector)		in-house exchange of partner collaboration between responsible organizations
Amsterdam Rainproof (The Netherlands)	Public Water Cycle company of Amsterdam, Waternet		Facilitating / connecting all public and private stakeholders involved Working with middleman to reach wider audience
Rotterdam Approach (The Netherlands)	City of Rotterdam		Design process with surrounding community
Copenhagen Cloudburst Management Plan (Denmark)	City of Copenhagen		Identifying projects through interdisciplinary approach – focusing first on public departments followed by private sector
City of 1000 tanks Chennai (India)	Water as leverage for resilient cities Asia by various international organizations (including world bank and NL)		Workshops with experts, vulnerable communities (women/children), government officials

Stormwater flooding | Water quality | Riverine Flooding | Coastal Flooding | Freshwater supply Drought

SCALE	FUNDING MECHANISM	IMPLEMENTATION STRATEGIES	KEY LESSONS
City	Various, including EPA + leverage funding from Portland Affordable transportation fund + local improvement districts	Through mainstreaming in green projects and showcasing projects	Expand existing programs to encompass various green programs
City Neighborhood Parcel	City's capital investment + local and federal funds	Capital projects and community members	Clear outreach and information on measures and what to do during and following an event
City Neighborhood	Small scale measures on private land are privately funded	Creating awareness and capacity building skills	Empowering communities through community engagement and collaborating with local businesses
City	Various including trust funds, leverage funds, federal grants, and municipal bonds	Identification of suitable projects in sewersheds	Use of data for identifying projects in sewersheds
Country Region	Funding by national government + often leveraged by regional public partners	National responsibility for overall program + local responsibility per river branche	Combined goal of water safety + spatial quality Flexibility of program approach with tools
Country Region	Deltafund and labor by collaborators	Daily collaboration with short lines of communication to avoid crises	Shared online information platform with real time data, Creating collaborative lines of reasoning prior to crisis
City Neighborhood Parcel	Sewage tax with leverage in hours by all stakeholders involved	Mainstreaming rainproof by capacity building in all policies, strategies and actions of public and private stakeholders	Taking climate change into account in every investment made Integrated social network approach
City Neighborhood Parcel	Capital investment of city, water authority and funds of Europe + Public works pays others per per m3 water detained	Vulnerability models calculate extent and cost of water that must be detained and making it part of yearly capital budget per neighborhood	An economic number per gallon water detained helps Adding water detention to large scale public/ private infrastructure
City Neighborhood	Public funding supported by an analysis what 'to do nothing' would cost + a socio-economic cost benefit analysis for green over grey	Creating a cloudburst plan per catchment area of the city to mainstream cloudburst in each public street and space design	Creating integrated below and above ground GIS model + cloudburst plans + calculating in economic quantities
Region City Neighborhood	Engaging early with potential (international) financers to ensure long-term bankability. Funding incremental	Incremental implementations for flexibility with attention to culture and awareness programs, and upscaling with flagship projects	Making local communities main stakeholder and innovative practices of funding

Greens Bayou Coalition
volunteers pick up litter
Image Credit: Greens Bayou Coalition

6. KEY LESSONS FOR HOUSTON

6. KEY LESSONS LEARNED FOR HOUSTON

The best practices for watershed management provide examples the City of Houston, the region, and the neighborhood communities can consider adopting within their own jurisdictions. In some cases, implementing the suggested measures may mean taking action oneself, implementation might also mean advocating for an action that must be carried out by others, or becoming informed to increase awareness. Therefore, the roles of "build awareness," "advocate for," and "take action" are delegated to the neighborhood community, the City of Houston, or Harris County Flood Control District for each lesson to guide collaboration.

1. EVERY INVESTMENT STORMWATER PROOF:
Each day, Houstonians and the City invest in the physical transformation of the built environment. Houstonians upgrade gardens, yards, roofs, and driveways and build houses. The City maintains streets, constructs new infrastructure, and refurbishes parks. Every small- or large-scale investment decision by community members and the City alike can consider how each action incorporates mitigation strategies for reducing future risks associated with climate change. Over time, these daily practices help build resilience at the city level. Landscape strategies, modern building practices, and infrastructure improvements that improve resilience do not necessarily need to cost more than typical landscape strategies, building practices, or infrastructure. As an incentive to promote resiliency, the city could assign an economic value per gallon of rainwater diverted or detained from entering bayous, streets, or stormwater sewers. This may help promote new and innovative rainwater storage strategies on public and private property.

The City of Houston can encourage City departments to design additional stormwater mitigation strategies, such as underground storage capacity or above ground detention areas. Water detention areas can be added to any park, public square, or large-scale structure within public spaces. Future city projects should maximize the capacity of stormwater infrastructure by redirecting and detaining additional water as a component of each project. The City of Houston could also pay landowners to increase their capacity to detain rainwater from surrounding areas by improving or restoring natural systems or contributing additional detention through infrastructure improvements (such as subsurface parking lots).

- City of Houston: Take Action
- Neighborhood Community: Take Action (locally) or Advocate For (city-wide)

2. CREATING ROOM FOR THE BAYOUS AND SURFACE STORMWATER IN THE NEIGHBORHOODS:
Harris County Flood Control District and the Army Corps of Engineers are constructing more detention areas, such as Buffalo Bayou Park and the Reservoirs, to create room for stormwater. Additionally, the City of Houston and Harris County Flood Control District can collaborate to create even more space for stormwater detention by establishing an integrated, flexible program focused on the dual goals of ensuring water safety and improving spatial quality. These combined aims create possibilities for addressing multiple regional and neighborhood concerns, facilitating the enlargement of retention areas in the bayous and in public and private spaces within the neighborhoods including parks, squares, and streets. In addition to leveraging existing improvement projects, an integrated, flexible program helps create capacity to adapt to new insights and changing social, financial, and physical constraints.

- Harris County Flood Control and City of Houston: Take Action
- Neighborhood Community: Advocate For

3. CLEAR COMMUNICATION FOR COMMUNITY OUTREACH:
Setting up a social network approach to connect all residents and stakeholders who are involved in the physical transformation of neighborhoods can help facilitate stormwater-proof investments. Producing clear communication materials that are easy to understand helps community members become more aware of what is going on, connect ideas to their own apartments, houses, streets, parks, and neighborhoods, and inform them of what they can do to build resilience (from implementing measures to purchasing flood insurance). An approach such as Rainproof Houston could be considered for this.

- City of Houston: Take Action
- Community: Take Action and Advocate For

4. ONLINE DATA AND SHARED INFORMATION BETWEEN AGENCIES:
As water flows across juridical boundaries, providing real-time data on a shared, online platform helps with collaboration between agencies, so that Houston can maintain daily operations as long as possible and avoid upstream actions that may cause downstream flooding. It can also help to warn people of impending hazards such as flooding due to extreme rainfall or storm surge. Harris County Flood Control District has an online platform showing flooding of the bayous where people can see the rainfall volumes, current and past water levels, and soil saturation levels and receive warning notifications for possible flooding. The City of Houston could invest in an online platform for stormwater flooding in the neighborhoods to promote transparency, provide real time information to residents during an emergency, and help facilitate cross-departmental and cross-organizational collaboration. The platform could also display projected stormwater runoff at the street level, which could be linked to Harris County Flood Control's online platform.

- City of Houston: Take Action
- Community: Advocate For

5. MODELING STORMWATER STREET RUNOFF:
Building a stormwater model showing street runoff during various storm events is a prerequisite for the following actions:

1. Calculating the type of best watershed management practices (BMPs) and the volume of large rainwater infrastructure for reducing total runoff volume (e.g. bioswales, rainwater retention zones, sub-ground rainwater storage tanks).
2. Creating cloudburst management plans that show integrated neighborhood approaches to designating and establishing streets for detention and streets for sheet-flow
3. Creating a shared, online data platform
4. Assigning an economic value per gallon of rainwater detained, to remove runoff from stormwater sewers

- City of Houston: Take Action
- Community: Advocate for

APPENDIX

Buffalo Bayou, 1935
Image Credit: Museum of Houston and the Houston Metropolitan Research Center via Rice Digital Scholarship Archive

APPENDIX

LINKS TO INFORMATION:

POLICIES:

State of Texas
- TxDOT
  http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm
- TCEQ
  https://texreg.sos.state.tx.us/public/readtac%24ext.ViewTAC?tac_view=3&ti=30&pt=1

Harris County (HC)
- Subdivision Rules and Regulations
  https://www.eng.hctx.net/Portals/23/Publications/Regulations_for_Approval_Acceptance_of_Infrastructure.pdf
- Regulations of Harris County, Texas for Floodplain Management
  https://www.eng.hctx.net/Portals/23/FPMRegs-Effect190709.pdf

Harris County Flood Control District (HCFCD)
- Floodplain Management Plan
  https://www.eng.hctx.net/Portals/23/Publications/FP_floodplain_management_plan.pdf
- Harris County Flood Control District Policy Criteria and Procedures Manual
  https://www.hcfcd.org/Resources/Technical-Manuals/2019-Atlas-14-Policy-Criteria-and-Procedures-Manual-PCPM?folderId=16290&view=gridview&pageSize=10
- Harris County Flood Control District Hydraulic and Hydrology Manual
  https://www.hcfcd.org/Resources/Technical-Manuals/Hydrology-and-Hydraulics-Guidance-Manual?folderId=16301&view=gridview&pageSize=10

City of Houston (COH)
- City of Houston Infrastructure Design Manual
  https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards#agency-links-1471
- City of Houston Floodplain Rules & Regulations, (Chapter 19)
  https://library.municode.com/tx/houston/codes/code_of_ordinances?nodeId=COOR_CH19FL

Shared across HC, HCFCD, COH
- Low Impact Design (LID) Manual
  https://www.hcfcd.org/Resources/Technical-Manuals/Harris-County-Low-Impact-Development-Design-Criteria-Manual?folderId=16300&view=gridview&pageSize=10

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