CITY OF HOUSTON **HAZARD MITIGATION PLAN UPDATE**

ACTIVE DATES 2023 - 2028



OEM
OFFICE OF EMERGENCY MANAGEMENT

For more information, visit our website at:

houstonoem.org

Written comments should be forwarded to:

H2O Partners, Inc.

P. O. Box 160130

Austin, Texas 78716

info@h2opartnersusa.com

www.h2opartnersusa.com

SECTION 1 – INTRODUCTION

Background....1-1
Scope....1-2
Purpose....1-2
Authority....1-3
Summary of Sections....1-3

SECTION 2 – PLANNING PROCESS

Plan Preparation and Development....2-1
Review and Incorporation of Existing Plans....2-8
Timeline for Implementing Mitigation Actions....2-12
Public and Stakeholder Involvement....2-12

SECTION 3 – CITY PROFILE

Overview....3-1
Population and Demographics....3-3
Population Growth....3-4
Natural, Cultural, and Historic Resources....3-4
Economic Impact....3-5
Existing Land Use and Development Trends....3-6
Future Growth and Development....3-8

SECTION 4 – RISK OVERVIEW

Hazard Description....4-1
Natural Hazards and Climate Change....4-4
Overview of Hazard Analysis....4-5
Hazard Ranking....4-6

SECTION 5 – FLOOD

Hazard Description....5-1
Location....5-1
Extent....5-6
Historical Occurrences....5-9

Probability of Future Events 5-13
Vulnerability and Impact 5-13
Climate Change Consideration 5-18
NFIP Participation 5-18
Community Rating System 5-19
NFIP Compliance and Maintenance 5-20
Repetitive Loss 5-20

SECTION 6 – HURRICANE/TROPICAL STORM

Hazard Description 6-1
Location 6-1
Extent 6-2
Historical Occurrences 6-3
Probability of Future Events 6-6
Vulnerability and Impact 6-6
Climate Change Considerations 6-10

SECTION 7 – EXTREME HEAT

Hazard Description 7-1
Location 7-1
Extent 7-2
Historical Occurrences 7-5
Probability of Future Events 7-9
Vulnerability and Impact 7-9
Climate Change Considerations 7-12

SECTION 8 – DROUGHT

Hazard Description 8-1
Location 8-2
Extent 8-3
Historical Occurrences 8-5
Probability of Future Events 8-8
Vulnerability and Impact 8-8

Climate Change Considerations 8-13

SECTION 9 – THUNDERSTORM WIND

Hazard Description 9-1
Location 9-1
Extent 9-2
Historical Occurrences 9-3
Probability of Future Events 9-11
Vulnerability and Impact 9-11
Climate Change Considerations 9-14

SECTION 10 – DAM FAILURE

Hazard Description 10-1
Location 10-3
Extent 10-5
Historical Occurrences 10-7
Probability of Future Events 10-7
Vulnerability and Impact 10-7
Climate Change Considerations 10-10

SECTION 11 – EXPANSIVE SOILS

Hazard Description 11-1
Location 11-1
Extent 11-2
Historical Occurrences 11-3
Probability of Future Events 11-4
Vulnerability and Impact 11-4
Climate Change Considerations 11-7

SECTION 12 – TORNADO

Hazard Description 12-1
Location 12-2
Extent 12-3

Historical Occurrences 12-6
Probability of Future Events 12-8
Vulnerability and Impact 12-9
Climate Change Considerations 12-13

SECTION 13 – WINTER STORM

Hazard Description 13-1
Location 13-3
Extent 13-3
Historical Occurrences 13-5
Probability of Future Events 13-7
Vulnerability and Impact 13-7
Climate Change Considerations 13-10

SECTION 14 – WILDFIRE

Hazard Description 14-1
Location 14-1
Extent 14-2
Historical Occurrences 14-5
Probability of Future Events 14-7
Vulnerability and Impact 14-7
Climate Change Considerations 14-12

SECTION 15 – LIGHTNING

Hazard Description 15-1
Location 15-1
Extent 15-1
Historical Occurrences 15-3
Probability of Future Events 15-5
Vulnerability and Impact 15-5
Climate Change Considerations 15-9

SECTION 16 – HAIL

Hazard Description 16-1
Location 16-2
Extent 16-2
Historical Occurrences 16-3
Probability of Future Events 16-12
Vulnerability and Impact 16-12
Climate Change Considerations 16-16

SECTION 17 – MITIGATION STRATEGY

Mitigation Goals 17-1
Goal 1 17-1
Goal 2 17-2
Goal 3 17-2
Goal 4 17-2
Goal 5 17-3
Goal 6 17-3

SECTION 18 – PREVIOUS ACTIONS

Summary 18-1
City of Houston 18-2

SECTION 19 – MITIGATION ACTIONS

Summary 19-1
City of Houston 19-3

SECTION 20 – PLAN MAINTENANCE

Plan Maintenance Procedures 20-1
Incorporation 20-1
Monitoring and Evaluation 20-4
Updating 20-5
Continued Public Involvement 20-6

APPENDIX A – PLANNING TEAM

APPENDIX B – PUBLIC SURVEY RESULTS

APPENDIX C – CRITICAL FACILITIES

APPENDIX D – DAM LOCATIONS

APPENDIX E – MEETING DOCUMENTATION

APPENDIX F – CAPABILITY ASSESSMENT

APPENDIX G – SWAT PROJECT LOG

APPENDIX H – PUBLIC ENGAGEMENT PLAN

APPENDIX I – CRS REQUIREMENTS

APPENDIX J – STATE AND FEDERAL FUNDING OPPORTUNITIES

SECTION 1
INTRODUCTION



OFFICE OF EMERGENCY MANAGEMENT

SECTION 1: INTRODUCTION

Background 1
Scope 2
Purpose 2
Authority 3
Summary of Sections 3

BACKGROUND

The City of Houston is the most populous city in the state of Texas, and the fourth-most populous city in the United States.[1] Located in Southeast Texas near the Gulf of Mexico, it is the principal city of the Greater Houston metro area, which is the fifth-most populated Metropolitan Statistical Area in the United States. The City of Houston is the county seat for Harris County and is located 165 miles east of Austin, 112 miles west of the Louisiana border, and 250 miles south of Dallas.

Texas is prone to extremely heavy rains and flooding with half of the world record rainfall rates (48 hours or less).[2] While flooding is a well-known risk, the City of Houston is susceptible to a wide range of natural hazards, including but not limited to extreme heat, tornadoes, hail, and wildfires. These life-threatening hazards can destroy property, disrupt the economy, and lower the overall quality of life for individuals.

While it is impossible to prevent an event from occurring, the impacts from many hazards to people and property can be lessened. This concept is known as hazard mitigation, which is defined by the Federal Emergency Management Agency (FEMA) as *sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects.*[3] Communities participate in hazard mitigation by developing hazard mitigation plans. The Texas Division of Emergency Management (TDEM) is required to review the plan and FEMA has the authority to review and approve hazard mitigation plans through the Disaster Mitigation Act of 2000 (DMA).

In 2005-2006, the City of Houston originally developed their Hazard Mitigation Plan (HMP) in compliance with the Disaster Mitigation Act of 2000, as amended and was designed to be implemented through hazard mitigation measures intended to eliminate or reduce the effects of future disasters. The plan was updated in 2011-2012 to include revisions made in compliance with FEMA's new plan guidance and requirements, and again in 2018 per DMA requirements. This Plan was approved by FEMA in March 2018.

The Disaster Mitigation Act requires that hazard mitigation plans be reviewed and revised every five years to maintain eligibility for Hazard Mitigation Assistance (HMA) grant funding. Since FEMA approved the City of Houston HMP Update in 2018, the City began the process of developing the 2023 Hazard Mitigation Action Plan Update in order to maintain eligibility for grant funding within the five-year window. The HMAP Update planning process provided an opportunity for the City of Houston to evaluate successful mitigation actions and explore opportunities to avoid future

[1] https://ballotpedia.org/Largest_cities_in_the_United_States_by_population
[2] http://www.floodsafety.com/texas/regional-info/san-antonio-flooding/
[3] http://www.fema.gov/hazard-mitigation-planning-resources

disaster loss. The 2018 HMAP expired in 2023, therefore the City of Houston selected Dewberry, H2O Partners, Inc., and CAS Group to write and develop the 2023 HMAP Update, hereinafter titled: "The City of Houston Hazard Mitigation Plan Update 2023: Maintaining a Safe, Secure, and Sustainable Community" (Plan or Plan Update). The HMAP Update planning process provided an opportunity for the City of Houston to evaluate successful mitigation actions and explore opportunities to avoid future disaster loss.

Hazard mitigation activities are an investment in a community's safety and sustainability. It is widely accepted that the most effective hazard mitigation measures are implemented at the local government level, where decisions on the regulation and control of development are ultimately made. A comprehensive review of a hazard mitigation plan addresses hazard vulnerability that exists today and in the foreseeable future. Therefore, it is essential that a plan identify projected patterns of how future development will increase or decrease a community's overall hazard vulnerability.

SCOPE

The focus of the Plan Update is to identify activities to mitigate hazards classified as "high" or "moderate" risk, as determined through a detailed hazard risk assessment conducted for the City of Houston. The hazard classification enables the City to prioritize mitigation actions based on hazards which can present the greatest risk to lives and property in the geographic scope.

PURPOSE

The Plan Update was prepared by the City of Houston, Dewberry, H2O Partners, Inc., and CAS Group. The purpose of the Plan Update is to protect people and structures and to minimize the costs of disaster response and recovery. The goal of the Plan Update is to minimize or eliminate long-term risks to human life, property, operations, and the environment from known hazards by identifying risks and implementing cost-effective hazard mitigation actions. The planning process is an opportunity for the City of Houston, stakeholders, and the general public to evaluate and develop successful hazard mitigation actions to reduce future risk of loss of life and damage to property resulting from a disaster in the City of Houston.

The Mission Statement of the Plan Update is, "*Maintaining a secure and sustainable future through the revision and development of targeted hazard mitigation actions to protect life and property.*"

The City of Houston Planning Team identified twelve natural hazards to be addressed by the Plan Update. The specific goals of the Plan Update are to:

- Provide a comprehensive update to the 2018 HMAP;
- Minimize disruption to the City of Houston following a disaster;
- Streamline disaster recovery by articulating actions to be taken before a disaster strikes to reduce or eliminate future damage;
- Demonstrate a firm local commitment to hazard mitigation principles;
- Serve as a basis for future funding that may become available through grant and technical assistance programs offered by the State or Federal government. The Plan will enable the City of Houston to take advantage of rapidly developing mitigation grant opportunities as they arise; and

- Ensure that the City of Houston maintains eligibility for the full range of future Federal disaster relief.

AUTHORITY

The Plan is tailored specifically for the City of Houston and plan participants including Planning Team members, stakeholders, and the general public who participated in the Plan Update development process. The Plan complies with all requirements promulgated by the Texas Division of Emergency Management (TDEM) and all applicable provisions of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Section 104 of the Disaster Mitigation Act of 2000 (DMA 2000) (P.L. 106-390), and the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (P.L. 108–264), which amended the National Flood Insurance Act (NFIA) of 1968 (42 U.S.C. 4001, et al). Additionally, the Plan complies with the Interim Final Rules for the Hazard Mitigation Planning and Hazard Mitigation Grant Program (44 CFR, Part 201), which specify the criteria for approval of mitigation plans required in Section 322 of the DMA 2000 and standards found in FEMA's "Local Mitigation Policy Guide" (Effective April 19, 2023), and the "Local Mitigation Planning Handbook" (March 2013). Additionally, the Plan is developed in accordance with FEMA's Community Rating System (CRS) Floodplain Management Plan standards and policies.

SUMMARY OF SECTIONS

Sections 1 and 2 of the Plan Update outline the Plan's purpose and development, including how Planning Team members, stakeholders, and members of the general public were involved in the planning process. Section 3 profiles the City of Houston's population and economy.

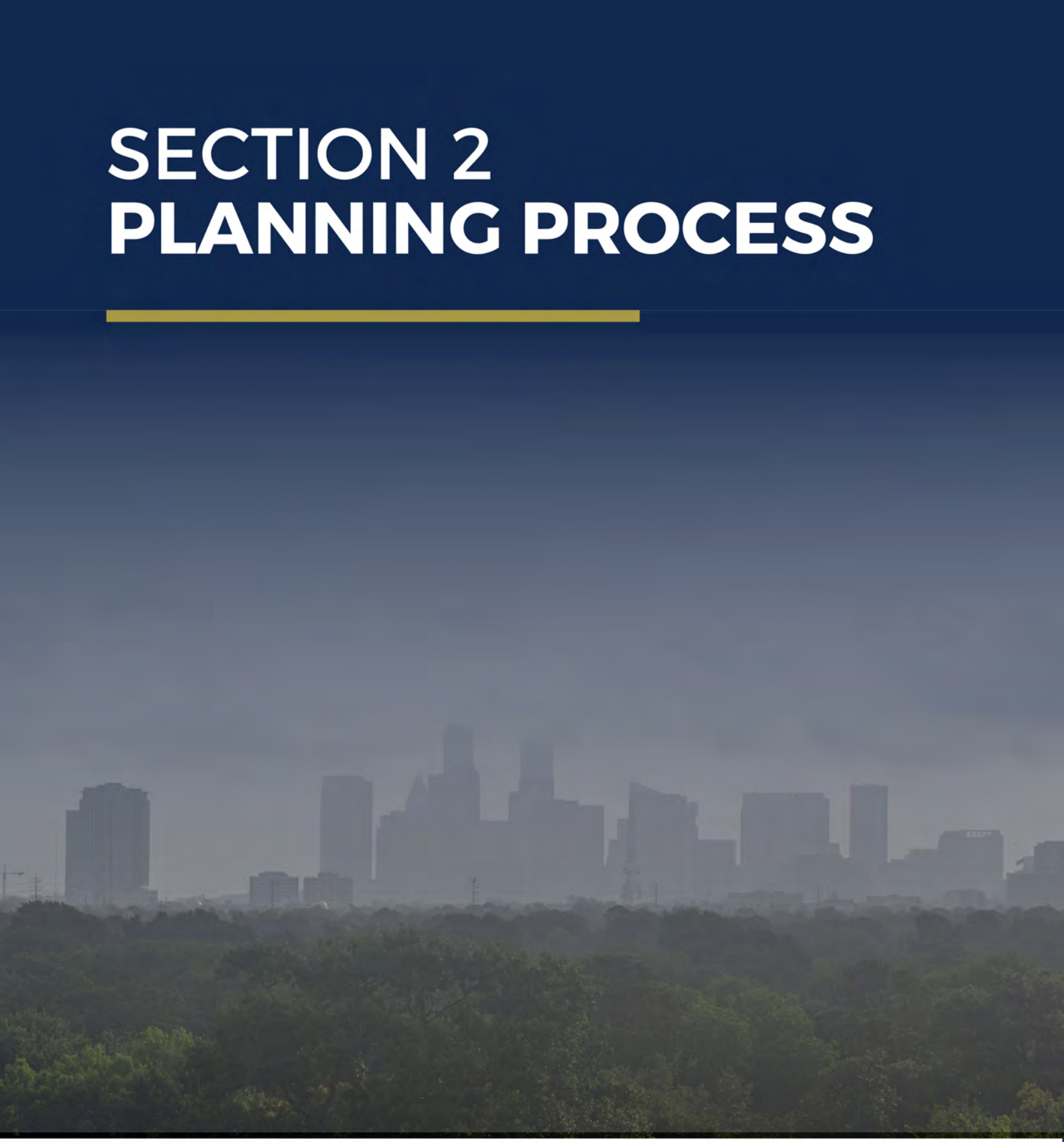
Sections 4 through 16 present a hazard overview and information on individual natural hazards in the planning area. The hazards generally appear in order of priority based on potential losses to life and property, and other community concerns. For each hazard, the Plan Update presents a description of the hazard, a list of historical hazard events, and the results of the vulnerability and risk assessment process.

Section 17 presents hazard mitigation goals and objectives. Section 18 gives an analysis for the previous actions and Section 19 presents hazard mitigation actions for the City of Houston. Section 20 identifies Plan maintenance mechanisms.

The list of planning team members and stakeholders is located in Appendix A. Public survey results are analyzed and presented in Appendix B. Appendix C contains a detailed list of critical facilities for the area. Appendix D contains information regarding Dam locations within the City of Houston and Harris County. Appendix E contains information regarding workshops and meeting documentation. Capability Assessment results are located in Appendix F. Appendix G includes the City of Houston Storm Water Action Team's project log and Appendix H includes the Public Engagement and Outreach Plan and Summary Report. Additional CRS requirements are located in Appendix I and Appendix J includes State and Federal Funding Opportunities. [4]

[4] Information contained in some of these appendices are exempt from public release under the Freedom of Information Act (FOIA).

SECTION 2
PLANNING PROCESS



OFFICE OF EMERGENCY MANAGEMENT

SECTION 2: PLANNING PROCESS

Plan Preparation and Development 1

Overview of the Plan 1

Planning Team 2

Planning Process 5

Kickoff Workshop 6

Hazard Identification 6

Risk Assessment 7

Mitigation Review and Development 7

Review and Incorporation of Existing Plans 8

Review 8

Incorporation of Existing Plans into the HMAP Process 8

Incorporation of the HMAP into Other Planning Mechanisms 9

Plan Review and Plan Update 12

Timeline for Implementing Mitigation Actions 12

Public and Stakeholder Involvement 12

Stakeholder Involvement 13

Public Meetings 19

Public Participation Survey 19

PLAN PREPARATION AND DEVELOPMENT

Hazard mitigation planning involves coordination with various constituents and stakeholders to develop a more disaster-resistant community. Section 2 provides an overview of the planning process including the identification of key steps and a detailed description of how stakeholders and the public were involved.

OVERVIEW OF THE PLAN

The City of Houston hired Dewberry, H2O Partners, Inc., and CAS Group (Consultant Team), to provide technical support and oversee the development of the City of Houston Hazard Mitigation Action Plan Update 2023. The Consultant Team used the FEMA "Local Mitigation Planning Policy Guide" (Effective April 19, 2023), and the "Local Mitigation Planning Handbook" (March 2013) to develop the Plan Update. The overall planning process is shown in Figure 2-1 below.

Figure 2-1. Mitigation Planning Process



The City of Houston and the Consultant Team met in October 2022, to begin organizing resources, identify Planning Team members, and conduct a Capability Assessment.

PLANNING TEAM

Key members of the Consultant Team developed the Plan Update in conjunction with the Planning Team. The Planning Team was established using a direct representation model. Some of the responsibilities of the Planning Team included: completing Capability Assessment surveys, providing input regarding the identification of hazards, identifying mitigation goals, and developing mitigation strategies. An Executive Planning Team consisting of key personnel from the Office of Emergency Management involved in hazard mitigation activities, shown in Table 2-1, was formed to coordinate planning efforts and request input and participation in the planning process. Participation in this planning process is defined as being engaged in the process through attending meetings, providing data and related information, providing updates on previous actions, and reviewing and commenting on draft versions of the plan. Table 2-2 reflects the Advisory Planning Team, consisting of additional representatives from City departments that participated throughout the planning process; those with the authority to regulate development are identified with an asterisk next to their title.

Table 2-1. Executive Planning Team

ORGANIZATION / DEPARTMENT	TITLE
Office of Emergency Management	Administrative Specialist
Office of Emergency Management	Community Outreach
Office of Emergency Management	Deputy Emergency Management Coordinator

ORGANIZATION / DEPARTMENT	TITLE
Office of Emergency Management	Emergency Management Coordinator
Office of Emergency Management	Mass Care Coordinator
Office of Emergency Management	Planner I
Office of Emergency Management	Planner II

Table 2-2. Advisory Planning Team[1]

ORGANIZATION / DEPARTMENT	TITLE
Finance Department	Assistant Director
Finance Department	Deputy Director
Finance Department	Division Manager
Finance Department	Financial Analyst
Finance Department	Financial Analyst IV
Housing and Community Development Department	Deputy Assistant Director*
Housing and Community Development Department	Deputy Assistant Director Planning and Grants Reporting*
Housing and Community Development Department	Deputy Director*
Housing and Community Development Department	Director*
Housing and Community Development Department	Division Manager*
Housing and Community Development Department	Grants Analyst*
Housing and Community Development Department	Planner*
Housing and Community Development Department	Planning and Grants Reporting
Houston Fire Department	Accreditation Manager / Management Analyst IV
Houston Fire Department	Executive Assistant Chief
Houston Fire Department	Assistant Fire Chief / Fire Marshal
Houston Office of the Mayor	Mayor*

[1] *Authority to regulate development

ORGANIZATION / DEPARTMENT	TITLE
Houston Police Department	Sergeant / Planning
Houston Public Works	Administrative Assistant
Houston Public Works	Assistant Director*
Houston Public Works	Chief of Staff*
Houston Public Works	Community Rating System Coordinator
Houston Public Works	Emergency Management Coordinator
Houston Public Works	Deputy Emergency Management Coordinator
Houston Public Works	Employee Engagement Coordinator
Houston Public Works	Floodplain Administrator*
Houston Public Works	Planner Manager / Urban Designer
Houston Public Works	Senior Assistant Director
Houston Public Works	Senior Staff Analyst
Houston Public Works	Staff Analyst
Parks and Recreation Department	City Forester
Parks and Recreation Department	Deputy Director of Management and Finance
Parks and Recreation Department	Director of Greenspace Management Division*
Parks and Recreation Department	Division Manager
Parks and Recreation Department	Director
Parks and Recreation Department	Superintendent
Planning and Development Department	Community and Regional Planning
Planning and Development Department	Director*
Planning and Development Department	Division Manager*
Planning and Development Department	Planner for Sunnyside and Acres Home
Solid Waste Management Department	Deputy Director
Solid Waste Management Department	Director

Additionally, a Stakeholder Group was invited via email to participate in the planning process by attending meetings, commenting on draft versions of the plan, and/or by providing data to inform

the planning process. The Consultant Team, Planning Teams, and Stakeholder Group coordinated to identify mitigation goals, and develop mitigation strategies and actions for the Plan Update. Appendix A provides a complete listing of all participating Planning Team members and stakeholders by organization and title. Stakeholder involvement is discussed further below.

Based on results of the completed Capability Assessment survey, the City of Houston described methods for achieving future hazard mitigation measures by expanding existing capabilities. For example, the City of Houston may consider taking steps to improve the City's floodplain management program and increase their Community Rating System (CRS) class (refer to Appendix I CRS Requirements). Another possible enhancement of existing capabilities would be to integrate data from the Harris County Flood Control District's Modeling, Assessment and Awareness Project (MAAPnext), a FEMA funded project, into planning decisions around flood risk[2]. Other options for improving capabilities include the following:

- Integrate risk information into future updates of Plan Houston, Resilient Houston, and Neighborhood Resilience Plans.
- Add the Hazard Mitigation Plan Update 2023 to the Plan Houston online planning coordination tool.
- Integrate risk information into the Houston Fire Department's Capital Improvement Plan and Community Risk Assessments.
- Identify opportunities for cross-training or increase the technical expertise of staff by attending free training available through FEMA and the Texas Division of Emergency Management (TDEM), and monitoring classes and availability through preparingtexas.org.
- Review current floodplain ordinances for opportunities to increase resiliency, (above current standards) such as modifying permitting or building codes.
- Develop ordinances that will require all new developments to conform to the higher mitigation standards, exceeding current requirements.

Sample hazard mitigation actions developed with similar hazard risk were shared at the meetings. These important discussions resulted in the development of multiple mitigation actions that are included in the Plan Update to further mitigate risk from natural hazards in the future.

The Planning Team developed hazard mitigation actions for mitigating risk from all the identified hazards within this Plan Update; these actions include acquiring land to prevent future development in floodplain areas and preserve these areas as open space and raising electrical components of lift stations above the Base Flood Elevation. The Plan Update also includes an action to acquire and install quick connects for back-up generators at all critical facilities to ensure continuity of operations after a hazard event.

PLANNING PROCESS

The process used to prepare the Plan Update followed the four major steps included at Figure 2-1. After the Planning Team was organized, a capability assessment was developed and distributed at the Kick-Off Workshop. Hazards were identified and assessed, and results associated with each of the hazards were provided at the Risk Assessment Workshop. Based on the City of Houston's

[2] https://www.maapnext.org/about

identified vulnerabilities, specific mitigation strategies were discussed and developed at the Mitigation Strategy Workshop. Finally, Plan maintenance and implementation procedures were developed and are included in Section 20. Participation of Planning Team members, stakeholders, and the public at each of the workshops is documented in Appendix E.

At the Plan development workshops held throughout the planning process described herein, the following factors were taken into consideration:

- The nature and magnitude of risks currently affecting the community;
- Hazard mitigation goals to address current and expected conditions;
- Whether current resources will be sufficient for implementing the Plan Update;
- Implementation problems, such as technical, political, legal, and coordination issues that may hinder development;
- Anticipated outcomes; and
- How the City of Houston, agencies, and partners will participate in implementing the Plan Update.

KICKOFF WORKSHOP

The Kickoff Workshop was held on November 2, 2022 at the City of Houston City Hall with a virtual attendance option available through Microsoft Teams. The initial workshop informed participating officials and key department personnel about how the planning process pertained to their distinct roles and responsibilities and engaged stakeholder groups including, but not limited to American Red Cross, Harris County Animal Task Force, University of Houston, local medical partners, news outlets, and Harris County OEM and Engineering departments. In addition to the kickoff presentation, participants received the following information:

- Project overview regarding the planning process;
- Public survey access information;
- Hazard Ranking form; and
- Capability Assessment survey for completion.

A risk ranking exercise was conducted at the Kickoff Workshop to get input from the Planning Team and stakeholders pertaining to various risks from a list of natural hazards affecting the planning area. Participants ranked hazards high to low in terms of perceived level of risk, frequency of occurrence, and potential impact.

HAZARD IDENTIFICATION

At the Kickoff Workshop, and through email and phone correspondence, the Planning Team conducted preliminary hazard identification. The Planning Team in coordination with the Consultant Team reviewed and considered a full range of natural hazards. Once identified, the teams narrowed the list to significant hazards by reviewing hazards affecting the area as a whole, the 2018 State of Texas Hazard Mitigation Plan, and initial study results from reputable sources such as federal and state agencies. Based on this initial analysis, the teams identified a total of twelve natural hazards which pose a significant threat to the planning area.

Risk Assessment

An initial risk assessment for the City of Houston was completed in December 2022 and results were presented to Planning Team members at the Risk Assessment Workshop held on December 15, 2022, at the City of Houston City Hall with a virtual attendance option available. At the workshop, the characteristics and consequences of each hazard were evaluated to determine the extent to which the planning area would be affected in terms of potential danger to property and citizens.

Property and crop damages were estimated by gathering data from the National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA). The assessment also examined the impact of various hazards on the built environment, including general building stock, critical facilities, lifelines, and infrastructure. The resulting risk assessment profiled hazard events provided information on previous occurrences, estimated probability of future events, and detailed the spatial extent and magnitude of impact on people and property. A hazard profile and vulnerability analysis for each of the hazards can be found in Sections 4 through 16.

Mitigation Review and Development

Developing the Mitigation Strategy for the Plan involved identifying mitigation goals and new mitigation actions. A Mitigation Workshop was held on February 16, 2023, at the City of Houston Office of Emergency Management with a virtual attendance option available. In addition to the Planning Team, stakeholder groups were invited to attend the workshop. The City was proactive in identifying mitigation actions to lessen the risk of all the identified hazards included in the Plan Update.

An inclusive and structured process was used to develop and prioritize new hazard mitigation actions for the Plan Update. The prioritization method was based on FEMA's STAPLE+E criteria and included social, technical, administrative, political, legal, economic, and environmental considerations. As a result, each Planning Team Member assigned an overall priority to each hazard mitigation action. The overall priority of each action is reflected in the hazard mitigation actions found in Section 19.

Planning Team Members then developed action plans identifying proposed actions, costs and benefits, the responsible organization(s), effects on new and existing buildings, implementation schedules, priorities, and potential funding sources.

Specifically, the process involved:

- Listing optional hazard mitigation actions based on information collected from previous plan reviews, studies, and interviews with federal, state, and local officials. Workshop participants reviewed the optional mitigation actions and selected actions that were most applicable to their area of responsibility, cost-effective in reducing risk, easily implemented, and likely to receive institutional and community support.
- Workshop participants inventoried federal and state funding sources that could assist in implementing the proposed hazard mitigation actions. Information was collected, including the program name, authority, purpose of the program, types of assistance and eligible

projects, conditions on funding, types of hazards covered, matching requirements, application deadlines, and a point of contact.

- Planning Team Members considered the benefits that would result from implementing the hazard mitigation actions compared to the cost of those projects. Although detailed cost-benefit analyses were beyond the scope of the Plan Update, Planning Team Members utilized economic evaluation as a determining factor between hazard mitigation actions.
- Planning Team Members then selected and prioritized mitigation actions.

Hazard mitigation actions identified in the process were made available to the Planning Team for review. The draft Plan Update was maintained on file by the City of Houston Office of Emergency Management and was made available to the general public for review.

REVIEW AND INCORPORATION OF EXISTING PLANS

REVIEW

Background information utilized during the planning process included various studies, plans, reports, and technical information from sources such as FEMA, the United States Army Corps of Engineers (USACE), the U.S. Fire Administration, National Oceanic and Atmospheric Administration (NOAA), the Texas Water Development Board (TWDB), the Texas Commission on Environmental Quality (TCEQ), the Texas State Data Center, Texas Forest Service, the Texas Division of Emergency Management (TDEM), and the 2018 Texas State Hazard Mitigation Plan. Section 4 and the hazard-specific sections of the Plan (Sections 5-16) summarize the relevant background information.

Specific background documents, including those from FEMA, provided information on hazard risk, hazard mitigation actions currently being implemented, and potential mitigation actions. Previous hazard events, occurrences, and descriptions were identified through NOAA's National Centers for Environmental Information (NCEI). Results of past hazard events were found through searching the NCEI Storm Event Database. The USACE studies were reviewed for their assessment of risk and potential projects in the region. Information from the State Demographer was reviewed for population and other projections and included in Section 3 of the Plan. Information from the Texas Forest Service was used to appropriately rank the wildfire hazard, and to help identify potential grant opportunities. Materials from FEMA and TDEM were reviewed for guidance on Plan Update development requirements.

INCORPORATION OF EXISTING PLANS INTO THE HMAP PROCESS

A Capability Assessment was completed by key departments from the City of Houston which provided information pertaining to existing plans, policies, ordinances, and regulations to be integrated into the goals and objectives of the Plan Update. The relevant information was included in a master Capability Assessment, Appendix F.

Existing projects and studies were utilized as a starting point for discussing hazard mitigation actions among Planning and Consultant Team members. For example, ongoing Capital Improvement Program (CIP) flood risk reduction projects have been identified through the Harris County Flood Control District, and these cost-effective structural drainage improvements as well as acquisition/demolition projects have been included in this Plan Update. Additionally, projects identified in the City of Houston's first three pilot Neighborhood Resilience Plans were carried forward into this Plan Update as new mitigation actions (Actions #25 through #31). Other plans were reviewed, such as Plan Houston, which describes a vision and goals for the community and identifies twelve core strategies that represent the City's approach for achieving the vision. The Climate Impact Assessment and Resilient Houston were reviewed and information on the impacts of climate change on the City was included in the Risk Assessment.

The Planning Team also discussed success in past mitigation actions including the Inwood Forest Flood Mitigation project that was identified in the 2018 plan. The project aims to reduce localized flood risk following the devasting damage caused by Hurricane Harvey and includes $52.6 million for improvements to the Inwood Forest stormwater detention basins. The City was successful in receiving funding for the project through FEMA's Hazard Mitigation Grant Program.

Finally, the 2018 State of Texas Hazard Mitigation Plan, developed by TDEM, was discussed in the initial planning meeting in order to develop a specific group of hazards to address in the planning effort. The 2018 State Plan was also used as a guidance document, along with FEMA materials, in the development of the City of Houston Hazard Mitigation Action Plan Update 2023.

INCORPORATION OF THE HMAP INTO OTHER PLANNING MECHANISMS

Planning Team members will integrate implementation of the Plan Update with other planning mechanisms for the City of Houston, such as the Comprehensive Emergency Operation Plan and future updates to Plan Houston and Resilient Houston. This section discusses how the Plan will be implemented by the City of Houston. It also addresses how the Plan will be evaluated and improved over time, and how the public will continue to be involved in the hazard mitigation planning process.

The City of Houston will be responsible for implementing hazard mitigation actions contained in Section 19. Each hazard mitigation action has been assigned to a specific City department that is responsible for tracking and implementing the action.

A funding source has been listed for each identified hazard mitigation action and may be utilized to implement the action. An implementation time period has also been assigned to each hazard mitigation action as an incentive and to determine whether actions are implemented on a timely basis.

The City of Houston will integrate hazard mitigation actions contained in the Plan Update with existing planning mechanisms such as floodplain ordinances, Emergency Operation Plans, Evacuation Plans, and other local and area planning efforts. The City of Houston will work closely with area organizations to coordinate implementation of hazard mitigation actions that benefit the planning area financially and economically.

Upon formal adoption of the Plan Update, Planning Team members will review existing plans along with building codes to guide development and ensure that hazard mitigation actions are implemented. Each of the City departments will be responsible for coordinating periodic review of the Plan Update with members of the Advisory Planning Team to ensure integration of hazard mitigation strategies into these planning mechanisms and codes. The Planning Team will also conduct periodic reviews of various existing planning mechanisms and analyze the need for any revisions or updates in light of the approved Plan Update. The City of Houston will ensure that future long-term planning objectives will contribute to the goals of the Plan to reduce the long-term risk to life and property from moderate and high-risk hazards. Within one year of formal adoption of the Plan, existing planning mechanisms will be reviewed and analyzed as they pertain to the Plan Update.

Planning Team members will review and revise, as necessary, the long-range goals and objectives in its strategic plan and budgets to ensure that they are consistent with the Plan Update.

Furthermore, the City of Houston will work with neighboring jurisdictions to advance the goals of the Plan Update as it applies to ongoing, long-range planning goals and actions for mitigating risk to natural hazards throughout the planning area.

Table 2-3 identifies types of planning mechanisms and examples of methods for incorporating the Plan into other planning efforts.

Table 2-3. Examples of Methods of Incorporation

PLANNING MECHANISM	INCORPORATION OF PLAN
Annual Budget Review	Various departments and key personnel that participated in the planning process will review this Plan Update and mitigation actions therein when conducting their annual budget review. Allowances will be made in accordance with grant applications sought, and mitigation actions that will be undertaken, according to the implementation schedule of the specific action.
Capital Improvement Plans	Prior to any revisions to the Capital Improvement Plan (CIP), City departments will review the risk assessment and mitigation strategy sections of this Plan Update, as limiting public spending in hazardous zones is one of the most effective long-term mitigation actions available to local governments.
General Plan	The City of Houston adopted Plan Houston, the City's General Plan, in 2015. In future revisions and updates to the General Plan, the mitigation vision and goals of this Plan Update will be reviewed.
Floodplain Management Plans	Floodplain management plans include preventative and corrective actions to address the flood hazard. Therefore, the actions for flooding and information

PLANNING MECHANISM	INCORPORATION OF PLAN
	found in Section 5 of this Plan Update discussing the people and property at risk of flooding will be reviewed and revised when updating the flood management plans or developing new plans.
Grant Applications	This Plan Update will be evaluated when grant funding is sought for mitigation projects. If a project is not in the Plan Update, a Plan Revision may be necessary to include the action in the Plan.
Regulatory Plans	Currently, the City of Houston has regulatory plans in place, such as Emergency Management Plans, Continuity of Operations Plans, Land Use Plans, and Evacuation Plans. This Plan Update will be consulted when City departments review or revise their current regulatory planning mechanisms or in the development of regulatory plans that are not currently in place.

Appendix F Capability Assessment provides an overview of the City's existing planning and regulatory capabilities. These existing capabilities provide the mechanisms to implement the City's mitigation strategy. For example, the adoption of building codes and implementation of land use regulations have been demonstrated to help communities avoid losses from natural hazard events. The City of Houston adopted the 2015 International Building Code and City of Houston Amendments, effective April 1, 2022. The Houston Construction Code establishes minimum standards for the construction, alteration, maintenance, repair, and demolition of buildings and other structures to protect the life and safety of the public. Land use regulations in the City of Houston's Code of Ordinances acknowledge the City's risk to natural hazards and each provide the mechanisms to prevent future development in creating or increasing existing vulnerabilities. These land use regulations include floodplain management regulations (Chapter 19), stormwater management regulations (Chapter 47) and subdivision ordinances (Chapter 42).

It should be noted for the purposes of the Plan Update that the 2018 HMAP has been used as a reference when reviewing and updating all plans and ordinances for the entire planning area. The Emergency Management Plan, which provides strategic guidance for city departments, is updated every 5 years and incorporates goals, objectives and actions identified in the current mitigation plan. The City's Comprehensive Emergency Management Plan is on the same update schedule as the Hazard Mitigation Plan, helping to integrate information between the two plans. During the 2023 planning process both plans were in the process of being updated and public outreach efforts were used to inform updates to both plans.

Additionally, the City of Houston Office of Emergency Management maintains a variety of operational plans that utilize the mitigation strategies in the current Plan, which helps determine how the City of Houston responds to different situations, including hazard-specific plans, such as the Hurricane Response & Recovery Plan, and functions, such as the Emergency Public Information Plan. In addition, the City of Houston Storm Water Maintenance Branch (SWMB) incorporates

many of the mitigation strategies identified in the current plan to prioritize and implement drainage mitigation projects throughout the city.

PLAN REVIEW AND PLAN UPDATE

As with the development of Plan Update, the City of Houston will oversee the review and update process for relevance and if necessary, make adjustments. At the beginning of each fiscal year, Planning Team Members will meet to evaluate the Plan and review other planning mechanisms to ensure consistency with long-range planning efforts. In addition, planning participants will also meet once a year, by conference call or presentation, to re-evaluate prioritization of the hazard mitigation actions.

TIMELINE FOR IMPLEMENTING MITIGATION ACTIONS

Both the Executive Planning Team (Table A-1, Appendix A) and the Advisory Planning Team (Table A-2, Appendix A) will engage in discussions regarding a timeframe for how and when to implement each hazard mitigation action. Considerations include when the action will be started, how existing planning mechanisms' timelines affect implementation, and when the action should be fully implemented. Timeframes may be general, and there will be short, medium, and long-term goals for implementation based on prioritization of each action, as identified on individual Hazard Mitigation Action worksheets included in the Plan Update for the City of Houston.

Both the Executive and Advisory Planning Team will evaluate and prioritize the most suitable hazard mitigation actions for the community to implement. The timeline for implementation of actions will partially be directed by the City's comprehensive planning process, budgetary constraints, and community needs. The City of Houston is committed to addressing and implementing hazard mitigation actions that may be aligned with and integrated into the Plan Update.

Overall, the Planning Team is in agreement that goals and actions of the Plan Update shall be aligned with the timeframe for implementation of hazard mitigation actions with respect to annual review and updates of existing plans and policies.

PUBLIC AND STAKEHOLDER INVOLVEMENT

An important component of hazard mitigation planning is public participation and stakeholder involvement. Input from individual citizens and the community as a whole provides the Planning Team with a greater understanding of local concerns and increases the likelihood of successfully implemented hazard mitigation actions. If citizens and stakeholders, such as local businesses, non-profits, hospitals, and schools are involved, they are more likely to gain a greater appreciation of the risks that hazards may present in their community and take steps to reduce or mitigate their impact.

The public was involved in the development of the City of Houston Hazard Mitigation Action Plan Update 2023 at different stages prior to official Plan approval and adoption. Public input was sought using three methods: (1) open public meetings; (2) survey instruments; and (3) making the

draft Plan Update available for public review on the City of Houston's Office of Emergency Management website.

The draft Plan Update was made available to the general public for review and comment on the City of Houston's OEM website. The public was notified at the public meetings that the draft Plan Update would be available for review.

No feedback was received on the draft Plan Update, although it was given on the public survey, and all relevant information was incorporated into the Plan Update. Public input was utilized to assist in identifying hazards that were of most concern to the citizens of the City and what actions they felt should be included and prioritized.

The Plan Update will be advertised and posted on City of Houston's Office of Emergency Management website upon approval from FEMA and a copy will be kept in the Houston Emergency Center (HEC).

STAKEHOLDER INVOLVEMENT

Stakeholder involvement is essential to hazard mitigation planning since a wide range of stakeholders can provide input on specific topics and from various points of view. Throughout the planning process, members of community groups, local businesses, neighboring jurisdictions, schools and universities, and hospitals were invited to participate in development of the Plan Update. The Stakeholder Working Group (Table A-3 in Appendix A, and Table 2-4, below), included a broad range of representatives from both the public and private sector and served as a key component in the City's outreach efforts for development of the Plan Update. The Stakeholder Group was organized around the following types (refer to Appendix A):

- Involved in hazard mitigation activities
- Authority to regulate development
- Neighboring communities
- Business, academia and other private organizations
- Nonprofit organizations including community-based organizations

Documentation of stakeholder meetings is found in Appendix E. The following agencies were invited to participate in the planning process via email, those that participated by attending meetings, commenting on draft versions of the plan, and/or by providing data to inform the planning process are identified in Table 2-4 below.

Table 2-4. Stakeholder Working Group

AGENCY	TITLE	PARTICIPATED
AARP	Director of Programs	
American Red Cross	Disaster Program Manager	
American Red Cross	Regional Disaster Officer	
Catholic Charities	Manager	

AGENCY	TITLE	PARTICIPATED
Chinese Community Center	Chief Executive Officer	
City of Houston	Chief of Staff for At-Large 1	
City of Houston	Chief of Staff for District A	
City of Houston	Chief of Staff for District C	
City of Houston	Chief of Staff for District E	X
City of Houston	Chief of Staff for District F	X
City of Houston	Chief of Staff for District G	X
City of Houston	Chief of Staff for District H	
City of Houston	Chief of Staff for District J	
City of Houston	Chief of Staff for District K	X
City of Houston	Council Member for At-Large 3	
City of Houston	Council Member for District B	
City of Houston	Council Member for District D	
City of Houston	Council Member for District H	
City of Houston	Council Member for District I	
City of Houston	Deputy Chief of Staff for At-Large 2	
City of Houston	Deputy Chief of Staff for At-Large 4	X
City of Houston	Deputy Chief of Staff for At-Large 5	X
City of Houston	Deputy Chief of Staff for District G	X
City of Houston	Director of Constituent Services & Housing Research Assistant for District F	X
City of Houston	Director of Department of Neighborhoods	
City of Houston	Director of General Services Department	
City of Houston	Permitting Center Managing Engineer	
Consulate of Argentina	Consul General	

AGENCY	TITLE	PARTICIPATED
Consulate of France	Press & Communications Officer	
Consulate of Colombia	Consul General	
Consulate of Colombia	Consul General	
Consulate of Guatemala	Consul General	
Consulate of Mexico	Consul of Prevention	
Consulate of Salvador	Consul General	
Consulate of Spain	Consul General	
Consulate of Qatar	Vice Consul	
Consulate of Vietnam	Citizens Protection	
FEMA	Community Planner	X
Greater Houston Flood Mitigation Consortium	Vice President / Director of Planner	
Harris County Engineering Department	Project Manager	
Harris County Engineering Department	Team Lead Project Manager for Recovery and Resiliency Division	
Harris County Flood Control District	Planning Division Director	X
Harris County Flood Control District	Resilience Division Manager	X
Harris County Office of Homeland Security and Emergency Management	Emergency Management Coordinator	X
Harris County Office of Homeland Security and Emergency Management	Flood Control Risk Manager	X
Harris County Office of Homeland Security and Emergency Management	Mitigation Planner	X
Harris County Office of Homeland Security and Emergency Management	Planning Section Chief	X
Houston Airport System	Division Manager	X

AGENCY	TITLE	PARTICIPATED
Houston County SPC / Harris County Disaster Animal Task Force	Director of Emergency Management	
Houston Food Bank	Coordinator	
Houston Food Bank	Lead Associate / Manager	
Houston – Galveston Area Council	Director of Communications and Outreach	
Houston – Galveston Area Council	Emergency Preparedness/Homeland Security Planner	
Houston – Galveston Area Council	Manager of Hurricane Evacuation and Evacuation Zones	X
Houston Health Department	Public Health Preparedness Bureau Chief	X
Houston Health Department	Staff Analyst	X
Houston Hispanic Chamber of Commerce	President / CEO	
Houston Independent School District (ISD)	Receptionist	
Houston Independent School District (ISD)	Senior Manager for Nutrition Services	
Houston Independent School District (ISD)	Senior Manager for Risk Management	
Houston Office of the Mayor	Chief Resilience and Recovery Officer	X
Houston Office of the Mayor	Chief Resilience and Sustainability Officer	
Houston Office of the Mayor	Deputy Assistant Director of Internal Operations for Complete Communities Division	X
Houston Office of the Mayor	Director of Complete Communities Division	X
Houston Office of the Mayor	Community Liaison for People with Disabilities Division	X
Houston Office of the Mayor	Director of People with Disabilities Division	
Houston Office of the Mayor	Director of Public Safety and Homeland Security	X

AGENCY	TITLE	PARTICIPATED
Houston Office of the Mayor	Staff Analyst of Resiliency and Sustainability Division	X
Houston Office of the Mayor	Staff Representative of Complete Communities Division	X
Houston Parks Board	Interim Director of Capital Improvements	
Houston Parks Board	Director of Conservation and Maintenance	X
Houston Police Department	Disaster Management / Catastrophic Planning	X
Jewish Community Center	Chief Executive Officer	
KHOU	Managing Editor	X
KPRC	Assignment Editor	X
KRIV	Representative	X
KTRK	Assignments Manager	X
Lockwood, Andrews, & Newnam, Inc. (LAN)	CRS/Floodplain Mitigation Manager	X
Lone Star College – Kingwood	President	
METRO	Chief of Safety Officer	
METRO	Director of Risk Management	X
METRO	Emergency Management Coordinator	
METRO	Risk Manager	
National Weather Service	Warning Coordination Meteorologist	X
Partnership Lake Houston	Chief Economic Development Officer	
Partnership Lake Houston	Interim President / CEO	
Port of Houston	Director of Community Relations	
Port of Houston	Emergency Preparedness Coordinator	
Region IV Education Service Center	Director of Emergency Management & School Safety	
Region IV Education Service Center	Executive Director	

AGENCY	TITLE	PARTICIPATED
Rice University Kinder Institute	Senior Director of Research	X
Rice University Kinder Institute	Staff Representative	X
San Jacinto College	Executive Director	X
SouthEast Texas Regional Advisory Council (SETRAC)	Chief Executive Officer	
Texas Children's Hospital (TCH)	Emergency Management Coordinator	
TEEX Community Watershed	Infrastructure Training & Safety Representative	
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Specialist	
Texas Division of Emergency Management (TDEM)	District Coordinator	X
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Coordinator for Region 2	X
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Specialist for Region 2	X
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Unit Chief for Region 2	X
Texas Division of Emergency Management (TDEM)	Recovery Coordinator	X
Texas Division of Emergency Management (TDEM)	Regional Mitigation Coordinator for Region 2	X
Texas Division of Emergency Management (TDEM)	Regional Preparedness Coordinator / Planner for Region 2	X
Texas Division of Emergency Management (TDEM)	STEAR Program Manager	X
Texas Medical Center (TMC)	Emergency Management Coordinator	
Texas Medical Center (TMC)	Director of Strategy	
Texas Medical Center (TMC)	Vice President of Planning	X
Texas State Legislature	District 29	
Transtar	Director	
Transtar	Executive Director	X
UTHealth and Safety	Governmental Relations Director	

AGENCY	TITLE	PARTICIPATED
United Way	211 Senior Manager of Information and Referral	
United Way	Disaster and Outreach Coordinator	X
United Way	Information Referral Specialist	
University of Houston	Director of OEM	X
University of Houston	Risk & Emergency Program Manager II	X
Work for Solutions	Career Office Manager	
Work for Solutions	Senior Manager	

Stakeholders and participants from neighboring communities that attended the Planning Team and public meetings played a key role in the planning process. For example, Rice University's Kinder Institute for Urban Research provided ideas new mitigation actions where the City and University could partner on, including actions related to developing a hazard awareness program (Action #38) and improving data collection of hazard information (Action # 39).

PUBLIC MEETINGS

A series of public meetings were held throughout the planning area to collect public and stakeholder input. Topics of discussion included the purpose of hazard mitigation, discussion of the planning process, and types of natural hazards. The City of Houston released information regarding the public meetings in their area to increase public participation in the Plan Update development process, through posting on their website, on social media sources including Facebook and Twitter, through the local media, and/or posting the information on bulletin boards in public facilities. A sampling of these notices can be found in Appendix E, along with the documentation on the public meetings. All three of the public meetings were held in Complete Communities. The City of Houston's Complete Communities initiative is focused on ten historically under-resourced neighborhoods and providing resources and opportunities to residents without barriers. Representatives from area neighborhood associations and area residents were invited to participate.

Public meetings were held on the following dates and locations:

- January 19, 2023, Acres Home Multi-Service Center, Acres Home Neighborhood
- February 4, 2023, Hartman Community Center, Magnolia Park – Manchester Neighborhood
- February 16, 2023, Sunnyside Multi-Service Center, Sunnyside Neighborhood

Public Participation Survey

In addition to public meetings, the Planning and Consultant Teams developed a public survey, in both English and Spanish, designed to solicit public input during the planning process from citizens

and stakeholders and to obtain data regarding the identification of any potential hazard mitigation actions or problem areas. The survey was promoted by local officials and a link to the survey was posted on the City of Houston's Office of Emergency Management website. Paper versions of the survey were also provided at each of the public meetings. A total of 489 surveys were completed online and as paper copies. The survey results are analyzed in Appendix B. The Planning Team reviewed the input from the surveys and decided which information to incorporate into the Plan as hazard mitigation actions. For example, many citizens were concerned with flooding, and provided specific locations of concern including locations within the Maplewood and Meyerland area, and District G. Survey responses also showed the public has an interest in the City implementing mitigation projects related to restoring natural systems to mitigate flood risk and protect floodplains. As a result of the public survey many of these suggested actions have been included in the mitigation strategy.

SECTION 3
CITY PROFILE



OFFICE OF EMERGENCY MANAGEMENT

SECTION 3: CITY PROFILE

Overview 1
Population and Demographics 3
Population Growth 4
Natural, Cultural, and Historic Resources 4
Economic Impact 5
Existing Land Use and Development Trends 6
Future Growth and Development 8

OVERVIEW

The City of Houston was founded on August 30,1836 near the banks of Buffalo Bayou and incorporated as a city on June 5, 1837. The city was named after former General Sam Houston, who was president of the Republic of Texas and had commanded and won at the Battle of San Jacinto 25 miles east of where the city was established.

In the mid-20th century, Houston became the home of the Texas Medical Center – the world's largest concentration of healthcare and research institutions – and NASA's Johnson Space Center, where the Mission Control Center is located. The Greater Port of Houston ranks first in the United States in international waterborne tonnage handled and second in total cargo tonnage handled.

The City has a total area of 656.3 square miles, of which 634 square miles is land and 22.3 square miles is covered by water. Most of Houston is located on the gulf coastal plain and its vegetation is classified as temperate grassland and forest. Much of the city was built on forested land, marshes, swamp, or prairie which resembles the Deep South, and are all still visible in surrounding areas. The flatness of the local terrain, when combined with urban sprawl, has made flooding a recurring problem for the City. Downtown stands about 50 feet above sea level, and the highest point in far northwest Houston is about 125 feet in elevation.

Houston has four major bayous passing through the city that accept water from the extensive drainage system. Buffalo Bayou runs through downtown and the Houston Ship Channel, and has three tributaries: White Oak Bayou, Brays Bayou, and Sims Bayou. The ship channel continues past Galveston and then into the Gulf of Mexico.

Figure 3-1 shows the general location of the City of Houston relative to other area communities within and adjacent to Harris County.

Figure 3-1. Location of City of Houston

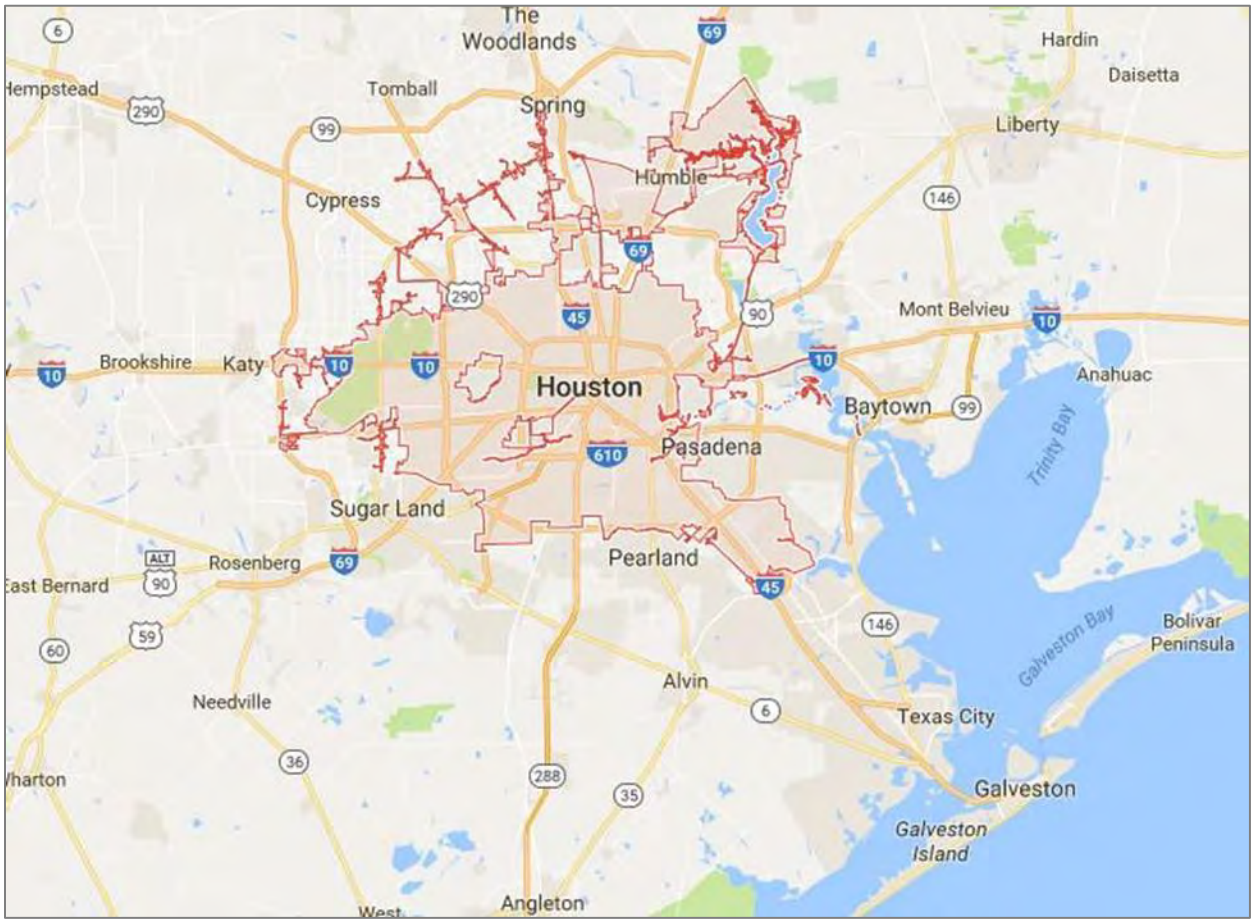
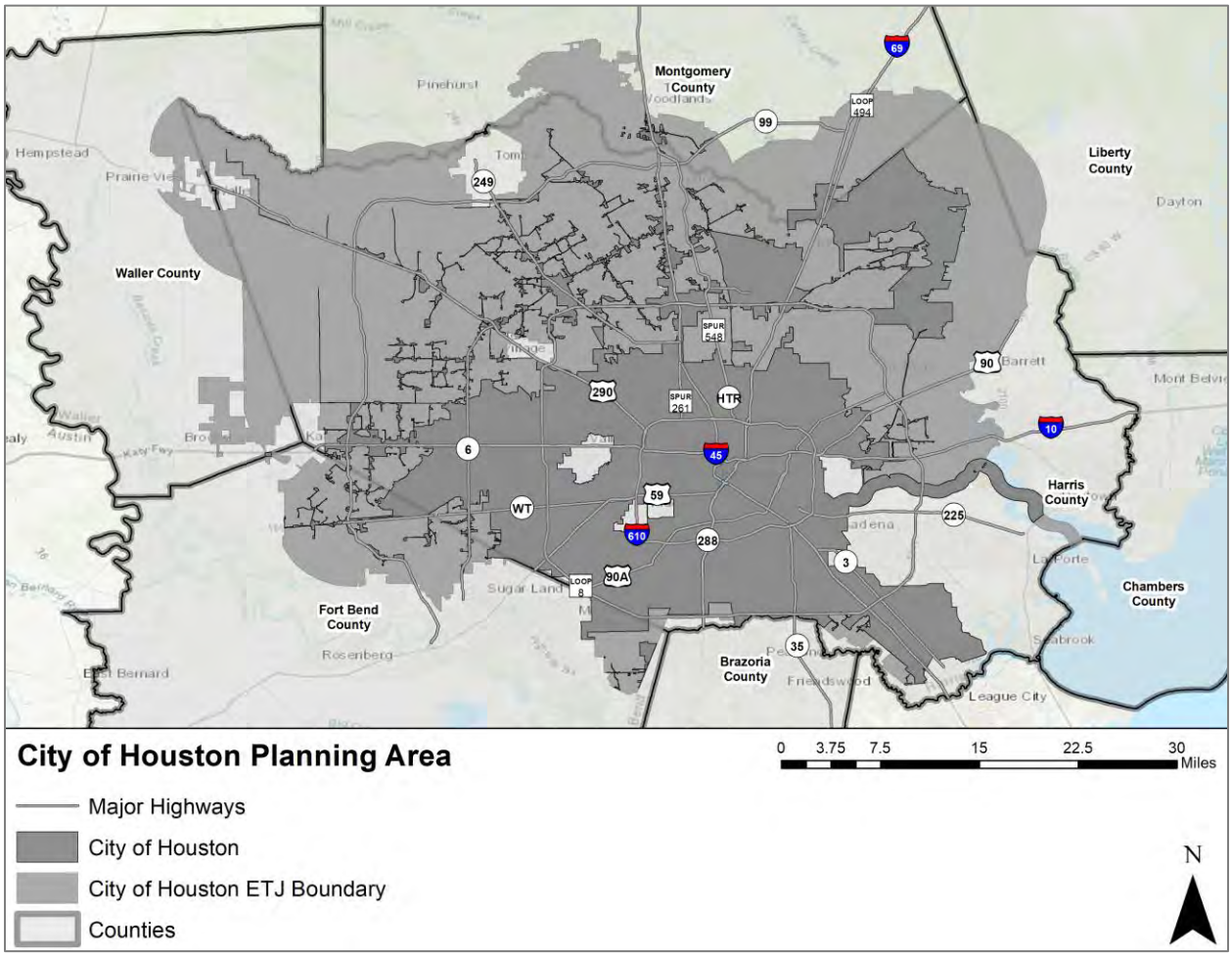


Figure 3-2 shows the city limits of the City of Houston, which makes up the planning area. All areas of the City's corporate limits are covered in the risk assessment analysis of the Plan.

Figure 3-2. City of Houston Planning Area



POPULATION AND DEMOGRAPHICS

According to the 2020 Census population count, the City of Houston has an official population of 2,304,580 residents, a 10 percent increase since the 2010 census.[1] Table 3-1 summarizes select characteristics of vulnerable or sensitive populations in the City of Houston using data from the U.S. Census Bureau 2021 American Community Survey (ACS) five-year estimates. Note that in some cases the 2021 ACS estimates may differ from the 2020 Census counts; the ACS estimates are used throughout this section for consistency.

[1] Source: https://demographics.texas.gov/Data/Decennial/2010/, https://www.census.gov/en.html and https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2020/

Table 3-1. City of Houston Vulnerable and Sensitive Populations, 2021

TOTAL 2021 POPULATION	ESTIMATED VULNERABLE OR SENSITIVE POPULATIONS[2]						
	Youth (Under 5)	% of Total Population	Elderly (Over 65)	% of Total Population	% Below Poverty Level	% Language other than English spoken at home	% Speak English less than "very well"
2,293,288	164,775	7%	255,522	11%	19.5%	46%	22%

POPULATION GROWTH

The official 2020 City of Houston population is 2,304,580. Overall, the City of Houston experienced an increase in population between 1980 and 2020 of 44 percent, or an increase of 709,442 residents. The City continued to have population growth between 2010 and 2020 by 10 percent, or 205,129 residents. Table 3-2 provides historic growth rates in the City of Houston. Population growth since the last plan was considered when updating this plan. A larger population means an increase in vulnerability as well as a growth in vulnerable populations.

Table 3-2. Population for City of Houston, 1980-2020

1980	1990	2000	2010	2020	POP CHANGE 1980-2020	PERCENT OF CHANGE	POP CHANGE 2010-2020	PERCENT OF CHANGE
1,595,138	1,630,864	1,953,631	2,099,451	2,304,580	709,442	44%	205,129	10%

NATURAL, CULTURAL, AND HISTORIC RESOURCES

Natural resources are crucial for a functioning environment as well as providing many benefits in the overall reduction of the impacts of natural hazards. Protection of these natural resources is important to consider when identifying mitigation projects and may be used to leverage additional funding for projects that not only contribute to this plan's goals, but also provide for protection of sensitive natural resources. For instance, protecting wetland areas protects sensitive habitat as well as attenuates and stores floodwaters, increasing tree canopy coverage helps reduce the impacts of extreme heat and pollution, and protecting and planting native vegetation over invasive species helps reduce water usage and the impacts of drought.

The Houston Parks and Recreation Department's Greenspace Management Division created the Natural Resources Management Program (NRMP) to manage the oversite of natural areas within City parks. "The Natural Resources Management Program works to preserve the biodiversity and natural heritage of Houston and surrounding areas by supporting green space preservation,

[2] The Estimated Vulnerable or Sensitive Populations are based off the 2021 American Community Survey 5-Year Estimates Data Profiles.

protecting and restoring natural communities, and cultivating a sense of environmental awareness through research, education, and stewardship."[3] The following are a sample of the initiatives under the Natural Resources Management Program.

The Natural Area Ordinance (Chapter 32-10) addresses the creation of natural areas on private land. The ordinance allows citizens to create and maintain natural habitats and wildlife friendly habitats in their yards. Interested residents are encouraged to receive a Natural Area Permit prior to creation and maintenance of these areas.

The Natural Preserve Ordinance was approved by the City Council in 2022. The policy has a focus on habitat protection and passive recreation and protects 7,423 acres of natural habitats in 26 city parks. These areas will be protected from future development and help to mitigate flooding, store carbon, reduce urban heat island effects and improve water and air quality.[4]

The Riparian Restoration Initiative, announced in February 2020, targets 70 parks adjacent to bayous and tributaries for the revitalization of forested riparian buffers by removing invasive species and installing a diverse mix of native trees and shrubs.[5] The goal of the initiative is to mitigate flooding, improve water quality, reduce erosion and create wildlife habitat. The Riparian Restoration Initiative will result in the restoration of over 1,000 acres of habitat in city parks, along with the planting of 200,000 native trees in Houston parks and greenspaces by 2030. The Initiative is also noted in the Houston Climate Action Plan.[6]

The City of Houston has a rich history that is preserved through its designated historic districts and landmarks. Throughout the City there are 12 Historic Districts on the National Park Service's National Register of Historic Places as well as 21 Historic Districts and 1 Heritage District designated by the City of Houston. There are also 265 buildings and sites listed on the National Register of Historic Places. Historic buildings are vulnerable to natural hazards as their construction pre-dates modern building codes. There are also historic preservation considerations and requirements for historic structures when they are included in mitigation or recovery projects.

ECONOMIC IMPACT

Building and maintaining infrastructure depends on the economy, and therefore, protecting infrastructure from risk due to natural hazards in the planning area is important to the City of Houston.

The City of Houston is recognized worldwide for its energy industry – particularly for oil and natural gas – as well as for biomedical research and aeronautics. Renewable energy sources – wind and solar – are also growing economic bases in the City. In 1981, the economic base was dominated by energy-related businesses with nearly 85 percent of all jobs in those sectors. Today, nearly half of all jobs are in non-energy fields, such as educational services, health care,

[3] Source: https://www.houstontx.gov/parks/naturalresources.html
[4] Source: https://www.houstontx.gov/parks/naturalresources.html
[5] Source: https://www.houstontx.gov/parks/pdfs/2020/RiparianRestorationInitiative.pdf
[6] Source: http://greenhoustontx.gov/climateactionplan/CAP-April2020.pdf

management construction and retail trade. Twenty-four Fortune 500 companies are headquartered in the City of Houston, the third highest concentration in the U.S.[7]

The City of Houston's economy is also strengthened by three major airports, which form the sixth-largest airport system in the world, and a massive trucking and rail system that links the southern, south central, mid-western and western United States. More than 600 trucking firms operate in the City of Houston, and two major rail systems operate 14 mainline tracks radiating from the City of Houston. The City of Houston is also home to the largest port in the U.S. in foreign tonnage.[8] The Greater Port of Houston is comprised of a 25-mile-long complex and the 52-mile-long Houston Ship Channel. Annually nearly 285 million tons of cargo carried by 9,000 vessels and 200,000 barges moves through the Greater Port of Houston.[5]

The City of Houston offers a richly diverse pool of highly skilled, multilingual, multicultural workers. Of adults 25 years and older 20 percent have completed four years of college and 14 percent have a graduate or professional degree. More than 90 languages are spoken in the City of Houston.[9]

Based on the American Community Survey 2021 estimates, 62 percent of the population 16 years and over is employed in the labor force. The per capita income is $36,265 and the median household income in the City is $55,499. It is estimated that nearly half of households (46 percent) have incomes below $50,000. Families with incomes below the poverty level in 2021 made up 16 percent of all families. Of families that have children under 18 years old 24 percent are below the poverty level.

EXISTING LAND USE AND DEVELOPMENT TRENDS

Development trends in the City of Houston have been shaped by the availability of inexpensive land on the edges of urban development rather than by public transportation or proximity to employment centers. The City of Houston Planning and Development Department estimates that for every single-family building permit issued within the city limits, there are four more issued in the city's extra-territorial jurisdiction (ETJ).[10]

The Planning and Development Department's mission is to work to ensure that the City of Houston remains a vibrant and sustainable city by partnering with decision makers and the community to balance a spectrum of needs and interests while addressing the dynamics of growth and change. The Department of Planning and Development regulates land development in the City of Houston and within its ETJ, which spans a five-county area. The City of Houston does not have zoning, instead development is governed by codes that address how property can be subdivided. The Department checks subdivision plats for the proper subdivision of land and for adequate street or right-of-way, building lines and for compliance with Chapter 42 of the City's land development ordinance. Development site plans are checked for compliance with regulations that

[7] Source: https://www.houston.org/news/houston-home-24-fortune-500-companies-3rd-highest-concentration-us
[8] Source: https://www.houstontx.gov/motia/trade-intl-bus-dev.html
[9] Source: City of Houston, Business Overview https://www.houstontx.gov/abouthouston/business.html
[10] Source: Resilient Houston, February 2020, https://www.houstontx.gov/mayor/Resilient-Houston-20200518-single-page.pdf

include parking, tree and shrub requirements, setbacks, and access. Between 2017 and 2020 there were 193,171 submittals to the Planning Department for subdivisions.[11]

According to the 2021 American Community Survey five-year estimates there are a total of 990,632 housing units in the City of Houston, of which 878,906 are occupied units (89 percent of total units) and 111,726 vacant units. Of the occupied housing units, 42 percent are owner-occupied, and 58 percent are renter-occupied; 13 percent higher than the County and 20 percent higher than the nationwide estimates of renter-occupied units.[12] Homeownership can reflect an individual's connection to a community and place attachment and ownership of their community. Homeownership can also be used as a measure of a community's economic strength. Low levels of homeownership can be an indication of a fluctuating local economy and may indicate a population with less than long-term commitment to the local community, "which could hamper [implementation of] both individual and community mitigation actions" before a disaster as well as during recovery periods.[13]

A review of building permits gives a picture of the built environment and the number of buildings that are being constructed in the City. Table 3-3 lists the number of residential buildings and total units authorized through a permit from the City of Houston between 2000 and 2021. The data includes total buildings, total units and the total value of construction costs to show the potential increase in vulnerability of structures to the various hazards assessed in the HMAP risk assessment. The increase in vulnerability can be attributed to the higher construction costs that would be factored into repairing or replacing a structure using current market values. Permits are reported annually in September and the data includes that from 2000 through 2021 to demonstrate growth. Of the residential building permits issued in this period, 59 percent were for multi-family residential units and 41 percent for single family units. Housing type can also be an indication of an individual's ability to recover from a disaster.[14]

Table 3-3. City of Houston Residential Building Permits Issued, 2000-2021[15]

YEAR	TOTAL BUILDINGS	TOTAL UNITS	TOTAL VALUE
2000	5,010	9,506	$983,087,743
2001	4,666	9,887	$919,141,398
2002	5,024	11,220	$974,076,421
2003	5,959	13,800	$1,221,031,064

[11] Source: City of Houston Planning and Development Department https://www.houstontx.gov/planning/Demographics/docs_pdfs/2020/Subdivision%20Lot%20Submittals%202017-2020.pdf
[12] U.S. Census Bureau American Community Survey Five-Year Estimates, 2017-2021
[13] Source: FEMA Community Resilience Indicator Analysis, September 2021, https://www.fema.gov/sites/default/files/documents/fema_community-resilience-indicator-analysis_2022.pdf
[14] Source: Evidence from Hurricane Ike, International Journal of Disaster Risk Reduction, Volume 57, 2021,102149, ISSN 2212-4209, https://doi.org/10.1016/j.ijdrr.2021.102149. (https://www.sciencedirect.com/science/article/pii/S2212420921001151)
[15] Source: U.S. Census Bureau, Building Permit Survey, 1992-2021, https://www.census.gov/construction/bps/

YEAR	TOTAL BUILDINGS	TOTAL UNITS	TOTAL VALUE
2004	6,419	11,757	$1,193,420,572
2005	7,421	11,794	$1,382,226,682
2006	7,982	17,491	$2,092,844,964
2007	6,525	15,051	$1,883,719,445
2008	3,922	9,723	$1,174,481,674
2009	2,686	4,289	$566,203,883
2010	2,549	4,591	$563,623,844
2011	2,688	7,735	$770,405,127
2012	3,691	12,533	$1,371,929,596
2013	5,390	14,043	$1,690,618,533
2014	5,808	20,304	$2,399,525,794
2015	5,434	15,216	$2,139,026,726
2016	4,302	9,498	$1,609,559,430
2017	5,460	9,672	$1,868,328,031
2018	5,641	13,237	$2,313,659,849
2019	5,365	15,463	$2,539,168,887
2020	6,259	16,585	$2,400,863,075
2021	7,612	15,249	$2,474,712,519

FUTURE GROWTH AND DEVELOPMENT

To better understand how future growth and development in the City might affect hazard vulnerability, it is useful to consider population growth, vacant land, the potential for future development in hazard areas, and current planning and growth management efforts.

Population projections from 2015 to 2045 are listed in Table 3-4, as provided by the Houston-Galveston Area Council 2018 Regional Growth Forecasts[16] the best available data on future population growth at the time of this planning process. The population projection for the City of Houston shows a 40 percent increase (+919,984) in total household populations between 2015 and 2045.

[16] Source: Houston-Galveston Area Council, 2018 Regional Growth Forecasts, https://datalab.h-gac.com/rgf2018/

Table 3-4. City of Houston Regional Growth Forecast

2015	2020	2025	2035	2040	2045
HOUSEHOLD POPULATION GROWTH					
2,288,637	2,406,260	2,531,874	2,691,080	3,012,526	3,208,621
JOB GROWTH					
1,799,856	1,897,484	2,016,466	2,130,254	2,289,768	2,348,843

The estimated increase in population and continued growth will result in challenges to the City of Houston's transportation infrastructure and residential mobility. The Planning and Development Department works in partnership with numerous public and private agencies and with multiple departments within the City to analyze, evaluate, and address mobility issues in the City of Houston and its ETJ.

The Planning Department's Transportation Group is responsible for the Major Thoroughfare and Freeway Plan (the City's and its ETJ long range transportation plan). It also supports the development of the City's Transportation Policy and Regulations, provides technical support to the City's Transportation Advisory Committee and maintains the City's Travel Demand Model. It coordinates with the Houston-Galveston Area Council and other transportation agencies within the region and pursues federal funding opportunities for transportation planning studies and public-private partnerships.

SECTION 4
RISK OVERVIEW



OFFICE OF EMERGENCY MANAGEMENT

SECTION 4: RISK OVERVIEW

Hazard Description 1
Natural Hazards and Climate Change 4
Overview of Hazard Analysis 5
Hazard Ranking 6

HAZARD DESCRIPTION

Section 4 is the first phase of the Risk Assessment, providing background information for the hazard identification process and descriptions for the hazards identified. The Risk Assessment continues with Sections 5 through 16, which include hazard descriptions and vulnerability assessments.

Upon a review of the full range of natural hazards suggested under FEMA planning guidance, the City of Houston identified twelve natural hazards that are addressed in the 2023 Hazard Mitigation Plan Update and were identified as significant, as shown in Table 4-1. The hazards were identified through input from Planning Team members and a review of the current 2018 State of Texas Hazard Mitigation Plan (State Plan). Readily available online information from reputable sources such as federal and state agencies were also evaluated and utilized to supplement information as needed.

In general, there are three main categories of natural hazards: atmospheric, hydrologic, and technological. Atmospheric hazards are events or incidents associated with weather generated phenomenon. The atmospheric hazards that have been identified as significant for the Planning Area include extreme heat, hail, hurricane/tropical storm, lightning, thunderstorm wind, tornado and winter storm (Table 4-1).

Hydrologic hazards are events or incidents associated with water related damage and account for over 75 percent of Federal disaster declarations in the United States. Hydrologic hazards identified as significant for the Planning Area include flood, and drought.

Technological hazards refer to the origins of incidents that can arise from human activities, such as the construction and maintenance of dams. They are distinct from natural hazards primarily because they originate from human activity. The risks presented by natural hazards may be increased or decreased as a result of human activity, however they are not inherently human-induced. Therefore, dam failure is classified as a quasi-technological hazard and referred to as "technological" in Table 4-1 for purposes of description.

For the Risk Assessment, the wildfire and expansive soils hazards are considered "other," since the hazards are not considered atmospheric, hydrologic, nor technological.

Table 4-1. Hazard Descriptions

HAZARD	DESCRIPTION
ATMOSPHERIC	
Extreme Heat	Extreme heat is the condition whereby temperatures hover ten degrees or more above the average high temperature in a region for an extended period of time.
Hail	Hailstorms are a potentially damaging outgrowth of severe thunderstorms. Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and subsequent cooling of the air mass.
Hurricane / Tropical Storm	A hurricane is an intense tropical weather system of strong thunderstorms with a well-defined surface circulation and maximum sustained winds of 74 mph or higher.
Lightning	Lightning is a sudden electrostatic discharge that occurs during an electrical storm. This discharge occurs between electrically charged regions of a cloud, between two clouds, or between a cloud and the ground.
Thunderstorm Wind	A thunderstorm occurs when an observer hears thunder. Radar observers use the intensity of the radar echo to distinguish between rain showers and thunderstorms. Lightning detection networks routinely track cloud-to-ground flashes, and therefore thunderstorms.
Tornado	A tornado is a violently rotating column of air that has contact with the ground and is often visible as a funnel cloud. Its vortex rotates cyclonically with wind speeds ranging from as low as 40 mph to as high as 300 mph. The destruction caused by tornadoes ranges from light to catastrophic, depending on the location, intensity, size, and duration of the storm.
Winter Storm	Severe winter storms may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Blizzards, the most dangerous of all winter storms, combine low temperatures, heavy snowfall, and winds of at least 35 miles per hour, reducing visibility to only a few yards. Ice storms occur when moisture falls and freezes immediately upon impact on trees, power lines, communication towers, structures, roads, and other hard surfaces. Winter storms and ice storms can down trees, cause widespread power outages, damage property, and cause fatalities and injuries to human life.
HYDROLOGIC	
Drought	A prolonged period of less than normal precipitation such that the lack of water causes a serious hydrologic imbalance. Common effects of drought include crop failure, water supply shortages, and fish and wildlife mortality.

HAZARD	DESCRIPTION
Flood	The accumulation of water within a body of water, which results in the overflow of excess water onto adjacent lands, usually floodplains. The floodplain is the land adjoining the channel of a river, stream, ocean, lake, or other watercourse or water body that is susceptible to flooding. Most floods fall into the following three categories: riverine flooding, coastal flooding, and shallow flooding.
OTHER	
Expansive Soils	Expansive soils are soils and soft rock that tend to swell or shrink due to changes in moisture content. Changes in soil volume present a hazard primarily to structures built on top of expansive soils.
Wildfire	A wildfire is an uncontrolled fire burning in an area of vegetative fuels such as grasslands, brush, or woodlands. Heavier fuels with high continuity, steep slopes, high temperatures, low humidity, low rainfall, and high winds all work to increase the risk for people and property located within wildfire hazard areas or along the urban/wildland interface. Wildfires are part of the natural management of forest ecosystems, but most are caused by human factors.
TECHNOLOGICAL	
Dam Failure	Dam failure is the collapse, breach, or other failure of a dam structure resulting in downstream flooding. In the event of a failure, the energy of the water stored behind even a small dam is capable of causing loss of life and severe property damage if development exists downstream of the dam.

Hazards that weren't considered significant and were not included in the Plan Update are located in Table 4-2, along with the evaluation process used for determining the significance of each of these hazards. Hazards not identified for inclusion at this time may be addressed during future evaluations and updates.

Table 4-2. Other Hazards Deferred

HAZARD CONSIDERED	REASON FOR DETERMINATION
Coastal Erosion	The planning area is not located on the coast, therefore coastal erosion does not pose a risk.
Earthquake	According to the State Plan, an earthquake occurrence for the planning area is considered exceedingly rare. Although a small event is possible, it would pose little to no risk for the area. There is no history of impact to critical structures, systems, populations or other community assets or vial services as a result of earthquake and none is expected in the future.

HAZARD CONSIDERED	REASON FOR DETERMINATION
Land Subsidence	There are no historical occurrences of land subsidence for the planning area and it is located in an area where occurrences are considered rare. There is no history of impact to critical structures, systems, populations or other community assets or vital services as a result of land subsidence and none is expected in the future.

NATURAL HAZARDS AND CLIMATE CHANGE

Climate change is defined as a long-term hazard which can increase or decrease the risk of natural hazards. Global climate change is expected to exacerbate the risks of certain types of natural hazards impacted through rising sea levels, warmer ocean temperatures, higher humidity, the possibility of stronger storms, and an increase in wind and flood damages due to storm surges. Texas is considered one of the more vulnerable states in the U.S. to both abrupt climate changes and to the impact of gradual climate changes to the natural and built environments.

Climate change is expected to lead to an increase in average temperatures as well as an increase in frequency, duration and intensity of extreme heat events. With no reductions in emissions worldwide, Texas is projected to experience an additional 30 to 60 days per year above 100°F than what is experienced now.[1] The City of Houston is already experiencing the impacts of climate change; since 1950 the City has seen increases in temperature, hot days, warm nights and the length of summer has extended.[2] The following are the projected future changes for the City of Houston over the rest of this century according to the Climate Impact Assessment for the City of Houston[3].

- Increases in average temperature of all seasons
- Lengthening of Summer, with summer beginning earlier and ending later
- Increases in energy demand for cooling buildings for spring, summer, and fall seasons
- Increases in the number of hot days per year (defined as the maximum temperature above 100°F) and the number of warm nights per year (defined as the minimum temperature above 80°F)
- Increases in the temperature of the hottest days experienced each year
- Longer multi-day heatwaves
- Total annual precipitation is not expected to change much because summer precipitation is expected to decrease while fall precipitation is expected to increase
- Greater variability in day-to-day precipitation that includes both slight increases in number of dry days and increasing risk of drought due to soil moisture decreases resulting from

[1] Source: U.S. Global Change Research Program, Washington, DC, USA, pp. 987–1035. doi: 10.7930/NCA4.2018.CH23. https://nca2018.globalchange.gov/chapter/23/
[2] Source: Climate Impact Assessment for the City of Houston August 2020. https://www.houstontx.gov/mayor/Climate-Impact-Assessment-2020-August.pdf
[3] Source: Climate Impact Assessment for the City of Houston August 2020. https://www.houstontx.gov/mayor/Climate-Impact-Assessment-2020-August.pdf

higher temperatures, as well as increases in the precipitation falling during extreme precipitation events such as the wettest three-day period each year.

OVERVIEW OF HAZARD ANALYSIS

The methodologies utilized to develop the Risk Assessment are a historical analysis and a statistical approach. Both methodologies provide an estimate of potential impact by using a common, systematic framework for evaluation.

Records retrieved from National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA) were reported for the City of Houston. Remaining records identifying the occurrence of hazard events in the planning area and the maximum recorded magnitude of each event were also evaluated.

The use of geographic information system (GIS) technology to identify and assess risks for the City of Houston and evaluate community assets and their vulnerability to the hazards.

The four general parameters that are described for each hazard in the Risk Assessment include frequency of return, approximate annualized losses, a description of general vulnerability, and a statement of the hazard's impact.

Frequency of return was calculated by dividing the number of events in the recorded time period for each hazard by the overall time period that the resource database was recording events. Frequency of return statements are defined in Table 4-3, and impact statements are defined in Table 4-4 below.

Table 4-3. Frequency of Return Statements

PROBABILITY	DESCRIPTION
Highly Likely	Event is probable in the next year.
Likely	Event is probable in the next three years.
Occasional	Event is probable in the next five years.
Unlikely	Event is probable in the next ten years.

Table 4-4. Impact Statements

POTENTIAL SEVERITY	DESCRIPTION
Substantial	Multiple deaths. Complete shutdown of facilities for 30 days or more. More than 50 percent of property destroyed or with major damage.
Major	Injuries and illnesses resulting in permanent disability. Complete shutdown of critical facilities for at least two weeks. More than 25 percent of property destroyed or with major damage.

POTENTIAL SEVERITY	DESCRIPTION
Minor	Injuries and illnesses do not result in permanent disability. Complete shutdown of critical facilities for more than one week. More than 10 percent of property destroyed or with major damage.
Limited	Injuries and illnesses are treatable with first aid. Shutdown of critical facilities and services for 24 hours or less. Less than 10 percent of property destroyed or with major damage.

Each of the hazard profiles includes a description of a general Vulnerability Assessment. Vulnerability is the total of assets that are subject to damages from a hazard, based on historic recorded damages. Assets in the region were inventoried and defined in hazard zones where appropriate. The total amount of damages, including property and crop damages, for each hazard is divided by the total number of assets (building value totals) in that community to determine the percentage of damage that each hazard can cause to the community. Risk and consequences will be addressed and covered within each hazard profile under the Vulnerability and Impact section as well as under the Assessment of Impact sections, where applicable.

To better understand how future growth and development in the City of Houston might affect hazard vulnerability, it is useful to consider population growth, occupied and vacant land, the potential for future development in hazard areas, and current planning and growth management efforts. The City's vulnerability to hazards was considered based on recent development changes that occurred throughout the planning area. The population of the City of Houston has grown by 10 percent between 2010 and 2020 according to the U.S. Census Bureau, therefore the vulnerability to the population, infrastructure, and buildings has increased for hazards that do not have a geographical boundary.

Once loss estimates and vulnerability were identified, an impact statement was applied to relate the potential impact of the hazard on the assets within the area of impact.

HAZARD RANKING

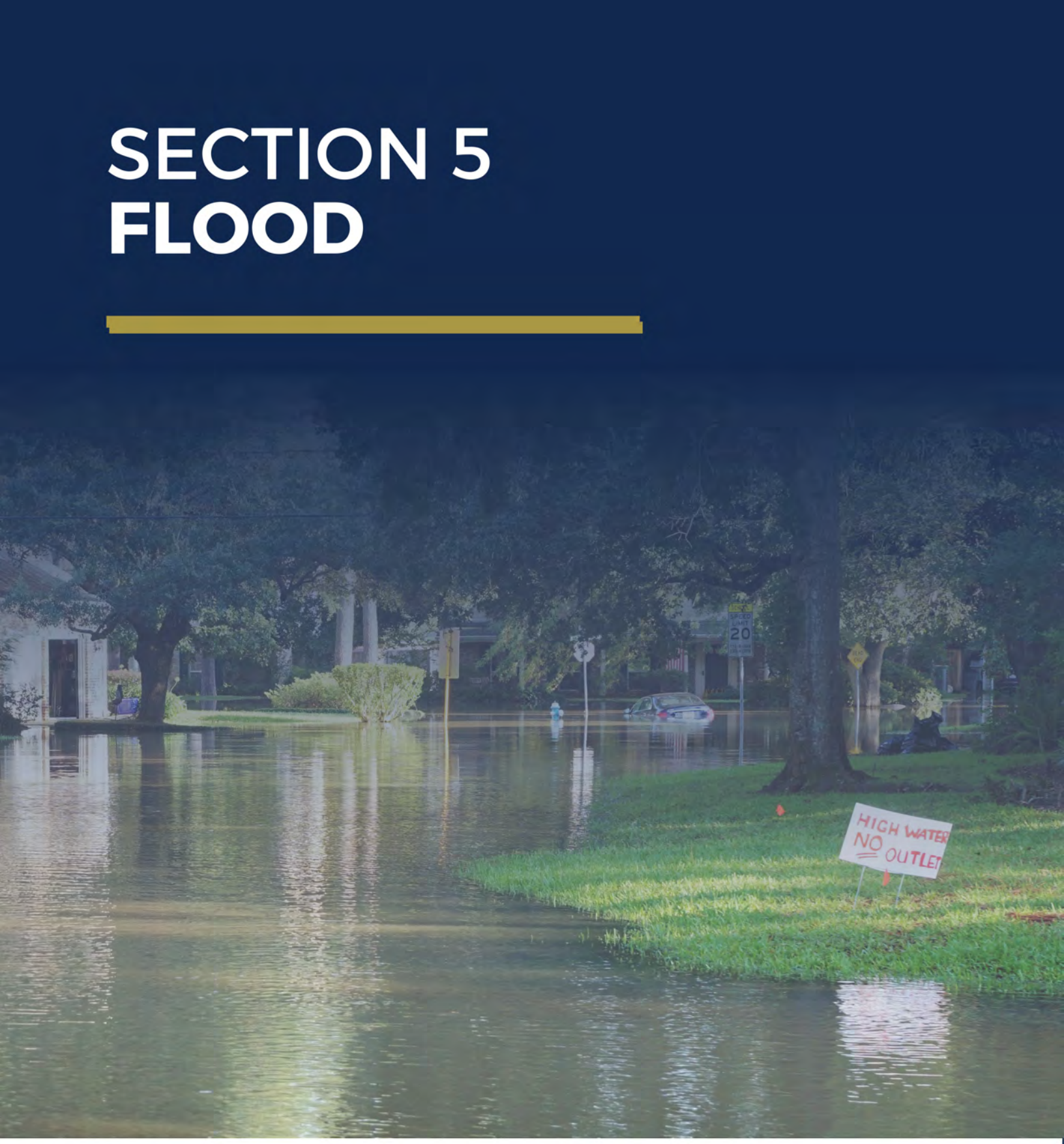
During the 2023 planning process the Planning Team determined that certain hazard rankings need to be updated from the 2018 rankings due to changes in priorities in the City of Houston and recent hazard events. Drought was ranked as moderate in 2018 and increased to high in 2023. Similarly, expansive soils', dam failure's, and winter storm's rankings were increased from low in 2018 to moderate ranking in 2023. Lightning was ranked as moderate in 2018 but ranking decreased in 2023 to low.

Table 4-5 portrays the results of the risk assessment analysis for the frequency of occurrence and potential severity and the City's self-assessment for hazard ranking, based local knowledge of past hazard events and impacts for each of the identified hazards. The definitions for frequency of occurrence and potential severity can be found in Table 4-3 and Table 4-4.

Table 4-5. Hazard Risk Ranking

HAZARD	FREQUENCY OF OCCURENCE	POTENTIAL SEVERITY	RANKING
Flood	Highly Likely	Substantial	**High**
Hurricane/Tropical Storm	Highly Likely	Substantial	**High**
Extreme Heat	Highly Likely	Substantial	**High**
Drought	Highly Likely	Minor	**High**
Thunderstorm Wind	Highly Likely	Substantial	**High**
Dam Failure	Unlikely	Substantial	**Moderate**
Expansive Soils	Likely	Limited	**Moderate**
Tornado	Likely	Substantial	**Moderate**
Winter Storm	Highly Likely	Limited	**Moderate**
Wildfire	Highly Likely	Limited	**Low**
Lightning	Highly Likely	Substantial	**Low**
Hail	Highly Likely	Limited	**Low**

SECTION 5
FLOOD



CITY OF HOUSTON
TEXAS

OEM
OFFICE OF EMERGENCY MANAGEMENT

SECTION 5: FLOOD

Hazard Description 1
Location 1
Extent 6
Historical Occurrences 9
Significant Events 15
Probability of Future Events 16
Vulnerability and Impact 17
Assessment of Impacts 19
Climate Change Considerations 21
National Flood Insurance Program (NFIP) Participation 22
Community Rating System 23
NFIP Compliance and Maintenance 23
Repetitive Loss 24

HAZARD DESCRIPTION

Floods generally result from excessive precipitation. The severity of a flood event is determined by a combination of several major factors, including: stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and the degree of vegetative clearing and impervious surface. Typically, floods are long-term events that may last for several days.

The primary types of general flooding are inland and coastal flooding (storm surge). Due to the City of Houston's inland location, only inland flooding is profiled in this section. Inland or riverine flooding is a result of excessive precipitation levels and water runoff volumes within the watershed of a stream or river. Inland or riverine flooding is overbank flooding of rivers and streams, typically resulting from large-scale weather systems that generate prolonged rainfall over a wide geographic area, thus it is a naturally occurring and inevitable event. Some river floods occur seasonally when winter or spring rainfalls fill river basins with too much water, too quickly. Torrential rains from decaying hurricanes or tropical systems can also produce river flooding.

The City of Houston area residents are subject to a tremendous amount of rainfall, which often occurs over an extremely short period. This is generally due to unstable tropical storms or hurricanes (see Section 6), and rain events which results in a substantial flooding problem. Floods are a natural and recurrent event. Floods take place every year and in all seasons.

LOCATION

Flooding is the foremost hazard facing the City of Houston. The Flood Insurance Rate Maps (FIRMs) prepared by FEMA provide an overview of flood risk but can also be used to identify the

areas of the city that are vulnerable to flooding. FIRMs are used to regulate new development and to control the substantial improvement and repair of substantially damaged buildings. Flood Insurance Studies (FIS) are often developed in conjunction with FIRMs. The FIS typically contains a narrative of the flood history of a community and discusses the engineering methods used to develop the FIRMs. The FIS also contains flood profiles for studied flood sources and can be used to determine Base Flood Elevations (BFEs) for some areas.

Revised or new studies are now presented as countywide FIS's and include incorporated areas. The revised FIS for Harris County is dated November 15, 2019, and includes the City of Houston. This FIS compiles all previous flood information and includes data collected on numerous waterways. Areas that are most vulnerable to flooding include low-lying areas in the eastern portion of the city. Thousands of residential homes are located in the identified flood hazard area. The City continues to acquire homes in these areas in an effort to save lives and decrease property damage. The City of Houston has 32 critical facilities located in the identified flood hazard area including the Westside Police Station located on South Dairy Ashford Road in east portion of the city.

The Flood Insurance Rate Map (FIRM) data provided by FEMA for the City of Houston shows the following flood hazard areas:

- Zone A: Areas subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance requirements and floodplain management standards apply.
- Zone AE: Areas subject to inundation by 1-percent-annual-chance shallow flooding. It is the base floodplain where BFEs are provided. AE zones are now used on new format FIRMs instead of A1-30 zones.
- Zone X: Moderate risk areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by a levee. No BFEs or base flood depths are shown within these zones.
- Zone AO: Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between one and three feet. Average flood depths derived from detailed hydraulic analyses are shown in this zone. Mandatory flood insurance purchase requirements and floodplain management standards apply.
- Zone VE: Coastal areas with a 1-percent-annual-chance of flooding and an additional hazard associated with storm waves. These areas have a 26-percent chance of flooding over the life of a 30-year mortgage. BFEs are provided.

Locations of flood zones in the City of Houston based on the digital Flood Insurance Rate Map (DFIRM) from FEMA are illustrated in Figures 5-1 to 5-4.

Figure 5-1. Estimated Flood Zones in Northwest City of Houston

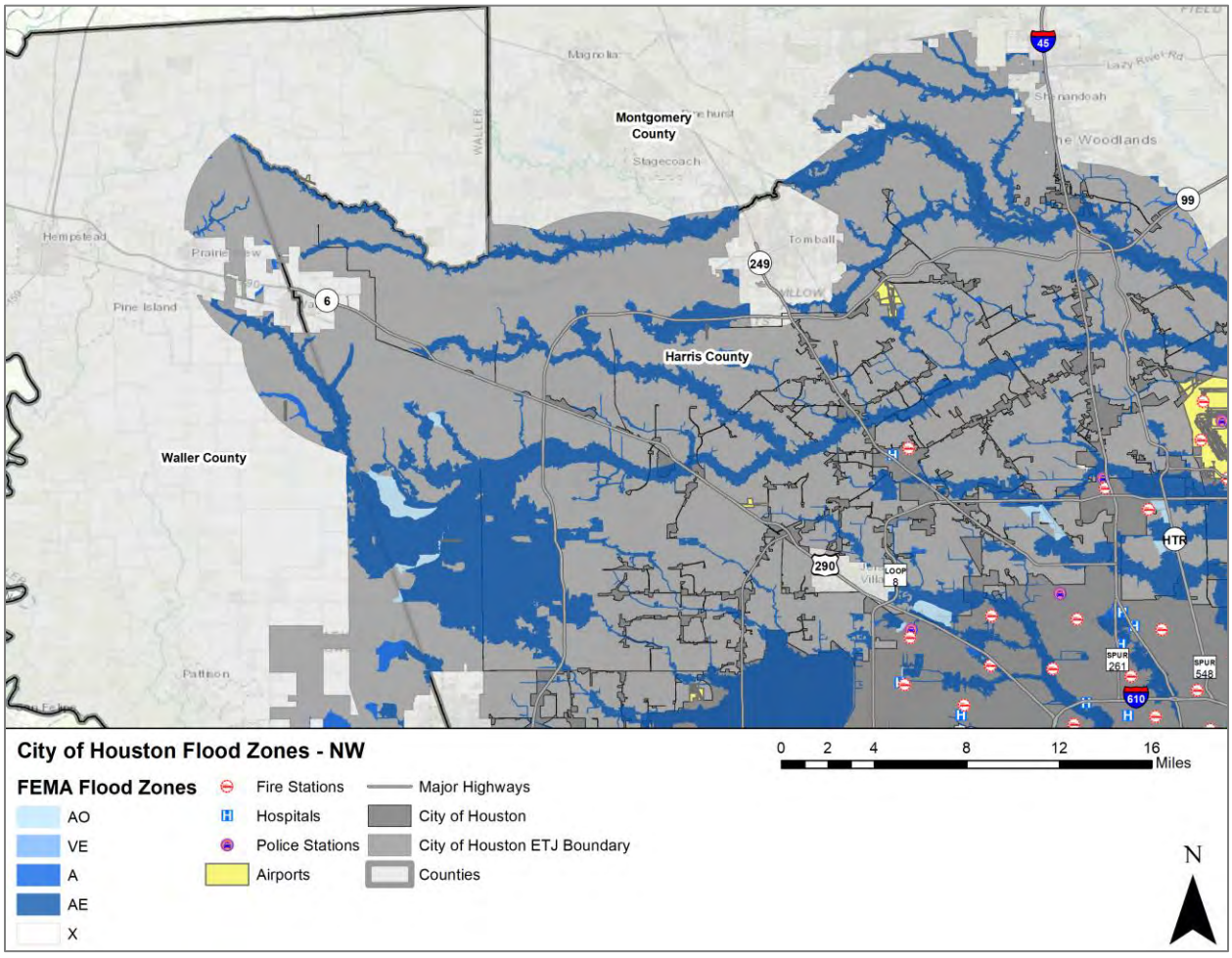


Figure 5-2. Estimated Flood Zones in Northeast City of Houston

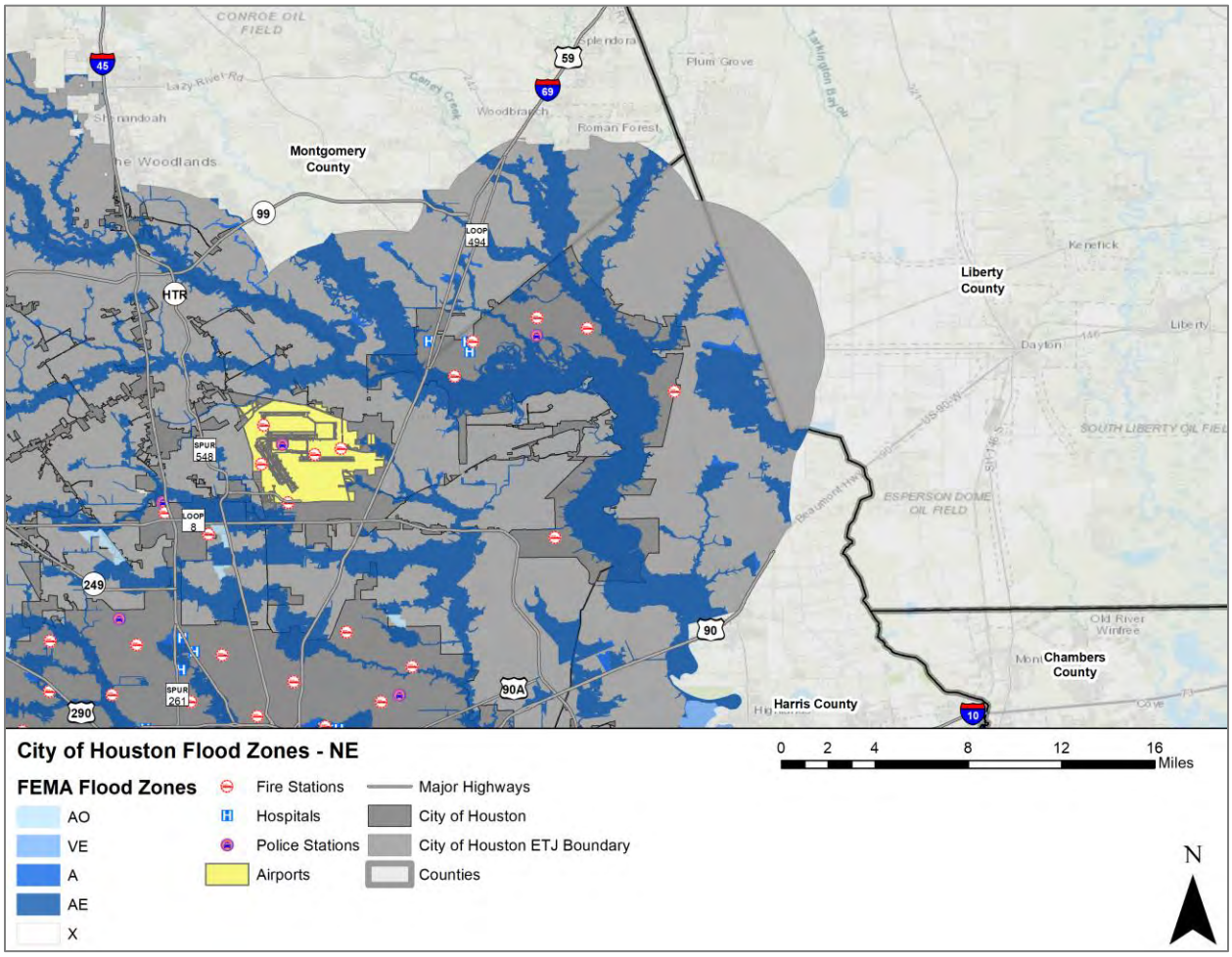


Figure 5-3. Estimated Flood Zones in Southeast City of Houston

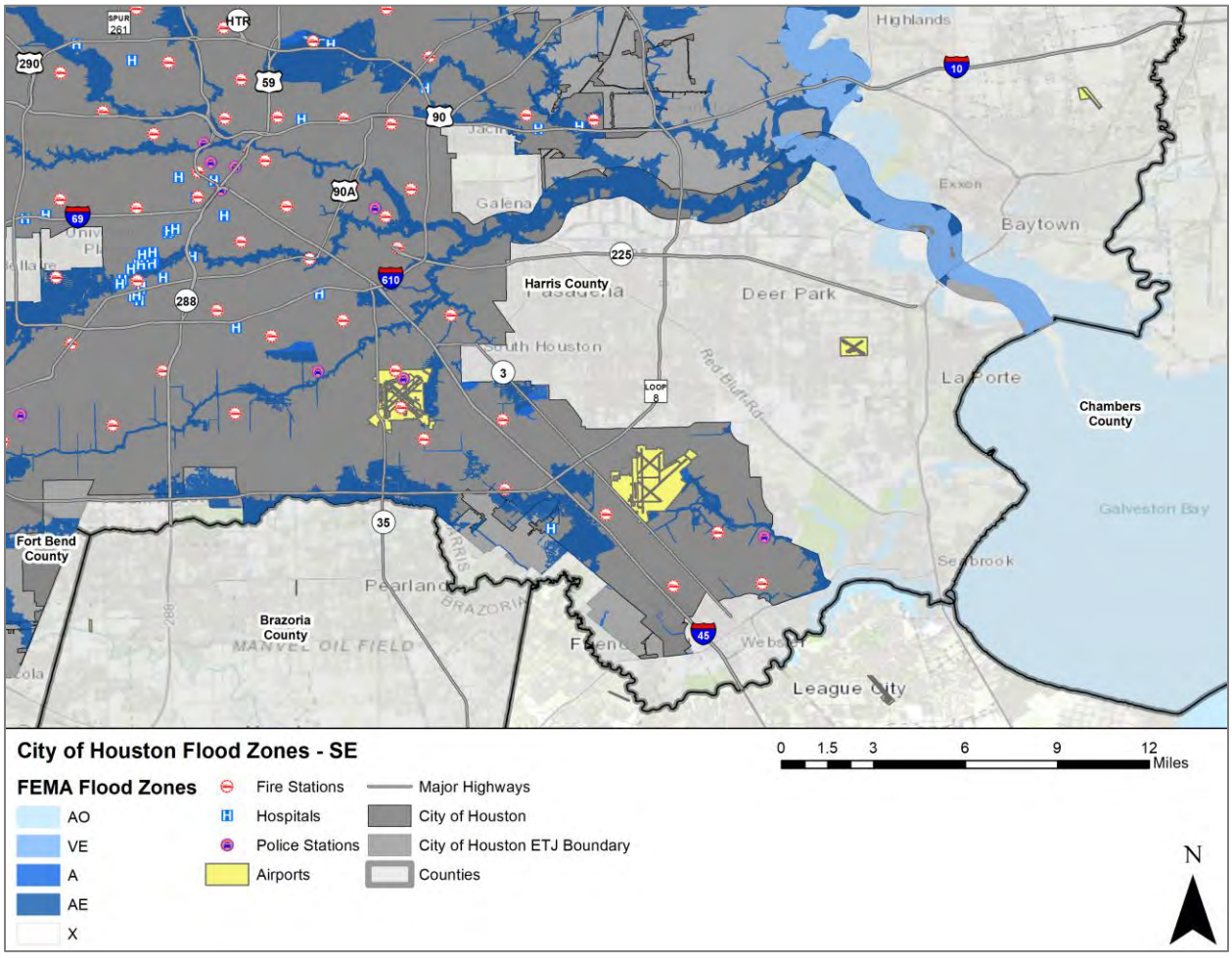
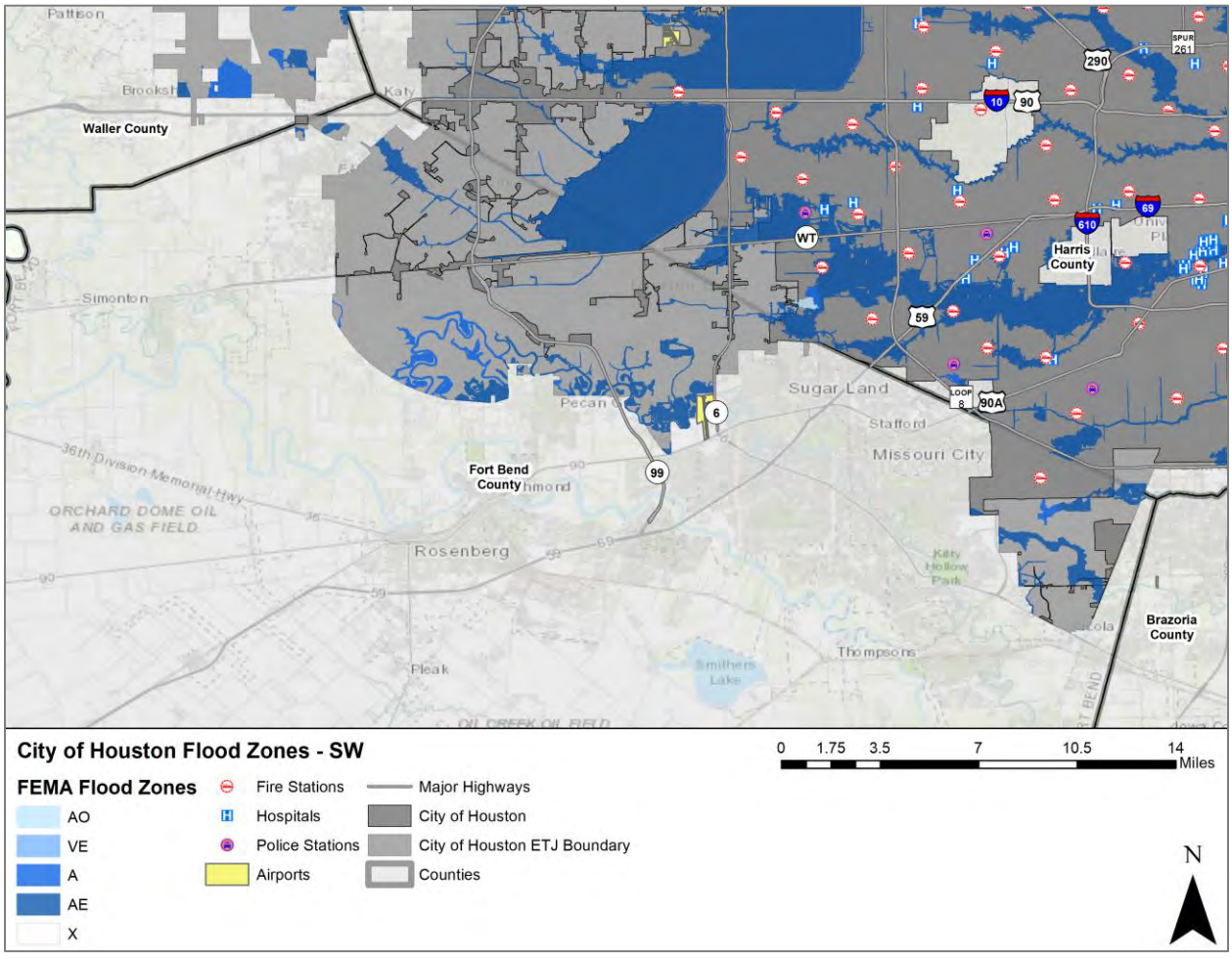


Figure 5-4. Estimated Flood Zones in Southwest City of Houston



EXTENT

The severity of a flood event is determined by a combination of several factors including stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and degree of vegetative clearing and impervious surface. Typically, floods are long-term events that may last for several days.

Determining the intensity and magnitude of a flood event is dependent upon the flood zone and location of the flood hazard area in addition to depths of flood waters. Extent of flood damages can be expected to be more damaging in the areas that will convey a base flood. FEMA categorizes areas on the terrain according to how the area will convey flood water. Flood zones are the categories that are mapped on Flood Insurance Rate Maps. Table 5-1 provides a description of FEMA flood zones and the flood impact in terms of severity or potential harm. Flood Zones AO, VE, A, AE, and X are the only hazard areas mapped in the planning area. Figures 5-1 through 5-4 should be read in conjunction with the extent for flooding in Tables 5-1 and 5-2 to determine the intensity of a potential flood event.

Table 5-1. Flood Zones

INTENSITY	ZONE	DESCRIPTION
HIGH	ZONE A	Areas with a one percent annual chance of flooding and a 26 percent chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.
	ZONE A1-30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a Base Flood Elevation (BFE) (old format).
	ZONE AE	The base floodplain where base flood elevations are provided. AE Zones are now used on the new format FIRMs instead of A1-A30 Zones.
	ZONE AO	River or stream flood hazard areas and areas with a one percent or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from one to three feet. These areas have a 26 percent chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
	ZONE AH	Areas with a one percent annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from one to three feet. These areas have a 26 percent chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
	ZONE A99	Areas with a one percent annual chance of flooding that will be protected by a federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.
	ZONE AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.
HIGH COASTAL	ZONE VE, V1-30	Coastal areas with a 1 percent or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26 percent chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.

INTENSITY	ZONE	DESCRIPTION
MODERATE to LOW	ZONE X 500	An area inundated by 500-year flooding; an area inundated by 100-year flooding with average depths of less than one foot or with drainage areas less than one square mile; or an area protected by levees from 100-year flooding.

Zone A is interchangeably referred to as the 100-year flood, the one percent-annual chance flood, the Special Flood Hazard Area (SFHA), or more commonly, the base flood. This is the area that will convey the base flood and constitutes a threat to the planning area. The impact from a flood event can be more damaging in areas that will convey a base flood.

Structures built in the SFHA are subject to damage by rising waters and floating debris. Moving flood water exerts pressure on everything in its path and causes erosion of soil and solid objects. Utility systems, such as heating, ventilation, air conditioning, fuel, electrical systems, sewage maintenance systems and water systems, if not elevated above base flood elevation, may also be damaged.

The intensity and magnitude of a flood event is also determined by the depth of flood waters. Table 5-2 describes the stream gauge data provided by the United States Geological Survey (USGS).

Table 5-2. Extent for City of Houston[1]

JURISDICTION[2]	PEAK FLOOD EVENT
City of Houston	Berry Bayou at Nevada Street in Houston Texas reached an overflow elevation of 33.3 in August 2018. The average overflow elevation for Berry Bayou is 24.3 feet at this site.
City of Houston	Sims Bayou in Houston Texas reached an overflow elevation of 33.2 in August 1983. The average overflow elevation for Sims Bayou is 22.8 feet at this site.
City of Houston	Buffalo Bayou at Turning Basin in Houston Texas reached an overflow elevation of 14.8 feet in September 2008. The average overflow elevation for Buffalo Bayou is 6.1 feet at this site.
City of Houston	Hunting Bayou at IH 610 in Houston Texas reached an overflow elevation of 42 feet in June 2001. The average overflow elevation for Hunting Bayou is 34.0 feet at this site.
City of Houston	Brays Bayou at MLK Jr Boulevard in Houston Texas reached an overflow elevation of 32.3 feet in August 2017. The average overflow elevation for Brays Bayou is 24.3 feet at this site.

[1] Severity estimated by averaging floods at certain stage level over the history of flood events. Severity and peak events are based on U.S. Geological Survey data.
[2] Severity is provided for jurisdictions where peak data was provided.

JURISDICTION[2]	PEAK FLOOD EVENT
City of Houston	Whiteoak Bayou at Main Street in Houston Texas reached an overflow elevation of 38.6 feet in June 2001. The average overflow elevation for Whiteoak Bayou is 22.2 feet at this site.
City of Houston	Little Whiteoak Bayou at Trimble Street in Houston Texas reached an overflow elevation of 46.2 feet in June 2001. The average overflow elevation for Little Whiteoak Bayou is 37.7 feet at this site.
Harris County	Keegans Bayou at Roark Road near Houston Texas reached an overflow elevation of 76.4 feet in November 2003. The average overflow elevation for Keegans Bayou is 71.9 feet at this site.
City of Houston	Buffalo Bayou at W Belt Drive in Houston Texas reached an overflow elevation of 71.2 feet in August 2017. The average overflow elevation for Buffalo Bayou is 58.3 feet at this site.
City of Houston	Brickhouse Gully at Costa Rica Street in Houston Texas reached an overflow elevation of 73 feet in June 2001. The average overflow elevation for Brickhouse Gully is 65.6 feet at this site.
Harris County	Greens Bayou near US Highway 75 near Houston Texas reached an overflow elevation of 91.1 feet in August 2017. The average overflow elevation for Greens Bayou is 84.1 feet at this site.

The range of flood intensity that the planning area can experience is high, or Zone A. Based on historical occurrences, the extent of flooding in the City of Houston can reach water depths up to ten feet deep in structures located in the identified flood hazard areas.

The data described in Tables 5-1 and 5-2, together with Figures 5-1 through 5-4, and historical occurrences for the area, provides an estimated potential magnitude and severity for the City of Houston.

HISTORICAL OCCURRENCES

Historical evidence indicates that areas within the planning area are susceptible to flooding, especially in the form of flash flooding. It is important to note that only flood events that have been reported have been factored into this risk assessment, therefore it is likely that additional flood occurrences have gone unreported before and during the recording period. Table 5-3 identifies historical flood events in the City of Houston planning area. Historical data is provided by planning team members and the Storm Prediction Center (NOAA), NCEI database for the City of Houston.

Table 5-3. Historical Flood Events, 1996-2022[3]

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	9/18/1996	0	0	$2,815,314	$0
City of Houston	9/27/1996	0	0	$18,769	$0
Countywide	1/27/1997	0	0	$3,481	$0
City of Houston	3/12/1997	0	0	$5,553	$0
City of Houston	3/12/1997	0	0	$240,639	$0
City of Houston	4/4/1997	0	0	$9,244	$0
Countywide	4/25/1997	0	0	$172,859	$0
City of Houston	4/25/1997	0	0	$18,488	$0
City of Houston	5/21/1997	1	0	$92,496	$0
City of Houston	5/24/1997	0	2	$462,478	$0
Countywide	5/30/1997	0	0	$10,378	$0
Countywide	11/28/1997	0	0	$2,058	$0
City of Houston	12/20/1997	0	0	$36,723	$0
Countywide	1/4/1998	0	0	$2,056	$0
Countywide	1/6/1998	0	0	$2,056	$0
Countywide	1/6/1998	0	0	$1,371	$0
Countywide	1/21/1998	0	0	$3,427	$0
Countywide	9/14/1998	0	0	$3,385	$0
Countywide	10/4/1998	0	0	$3,377	$0
City of Houston	10/17/1998	1	0	$0	$0
Countywide	10/18/1998	0	0	$6,754	$0
City of Houston	10/18/1998	0	0	$180,592	$0
Countywide	11/12/1998	0	0	$2,026	$0
City of Houston	11/12/1998	0	0	$9,030	$0

[3] Only recorded events with fatalities, injuries, and/or damages are listed, values are in 2022 dollars. Historical events are listed from January 1996 through October 2022. Countywide damages have been adjusted to reflect only a percentage (37.4%) of the damages attributed to the City of Houston.

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	11/13/1998	0	0	$9,030	$0
City of Houston	11/13/1998	0	0	$18,059	$0
Countywide	3/19/1999	0	0	$201,396	$0
Countywide	4/2/2000	0	0	$32,332	$0
Countywide	5/19/2000	0	0	$129,175	$0
Countywide	5/19/2000	0	0	$129,175	$0
City of Houston	3/28/2001	0	0	$33,618	$0
City of Houston	3/28/2001	0	0	$25,213	$0
Countywide	8/30/2001	0	0	$31,202	$0
Countywide	9/1/2001	0	0	$15,531	$0
Countywide	4/8/2002	0	0	$12,321	$0
City of Houston	4/8/2002	0	0	$16,472	$0
Countywide	8/15/2002	0	0	$36,780	$0
City of Houston	8/22/2002	0	0	$16,390	$0
Countywide	9/8/2002	0	0	$9,180	$0
City of Houston	9/19/2002	0	0	$89,997	$0
Countywide	10/24/2002	0	0	$61,096	$0
City of Houston	10/28/2002	0	0	$939,318	$0
Countywide	12/4/2002	0	0	$6,123	$0
Countywide	8/31/2003	0	0	$1,800	$0
Countywide	11/16/2003	0	0	$1,801	$0
City of Houston	11/17/2003	1	1	$4,815,789	$0
City of Houston	5/1/2004	0	0	$4,699	$0
Countywide	5/13/2004	0	0	$4,100	$0
City of Houston	6/13/2004	0	0	$78,063	$0
Countywide	11/22/2004	0	0	$8,699	$0
Countywide	5/29/2005	0	0	$5,698	$0

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Countywide	7/14/2005	0	0	$65,191	$0
City of Houston	12/14/2005	0	0	$60,197	$0
City of Houston	5/29/2006	0	0	$10,238	$0
City of Houston	6/19/2006	0	0	$4,816,975	$0
Countywide	6/22/2006	0	0	$109,185	$0
Countywide	10/16/2006	0	0	$27,445	$0
City of Houston	10/16/2006	0	0	$1,100,735	$0
City of Houston	10/16/2006	2	0	$17,612	$0
Countywide	10/26/2006	0	0	$54,890	$0
Countywide	10/26/2006	0	0	$27,445	$0
Countywide	5/10/2007	0	0	$7,990	$0
Countywide	5/10/2007	0	0	$7,990	$0
Countywide	5/10/2007	0	0	$39,950	$0
Countywide	5/10/2007	0	0	$7,990	$0
Countywide	5/10/2007	0	0	$5,327	$0
Countywide	5/10/2007	0	0	$23,970	$0
Countywide	5/10/2007	0	0	$15,980	$0
Countywide	5/10/2007	0	0	$7,990	$0
City of Houston	5/10/2007	0	0	$925,761	$0
City of Houston	7/6/2007	0	0	$71,093	$0
City of Houston	8/16/2007	3	0	$1,068,351	$0
Countywide	10/15/2007	0	0	$2,651	$0
City of Houston	9/14/2008	0	0	$40,612	$0
City of Houston	9/14/2008	0	0	$67,686	$0
City of Houston	10/15/2008	0	0	$27,351	$0
Countywide	4/18/2009	0	0	$1,818,082	$0
Countywide	4/24/2009	0	0	$519,452	$0

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Countywide	4/27/2009	0	0	$2,597	$0
Countywide	4/28/2009	1	0	$7,791,781	$0
Countywide	4/28/2009	0	0	$5,195	$0
City of Houston	10/22/2009	0	0	$5,480	$0
Countywide	10/29/2009	0	0	$3,074	$0
City of Houston	10/29/2009	0	0	$6,850	$0
City of Houston	10/29/2009	0	0	$6,850	$0
Countywide	5/14/2010	1	0	$2,538	$0
Countywide	7/2/2010	0	0	$889,147	$0
City of Houston	1/9/2012	0	0	$26,133	$0
Countywide	1/25/2012	0	0	$12,217	$0
Countywide	5/12/2012	0	0	$19,279	$0
Countywide	7/12/2012	0	0	$483	$0
Countywide	7/12/2012	0	0	$1,450	$0
Countywide	7/12/2012	0	0	$1,450	$0
Countywide	7/12/2012	0	0	$2,417,416	$4,835
City of Houston	7/13/2012	0	0	$2,585	$0
City of Houston	7/13/2012	0	0	$3,878	$0
Countywide	4/27/2013	0	0	$1,429,073	$0
Countywide	5/10/2013	0	0	$356,633	$0
Countywide	9/20/2013	0	0	$35,480	$0
Countywide	7/3/2014	0	0	$2,325	$0
Countywide	8/1/2014	0	0	$46,570	$0
Countywide	9/18/2014	0	0	$11,634	$0
City of Houston	9/19/2014	0	0	$1,244	$0
City of Houston	4/16/2015	0	0	$7,511	$1,252
Countywide	4/17/2015	0	0	$140,450	$0

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Countywide	5/12/2015	1	0	$372,635	$0
Countywide	5/25/2015	6	0	$11,644,830	$0
Countywide	5/30/2015	0	0	$46,579	$0
Countywide	6/30/2015	0	0	$23,208	$0
Countywide	10/31/2015	2	0	$465,729	$0
Countywide	4/17/2016	6	0	$16,203,553	$0
Countywide	5/14/2016	0	0	$23,055	$0
City of Houston	6/1/2016	0	0	$6,144	$0
Countywide	6/2/2016	0	0	$2,298	$0
City of Houston	6/2/2016	0	0	$12,288	$0
Countywide	6/4/2016	0	0	$4,596	$0
City of Houston	1/18/2017	0	0	$609,809	$0
City of Houston	6/4/2017	0	0	$3,627	$0
Countywide	6/24/2017	0	0	$452	$0
Countywide	6/25/2017	0	0	$904	$0
Countywide	8/26/2017	36	0	$0	$45,116
Countywide	9/21/2017	0	0	$2,244	$0
Countywide	5/7/2019	0	0	$21,627	$0
Countywide	5/9/2019	0	0	$8,651	$0
Countywide	9/18/2019	0	0	$2,157	$0
Countywide	9/19/2019	0	0	$86,281,652	$0
Countywide	9/19/2019	1	0	$0	$0
City of Houston	9/19/2019	1	0	$0	$0
Countywide	5/15/2020	0	0	$43,202	$0
Countywide	6/25/2020	0	0	$4,340	$0
Countywide	9/21/2020	0	0	$21,279	$0
Countywide	9/21/2020	0	0	$42,557	$0

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Countywide	9/21/2020	0	0	$42,557	$0
Countywide	9/21/2020	0	0	$42,557	$0
Countywide	9/21/2020	0	0	$212,786	$0
City of Houston	9/21/2020	0	0	$113,789	$0
Countywide	5/18/2021	0	0	$1,234	$0
Countywide	6/21/2021	0	0	$2,038	$0
Countywide	7/21/2021	0	0	$10,143	$0
Countywide	1/9/2022	0	0	$7,880	$0
Countywide	1/9/2022	0	0	$39,398	$0
Countywide	1/9/2022	0	0	$39,398	$0
TOTALS		63	3	$151,372,269	$51,203

Based on the list of historical flood events for the City of Houston planning area (listed above), twenty-six of the events have occurred since the 2018 Plan.

SIGNIFICANT EVENTS

Flash Flood on November 17, 2003 – City of Houston
Heavy rainfall throughout the evening of November 17 caused extensive flooding in and around the Sharpstown area. One 17 year old female was killed and one 18 year old male was injured when the van they were driving became flooded outside of the high school. The flooding extended into the Houston metro area with numerous flooded or completely submerged vehicles. Approximately 300 homes flooded, and property damage estimates exceeded $3.9 million (2017) dollars.

Flash Flood on June 19, 2006 – City of Houston
Approximately 3,370 homes were flooded with some water rescues in the Interstate 45 and Beltway 610 vicinity (Belfort and Telephone Roads). The Washburn Tunnel was flooded and impassable while Interstate 10 at Federal Street's bypass was under water. Sections of Sims, Halls, and Hunting Bayous with Vogel and White Oak Creeks experienced significant flooding. Homes along these bayous and creeks had flood water in them from 2 to 8 inches to as high as 18 to 20 inches. Damage estimates exceeded $3.9 million (2017) dollars.

Flash Flood on May 25, 2015 – City of Houston (Memorial Day Flood)
Within a nine-hour span from the night of May 25, 2015, to the morning of May 26, heavy rain produces as much as 11 inches of rain fell on parts of the region. The average rainfall in Harris County during the storm was 5.3 inches, according to the Harris County Flood Control District. That works out to about 162 billion gallons of water. A total of 3,015 homes and more than 3,500

multifamily units were flooded. Multiple water rescues were conducted. Numerous roads were impassable due to flooding that was as high as six feet deep. Hundreds of vehicles were stranded in the flood water. Eight fatalities were directly attributed to the flood event.

Flash Flood on April 17, 2016 – City of Houston (Tax Day Flood)
A slow moving upper low over the Southwestern U.S. combined with near record level moisture aided in producing extremely heavy rainfall and devastating flooding over portions of Harris, Waller and Fort Bend Counties. Heavy rain caused extensive flooding especially over the western half of the county where 10 to 15 inches of rain fell in less than a 12 hour period. An estimated 40,000 vehicles and 10,000 homes were flooded. Seven people in Harris County drowned in their vehicles when they drove into flooded roadways. There were numerous high water rescues. Damage estimates exceeded $35 million (2017) dollars.

Hurricane Harvey August 16, 2017 – September 2, 2017 – City of Houston[4] (DR-4332)
Hurricane Harvey made landfall as a Category 4 hurricane near Rockport, Texas during the evening of August 25th. The storm then weakened to a tropical storm and slowed, looping back and tracking over southeast Texas then back over the Gulf of Mexico making a second landfall along the Louisiana coast during the early morning hours of August 30th. Over that 5 day period over Southeast Texas, Tropical Storm Harvey produced catastrophic flooding with a large area of 30 to 60 inches of rain, 23 tornadoes, tropical storm force winds and a moderate storm surge near Matagorda Bay. In some of the heavier bands of rain fell at a rate of over 5 inches per hour. This copious record amount of rain over a short period led to catastrophic flooding. Thousands of homes, businesses, and roads were flooded due to flash flooding and sheet flow from long duration intense rain. Main stem rivers and adjoining tributaries, creeks and bayous reached full capacity and came out of their banks, contributing to the massive flooding across southeastern Texas.

There were numerous water rescues within the City of Houston and the surrounding suburbs. Flood waters completely inundated thousands of homes and businesses. Roads and highways in and around the City of Houston were flooded and closed for extended time periods. Catastrophic flooding occurred on nearly every one of the twenty-two watersheds in Harris County. Ten out of the nineteen bayous in the county reached record crests and flooding. There was widespread flooding along Buffalo Bayou and upstream and downstream of both Addicks and Barkers Reservoirs due to record level pool elevations. There was major flooding of hundreds of homes within numerous neighboring subdivisions along the San Jacinto River and the East Fork of the San Jacinto River.

PROBABILITY OF FUTURE EVENTS

Based on 210 recorded historical occurrences within a 27-year reporting period within the City of Houston planning area, flooding is highly likely with 7 to 8 events per year anticipated. The City of Houston is projected to experience an increase in the number of extreme precipitation days

[4] Flood damages for Hurricane Harvey were not reported separately and apart from hurricane damages. The combined total in damages, as reported by Greater Houston Partnership, have been included in the hurricane hazard profile of this plan (Section 6).

because of climate change.[5] See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

A property's vulnerability to a flood depends on its location and proximity to the floodplain. Structures that lie along banks of a waterway are the most vulnerable and are often repetitive loss structures. The City of Houston encourages development outside of the floodplain, and the impact for flood for the entire planning area is "Minor" as facilities and services would be shut down for one week, more than 10 percent of property destroyed or with major damage, and injuries or illness that would not potentially result in permanent disability. However, with nine reported fatalities and three injuries, the impact is considered "substantial", with multiple deaths possible depending on the size and magnitude of the flood event.

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by flood events.

Table 5-4. Critical Facilities Vulnerable to Flood Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations (14 within flood hazard areas), 18 Police Stations (1 within flood hazard areas)	■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Emergency vehicles can be damaged by rising flood waters. ■ Flood-related rescues may be necessary at swift and low water crossings or in flooded neighborhoods where roads have become impassable, placing first responders in harm's way. ■ Evacuations may be required for entire neighborhoods because of rising floodwaters, further taxing limited response capabilities and increasing sheltering needs for displaced residents. ■ Power outages could disrupt communications, delaying emergency response times. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Washed out roads and bridges can impede emergency response vehicle access to areas. ■ Increased number of structure fires due to gas line ruptures and downed power lines, further straining the capacity and resources of emergency personnel. ■ First responders are exposed to downed power lines, contaminated and unusual debris, hazardous materials, and generally unsafe conditions. ■ Extended power outages and evacuations may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.

[5] Houston Climate Impact Assessment 2.0 https://storymaps.arcgis.com/stories/ab02f9edd0904f3f83fbf080f41ad3f6

CRITICAL FACILITIES	POTENTIAL IMPACTS
64 Hospitals (7 within flood hazard areas)	■ Structures can be damaged by rising flood waters. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged, inundated or otherwise inoperable. ■ Critical staff may be impacted and unable to report for duty, limiting response capabilities. ■ Evacuations may be necessary due to extended power outages, gas line ruptures, or inundation of facilities.
21 Airports	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications, and emergency operations. ■ Temporary break in operations may significantly inhibit post event evacuations. ■ Damaged or destroyed highway infrastructure may substantially increase the need for airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

Historic loss estimates due to flood are presented in Table 5-5 below. Considering 69 flood events over a 27-year period, frequency is approximately two to three events every year.

Table 5-5. Potential Annualized Losses

JURISDICTION	PROPERTY & CROP LOSS	ANNUAL LOSS ESTIMATES
City of Houston	$18,969,844	$702,587

While all citizens are at risk to the impacts of a flood, forced relocation and disaster recovery drastically impacts low-income residents who lack the financial means to travel, afford a long-term stay away from home, and to rebuild or repair their homes. An estimated 19.5 percent of the planning area population live below the poverty level. Similarly, renters tend to be more vulnerable

to the impacts of flood events. Their ability to recover after a flood is often disproportionally impacted by limited affordable replacement housing, financial constraints and often do not carry flood insurance to cover losses. Within the City 58 percent of housing units are renter-occupied. While warning times for these type of hazard events should be substantial enough for these individuals to seek shelter, individuals who work and recreate outside are also vulnerable to potential impacts of a flood event.

Table 5-6. Populations at Greatest Risk[6]

JURISDICTION	POPULATION BELOW POVERTY LEVEL	RENTER OCCUPIED UNITS
City of Houston	447,191	505,745

The severity of a flooding event varies depending on the relative risk to citizens and structures located within the city. Table 5-7 depicts the level of impact for the City of Houston.

Table 5-7. Level of Impact Summary

JURISDICTION	IMPACT	DESCRIPTION
City of Houston	Substantial	While it is anticipated that the City of Houston could anticipate an impact of "minor" with critical facilities shut down for a week or more, and more than 10 percent of property would be destroyed or damaged, the historical injuries and fatalities resulting from flood indicate a "substantial" impact.

ASSESSMENT OF IMPACTS

Flooding is the deadliest natural disaster that occurs in the U.S. each year, and it poses a constant and significant threat to the health and safety of the people in the City of Houston planning area. Worsening flood conditions can be frequently associated with a variety of impacts, including:

- Evacuations may be required for entire neighborhoods because of rising floodwaters, further taxing limited response capabilities and increasing sheltering needs for displaced residents.
- Health risks and threats to residents are elevated after the flood waters have receded due to contaminated flood waters (untreated sewage and hazardous chemicals) and mold growth typical in flooded buildings and homes.
- Significant flood events often result in widespread power outages increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outage can result in an increase in structure fires and/or carbon monoxide poisoning as individuals attempt to cook or heat their home with alternate, unsafe cooking or heating devices, such as grills.

[6] US Census Bureau American Community Survey Five-Year Estimates 2017-2021 data for the City of Houston.

- Floods can destroy or make residential structures uninhabitable, requiring shelter or relocation of residents in the aftermath of the event.
- 265 buildings and sites in the City are on the National Register of Historic Places. These structures would typically be built at lower elevations and may be more susceptible to flooding.
- First responders are exposed to downed power lines, contaminated and potentially unstable debris, hazardous materials, and generally unsafe conditions, elevating the risk of injury to first responders and potentially diminishing emergency response capabilities.
- Emergency operations and services may be significantly impacted due to damaged facilities.
- Significant flooding can result in the inability of emergency response vehicles to access areas of the community.
- Critical staff may suffer personal losses or otherwise be impacted by a flood event and unable to report for duty, limiting response capabilities.
- City departments may be flooded, delaying response and recovery efforts for the entire community.
- Private sector entities that the jurisdiction and its residents rely on, such as utility providers, financial institutions, and medical care providers may not be fully operational and may require assistance from neighboring communities until full services can be restored.
- Damage to infrastructure may slow economic recovery since repairs may be extensive and lengthy.
- Some businesses not directly damaged by the flood may be negatively impacted while utilities are being restored or water recedes, further slowing economic recovery.
- When the community is affected by significant property damage it is anticipated that funding would be required for infrastructure repair and restoration, temporary services and facilities, overtime pay for responders, and normal day-to-day operating expenses.
- Displaced residents may not be able to immediately return to work, further slowing economic recovery.
- Residential structures substantially damaged by a flood may not be rebuilt for years and uninsured or underinsured residential structures may never be rebuilt, reducing the tax base for the community.
- Large floods may result in a dramatic population fluctuation, as people are unable to return to their homes or jobs and must seek shelter and/or work outside of the affected area.
- Businesses that are uninsured or underinsured may have difficulty reopening, which results in a net loss of jobs for the community and a potential increase in the unemployment rate.
- Flooding may cause significant disruptions of clean water and sewer services, elevating health risks and delaying recovery efforts.
- The psycho-social effects on flood victims and their families can traumatize them for long periods of time, creating long term increases in medical treatment and services.
- Extensive or repetitive flooding can lead to decreases in property value for the affected community.

- Flood poses a potential catastrophic risk to annual and perennial crop production and overall crop quality leading to higher food costs.
- Flood related declines in production may lead to an increase in unemployment.
- Large floods may result in loss of livestock, potential increased livestock mortality due to stress and water borne disease, and increased cost for feed.
- Recreation activities at areas such as Buffalo Bayou and Hermann Park may be unavailable and tourism can be unappealing for years following a large flood event, devastating directly related local businesses and negatively impacting economic recovery.
- Vegetation in the City's urban parks may become destroyed or oversaturated from flood waters, impacting air quality and public health.
- Parks, recreational areas and nature preserves, such as the Armand Bayou Nature Center may suffer significant wildlife mortality during and following a flood due to damaged or destroyed ecosystems and water contamination.

The overall extent of damages caused by floods is dependent on the extent, depth and duration of flooding, and the velocities of flows in the flooded areas. The level of preparedness and pre-event planning done by the City, local businesses, and citizens will contribute to the overall economic and financial conditions in the aftermath of a flood event.

CLIMATE CHANGE CONSIDERATIONS

Extreme precipitation events have caused significant flood-related damages to the City of Houston and surrounding area. Utilizing historic events in five-year increments, an analysis was completed to estimate the change rate for flood events for the last three planning cycles. Table 5-8 shows the estimated change rate (+/-) for flood events for these cycles.

Table 5-8. Historic Flood Event Overview by Planning Cycle[7]

EVENTS 2008-2012	EVENTS 2013-2017	PERCENT CHANGE	EVENTS 2018-2022	PERCENT CHANGE
23	35	+52%	27	-23%

River flooding in Texas is projected to have no substantial change through 2036. This is in large part due to the construction of dams and reservoirs for flood management in the 20th century. There is a mixture of historical trends categorized by season, with no one clear trend to project. In addition, meteorological drivers of river flooding (increased rainfall intensity, decreased soil moisture) are projected to have competing influences. On balance, if an increasing trend is present in river flooding, it will be at the most extreme flood events or in the wettest parts of the state where there is so much rainfall that a decrease in soil moisture would have little mitigating impact.[8]

[7] Variations of reported impacts or events from one planning cycle to the next may be the result of changes in event reporting and not an indication of changing weather patterns.

[8] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

Future projections show a slight increase in the amount of precipitation falling in the wettest 3-day event for the planning area in the coming 20-year period. Single day events with precipitation above four inches are also projected to increase slightly toward the end of the century.[9]

NATIONAL FLOOD INSURANCE PROGRAM (NFIP) PARTICIPATION

Flood insurance offered through the National Flood Insurance Program (NFIP) is one of the best ways for home and business owners to protect themselves financially against the flood hazard. The City of Houston is currently participating in the NFIP and is in good standing.

The City of Houston currently has adopted higher standards above the NFIP minimum such as 2 foot of freeboard (above the 500-year floodplain) for new construction and substantial improvements of structures.

The flood hazard areas throughout the planning area are subject to periodic inundation, which may result in loss of life and property, health and safety hazards, disruption of commerce and governmental services, and extraordinary public expenditures for flood protection and relief, of which adversely affect public safety.

These flood losses are created by the cumulative effect of obstructions in floodplains which cause an increase in flood heights and velocities, and by the occupancy of flood hazard areas by uses vulnerable to floods and hazardous to other lands because they are inadequately elevated, flood-proofed or otherwise protected from flood damage. Mitigation actions are included to address flood maintenance issues as well, including routinely clearing debris from drainage systems and bridges and expanding drainage culverts and storm water structures to more adequately convey flood waters.

It is the purpose of the City of Houston to continue to promote the public health, safety and general welfare by minimizing public and private losses due to flood conditions in specific areas. The City is guided by their local Flood Damage Prevention Ordinance. The community will continue to comply with NFIP requirements through local permitting, inspection, and record-keeping requirements for new and substantially developed construction. Further, the NFIP program promotes sound development in floodplain areas and includes provisions designed to:

- Protect human life and health;
- Minimize expenditure of public money for costly flood control projects;
- Minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;
- Minimize prolonged business interruptions;
- Minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets, and bridges located in floodplains;
- Help maintain a stable tax base by providing for the sound use and development of flood-prone areas in such a manner as to minimize future flood blight areas; and

[9] *Climate Impact Assessment for the City of Houston*, August 2020, ATMOS Research & Consulting

- Ensure that potential buyers are notified that property is in a flood area.

In order to accomplish these tasks, the City of Houston seeks to follow these guidelines to achieve flood mitigation by:

- Restrict or prohibit uses that are dangerous to health, safety, or property in times of flood, such as filling or dumping, that may cause excessive increases in flood heights and/or velocities;
- Require that uses vulnerable to floods, including facilities, which serve such uses, be protected against flood damage at the time of initial construction as a method of reducing flood losses;
- Control the alteration of natural floodplains, stream channels, and natural protective barriers, which are involved in the accommodation of floodwaters;
- Control filling, grading, dredging, and other development, which may increase flood damage; and
- Prevent or regulate the construction of flood barriers which will unnaturally divert floodwaters or which may increase flood hazards to other lands.

COMMUNITY RATING SYSTEM

The City of Houston is an active participant in the Community Rating System (CRS). CRS is a voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the NFIP. Approximately 1,500 communities participate in the CRS, which is less than 10 percent of current NFIP participating communities nationwide. Lower class ratings mean lower flood insurance premiums for residents.

Out of a 10 point rating system (where 1 is the best), the City of Houston currently has a class rating of 5. This equates to a 25 percent insurance discount for the residents of Houston. Approximately 200 participating CRS communities currently have a rating of 5 or lower. The City of Houston continues to exceed minimum national standards to provide financial relief to homeowners in terms of insurance discounts, as well as significant improvements to construction standards. Please see Appendix I for additional information on the CRS.

NFIP COMPLIANCE AND MAINTENANCE

The City of Houston has developed mitigation actions that relate to either NFIP maintenance or compliance. Compliance and maintenance actions can be found in Section 19.

Flooding was identified as a high-risk hazard during hazard ranking activities at the Risk Assessment Workshop by the vast majority of the planning team. As such, many of the mitigation actions were developed with flood mitigation in mind. A majority of these flood actions address compliance with the NFIP and implementing flood awareness programs. The City recognizes the need and is continually working towards adopting higher NFIP regulatory standards to further minimize flood risk in their community.

In addition, the City is focusing on public flood awareness activities. This includes promoting the availability of flood insurance by placing NFIP brochures and flyers in public libraries or public meeting places around the City.

The City has a designated floodplain administrator. The floodplain administrator for the planning area will continue to maintain compliance with the NFIP including continued floodplain administration, zoning ordinances, and development regulation. The floodplain ordinance adopted by the City outlines the requirements for development in special flood hazard areas.

REPETITIVE LOSS

The Severe Repetitive Loss (SRL) Grant Program under FEMA provides federal funding to assist states and communities in implementing mitigation measures to reduce or eliminate the long-term risk of flood damage to severe repetitive loss residential structures insured under the NFIP. The Texas Water Development Board (TWDB) administers the SRL grant program for the State of Texas. One of the goals of the Flood Mitigation Assistance (FMA) program is to reduce the burden of repetitive loss and severe repetitive loss properties on the NFIP through mitigation activities that significantly reduce or eliminate the threat of future flood damages.

Repetitive Loss properties are defined as structures that are:

- Any insurable building for which 2 or more claims of more than $1,000 each, paid by the National Flood Insurance Program (NFIP) within any 10-year period, since 1978;
- May or may not be currently insured under the NFIP.

Severe Repetitive Loss properties are defined as residential properties that are:

- Covered under the NFIP and have at least four flood related damage claim payments (building and contents) over $5,000 each, and the cumulative amount of such claims payments exceed $20,000; or
- At least two separate claim payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

In either scenario, at least two of the referenced claims must have occurred within any ten-year period and must be greater than 10 days apart.[10] Table 5-9 shows repetitive loss and severe repetitive loss properties for the City of Houston planning area. Please see Appendix I for additional information on repetitive loss properties.

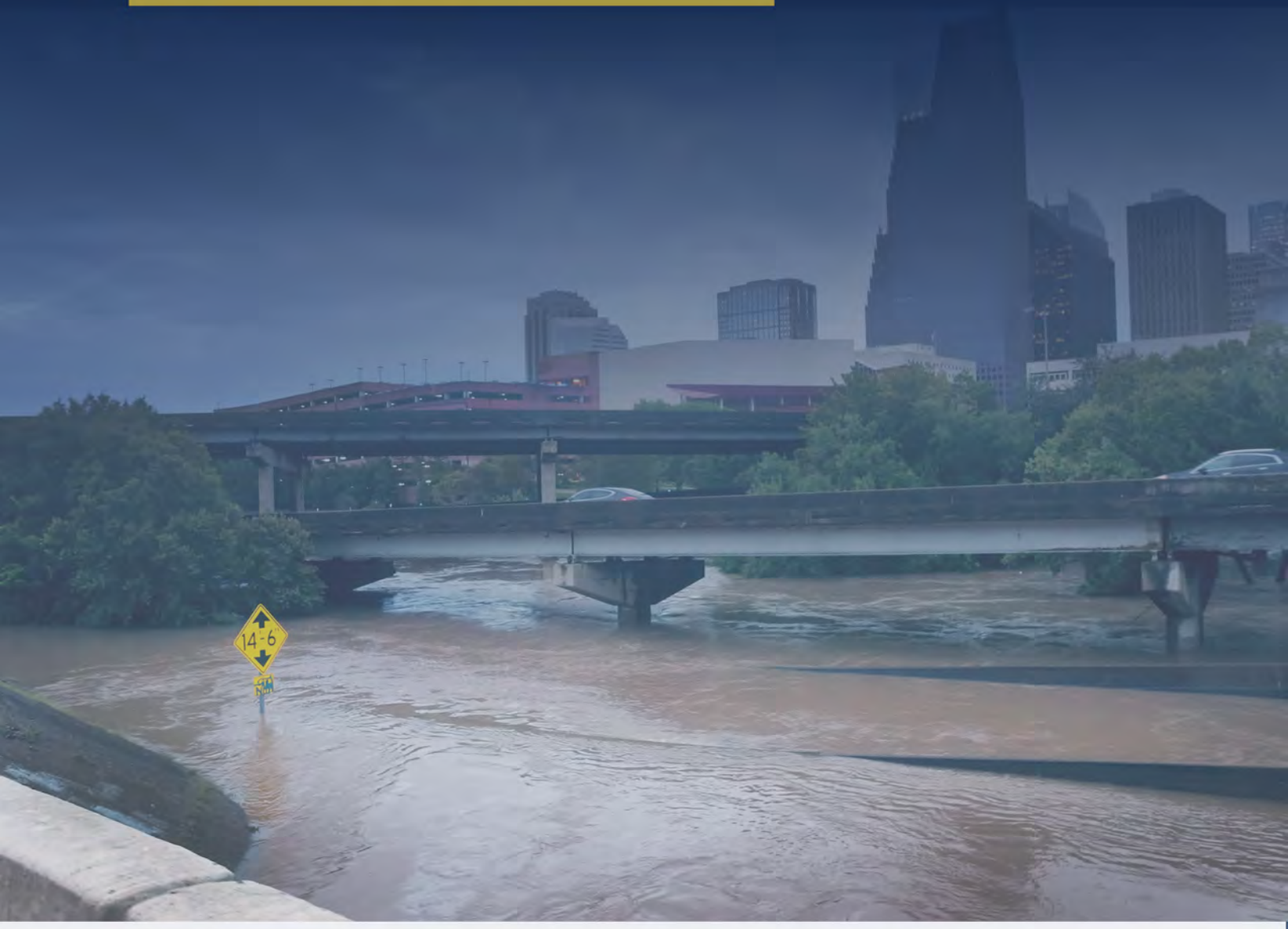
Table 5-9. Repetitive Loss and Severe Repetitive Loss Properties

JURISDICTION	BUILDING TYPE	NUMBER OF STRUCTURES	NUMBER OF LOSSES
City of Houston	Single Family	10,179	31,827
	Other-Nonresidential	289	926
	2-4 Family	94	303
	Assumed Condo	145	644
	Other Residential	287	851

[10] Source: Texas Water Development Board

JURISDICTION	BUILDING TYPE	NUMBER OF STRUCTURES	NUMBER OF LOSSES
	Business-Nonresidential	355	1,192

SECTION 6
HURRICANE/TROPICAL STORM



OFFICE OF EMERGENCY MANAGEMENT

SECTION 6: HURRICANE/TROPICAL STORM

Hazard Description **1**
Location **1**
Extent **2**
Historical Occurrences **3**
Significant Events 5
Probability of Future Events **6**
Vulnerability and Impact **6**
Assessment of Impacts 9
Climate Change Considerations **10**

HAZARD DESCRIPTION

According to the National Oceanic and Atmospheric Administration (NOAA), a hurricane is an intense tropical weather system of strong thunderstorms with well-defined surface circulation and maximum sustained winds of 74 mph or higher. In the Northern Hemisphere circulation of winds near the Earth's surface is counterclockwise.



Hurricanes often begin as tropical depressions that intensify into tropical storms when maximum sustained winds increase to between 35 – 64 knots (39 – 73 mph). At these wind speeds, the storm becomes more organized and circular in shape and begins to resemble a hurricane. Tropical storms resulting in high winds and heavy rainfall can be equally problematic without ever becoming a hurricane and can be dangerous to people and property, resulting in high winds and heavy rainfall, as Tropical Storm Frances did for southeast Texas in September 1998. Once sustained winds reach or exceed 74 mph, the storm becomes a hurricane. The intensity of a land falling hurricane is expressed in categories relating wind speeds to potential damage. Tropical storm-force winds are strong enough to be dangerous to those caught in them. For this reason, emergency managers plan to have evacuations completed and personnel sheltered before winds of tropical storm-force arrive, which precedes the arrival of hurricane-force winds.

LOCATION

The location of the City of Houston near the coast makes the planning area vulnerable to threats directly and indirectly related to a hurricane event, such as high-force winds and flooding. While the City is not located along the Gulf coast, the southeast jurisdictional boundary is located approximately 20 miles from the Gulf of Mexico coast, making it susceptible to hurricanes. Hurricanes and/or tropical storms can impact the City of Houston from June to November, the

official Atlantic U.S. hurricane season. The City of Houston planning area is in a moderate to high risk area for hurricane wind speeds up to 155 miles per hour (mph).

EXTENT

As a hurricane develops, the barometric pressure (measured in millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm, given a name, and closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane.

Hurricanes are categorized according to the strength and intensity of their winds using the Saffir-Simpson Hurricane Scale (Table 6-1). A Category 1 storm has the lowest wind speeds, while a Category 5 hurricane has the highest. However, a lower category storm can inflict greater damage than higher category storms depending on where they strike, the amount of storm surge, other weather they interact with, and how slow they move.

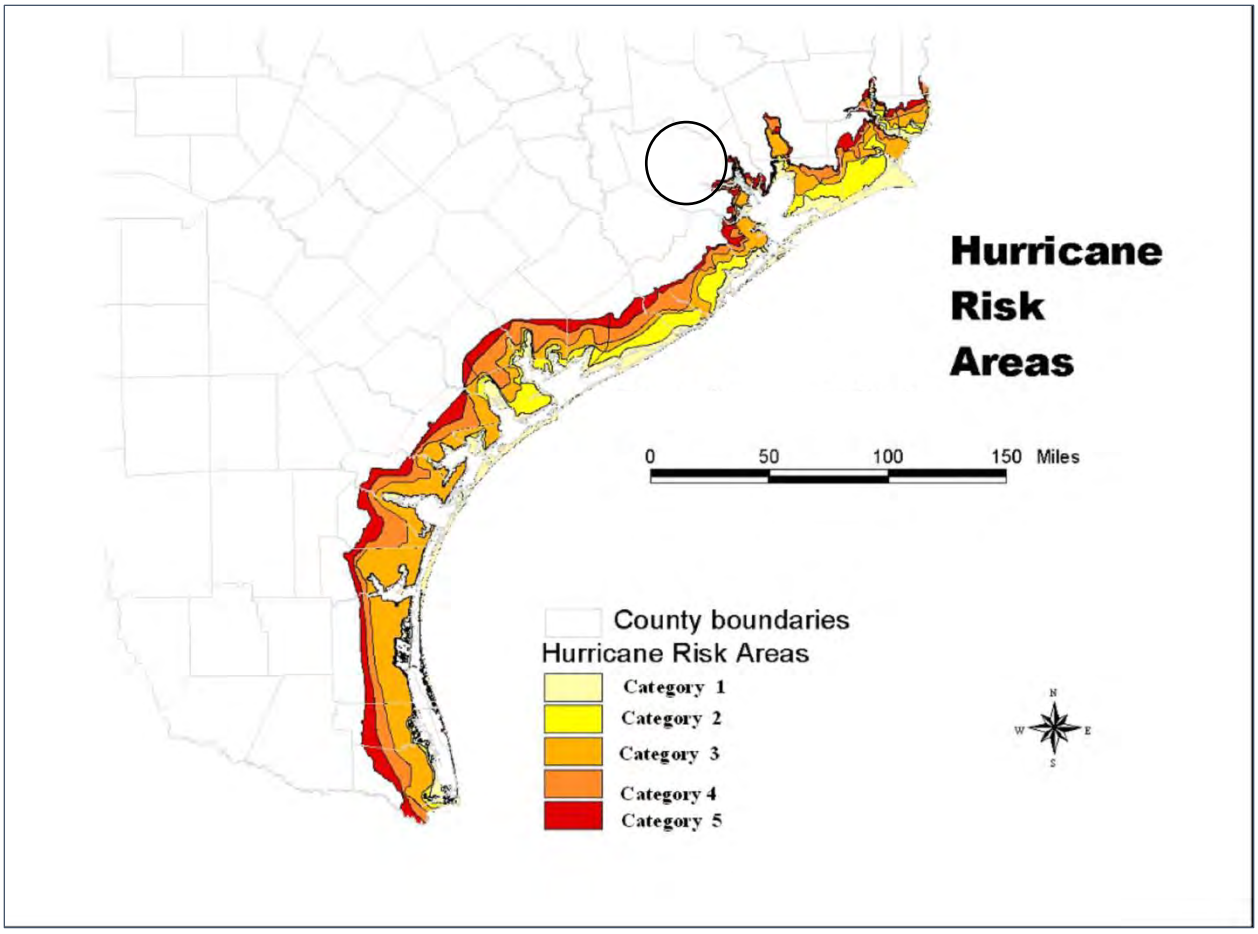
Table 6-1. Extent Scale for Hurricanes[1]

CATEGORY	MAXIMUM SUSTAINED WIND SPEED (mph)	MINIMUM SURFACE PRESSURE (millibars)	STORM SURGE (feet)
1	74 – 95	Greater than 980	3 – 5
2	96 – 110	979 – 965	6 – 8
3	111 – 130	964 – 945	9 – 12
4	131 – 155	944 – 920	13 – 18
5	155 +	Less than 920	19+

Based on the historical storm tracks for hurricanes and tropical storms, as well as the location of the City of Houston, the average extent to be mitigated for is a Category 3 storm. The City of Houston planning area has experienced wind speeds up to 130 mph, therefore a Category 3 should be mitigated in the event of a hurricane. Figure 6-1 displays the location of hurricane risk by storm category along the Gulf Coast.

[1] Source: National Hurricane Center, https://www.nhc.noaa.gov/HAW2/english/basics/saffir_simpson.shtml

Figure 6-1. Location of Hurricane Risk along the Texas Coast



HISTORICAL OCCURRENCES

Previous occurrences include storms that had a direct path through the City of Houston study area as well as large storms that impacted the planning area without directly passing over the City. Table 6-2 lists the storms that have impacted the City of Houston planning area from 1996 through 2022. Historical hurricane data for the City of Houston is provided on a countywide basis per the NCEI and NOAA databases.

Figure 6-2. Location of Historic Hurricane Tracks

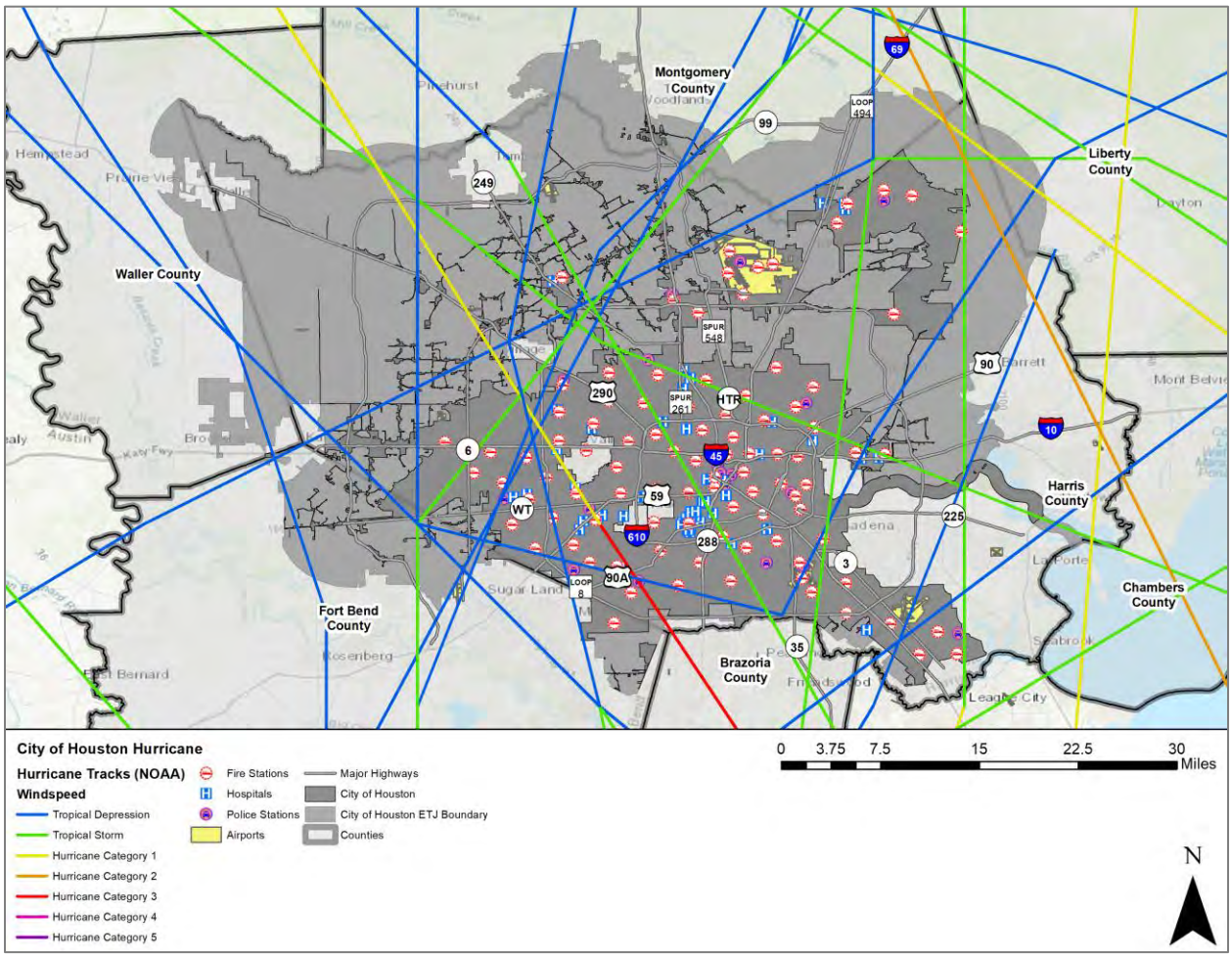


Table 6-2. Historical Hurricane/Tropical Storm Events, 1996-2022[2]

YEAR	STORM NAME	CATEGORY	PROPERTY DAMAGE	CROP DAMAGE
1998	Charley	Tropical Storm	$0	$0
1998	Frances	Tropical Storm	$51,956,649	$0
2001	Allison	Tropical Storm	$8,437,238,921	$0
2003	Claudette	Category 1	$0	$0
2003	Grace	Tropical Storm	$12,835	$0
2005	Rita	Category 3	$134,081,439	$0
2008	Edouard	Tropical Storm	$0	$0
2008	Ike	Category 2	$2,804,729,094	$0

[2] Values are in 2022 dollars.

YEAR	STORM NAME	CATEGORY	PROPERTY DAMAGE	CROP DAMAGE
2015	Bill	Tropical Storm	$0	$0
2017	Cindy	Tropical Storm	$0	$0
2017	Harvey	Category 4	$148,750,000,000[3]	$0
2019	Imelda	Tropical Storm	$229,292,606	$0
2020	Beta	Tropical Storm	$1,074,229	$0
2021	Nicholas	Category 1	$0	$0
COUNTY TOTALS			$160,408,385,773	
CITY OF HOUSTON[4]			$56,592,078,501	

Based on the list of historical hurricane events for the City of Houston planning area (listed above) five events have occurred since the 2018 Plan.

SIGNIFICANT EVENTS

Hurricane Rita, September 18-26, 2005 – City of Houston
Hurricane Rita made landfall just east of the Texas - Louisiana border. The hurricane moved northwest and across southeast Texas in the morning hours of September 24th as a dangerous Category 3 hurricane with sustained winds of 120 mph. The City of Houston planning area experienced tropical storm force sustained winds with gusts near 60 mph caused numerous trees to be blown down resulting in widespread power outages that lasted for six days in some areas. Roof, fence, sign, and glass damage estimates was around $90 million. The greatest loss was to inventory spoilage of food due to power outages. There were at least 34 indirect fatalities before, during and after Hurricane Rita. The majority of these fatalities occurred during the evacuation prior to Rita and were the result of excessive heat and transporting the elderly. Winds blew over 100 mph across the entire region, snapping and uprooting trees, and damaged over 125,000 homes and businesses.

Hurricane Ike, September 12-13, 2008 – City of Houston
Hurricane Ike caused wind damage and significant storm surge flooding across southeast Texas. Ike made landfall near Galveston, Texas, early in the morning on September 13th as a strong Category 2 hurricane. Collectively, damage amounts are estimated to be near 14 billion dollars over the counties of Harris, Chambers, Galveston, Liberty, Polk, Matagorda, Brazoria, Fort Bend, San Jacinto, and Montgomery with an estimated 8 billion of that due to storm surge in coastal Galveston, Harris and Chambers Counties. Fresh water flooding also occurred near the City of

[3] Hurricane Harvey damages reported by Greater Houston Partnership at https://www.houston.org/news/hurricane-harveys-lasting-impact-houston#:~:text=Five%20years%20ago%2C%20Hurricane%20Harvey,people%20in%20Harris%20County%20alone.
[4] Calculated as a percentage (35.28) of Harris County

Houston where up to 14 inches of rain fell over a two day period, first from Ike, then from a line of thunderstorms associated with a cold front moving through the following day.

Hurricane Harvey, August 16 – September 2, 2017 – City of Houston
Hurricane Harvey made landfall as a Category 4 hurricane near Rockport, Texas during the evening of August 25th. The storm then weakened to a tropical storm and slowed, looping back and tracking over southeast Texas then back over the Gulf of Mexico making a second landfall along the Louisiana coast during the early morning hours of August 30th. Over that 5 day period over Southeast Texas Tropical Storm Harvey produced catastrophic flooding with a large area of 30 to 60 inches of rain, 23 tornadoes, tropical storm force winds and a moderate storm surge near Matagorda Bay. In some of the heavier bands of rain fell at a rate of over 5 inches per hour. This copious record amount of rain over a short period led to catastrophic flooding. Thousands of homes, businesses, and roads were flooded due to flash flooding and sheet flow from long duration intense rain. Main stem rivers and adjoining tributaries, creeks and bayous reached full capacity and came out of their banks, contributing to the massive flooding across southeastern Texas.

There were numerous water rescues within the City of Houston and the surrounding suburbs. Flood waters completely inundated thousands of homes and businesses. Roads and highways in and around the City of Houston were flooded and closed for extended time periods. Catastrophic flooding occurred on nearly every one of the twenty-two watersheds in Harris County. Ten out of the nineteen bayous in the county reached record crests and flooding. There was widespread flooding along Buffalo Bayou and upstream and downstream of both Addicks and Barkers Reservoirs due to record level pool elevations. There was major flooding of hundreds of homes within numerous neighboring subdivisions along the San Jacinto River and the East Fork of the San Jacinto River.

PROBABILITY OF FUTURE EVENTS

Based on historical occurrences of significant hurricane events, the probability of future events is “Highly Likely”, with an event likely every one to two years for the City of Houston planning area. Impacts of climate change are not expected to increase the average frequency of events but may lead to an increase in the intensity of these storms. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Hurricane and tropical storm events can cause major damage to large areas; hence all existing buildings, facilities, and populations are equally exposed and vulnerable to this hazard and could potentially be impacted. The City of Houston planning area features multiple mobile or manufactured home parks throughout the planning area. These parks are typically more vulnerable to hurricane events than typical site-built structures. In addition, manufactured homes are located sporadically throughout the planning area. These homes would also be more vulnerable. The US Census data indicates a total of 9,450 manufactured homes located in the City of Houston planning area (Table 6-3). In addition, 51.0 percent of the single family residential (SFR) structures in the City of Houston were built before 1980.[5] These structures would typically be built to lower

[5] Source: US Census Bureau data estimates for 2022.

or less stringent construction standards than newer construction and may be more susceptible to damages during significant events.

In addition, renters tend to be more vulnerable to the impacts of hurricane events. Their ability to recover after a hurricane is often disproportionally impacted by limited affordable replacement housing, financial constraints and lack of insurance to cover losses. Within the City 58 percent of housing units are renter-occupied.

Table 6-3. Structures at Greater Risk

JURISDICTION	MANUFACTURED HOMES	SFR STRUCTURES BUILT BEFORE 1980	RENTER OCCUPIED UNITS
City of Houston	9,450	504,772	505,745

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by hurricane events.

Table 6-4. Critical Facilities Vulnerable to Hurricane Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Emergency vehicles can be damaged by falling trees or flying debris. ■ Power outages could disrupt communications, delaying emergency response times. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Debris/downed trees can impede emergency response vehicle access to areas. ■ Increased number of structure fires due to gas line ruptures and downed power lines, further straining the capacity and resources of emergency personnel. ■ First responders are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions. ■ Extended power outages and evacuations may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.
64 Hospitals	■ Structures can be damaged by falling trees or flying debris. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Evacuations may be necessary due to extended power outages, gas line ruptures, or structural damages to facilities.

CRITICAL FACILITIES	POTENTIAL IMPACTS
21 Airports	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications and emergency operations. ■ Temporary break in operations may significantly inhibit post event evacuations. ■ Damaged or destroyed highway infrastructure may substantially increase the need for airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

Table 6-5 shows impact or loss estimation for storms impacting the City. Damages within the NCEI database are reported on a countywide basis and are not specifically available for the City of Houston. The planning area losses are calculated as a percentage of the reported countywide damages. Annual loss estimates were based on the 27-year reporting period for such damages. The average annual loss estimate for the City of Houston is approximately $2.1 billion.

Table 6-5. Summary of Hurricane Events and Potential Annualized Losses, 1996-2022[6]

JURISDICTION	PROPERTY & CROP LOSS	ANNUAL LOSS ESTIMATE
Harris County	$160,408,385,773	$5,941,051,325
City of Houston[7]	$56,592,078,501	$2,096,002,907

The potential severity of impact from a hurricane for the City of Houston planning area is classified as “substantial” as a result of property damages, fatalities and injuries, meaning a complete

[6] Values are in 2022 dollars.
[7] Calculated as a percentage (35.28) of Harris County

shutdown of critical facilities and services for thirty days or more, and more than 50 percent of property could be destroyed or have major damage.

ASSESSMENT OF IMPACTS

Hurricane events have the potential to pose a significant risk to people and can create dangerous and difficult situations for public health and safety officials. Impacts to the planning area can include:

- Individuals exposed to the storm can be struck by flying debris, falling limbs, or downed trees causing serious injury or death.
- Structures can be damaged or crushed by falling trees, which can result in physical harm to the occupants.
- Driving conditions in the planning area may be dangerous during a hurricane event, especially over elevated bridges, elevating the risk of injury and accidents during evacuations if not timed properly.
- Emergency evacuations may be necessary prior to a hurricane landfall, requiring emergency responders, evacuation routing, and temporary shelters.
- Significant debris and downed trees can result in emergency response vehicles being unable to access areas of the community.
- Downed power lines may result in roadways being unsafe for use, which may prevent first responders from answering calls for assistance or rescue.
- During hurricane landfall, first responders may be prevented from responding to calls as the winds may reach a speed in which their vehicles and equipment are unsafe to operate.
- Hurricane events often result in widespread power outages increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outage often results in an increase in structure fires and carbon monoxide poisoning as individuals attempt to cook or heat their homes with alternate, unsafe cooking or heating devices, such as grills.
- Extended power outages can also be deadly for individuals reliant on electricity to live independently in their homes.
- Extreme hurricane events may rupture gas lines and down trees and power lines, increasing the risk of structure fires during and after a storm event.
- Extreme hurricane events may lead to prolonged evacuations during search and rescue, and immediate recovery efforts requiring additional emergency personnel and resources to prevent entry, protect citizens, and protect property.
- First responders are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions.
- Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications.
- Critical staff may be unable to report for duty, limiting response capabilities.
- City departments may be damaged, delaying response and recovery efforts for the entire community.

- Private sector entities that the City and its residents rely on, such as utility providers, financial institutions, and medical care providers may not be fully operational and may require assistance from neighboring communities until full services can be restored.
- Economic disruption negatively impacts the programs and services provided by the community due to short and long term loss in revenue.
- Some businesses not directly damaged by the hurricane may be negatively impacted while roads are cleared and utilities are being restored, further slowing economic recovery.
- Older structures built to less stringent building codes may suffer greater damage as they are typically more vulnerable to hurricane damage. 51 percent of homes in the City were built before 1980. 265 buildings and sites in the City are on the National Register of Historic Places, many of which pre-date modern building codes.
- Vegetation in the City's urban parks may become flattened or oversaturated from high winds and heavy rains.
- Large scale hurricanes can have significant economic impact on the affected area, as it must now fund expenses such as infrastructure repair and restoration, temporary services and facilities, overtime pay for responders, as well as normal day-to-day operating expenses. Businesses that are more reliant on utility infrastructure than others may suffer greater damages without a backup power source.
- As the City of Houston continues to add population, the number of people and housing developments exposed to the hazard increases. Continued public education on the City's risks to hurricane events will continue to be key to the city's overall mitigation strategy.

The level of preparedness and pre-event planning done by the county, communities, local businesses, and citizens will also contribute to the overall economic and financial conditions in the aftermath of any hurricane event.

CLIMATE CHANGE CONSIDERATIONS

Hurricane and tropical storm events have the potential to pose a significant risk to people and property. Such events can create dangerous situations for public health and safety officials and cause catastrophic damages. The impact of climate change could produce larger, more severe hurricane events, exacerbating the current hurricane impacts. The economic and financial impacts of hurricanes and tropical storms will depend entirely on the scale of the events, what is damaged, and how quickly repairs to critical components of the economy can be implemented.

The number of hurricane and tropical storm events impacting the planning area has been calculated in five year planning cycle increments to show upward or downward trends for events over the last three planning cycles. Table 6-6 provides the estimated percent change for hurricane or tropical storm events for the planning area from one planning cycle to the next.

Table 6-6. Historic Hurricane Event Overview by Planning Cycle[8]

EVENTS 2008-2012	EVENTS 2013-2017	PERCENT CHANGE	EVENTS 2018-2022	PERCENT CHANGE
2	3	+50%	3	-0-

The current climate assessment report for Texas indicates an expected increase in the intensity of very strong hurricanes, despite an expected lack of increase, or even a decrease, in hurricane frequency overall. Different research studies have produced some conflicting results. While some recent research has pointed to an apparent trend for U.S. tropical cyclones to move more slowly at landfall, much like Hurricane Harvey, other research suggests that Texas may be spared from such a slowdown. At this point, the enhanced risk is difficult to quantify, but substantial scientific progress on this topic is likely as climate models become better able to simulate the observed spatial distribution, frequency, and intensity of hurricanes.[9]

[8] Variations of reported impacts or events from one planning cycle to the next may be the result of changes in event reporting and not an indication of changing weather patterns.
[9] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 7
EXTREME HEAT



OFFICE OF EMERGENCY MANAGEMENT

SECTION 7: EXTREME HEAT

Hazard Description 1
Location 1
Extent 2
Historical Occurrences 5
Significant Events 8
Probability of Future Events 9
Vulnerability and Impact 9
Assessment of Impacts 11
Climate Change Considerations 12

HAZARD DESCRIPTION



Extreme heat is a prolonged period of excessively high temperatures and exceptionally humid conditions. Extreme heat during the summer months is a common occurrence throughout the State of Texas, and the City of Houston is no exception. The City typically experiences extended heat waves or an extended period of extreme heat and is often accompanied by high humidity. In addition, the City also has urban heat islands or areas where there is a concentration of structures such as buildings and pavement and a limited amount of greenery causing higher temperatures relative to outlying areas. The urban heat island effect results in daytime temperatures to that are 1-7°F higher than temperature in outlying areas and nighttime temperatures are 2-5°F higher.[1] The City of Houston ranks fourth in the nation for urban heat island intensity.[2]

Although heat can damage buildings and facilities, it presents a more significant threat to the safety and welfare of citizens. The major human risks associated with extreme heat include heat cramps; sunburn; dehydration; fatigue; heat exhaustion; and even heat stroke. The most vulnerable population to heat casualties are children and the elderly or infirmed who frequently live on low fixed incomes and cannot afford to run air-conditioning on a regular basis. This population is sometimes isolated, with no immediate family or friends to look out for their well-being.

LOCATION

While extreme heat events can occur throughout the entire City of Houston, the areas where heat stays throughout the day is largely dependent on the type of land use and ground cover. Areas with large amounts of impervious and dark surfaces such as roads and roofs, heat up quickly and remain hot throughout the day. These areas, which tend to be urban and industrial, are not able to

[1] Environmental Protection Agency, https://www.epa.gov/heatislands/learn-about-heat-islands
[2] Climate Central, Hot Zones: Urban Heat Islands, July 14, 2021

cool down overnight and start the day with higher morning temperatures in comparison to less dense areas that have more trees and vegetation.[3]

The Houston Harris Heat Action Team (H3AT) 2020 Heat Mapping Campaign (Action 16.1 in *Resilient Houston* (2020)) used citizen volunteers to collect data on heat and humidity at the street level in the City of Houston and Harris County. Data was collected during the morning (6-7am), afternoon (3-4pm) and evening (7-8pm) to help with mapping temperature differences throughout the day and between different areas. The results of the data collected were converted into maps to give snapshots on how heat waves vary across neighborhoods in the City and County as well as how landscape features affect temperature and humidity.

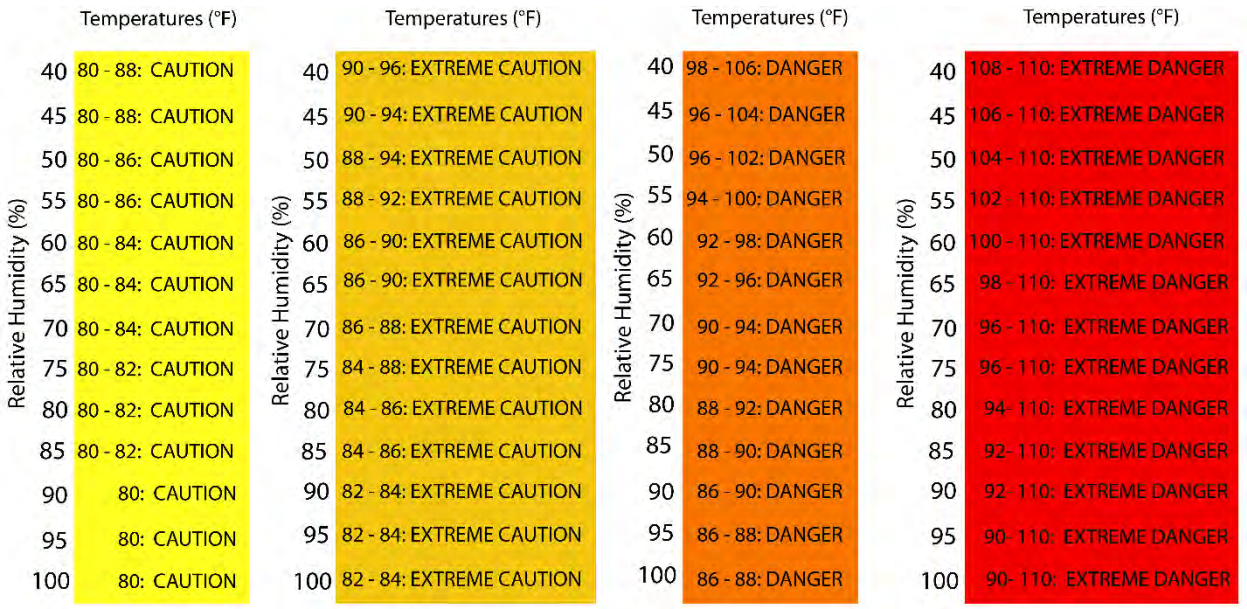
The results found that certain neighborhoods in the City have higher temperatures at certain times of day compared to other areas of the City and County. The study found a 10-degree difference in morning temperatures across the City and County with the warmest morning temperatures being observed in the following neighborhoods, near Downtown, East Downtown, Second Ward, Gulfton (along 59 SW), Texas Medical Center, Northeast Houston (around I-610 and I-10) and Spring Branch East (along 290). Results collected during the afternoon found a 17-degree difference in temperature. The highest observed temperature was 103 degrees measured north of Gulfton and south of Galleria. Higher afternoon temperatures, those above 99 degrees, were generally observed in north and southwest of City of Houston and included Upper Kirby, Larchmont (along Richmond Avenue), Sharpstown and Alief (along Beechnut Street). Evening temperatures saw a 12-degree difference across the City and County. The Acres Home neighborhood had the highest observed temperature as well as Downton (along Houston Avenue), East Downton, and areas north of I-610 and I-45. While extreme heat was found to be more prevalent in certain areas of the City, with no geographic boundary, extreme heat can occur anywhere in the City of Houston.

EXTENT

The magnitude or intensity of an extreme heat event is measured according to temperature in relation to the percentage of humidity. According to the National Oceanic Atmospheric Administration (NOAA), this relationship is referred to as the "Heat Index" and is depicted in Figure 7-1. This index measures how hot it feels outside when humidity is combined with high temperatures.

[3] Houston Harris Heat Action Team (H3AT) 2020 Heat Mapping Campaign, https://arcg.is/15D4rv

Figure 7-1. Extent Scale for Extreme Summer Heat[4]



The Extent Scale in Figure 7-1 displays varying categories of caution depending on the relative humidity combined with the temperature. For example, when the temperature is at 90 degrees Fahrenheit (°F) or lower, caution should be exercised if the humidity level is at or above 40 percent.

The shaded zones on the chart indicate varying symptoms or disorders that could occur depending on the magnitude or intensity of the event. "Caution" is the first category of intensity, and it indicates when fatigue due to heat exposure is possible. "Extreme Caution" indicates that sunstroke, muscle cramps, or heat exhaustion are possible, and a "Danger" level means that these symptoms are likely. "Extreme Danger" indicates that heat stroke is likely. The National Weather Service (NWS) initiates alerts based on the Heat Index as shown in Table 7-1.

Table 7-1. Heat Index and Warnings

CATEGORY	HEAT INDEX	POSSIBLE HEAT DISORDERS	WARNING TYPE
Extreme Danger	125°F and higher	Heat stroke or sun stroke likely.	An Excessive Heat Warning is issued if the Heat Index rises above 105°F at least 3 hours during the day or above 80°F at night.
Danger	103 – 124°F	Sunstroke, muscle cramps, and/or heat exhaustion are likely. Heatstroke possible with prolonged exposure and/or physical activity.	
Extreme Caution	90 – 103°F	Sunstroke, muscle cramps, and/or heat exhaustion possible	

[4] Source: NOAA

CATEGORY	HEAT INDEX	POSSIBLE HEAT DISORDERS	WARNING TYPE
		with prolonged exposure and/or physical activity.	A heat advisory will be issued to warn that the Heat Index may exceed 105°F.
Caution	80 – 90°F	Fatigue is possible with prolonged exposure and/or physical activity.	

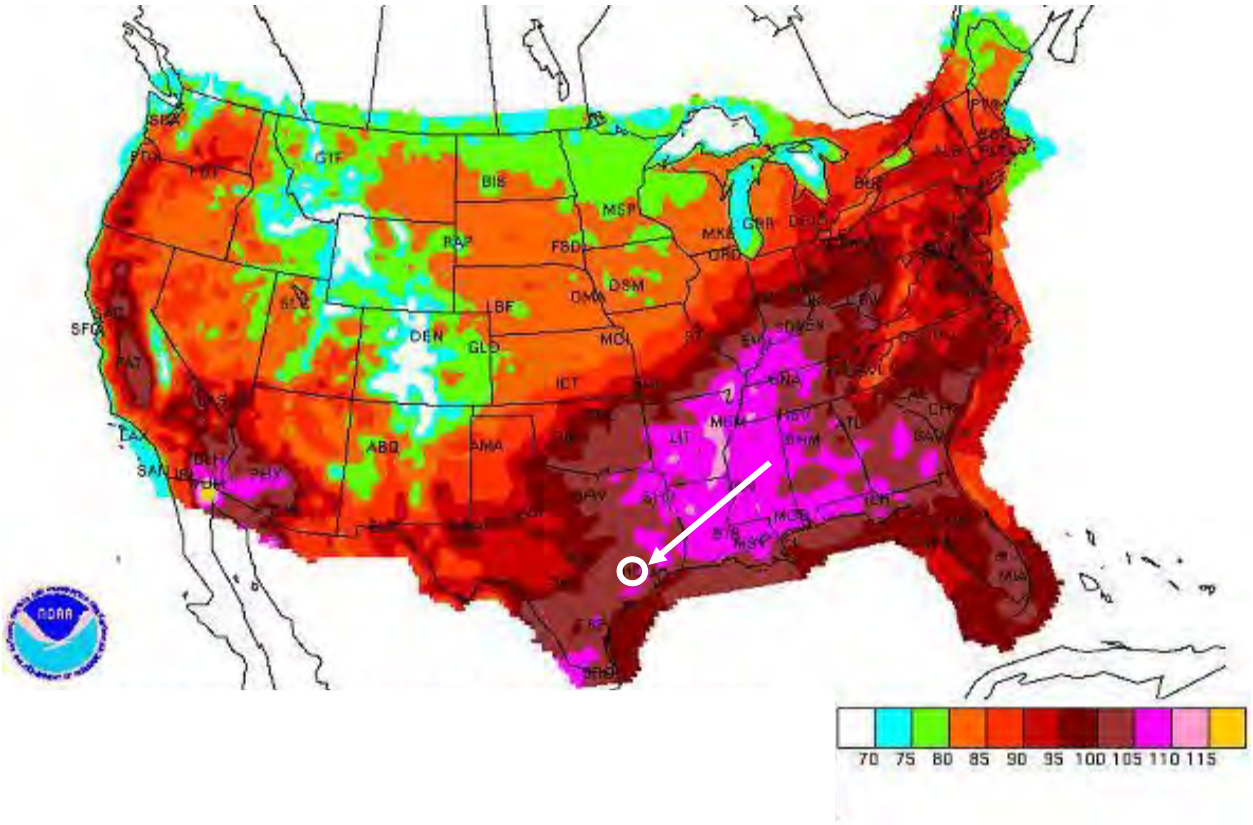
The City of Houston activates the Public Health Heat Emergency Plan when the heat index reaches 108 degrees on two consecutive days.[5] Activating the plan opens cooling centers throughout the City and provides the option of free transportation from METRO for those without adequate transportation.

The City of Houston lies largely in the northern portion of the Gulf coastal plain, a 40- to 50-mile-wide swath along the Texas Gulf Coast. Typically, elevation rises approximately one foot per mile inland. Northern and eastern portions of the area are largely forested; southern and western portions are predominantly prairie grassland; coastal areas are prairie and sand. Due to its geography and its warm, sunny, and humid subtropical climate, the City of Houston planning area can expect an extreme heat event each summer. Citizens, especially children and the elderly should exercise caution by staying out of the heat for prolonged periods when a heat advisory or excessive heat warning is issued. In addition, those working or remaining outdoors for extended periods of time are at greater risk.

Figure 7-2 displays the daily maximum heat index as derived from NOAA based on data compiled from 1838 to 2015. The white circle shows the City of Houston planning area. The City of Houston planning area is represented with primarily brown but also has a small amount of bright pink, which indicates an average daily heat index of 100°F to 110°F. Therefore, the City of Houston could experience dangerous heat from 100°F to 110°F, and should mitigate to the extent of "Danger," which can include sunstroke, muscle cramps, heat exhaustion and potential heat stroke. This is the highest temperature (extreme caution category) the planning area can anticipate based on historical events.

[5] City of Houston, Houston Health Department

Figure 7-2. Average Daily Maximum Heat Index Days[6]



HISTORICAL OCCURRENCES

Previous occurrences for extreme heat are derived from the NCEI database, which identifies extreme heat events on a county-wide level for each event. According to heat related incidents located solely within Harris County, there have been 64 extreme heat events on record for the county which includes the City of Houston (Table 7-2). Historical extreme heat information, as provided by the NCEI, shows extreme heat activity across a multi-county forecast area for each event, the appropriate percentage of the total property and crop damage reported for the entire forecast area has been allocated to each county impacted by the event.

Historical extreme heat data for the City of Houston are provided on a County-wide basis per the NCEI database from 1996 through October 2022, though no extreme heat events were reported in the database after 2017. Only extreme heat events that have been reported have been factored into this Risk Assessment. It is highly likely additional extreme heat occurrences have gone unreported before and during the recording period. Due to the limited number of reported events, average high temperatures have been analyzed in order to determine the probability of future events.

[6] NRDC and the white circle indicates the City of Houston planning area.

Table 7-2. Historical Extreme Heat Events, 1996-2022[7]

DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
8/2/1998	1	0	$0	$0
8/2/1998	1	0	$0	$0
8/3/1998	1	0	$0	$0
8/3/1998	1	0	$0	$0
8/3/1998	1	0	$0	$0
8/5/1998	1	0	$0	$0
8/5/1998	1	0	$0	$0
8/6/1998	1	0	$0	$0
8/5/1998	1	0	$0	$0
7/21/1998	1	0	$0	$0
7/26/1998	1	0	$0	$0
7/27/1998	1	0	$0	$0
7/29/1998	1	0	$0	$0
7/29/1998	1	0	$0	$0
6/9/1998	1	0	$0	$0
7/14/1998	1	0	$0	$0
5/9/1998	1	0	$0	$0
7/13/1998	1	0	$0	$0
7/15/1998	1	0	$0	$0
8/1/1999	6	0	$0	$0
6/26/1999	3	0	$0	$0
7/10/1999	1	0	$0	$0
6/7/1999	1	0	$0	$0
9/10/2000	1	0	$0	$0
9/1/2000	5	0	$0	$0
7/6/2000	17	0	$0	$0

[7] NOAA, NCEI Storm Events Database events reported from January 1996 through October 2022.

DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
8/10/2000	1	0	$0	$0
8/29/2000	3	0	$0	$0
8/3/2000	1	0	$0	$0
8/7/2000	2	0	$0	$0
8/9/2000	1	0	$0	$0
8/11/2000	2	0	$0	$0
8/12/2000	1	0	$0	$0
7/29/2000	1	0	$0	$0
7/31/2000	1	0	$0	$0
7/19/2001	1	0	$0	$0
8/6/2001	1	0	$0	$0
8/3/2001	1	0	$0	$0
8/1/2001	1	0	$0	$0
8/2/2001	1	0	$0	$0
8/2/2001	1	0	$0	$0
8/12/2001	1	0	$0	$0
7/5/2001	1	0	$0	$0
7/7/2001	1	0	$0	$0
7/11/2001	1	0	$0	$0
7/12/2001	1	0	$0	$0
8/5/2001	1	0	$0	$0
8/8/2001	1	0	$0	$0
8/9/2001	1	0	$0	$0
8/13/2001	1	0	$0	$0
8/14/2001	1	0	$0	$0
8/16/2001	1	0	$0	$0
6/11/2001	1	0	$0	$0
6/14/2001	1	0	$0	$0

DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
6/27/2001	1	0	$0	$0
6/28/2004	1	0	$0	$0
8/25/2004	1	0	$0	$0
9/21/2005	34[8]	0	$0	$0
7/4/2009	0	0	$0	$0
7/9/2009	0	0	$0	$0
6/24/2009	0	0	$0	$0
8/4/2011	1	0	$0	$0
7/13/2015	1	0	$0	$0
8/21/2017	1	0	$0	$0
Total	**125**	**0**	**$0**	**$0**

Based on the list of historical extreme heat events for the City of Houston planning area (listed above), one event was reported to the NCEI since the 2018 Plan.

SIGNIFICANT EVENTS

July 6, 2000

One of the most significant extreme heat hazard events occurred in the summer of 2000. Excessive heat impacted southeast Texas for much of the month of July. For a two-week period, high temperatures ranged from 98 to 103 degrees daily. The highest temperature recorded in the planning area during this heat event was 103 degrees at Houston Intercontinental Airport. Only traces of rainfall were observed during this period. Of the 19 heat related deaths reported during this period, 17 were in Harris County.

September 1, 2000

A record setting heat wave continued over southeast Texas through the first week of September 2000. The temperature at Houston Intercontinental Airport soared to 109 degrees on the 4th and 108 degrees on the 5th, setting new records for the all-time highest temperatures recorded in the City of Houston.

The temperature in College Station peaked at 112 degrees on the 4th and 111 degrees on the 5th, both the highest temperatures ever recorded in College Station. In Galveston, the all-time record high temperature of 101 degrees was tied on the 4th, then broken the next day when the temperature rose to 104 degrees. Temperatures over southeast Texas began to cool on the 6th. In all, the City of Houston recorded 6 consecutive days with temperatures of 104 degrees or higher

[8] All fatalities for this event were associated with the evacuation for Hurricane Rita, both before and after landfall. The number of heat related deaths within the City of Houston could not be confirmed.

and College Station recorded 6 consecutive days of 107 degrees or higher. Galveston reached 100 degrees or higher for the first time since 1939, and for the first time on record had more than one day in a season with 100-degree temperatures. A heat wave with temperatures of this duration and magnitude is unprecedented for southeast Texas. All 5 heat related deaths occurred in Harris County.

June - July 2022

The City of Houston experienced the hottest June and July in the City's history, with average temperatures reaching over 85 degrees both months.[9] [10] On July 10, 2022, temperatures reached as high as 105 degrees with a heat index of 114. This tied the City's record for July temperatures set in 1954. The Electric Reliability Council of Texas (ERCOT) issued a conversation appeal for residents statewide to voluntarily conserve electricity between 2 and 8 pm to prevent outages.[11] According to the National Weather Service, the record-setting heat was due to sustained high air pressure in the region which resulted in dry conditions and relatively few clouds.



PROBABILITY OF FUTURE EVENTS

According to historical records the City of Houston planning area has experienced 64 events in a 26-year reporting period. This provides a frequency of occurrence of approximately 3 events every year. This frequency supports a highly likely probability of future events. See additional information on the impacts of climate change at the end of this section.

VULNERABILITY AND IMPACT

There is no defined geographic boundary for extreme heat events. While the entirety of the City of Houston is exposed to extreme temperatures, existing buildings, infrastructure, and critical facilities are not likely to sustain significant damage from extreme heat events. Therefore, any estimated property losses associated with the extreme heat hazard are anticipated to be minimal across the area.

Every summer, the hazard of heat-related illness becomes a significant public health issue throughout much of the United States. Mortality from all causes increases during heat waves, and excessive heat is an important contributing factor to deaths from other causes, particularly among the elderly. Extreme temperatures present a significant threat to life and safety for the population of the City as a whole. Heat casualties, for example, are typically caused by a lack of adequate air-conditioning or heat exhaustion. The most vulnerable population to heat casualties are the elderly or infirmed who frequently live on low fixed incomes and cannot afford to run air-conditioning on a regular basis. This population is sometimes isolated, with no immediate family or friends to look out for their well-being. Children may also be more vulnerable if left unattended in vehicles.

[9] Faquih, Duaa, *June 2022 was the hottest June in Houston History*, Houston Public Media, July 1, 2022
[10] Zuvanich, Adam, *Houston just had its hottest July ever as 2022 heatwave continues breaking records*, August 2, 2022
[11] ERCOT, https://www.ercot.com/news/release?id=90030206-5cf5-db8e-13d1-f8fe2bd0128f

Students are also susceptible as sporting events and practices are often held outside during early fall or late spring when temperatures are at the highest. In addition, populations living below the poverty level are unable to run air-conditioning on a regular basis and are limited in their ability to seek medical treatment. Another segment of the population at risk are those whose jobs consist of strenuous labor outdoors.

The population over 65 in the City of Houston is estimated at 11 percent of the total population and children under the age of 5 are estimated at 7 percent, or an estimated total of 420,297 potentially vulnerable residents in the planning area based on age. In addition, an estimated 19.5 percent of the planning area population live below the poverty level. Under privileged populations disproportionately impacted by extreme heat events as they are less likely to be able to afford air conditioning during the hot summer months as well as less likely to have access to medical care.

Table 7-3. Populations at Greater Risk to Extreme Heat Events

JURISDICTION	YOUTH (UNDER 5)	ELDERLY (OVER 65)	POPULATION BELOW POVERTY LEVEL
City of Houston	164,775	255,522	453,395

Extreme high temperatures can have significant secondary impacts, leading to droughts, water shortages, increased fire danger, and prompt excessive demands for energy. The possibility of rolling blackouts increases with unseasonably high temperatures in what is a normally mild month with low power demands. Typically, more than 12 hours of warning time would be given before the onset of an extreme heat event.

In terms of vulnerability to structures, the impact from extreme heat would be negligible. It is possible that critical facilities and infrastructure could be shut down for 24 hours if cooling units are running constantly, leading to a temporary power outage. Less than ten percent of residential and commercial property could be damaged if extreme heat events lead to structure fires. Based on historical records over a 26-year period, annualized property and crop losses for the City of Houston planning area are negligible. However, the number of historical injuries and fatalities indicates a substantial impact for future events.

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by extreme heat events.

Table 7-4. Critical Facilities Vulnerable to Extreme Heat Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations, services and response times may be significantly impacted due to power outages, and/or loss of communications. ■ Exposure to heat can cause heat illnesses in first responders, especially for those in heavy equipment. ■ Roads may become impassable due to excessive heat causing asphalt roads to soften and concrete roads to shift or buckle impacting response times by emergency services. ■ Extended power outages due to increased usage may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.
64 Hospitals	■ Power outages due to increased usage could disrupt critical care. ■ Backup power sources could be damaged. ■ Evacuations may be necessary due to extended power outages, breaks in water main lines or other associated damages to facilities.
21 Airports	■ Facilities, infrastructure, or critical equipment including communications may be damaged, destroyed or otherwise inoperable. ■ Essential supplies like medicines, water, food, and equipment deliveries may be delayed. ■ Economic disruption due to power outages negatively impact airport services as well as area businesses reliant on airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

ASSESSMENT OF IMPACTS

The greatest risk from extreme heat is to public health and safety. Extreme heat conditions can be frequently associated with a variety of impacts, including:

- Vulnerable populations, particularly the elderly (11 percent of total population) and children under 5 (7 percent of total population), can face serious or life-threatening health problems from exposure to extreme heat including hyperthermia, heat cramps, heat exhaustion, and heat stroke (or sunstroke).

- Response personnel, including utility workers, public works personnel, and any other professions where individuals are required to work outside, are more subject to extreme heat related illnesses since their exposure would typically be greater.
- High energy demand periods can outpace the supply of energy, potentially creating the need for rolling brownouts which would elevate the risk of illness to vulnerable residents.
- Highways and roads may be damaged by excessive heat causing asphalt roads to soften and concrete roads to shift or buckle.
- Vehicle engines and cooling systems typically run harder during extreme heat events resulting in increases in mechanical failures.
- Extreme heat events during times of drought can exacerbate the environmental impacts associated with drought, decreasing water and air quality and further degrading wildlife habitat.
- Extreme heat increases ground-level ozone (smog), increasing the risk of respiratory illnesses.
- Negatively impacted water suppliers may face increased costs resulting from the transport of water resources or development of supplemental water resources.
- Tourism and recreational activities predominant in the City of Houston may be negatively impacted during extreme heat events, reducing seasonal revenue.
- Outdoor activities may see an increase in school injury or illness during extreme heat events.

The economic and financial impacts of extreme heat on the community will depend on the duration of the event, demand for energy, drought associated with extreme heat, and many other factors. The level of preparedness and the amount of planning done by the jurisdiction, local businesses, and citizens will impact the overall economic and financial conditions before, during, and after an extreme heat event.

CLIMATE CHANGE CONSIDERATIONS

Climate change is expected to lead to an increase in average temperatures as well as an increase in frequency, duration and intensity of extreme heat events. With no reductions in emissions worldwide, the state of Texas is projected to experience an additional 30 to 60 days per year above 100°F than what is experienced now.[12]

According to the City of Houston Climate Impact Assessment, it is projected the City will experience an increase in the number of hot days and warm nights per year. As well as increases in the temperatures of the hottest days experienced per year and longer multi-day heatwaves.[13]

[12] Gammon-Nielsen, John, Holman, Sara, Buley, Austin and Jorgensen, Savannah. Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, 2021 Update. Texas A&M University Office of the Texas State Climatologist. October 7, 2021. https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update

[13] Stoner, Anne and Hayhoe Katharine. Climate Impact Assessment for the City of Houston August 2020. https://www.houstontx.gov/mayor/Climate-Impact-Assessment-2020-August.pdf

SECTION 8
DROUGHT



OFFICE OF EMERGENCY MANAGEMENT

SECTION 8: DROUGHT

Hazard Description 1
Location 2
Extent 3
Historical Occurrences 5
Significant Events 7
Probability of Future Events 8
Vulnerability and Impact 8
Assessment of Impacts 11
Climate Change Considerations 13

HAZARD DESCRIPTION

Drought is a period of time without substantial rainfall that persists from one year to the next. Drought is a normal part of virtually all climatic regions, including areas with high and low average rainfall. Drought is the consequence of anticipated natural precipitation reduction over an extended period of time, usually a season or more in length. Droughts can be classified as meteorological, hydrologic, agricultural, and socioeconomic. Table 8-1 presents definitions for these different types of droughts.



Droughts are one of the most complex of all natural hazards as it is difficult to determine their precise beginning or end. In addition, droughts can lead to other hazards such as extreme heat and wildfires. Their impact on wildlife and area farming is enormous, often killing crops, grazing land, edible plants, and even in severe cases, trees. A secondary hazard to drought is wildfire because dying vegetation serves as a prime ignition source. Therefore, a heat wave combined with a drought is a very dangerous situation.

Table 8-1. Drought Classification Definitions[1]

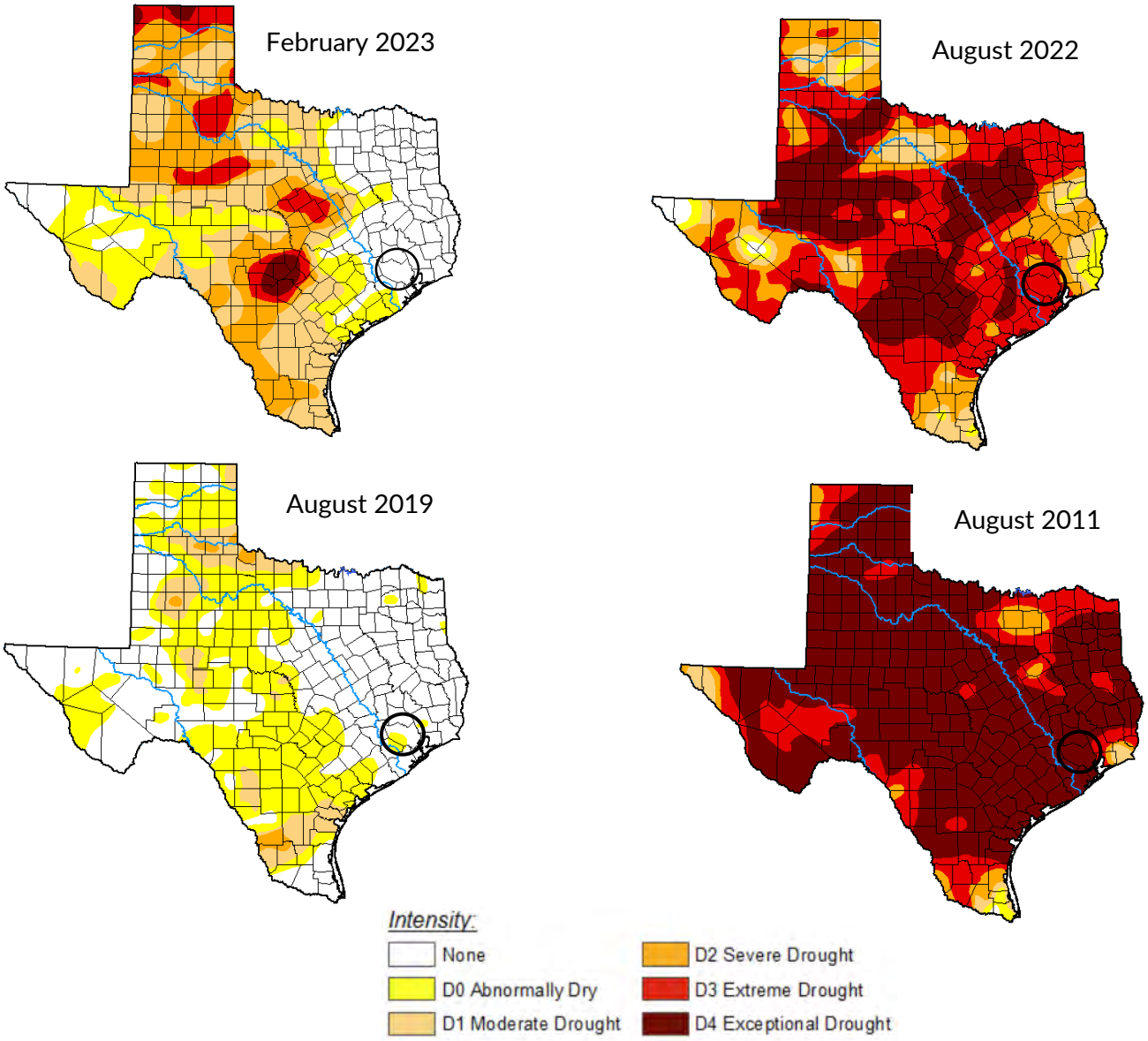
METEOROLOGICAL DROUGHT	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
HYDROLOGIC DROUGHT	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels.
AGRICULTURAL DROUGHT	Soil moisture deficiencies relative to water demands of plant life, usually crops.
SOCIOECONOMIC DROUGHT	The effect of demands for water exceeding the supply as a result of a weather-related supply shortfall.

[1] Multi-Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy, FEMA

LOCATION

Droughts occur regularly throughout Texas and the City of Houston and are considered a normal condition. However, they can vary greatly in their intensity and duration. The U.S. Drought Monitor, produced through a partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration, shows the planning area is currently not experiencing drought conditions but has experienced a range of conditions from abnormally dry to exceptional drought conditions over the last decade. There is no distinct geographic boundary to drought; therefore, it can occur throughout the City of Houston planning area equally.

Figure 8-1. U.S. Drought Monitor, February 2023, August 2022, August 2019, August 2011



EXTENT

The Palmer Drought Index is used to measure the extent of drought by measuring the duration and intensity of long-term drought-inducing circulation patterns. Long-term drought is cumulative, with the intensity of drought during the current month dependent upon the current weather patterns plus the cumulative patterns of previous months. The hydrological impacts of drought (e.g., reservoir levels, groundwater levels, etc.) take longer to develop. Table 8-2 depicts magnitude of drought, while Table 8-3 describes the classification descriptions.

Table 8-2. Palmer Drought Index

DROUGHT INDEX	DROUGHT CONDITION CLASSIFICATIONS						
	Extreme	Severe	Moderate	Normal	Moderately Moist	Very Moist	Extremely Moist
Z Index	-2.75 and below	-2.00 to -2.74	-1.25 to -1.99	-1.24 to +.99	+1.00 to +2.49	+2.50 to +3.49	n/a
Meteorological	-4.00 and below	-3.00 to -3.99	-2.00 to -2.99	-1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above
Hydrological	-4.00 and below	-3.00 to -3.99	-2.00 to -2.99	-1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above

Table 8-3. Palmer Drought Category Descriptions[2]

CATEGORY	DESCRIPTION	POSSIBLE IMPACTS	PALMER DROUGHT INDEX
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures; fire risk above average. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.	-1.0 to -1.9
D1	Moderate Drought	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent, voluntary water use restrictions requested.	-2.0 to -2.9
D2	Severe Drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed.	-3.0 to -3.9

[2] Source: National Drought Mitigation Center

CATEGORY	DESCRIPTION	POSSIBLE IMPACTS	PALMER DROUGHT INDEX
D3	Extreme Drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions.	-4.0 to -4.9
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells, creating water emergencies.	-5.0 or less

Drought is monitored nationwide by the National Drought Mitigation Center (NDMC). Indicators are used to describe broad scale drought conditions across the U.S. and correspond to the intensity of drought.

Based on the historical occurrences for drought and the location of the City of Houston can anticipate a range of drought from abnormally dry to exceptional, or D0 to D4, based on the Palmer Drought Category. The entire planning area has experienced exceptional drought conditions. This is the most extreme drought conditions the City can anticipate in the future.

The City monitors drought conditions and implements the City of Houston Drought Contingency Plan during periods of higher-than-normal temperatures and lower than normal rainfall.[3] The Drought Contingency Plan has four stages that include demand reduction goals and voluntary and mandatory water conservation measures that must be taken to meet those goals.



Table 8-4. Four Stages of the City of Houston Drought Contingency Plan[4]

STAGE	1	2	3	4
Demand Reduction Goal	5%	10%	20%	35%
Participation	Voluntary	Mandatory	Mandatory	Mandatory
Measure	2x week watering	2x week watering	No outdoor watering allowed	No outdoor watering allowed

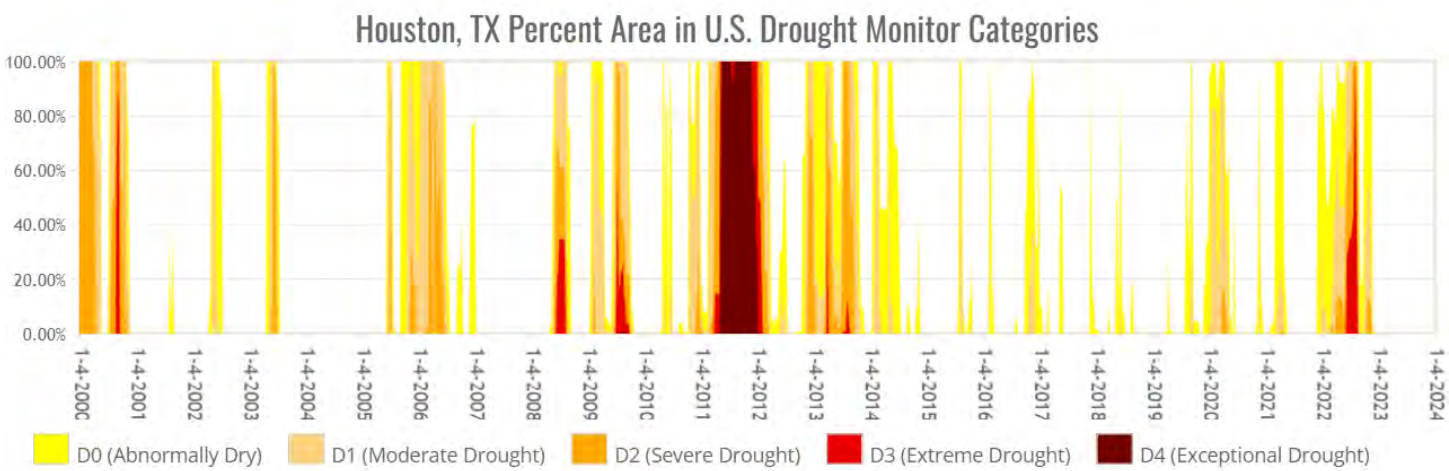
[3] City of Houston Public Works, Drought Contingency Plan, https://www.houstonpublicworks.org/drought-contingency-plan#230548828-3047462264

[4] City of Houston Public Works, https://www.houstonpublicworks.org/drought-contingency-plan#230548828-3047462264

HISTORICAL OCCURRENCES

The City of Houston may experience a severe drought in any given year. According to the U.S. Drought Monitor, in the 1,200 weeks between January 1, 2000, and December 31, 2022, the City of Houston spent 281 weeks (23 percent of the time) in some level of drought as defined as Abnormally Dry (D0) or worse conditions.

Figure 8-2. City of Houston Drought Intensity, January 2000-December 2022[5]



Historical drought information shows drought activity across a multi-county forecast area for each event, the appropriate percentage of the total property and crop damage reported for the entire forecast area has been allocated to each county impacted by the event. Historical drought data for are provided on a county-wide basis per the NCEI Storm Events database.

Table 8-5 lists historical events that have occurred in Harris County as reported in the National Centers for Environmental Information Storm Events Database (NCEI) and the U.S. Drought Monitor. A total of 24 unique drought periods have impacted Harris County between 1996 through December 2022. Additional events are listed under Significant Events below. Based on the historical drought events reported in the NCEI database for the Harris County and the City of Houston, in the past 26 years (1996-2022) events resulted in a total of $1,812,552 in property damages and $13,231,630 in crop damages countywide.

[5] U.S. Drought Monitor

Table 8-5. Historical Drought Years[6]

DROUGHT YEAR
1996
1998
2000
2001
2002
2003
2005
2006
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
24 unique events

[6] Historical data is reported from January 1996 through December 2022. No events were reported in the Storm Events Database for Harris County after September 2000. The US drought monitor data is only available from January 2000 to present.

Table 8-6. Total Losses Due to Drought Events

Jurisdiction	Total Property Damages	Total Crop Damages
Harris County	$1,812,552	$13,231,630
City of Houston[7]	$677,894	$4,948,630

Based on the list of historical drought events for the City of Houston planning area six events have occurred since the 2018 Plan.

SIGNIFICANT EVENTS

May 1998 – August 1998
Locations across southeast Texas were 8-12 inches below normal in rainfall amounts since March. Agriculture losses continue to escalate as well as heat related medical conditions. Afternoon highs were regularly around the century mark with overnight lows only falling into the upper 70s to lower 80s. With the exception of one day in July, afternoon highs remained above 96 degrees every day at Houston Intercontinental Airport as well as many other locations across the region. Relief came late in the month of August with rainfall and slightly cooler temperatures.

August 2000 – September 2000
The combination of excessive heat and dryness caused many wildfires to burn during the first week of the month. Water rationing was briefly instigated in the City of Houston. Water line breaks and small grass fires were a common problem across the planning area, especially at the beginning of the month of August.

September 2010 –April 2012
Statewide drought conditions began in fall 2010 and continued into spring of 2012 with the most exceptional conditions taking place in 2011. The National Weather Service noted 2011 as the driest year on record and second hottest for the state.[8] Impacts on the City of Houston included thousands of breaks in the water system and the loss of millions of trees throughout the city including half of the trees within Memorial Park.[9] [10] In total the City experienced 700 water main breaks a day in the summer of 2011, an increase of 200 breaks in a typical summer day.[11]

[7] Calculated as a percentage (37.4) of the county.
[8] Associated Press, "2011 was Texas' driest year on record", January 7, 2012. https://www.cbsnews.com/news/2011-was-texas-driest-year-on-record/
[9] Texas Comptroller of Public Accounts, "The Impact of the 2011 Drought and Beyond", February 6, 2012. https://texashistory.unt.edu/ark:/67531/metapth542095/m2/1/high_res_d/txcs-0790.pdf
[10] Williams, Jack, "Drought Killing at Least Half of Memorial Park Trees" October 3, 2011. https://www.houstonpublicmedia.org/articles/news/2011/10/03/30283/drought-killing-at-least-half-of-memorial-park-trees/
[11] City of Houston, "Houston Climate Impact Assessment 2.0", May 27, 2022. https://storymaps.arcgis.com/stories/ab02f9edd0904f3f83fbf080f41ad3f6

June 2022 – August 2022

In June 2022, Houston Public Works activated the first stage of the City's Drought Contingency Plan, after experiencing a below average monthly precipitation and higher-than-normal temperatures, with temperatures reaching above 100 degrees at both Houston Intercontinental Airport and Hobby Airports.[12] Drought conditions consisted into August 2022 causing the clay soil underground to become dry leading to the city's water pipes to shift and break.[13] Drought conditions largely subsided by September 2022 following a prolonged period of rain at the end of August into early September.[14]



PROBABILITY OF FUTURE EVENTS

Based on available records of historic events, there have been 24 extended time periods of drought within a 26-year reporting period. The probability of future events is 0.92 per year, or an event probable in the next year. This frequency supports a highly likely probability of future events. The City of Houston is included under the County. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Loss estimates were based on 26 years of statistical data from the NCEI. A drought event frequency-impact was then developed to determine an impact profile on agriculture products and estimate potential losses due to drought in the area. Table 8-7 shows annualized exposure.

Table 8-7. Potential Annualized Losses Due to Drought

JURISDICTION	PROPERTY & CROP LOSS	ANNUAL LOSS ESTIMATES
Harris County	$15,044,182	$578,622
City of Houston[15]	$5,626,524	$216,405

All existing and future buildings, facilities, and populations are exposed to this hazard and could potentially be impacted. However, drought impacts are mostly experienced in water shortages, breaks in water lines, or crop and livestock losses on agricultural lands and typically have minimal impact on buildings.

[12] Diaz, John, "City of Houston asks residents to conserve water due to drought conditions", June 22, 2022. https://www.khou.com/article/news/local/houston-residents-asked-to-conserve-water-amid-drought/285-990339d2-3e5b-435f-9d65-c8dfaa42d3b1

[13] Dougherty, Matt, "Houston drought conditions busting pipes throughout the city", August 10, 2022. https://www.khou.com/article/news/local/houston-drought-broken-pipes/285-91184918-29ba-4ebe-badd-4e00ec28a924

[14] Zuvanich, Adam "Much of Houston area moves out of drought after prolonged period of rainfall", September 12, 2022. https://www.houstonpublicmedia.org/articles/news/weather/2022/09/12/432766/much-of-houston-area-moves-out-of-drought-after-prolonged-period-of-rainfall/

[15] Calculated as a percentage (37.4) of the county.

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by drought events.

Table 8-8. Critical Facilities Vulnerable to Drought Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Increased law enforcement activities may be required to enforce water restrictions. ■ Firefighters may have limited water resources to aid in firefighting and suppression activities, increasing risk to lives and property. ■ Potential for increased number of emergency calls as drought events can lead to cascading hazard events such as wildfires and flash flooding.
64 Hospitals	■ Strain on staff as drought may cause health problems related to low water flows and poor water quality. ■ Water main breaks due to soil shrinking and swelling cycles could lead to facility closures. ■ Building foundations may crack due to soil shrinking and swelling cycles.
21 Airports	■ Operations dependent on water supply may be adversely impacted. ■ Economic disruptions due to cracked foundations and damaged infrastructure as a result of soil shrinking and swelling cycles.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

The City of Houston has a combination of over 1.2 billion gallons per day of reliable surface water rights and over 200 million gallons per day of available groundwater supplies.[16] Houston's Drinking Water Operations (DWO) is responsible for operating and maintaining three water purification plants and 56 ground water plants. Houston's water system serves approximately 2.2 million citizens each day and spans over 600 square miles serving four counties, therefore, making it one of the most complex water systems in the nation. Local lakes and rivers supply the surface water resources for the City of Houston. Eighty-seven percent of the planning areas water supply flows from the Trinity River into Lake Livingston, and from the San Jacinto River into Lake Conroe and Lake Houston. Deep underground wells drilled into the Evangeline and Chicot aquifers currently provide the other 13 percent of the City's water supply. While the planning area relies on multiple water resources, high demand can deplete these resources during extreme drought conditions. As

[16] Houston Public Works, Drinking Water Operations, https://www.houstonpublicworks.org/drinking-water-operations

resources are depleted, potable water is in short supply and overall water quality can suffer, elevating health concerns for all residents but especially vulnerable populations – typically children, the elderly, and the ill. In addition, potable water is used for drinking, sanitation, patient care, sterilization, equipment, heating and cooling systems, and many other essential functions in medical facilities.

The average person will survive only a few days without potable water, and this timeframe can be drastically shortened for those people with more fragile health – typically children, the elderly, and the ill. Population over 65 in the City of Houston planning area is estimated at 11 percent of the total population and children under the age of 5 are estimated at 7 percent, or an estimated total of 420,297 potentially vulnerable residents in the planning area based on age. In addition, an estimated 19.5 percent of the planning area population live below the poverty level which may contribute to overall health impacts of a drought.

This population is also vulnerable to food shortages when drought conditions exist, and potable water is in short supply. Potable water is used for drinking, sanitation, patient care, sterilization, equipment, heating and cooling systems, and many other essential functions in medical facilities. All residents in the City of Houston planning area could be adversely affected by drought conditions, which could limit water supplies and present health threats. During summer drought, or hot and dry conditions, elderly persons, small children, infants and the chronically ill who do not have adequate cooling units in their homes may become more vulnerable to injury and/or death.

The economic impact of droughts can be significant as they produce a complex web of impacts that spans many sectors of the economy and reach well beyond the area experiencing physical drought. This complexity exists because water is integral to our ability to produce goods and provide services. If droughts extend over a number of years, the direct and indirect economic impact can be significant.

Crop production can also suffer greatly during extreme drought conditions, limiting fresh local food supplies, driving up costs, and negatively impacting the local economy. The City of Houston has embraced community food production, from rooftop gardens to urban schoolyards. Drought conditions could adversely affect urban farming projects throughout the city.

Habitat damage is a vulnerability of the environment during periods of drought for both aquatic and terrestrial species. The environment also becomes vulnerable during periods of extreme or prolonged drought due to severe erosion and land degradation. The city's tree canopy and urban parks are also vulnerable to proloinged drought conditions as was experienced in during the 2011 drought.

Impact of droughts experienced in the City of Houston planning area, have not resulted injuries or fatalities supporting a " Minor" severity of impact meaning injuries and/or illnesses do not result in permanent disability, shutdown of facilities and services for more than one week, and more than 10 percent of property is destroyed or with major damage. Annualized estimated loss over the 26-year reporting period in the City of Houston is $216,405.

ASSESSMENT OF IMPACTS

The Drought Impact Reporter was developed in 2005 by the University of Nebraska-Lincoln to provide a national database of drought impacts. Droughts can have an impact on the agriculture; business and industry; energy; fire; plants and wildlife; relief, response, and restrictions; society and public health; tourism and recreation; and water supply and quality. The reports are submitted from individuals from Federal, State, and local agencies, as well as the general public. Table 8-7 lists the drought impacts to the City of Houston from 2005 to 2022 based on reports received by the Drought Impact Reporter.

Table 8-9. Drought Impacts, 2005-2022[17]

DROUGHT IMPACTS 2005-2022	
Agriculture	45
Business & Industry	6
Energy	1
Fire	20
Plants & Wildlife	41
Relief, Response & Restrictions	24
Society & Public Health	6
Tourism & Recreation	4
Water Supply & Quality	15

Drought has the potential to impact people in the City of Houston planning area. While it is rare that drought, in and of itself, leads to a direct risk to the health and safety of people in the U.S., severe water shortages could result in inadequate supply for human needs. Severe drought conditions can be frequently associated with a variety of impacts, including:

- Dry clay soil can lead to water main lines to shift and break. Often repair to water lines includes shutting off water to multiple homes at one time.
- The number of health-related low-flow issues (e.g., diminished sewage flows, increased pollution concentrations, reduced firefighting capacity, and cross-connection contamination) will increase as the drought intensifies.
- Public safety from forest/range/wildfires will increase as water availability and/or pressure decreases.
- Respiratory ailments may increase as the air quality decreases.
- There may be an increase in disease due to wildlife concentrations (e.g., rabies, Rocky Mountain spotted fever, Lyme disease).
- Residents may disagree with the City over water use/water rights, creating conflict.

[17] Drought Impact Reporter

- Political conflicts may increase between municipalities, counties, states, and regions.
- Water management conflicts may arise between competing interests.
- Severe water shortages could result in inadequate supply for human needs as well as lower quality of water for consumption.
- During drought there is an increased risk for wildfires and dust storms.
- The community may need increased operational costs to enforce water restriction or rationing.
- Prolonged drought can lead to increases in illness and disease related to drought.
- Utility providers can see decreases in revenue as water supplies diminish.
- Utilities providers may cut back energy generation and service to their customers to prioritize critical service needs.
- Hydroelectric power generation facilities and infrastructure would have significantly diminished generation capability. Dams simply cannot produce as much electricity from low water levels as they can from high water levels.
- Fish and wildlife food and habitat will be reduced or degraded over time during a drought and disease will increase, especially for aquatic life.
- Wildlife will move to more sustainable locations creating higher concentrations of wildlife in smaller areas, increasing vulnerability, and further depleting limited natural resources.
- Severe and prolonged drought can result in the reduction of a species or cause the extinction of a species altogether.
- Plant life will suffer from long-term drought. Wind and erosion will also pose a threat to plant life as soil quality will decline. The urban tree canopy, including city parks, are vulnerable to the impacts of prolonged drought.
- Dry and dead vegetation will increase the risk of wildfire.
- Drought poses a significant risk to annual and perennial crop production and overall crop quality leading to higher food costs.
- Drought related declines in production may lead to an increase in unemployment.
- Drought may limit livestock grazing resulting in decreased livestock weight, potential increased livestock mortality, and increased cost for feed.
- Negatively impacted water suppliers may face increased costs resulting from the transport water or develop supplemental water resources.
- Long term drought may negatively impact future economic development.
- Unlikely to have an impact on continuity of operations until prolonged severe or extreme levels are reached.
- Government functionality may be questioned and challenged if planning, response, and recovery are not timely and effective, impacting public confidence.

The overall extent of damages caused by periods of drought is dependent on its extent and duration. The level of preparedness and pre-event planning done by government, businesses, and citizens will contribute to the overall economic and financial conditions in the aftermath of a drought event.

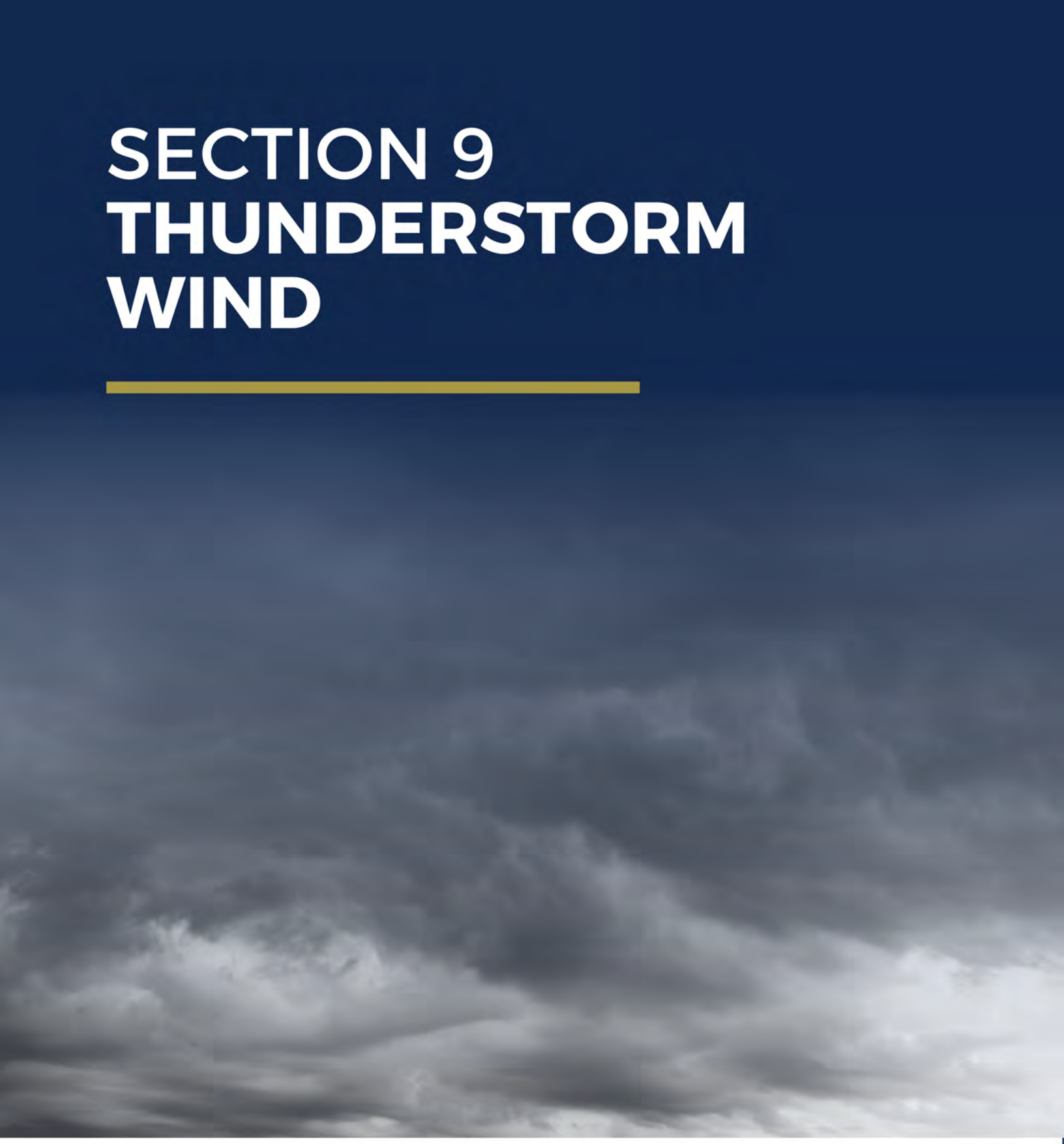
CLIMATE CHANGE CONSIDERATIONS

With the range of factors influencing drought conditions, it is impossible to make quantitative statewide projections of drought trends; however, many factors point toward increased drought severity. Drought will continue to be driven largely by precipitation variability over multiple decades, with long-term precipitation trends expected to be relatively small. Other factors affecting drought impacts, such as increased temperatures and improved plant water use efficiency, decrease water availability but will cause drought impact trends to be highly sector-specific, with the impacts possibly smaller for agriculture than for surface water supply.[18]

According to the Houston Climate Impact Assessment 2.0, the City of Houston will experience an increased likelihood of droughts in the future due to an estimated increase in the number of dry days in the City of Houston area. In addition, it is projected that future changes to the City of Houston will include increased temperatures, longer multi-day heatwaves and greater variability in precipitation, with an expected decrease in precipitation in the summer and increase in the fall.

[18] Cleaveland, M. K., T. H. Votteler, D. K. Stahle, R. C. Casteel, and J. L. Banner, 2011: Extended Chronology of Drought in South Central, Southeastern and West Texas. Texas Water Journal, 2, 54-96, as cited in Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 9
THUNDERSTORM WIND



OFFICE OF EMERGENCY MANAGEMENT

SECTION 9: THUNDERSTORM WIND

Hazard Description 1
Location 1
Extent 2
Historical Occurrences 3
Significant Events 10
Probability of Future Events 11
Vulnerability and Impact 11
Assessment of Impacts 13
Climate Change Considerations 14

HAZARD DESCRIPTION

Thunderstorms create extreme wind events which includes straight line winds. Wind is the horizontal motion of the air past a given point, beginning with differences in air pressures. Pressure that is higher at one place than another sets up a force pushing from the high toward the low pressure; the greater the difference in pressures, the stronger the force. The distance between the area of high pressure and the area of low pressure also determines how fast the moving air accelerates.

Thunderstorms are created when heat and moisture near the Earth's surface are transported to the upper levels of the atmosphere. By-products of this process are the clouds, precipitation, and wind that become the thunderstorm.



According to the National Weather Service (NWS), a thunderstorm occurs when thunder accompanies rainfall. Radar observers use the intensity of radar echoes to distinguish between rain showers and thunderstorms.

Straight line winds are responsible for most thunderstorm wind damages. One type of straight-line wind, the downburst, is a small area of rapidly descending air beneath a thunderstorm. A downburst can cause damage equivalent to a strong tornado and make air travel extremely hazardous.

LOCATION

Thunderstorm wind events can develop in any geographic location and are considered a common occurrence in Texas. Therefore, a thunderstorm wind event could occur at any location within the City of Houston's planning area, as these storms develop randomly and are not confined to any

geographic area within the City. It is assumed that the entire City of Houston planning area is uniformly exposed to the threat of thunderstorm winds.

EXTENT

The extent or magnitude of a thunderstorm wind event is measured by the Beaufort Wind Scale. Table 9-1 describes the different intensities of wind in terms of speed and effects, from calm to violent and destructive.

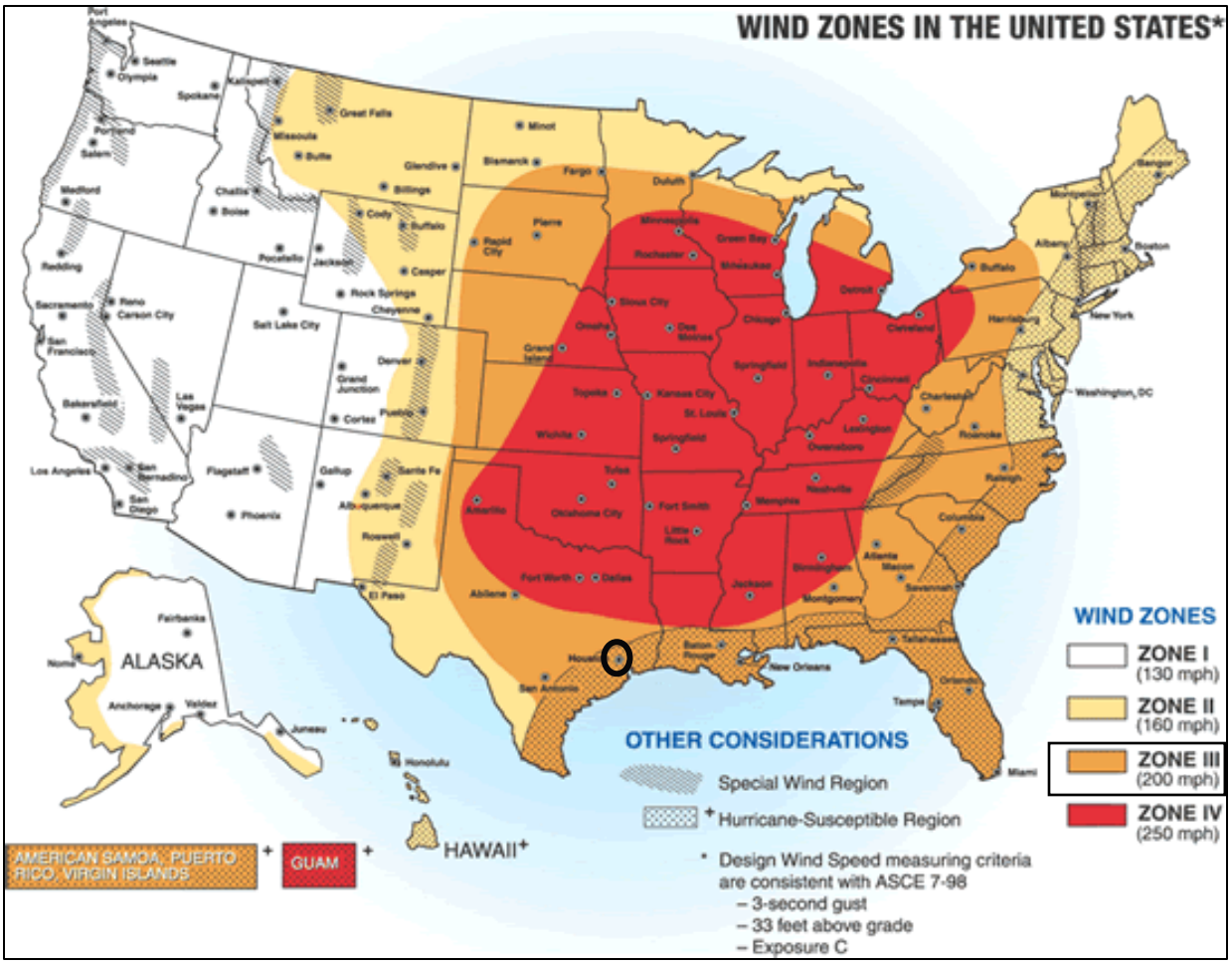
Table 9-1. Beaufort Wind Scale[1]

FORCE	WIND (MHP)	WMO CLASSIFICATION	APPEARANCE OF WIND EFFECTS
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-8	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	9-14	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	15-21	Moderate Breeze	Dust, leaves and loose paper lifted, small tree branches move
5	22-28	Fresh Breeze	Small trees in leaf begin to sway
6	29-36	Strong Breeze	Larger tree branches moving, whistling in wires
7	37-44	Near Gale	Whole trees moving, resistance felt walking against wind
8	45-53	Gale	Whole trees in motion, resistance felt walking against wind
9	54-62	Strong Gale	Slight structural damage occurs, slate blows off roofs
10	63-72	Storm	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	73-83	Violent Storm	If experienced on land, widespread damage
12	84+	Hurricane	Violence and destruction

Figure 9-1 displays the wind zones as derived from NOAA.

[1] Source: World Meteorological Organization

Figure 9-1. Wind Zones in the United States[2]



On average, the planning area experiences 7 to 8 thunderstorm wind events every year. The City is located within Wind Zone III, meaning it can experience winds up to 200 mph. The City of Houston has experienced a significant wind event, or an event with winds in the range of "Force 12" on the Beaufort Wind Scale with winds above 84 mph. This is the worst to be anticipated for the entire planning area. Based on a search of past events between 1955 and 2022, the greatest magnitude wind event the City of Houston has experienced was an 80 knots, or 92 mph, event at the Houston Hobby Airport on September 2, 1997. No impacts were reported as a result of this event.

HISTORICAL OCCURRENCES

The National Centers for Environmental Information (NCEI) Storm Events database is a national data source organized under the National Oceanic and Atmospheric Administration. The NCEI is the largest archive available for historic storm events data; however, it is important to note that the only incidents recorded are those that are reported to the NCEI from 1955 through 2022 have

[2] The City of Houston is indicated by the black circle.

been factored into this risk assessment. Tables 9-2 and 9-3 depict historical occurrences of thunderstorm wind events for the City of Houston planning area according to the NCEI database.

Since 1955, 188 thunderstorm wind events are known to have occurred in the City of Houston planning area; based upon NCEI records, 144 events resulted in damages. An additional thunderstorm event was reported by the planning team. Table 9-3 presents information on known historical events impacting the City of Houston planning area with resulting in damages, injuries, or fatalities. It is important to note that high wind events associated with other hazards, such as tornadoes, are not accounted for in this section. Property damage estimates are not always available. Where an estimate has been provided in a table for losses, the dollar amounts have been altered to indicate the damage in 2022 dollars.

Table 9-2. Historical Thunderstorm Wind Events with Reported Damages, 1955-2022

MAXIMUM WIND SPEED RECORDED (Knots)	NUMBER OF REPORTED EVENTS
0-30	10
31-40	0
41-50	15
51-60	30
61-70	10
71-80	1
81-90	0
91-100+	0
Unknown	82

Table 9-3. Historical Thunderstorm Wind Events, 1955-2022[3]

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	3/7/1995	4:00 AM	0	0	0	$97,811	$0
City of Houston	6/1/1995	1:00 AM	0	0	0	$48,553	$0
City of Houston	6/11/1995	2:55 AM	0	0	0	$194,210	$0
Alief	6/11/1995	3:40 AM	0	0	0	$1,942	$0
City of Houston	9/21/1995	1:35 PM	0	0	0	$96,662	$0
City of Houston	11/11/1995	1:45 AM	0	0	0	$28,923	$0

[3] Only recorded events with fatalities, injuries or damages are listed. Magnitude is listed when available. Damage values are in 2022 dollars.

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	11/11/1995	2:00 AM	0	0	0	$9,641	$0
City of Houston	12/17/1995	10:28 AM	0	0	0	$9,647	$0
City of Houston	12/17/1995	10:40 AM	0	0	2	$38,589	$0
City of Houston	12/18/1995	5:15 AM	0	0	0	$1,929,453	$0
City of Houston	4/22/1996	4:11 PM	Unknown	0	0	$9,474	$0
City of Houston	4/22/1996	4:26 PM	Unknown	0	0	$9,474	$0
City of Houston	5/11/1996	2:45 PM	Unknown	0	0	$37,825	$0
City of Houston	6/2/1996	4:40 PM	50	0	0	$9,450	$0
City of Houston	6/2/1996	4:50 PM	Unknown	0	0	$9,450	$0
City of Houston	6/2/1996	4:55 PM	Unknown	0	0	$9,450	$0
City of Houston	6/3/1996	2:20 PM	Unknown	0	0	$9,450	$0
City of Houston	6/4/1996	4:20 PM	Unknown	0	0	$9,450	$0
City of Houston	6/13/1996	3:20 PM	Unknown	0	0	$9,450	$0
City of Houston	6/18/1996	7:45 PM	Unknown	0	0	$9,450	$0
City of Houston	6/18/1996	8:05 PM	Unknown	0	0	$5,670	$0
City of Houston	6/20/1996	3:45 PM	Unknown	0	0	$28,351	$0
City of Houston	6/20/1996	4:00 PM	Unknown	0	0	$472,513	$0
(IAH) Houston Intl Airport	6/20/1996	4:22 PM	50	0	0	$9,450	$0
City of Houston	7/24/1996	1:25 PM	Unknown	0	0	$18,864	$0
City of Houston	8/10/1996	7:25 PM	Unknown	0	0	$9,414	$0
City of Houston	8/10/1996	7:30 PM	Unknown	0	0	$9,414	$0
City of Houston	8/10/1996	7:33 PM	Unknown	0	0	$9,414	$0
City of Houston	8/12/1996	1:40 PM	Unknown	0	0	$28,243	$0
Addicks	8/12/1996	1:40 PM	Unknown	0	0	$9,414	$0
City of Houston	8/12/1996	2:51 PM	Unknown	0	0	$56,485	$0
South Houston	8/19/1996	1:20 PM	Unknown	0	0	$94,142	$0
City of Houston	9/17/1996	2:50 PM	Unknown	0	0	$9,384	$0

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	9/17/1996	4:10 PM	Unknown	0	0	$9,384	$0
City of Houston	2/20/1997	5:00 PM	Unknown	0	0	$18,557	$0
City of Houston	2/20/1997	5:15 PM	Unknown	0	0	$9,279	$0
City of Houston	4/5/1997	1:00 AM	Unknown	0	0	$18,488	$0
City of Houston	4/11/1997	5:00 AM	Unknown	0	0	$9,244	$0
Clear Lake City	4/11/1997	5:00 AM	Unknown	0	0	$3,698	$0
City of Houston	5/28/1997	10:00 AM	Unknown	0	0	$9,250	$0
City of Houston	5/30/1997	10:42 PM	Unknown	0	0	$36,998	$0
City of Houston	5/30/1997	10:42 PM	Unknown	0	0	$46,248	$0
City of Houston	6/17/1997	10:50 AM	60	0	0	$27,714	$0
City of Houston	6/17/1997	10:55 AM	65	0	2	$55,428	$0
City of Houston	6/17/1997	10:55 AM	65	0	6	$55,428	$0
City of Houston	6/17/1997	11:00 AM	Unknown	0	0	$46,190	$0
City of Houston	6/17/1997	11:05 AM	65	0	0	$27,714	$0
City of Houston	6/17/1997	11:15 AM	Unknown	0	0	$369,521	$0
Clear Lake City	6/17/1997	11:30 AM	Unknown	0	0	$55,428	$0
Clear Lake City	6/17/1997	11:35 AM	Unknown	0	0	$46,190	$0
City of Houston	7/14/1997	5:16 PM	Unknown	0	0	$9,227	$0
City of Houston	9/2/1997	4:20 PM	Unknown	0	0	$9,186	$0
City of Houston	9/9/1997	6:10 PM	Unknown	0	0	$27,559	$0
City of Houston	12/23/1997	4:59 PM	Unknown	0	0	$73,446	$0
City of Houston	12/23/1997	5:25 PM	Unknown	0	0	$36,723	$0
City of Houston	2/10/1998	12:05 PM	Unknown	0	2	$137,201	$0
City of Houston	2/16/1998	5:49 PM	51	0	0	$5,488	$0
City of Houston	2/16/1998	5:50 PM	Unknown	0	0	$12,805	$0
City of Houston	7/14/1998	3:12 PM	61	0	0	$18,148	$0
City of Houston	7/14/1998	3:40 PM	Unknown	0	0	$45,369	$0

SECTION 9: THUNDERSTORM WIND

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	7/14/1998	2:56 PM	Unknown	0	0	$18,148	$0
City of Houston	7/17/1998	5:35 PM	Unknown	0	0	$27,222	$0
City of Houston	7/17/1998	7:00 PM	Unknown	0	0	$18,148	$0
City of Houston	8/3/1998	4:25 PM	Unknown	0	0	$9,063	$0
City of Houston	8/5/1998	4:45 PM	Unknown	0	0	$18,126	$0
City of Houston	10/6/1998	6:50 AM	52	0	0	$5,418	$0
City of Houston	1/1/1999	11:24 PM	52	0	0	$9,013	$0
City of Houston	3/13/1999	2:30 AM	Unknown	0	0	$44,874	$0
City of Houston	5/10/1999	5:15 AM	Unknown	0	0	$891,008	$0
City of Houston	5/12/1999	1:06 AM	Unknown	0	0	$26,730	$0
City of Houston	8/31/1999	3:10 PM	Unknown	0	0	$354,484	$0
City of Houston	8/31/1999	3:30 PM	Unknown	1	0	$1,754,694	$0
City of Houston	5/2/2000	1:15 AM	Unknown	0	0	$345,389	$0
City of Houston	5/2/2000	2:05 AM	69	0	0	$43,174	$0
City of Houston	5/3/2000	4:30 PM	Unknown	0	0	$86,347	$0
City of Houston	5/3/2000	4:55 PM	Unknown	0	0	$172,694	$0
City of Houston	5/4/2000	2:45 PM	Unknown	0	0	$25,904	$0
City of Houston	7/23/2000	2:45 PM	Unknown	0	0	$85,698	$0
City of Houston	7/23/2000	3:30 PM	Unknown	0	0	$25,709	$0
City of Houston	8/2/2000	3:45 PM	Unknown	0	0	$171,395	$0
City of Houston	8/2/2000	4:00 PM	Unknown	0	0	$171,395	$0
City of Houston	8/11/2000	6:45 PM	Unknown	0	0	$171,395	$0
South Houston	8/11/2000	7:20 PM	Unknown	0	0	$171,395	$0
(HOU) Houston Hobby Airport	8/22/2000	10:28 AM	68	0	0	$171,395	$0
City of Houston	11/5/2000	11:45 PM	Unknown	0	0	$85,058	$0
(HOU) Houston Hobby Airport	11/12/2000	8:01 PM	68	0	0	$25,517	$0
City of Houston	11/12/2000	7:40 PM	Unknown	0	2	$255,173	$0

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	11/12/2000	7:50 PM	Unknown	0	0	$255,173	$0
City of Houston	11/12/2000	7:25 PM	Unknown	0	0	$25,517	$0
City of Houston	3/14/2001	2:50 PM	Unknown	0	0	$33,618	$0
City of Houston	3/14/2001	3:05 PM	Unknown	0	0	$33,618	$0
City of Houston	4/16/2001	2:30 PM	Unknown	0	0	$25,113,426	$0
City of Houston	4/16/2001	3:45 PM	Unknown	0	0	$16,742,284	$0
City of Houston	6/1/2001	7:10 PM	Unknown	0	0	$16,639	$0
City of Houston	6/28/2001	5:30 PM	Unknown	0	0	$49,916	$0
City of Houston	8/6/2001	6:30 PM	Unknown	0	0	$33,371	$0
City of Houston	8/6/2001	6:30 PM	Unknown	0	0	$25,029	$0
City of Houston	8/6/2001	5:33 PM	Unknown	0	0	$25,029	$0
Houston Heights	8/26/2001	1:30 PM	Unknown	0	0	$16,686	$0
City of Houston	9/20/2001	6:20 PM	Unknown	0	0	$24,916	$0
City of Houston	9/20/2001	6:50 PM	Unknown	0	0	$8,305	$0
Alief	6/16/2002	5:25 AM	Unknown	0	0	$16,463	$0
City of Houston	8/3/2002	4:00 PM	Unknown	1	0	$24,585	$0
City of Houston	8/4/2002	5:20 PM	Unknown	0	0	$40,976	$0
City of Houston	12/23/2002	9:30 PM	52	0	0	$1,637	$0
City of Houston	12/23/2002	9:15 PM	61	0	0	$122,791	$0
City of Houston	12/23/2002	9:21 PM	52	0	0	$1,637	$0
Seabrook	7/11/2003	1:57 PM	60	0	0	$17,716	$0
(HOU) Houston Hobby Airport	7/18/2003	11:50 AM	58	0	0	$4,832	$0
City of Houston	4/10/2004	7:13 PM	50	0	0	$15,754	$0
Lake Houston	5/1/2004	8:55 AM	58	0	0	$78,311	$0
City of Houston	7/25/2004	2:30 PM	50	0	0	$117,280	$0
Addicks	5/8/2005	4:10 PM	52	0	0	$19,806	$0
City of Houston	5/8/2005	5:06 PM	51	0	0	$7,618	$0

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	5/29/2005	9:54 PM	53	0	0	$10,665	$0
City of Houston	7/6/2005	4:45 PM	50	0	0	$12,126	$0
City of Houston	7/13/2005	1:45 PM	57	0	0	$98,522	$0
City of Houston	10/31/2005	4:48 PM	52	0	0	$17,842	$0
Ellington Field	5/14/2006	3:05 PM	50	0	0	$10,238	$0
Alief	7/18/2006	11:15 AM	55	0	0	$29,108	$0
City of Houston	8/22/2006	6:17 PM	53	0	0	$14,525	$0
Addicks	10/10/2006	11:45 AM	50	0	0	$1,468	$0
Houston Heights	3/13/2007	9:09 PM	52	0	0	$21,634	$0
City of Houston	3/31/2007	5:30 AM	59	0	0	$281,241	$0
City of Houston	5/14/2007	3:15 PM	55	0	0	$49,849	$0
(IAH) Houston Intl Airport	6/28/2007	2:30 PM	56	0	0	$99,505	$0
Seabrook	1/31/2008	9:50 AM	52	0	0	$7,016	$0
(EFD) Ellington Air Force Base	8/26/2008	2:05 PM	70	0	0	$40,555	$0
Houston Heights	4/27/2009	5:25 PM	50	0	0	$694	$0
Houston Collier Airport	8/12/2009	4:00 PM	52	0	0	$6,861	$0
Houston Heights	5/28/2010	7:00 PM	50	0	0	$4,072	$0
Englewood	6/6/2011	2:20 PM	54	0	0	$13,121	$0
Houston Heights	3/20/2012	7:30 AM	52	0	0	$6,456	$0
Houston Lakeside Airport	6/26/2012	2:45 PM	65	0	0	$19,359	$0
Houston Heights	8/16/2013	4:57 PM	56	0	0	$0	$10,131
Englewood	10/6/2014	11:25 AM	50	0	0	$2,495	$0
Clear Lake City	4/17/2015	7:30 PM	60	0	0	$5,007	$0
Clear Lake City	4/17/2015	7:48 PM	71	0	0	$0	$18,777
(EFD) Ellington Air Force Base	12/7/2018	9:54 PM	52	0	0	$17,683	$0
Englewood	12/27/2018	5:30 AM	51	0	0	$0	$0

LOCATION	DATE	TIME	MAGNITUDE (Knots)	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Houston Heights	4/7/2019	11:30 AM	52	0	0	$0	$17,384
White Oak Acres	5/4/2019	1:30 AM	50	0	0	$5,783	$0
Clear Lake City	7/30/2019	3:45 PM	56	0	0	$0	$0
Houston Heights	8/28/2019	4:24 PM	50	0	0	$6,926	$0
Houston Weiser Airport	4/9/2020	4:47 PM	50	0	1	$11,552	$0
Englewood	5/27/2020	3:36 PM	51	0	0	$0	$2,426
Houston Heights	10/23/2020	1:44 PM	50	0	0	$455	$0
Englewood	6/15/2021	5:10 PM	50	0	0	$5,450	$0
Mt Houston	10/27/2021	8:00 AM	51	0	0	$3,212	$0
TOTAL				2	15	$53,419,942	$48,718

Based on the list of historical thunderstorm wind events for the City of Houston planning area (listed above) eleven of the events have occurred since the 2018 Plan that have caused impacts to the City.

SIGNIFICANT EVENTS

August 31, 1999
A construction worker was killed when the Hawthorne Suites Motel under construction at intersection of Beltway 8 and Stancliff collapsed. Roof damage was reported at Gillman Subaru at Bellaire and US 59, and a wall of glass was blown down at the Red Lion Hotel in the Galleria area. Multiple power lines were downed in the Westbury area. In addition, there were numerous reports of trees down across central and southwest Houston including along 5th Street in Alief and in the Westbury area. The highest wind gust was reported at 63 mph near US 59.

August 11, 2015
Record breaking daytime heat in combination with a weak southward sagging cold front and the inland moving sea breeze front produced late afternoon through early evening thunderstorms that became severe. This storm event included strong damaging winds and hail. Wind gusts were measured at 69 mph at the Houston Hobby Airport.

April 9, 2020
Severe thunderstorms produced a lot of wind damage and some hail. A tree was downed a fell onto a house near Timberlake Drive. One woman suffered a broken arm. The highest wind gust was reported as 58 mph and a total of $11,552 in property damage was reported.

PROBABILITY OF FUTURE EVENTS

Most thunderstorm winds occur during the spring and fall seasons and during the months of March, April, May, and September. Based on available records of historic events, there have been 188 events in a 72-year reporting period, which provides a probability of three events every year. Even though the intensity of thunderstorm wind events is not always damaging for the City of Houston, the frequency of occurrence for a thunderstorm wind event is highly likely. This means that an event is probable within the next year for the City of Houston planning area. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Vulnerability is difficult to evaluate since thunderstorm wind events can occur at different strength levels, in random locations, and can create relatively narrow paths of destruction. Due to the randomness of these events, all existing and future structures and facilities within the City of Houston planning area could potentially be impacted and remain vulnerable to possible injury and property loss from strong winds.

Trees, power lines and poles, signage, manufactured housing, radio towers, concrete block walls, storage barns, windows, garbage recepticles, brick facades, and vehicles, unless reinforced, are vulnerable to thunderstorm wind events. More severe damage involves windborne debris; in some instances, patio furniture and other lawn items have been reported to have been blown around by wind and, very commonly, debris from damaged structures in turn have caused damage to other buildings not directly impacted by the event. In numerous instances roofs have been reported as having been torn off of buildings. The portable buildings typically used at schools and construction sites would be more vulnerable to thunderstorm wind events than typical site-built structures and could potentially pose a greater risk for wind-blown debris.

According to the American Community Survey, five-year estimates for 2021, a total of 9,450 manufactured homes are located in the City of Houston planning area (1 percent), a 16 percent increase in these types of housing from 2018. Another factor of manufactured homes that may increase vulnerability is the age of installation. Inspection of manufactured home installations changed in 2011 when the process was revised statewide, therefore manufactured homes installed prior to 2011 may be more vulnerable to damages from wind events. In addition, 51 percent (approximately 504,772 structures) of the housing units were built before 1980. These structures would typically be built to lower or less stringent construction standards than newer construction and may be more susceptible to damage during significant wind events.

While all citizens are vulnerable to the impacts of thunderstorm wind, forced relocation and disaster recovery drastically impacts low-income residents who lack the financial means to travel, afford a long-term stay away from home, and to rebuild or repair their homes. An estimated 19.5 percent of the planning area population live below the poverty level. Renters also tend to be more vulnerable to the impacts of wind events and their ability to recover after an event. Within the City, 58 percent of housing units are renter-occupied. While warning times for these type of hazard events should be substantial enough for these individuals to seek shelter, individuals who work and recreate outside are also vulnerable to potential impacts of a thunderstorm wind event.

SECTION 9: THUNDERSTORM WIND

Critical facilities within the City including emergency services, health care, airports, and water, wastewater and water purification plants are all vulnerable to the impacts of thunderstorm wind event. Vulnerability of critical infrastructure to thunderstorms is greatest in power and communications facilities, which can result in loss of service and cascading impacts. The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by thunderstorm wind events.

Table 9-5. Critical Facilities Vulnerable to Thunderstorm Wind

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Emergency vehicles can be damaged by falling trees or flying debris. ■ Power outages could disrupt communications, delaying emergency response times. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Debris/downed trees can impede emergency response vehicle access to areas. ■ Increased number of structure fires due to gas line ruptures and downed power lines, further straining the capacity and resources of emergency personnel. ■ First responders are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions.
64 Hospitals	■ Structures can be damaged by falling trees or flying debris. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Evacuations may be necessary due to extended power outages, gas line ruptures, or structural damages to facilities.
21 Airports	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications and emergency operations. ■ Temporary break in operations may significantly inhibit post event evacuations. ■ Damaged or destroyed highway infrastructure may substantially increase the need for airport operations.

CRITICAL FACILITIES	POTENTIAL IMPACTS
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

A thunderstorm wind event can also result in traffic disruptions, injuries and in rare cases, fatalities. Impact of thunderstorms winds experienced in the City of Houston planning area has resulted in fifteen injuries and two fatalities. Impact of thunderstorm wind events experienced in the City of Houston, would be considered "Limited," with less than 10 percent of property expected to be destroyed and critical facilities shut down for less than 24-hours. However, with fifteen injuries and two fatalities, the impact is considered "Substantial" with multiple deaths possible depending on the severity of the event. Overall, in the past 72 years there has been a total of $53,468,660 damages (in 2022 dollars) in the City of Houston due to thunderstorm wind events. The estimated average annual loss from a thunderstorm wind event is $742,620.

ASSESSMENT OF IMPACTS

Thunderstorm wind events have the potential to pose a significant risk to people and can create dangerous and difficult situations for public health and safety officials. Thunderstorm wind conditions can be frequently associated with a variety of impacts, including:

- Individuals exposed to the storm can be struck by flying debris, falling limbs, or downed trees causing serious injury or death.
- Structures can be damaged or crushed by falling trees, which can result in physical harm to the occupants.
- Significant debris and downed trees can result in emergency response vehicles being unable to access areas of the community.
- Downed power lines may result in roadways being unsafe for use, which may prevent first responders from answering calls for assistance or rescue.
- During exceptionally heavy wind events, first responders may be prevented from responding to calls, as the winds may reach a speed in which their vehicles and equipment are unsafe to operate.
- Thunderstorm wind events often result in widespread power outages increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outage often results in an increase in structure fires and carbon monoxide poisoning, as individuals attempt to cook or heat their homes with alternate, unsafe cooking or heating devices, such as grills.

- First responders are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions.
- Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications.
- Critical staff may be unable to report for duty, limiting response capabilities.
- City departments may be damaged, delaying response and recovery efforts for the entire community.
- Private sector entities that the City and its residents rely on, such as utility providers, financial institutions, and medical care providers may not be fully operational and may require assistance from neighboring communities until full services can be restored.
- Economic disruption negatively impacts the programs and services provided by the community due to short- and long-term loss in revenue.
- Some businesses not directly damaged by thunderstorm wind events may be negatively impacted while roads are cleared and utilities are being restored, further slowing economic recovery.
- Older structures built to less stringent building codes may suffer greater damage as they are typically more vulnerable to thunderstorm winds. 51 percent of homes in the City were built before 1980. 265 buildings and sites in the City are on the National Register of Historic Places, many of which pre-date modern building codes.
- Large scale wind events can have significant economic impact on the affected area, as it must now fund expenses such as infrastructure repair and restoration, temporary services and facilities, overtime pay for responders, and normal day-to-day operating expenses.
- Businesses that are more reliant on utility infrastructure than others may suffer greater damages without a backup power source.
- Recreational areas and parks may be damaged or inaccessible due to downed trees or debris, causing temporary impacts to area businesses.

The economic and financial impacts of thunderstorm winds on the area will depend entirely on the scale of the event, what is damaged, and how quickly repairs to critical components of the economy can be implemented. The level of preparedness and pre-event planning done by the community, local businesses, and citizens will also contribute to the overall economic and financial conditions in the aftermath of any thunderstorm wind event.

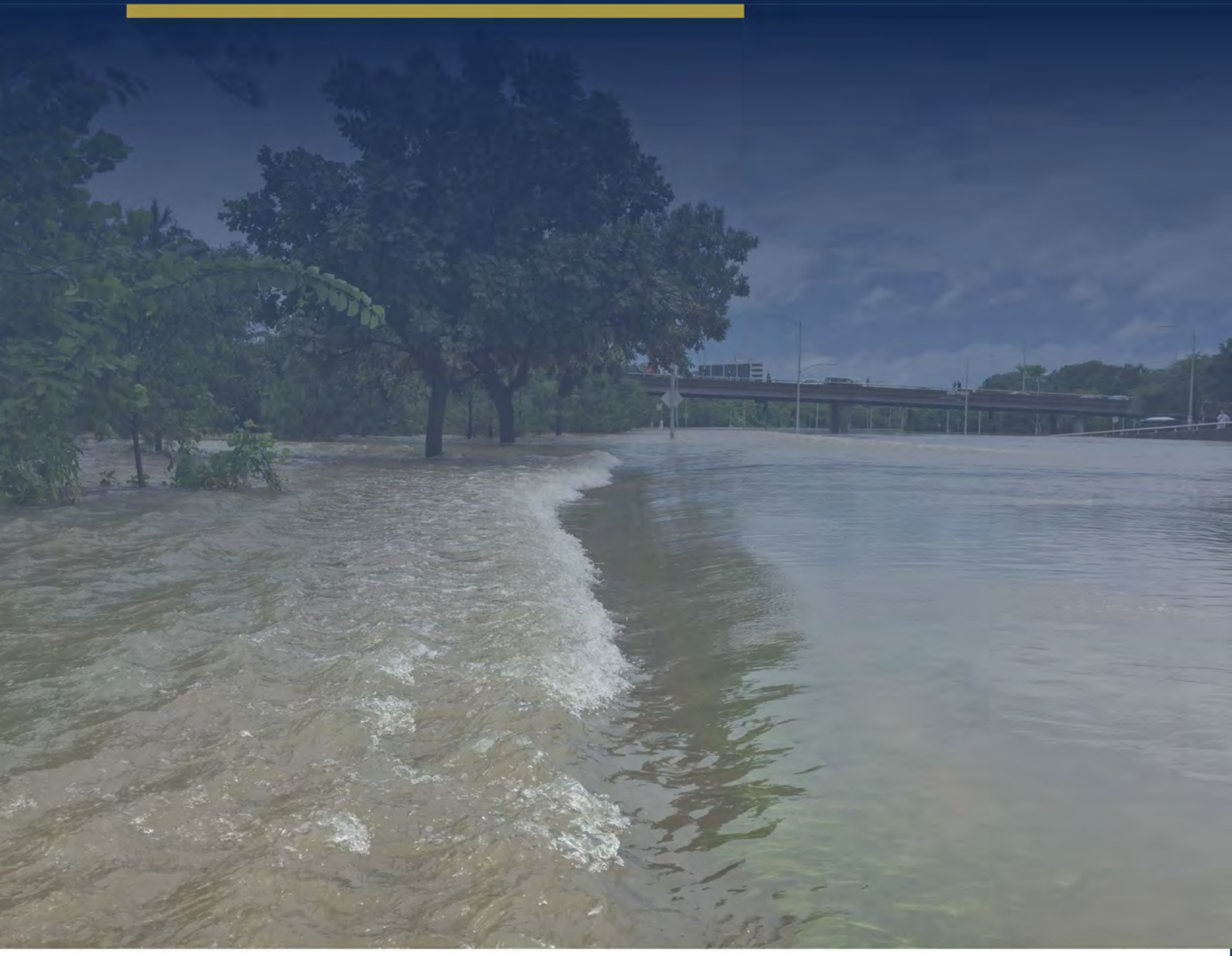
CLIMATE CHANGE CONSIDERATIONS

The impacts on the frequency and severity of severe thunderstorm wind events due to climate change are unclear. According to the Texas A&M 2021 Climate Report Update, changes in severe thunderstorm reports over time have been more closely linked to changes in population than changes in the hazard event. At this time there is low confidence of an ongoing trend in the overall frequency and severity of thunderstorm events, due to the lack of climate data records for severe thunderstorms. Based on climate models that are available, the environmental conditions needed

for severe thunderstorms are estimated to become more likely, resulting in an overall increase in the number of days capable of producing a severe thunderstorm event.[4]

[4] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 10
DAM FAILURE



OFFICE OF EMERGENCY MANAGEMENT

SECTION 10: DAM FAILURE

Portions of the City of Houston Hazard Mitigation Plan Update 2023 are considered confidential and not for release to the public. The information in this section is covered under Privacy Act of 1974 (5 U.S.C. Section 552a).

SECTION 11
EXPANSIVE SOILS



OFFICE OF EMERGENCY MANAGEMENT

SECTION 11: EXPANSIVE SOILS

Hazard Description 1
Location 1
Extent 2
Historical Occurrences 3
Probability of Future Events 4
Vulnerability and Impact 4
Assessment of Impacts 5
Climate Change Considerations 7

HAZARD DESCRIPTION



Expansive soils are soils and soft rocks with a relatively high percentage of clay minerals that are subject to changes in volume as they swell and shrink with changing moisture conditions. Expansive soils contain minerals such as smectite clays that are capable of absorbing water. When these clays absorb water, they increase in volume and expand. The change in soil volume and resulting expansion can exert enough force on a building or other structure to cause damage.

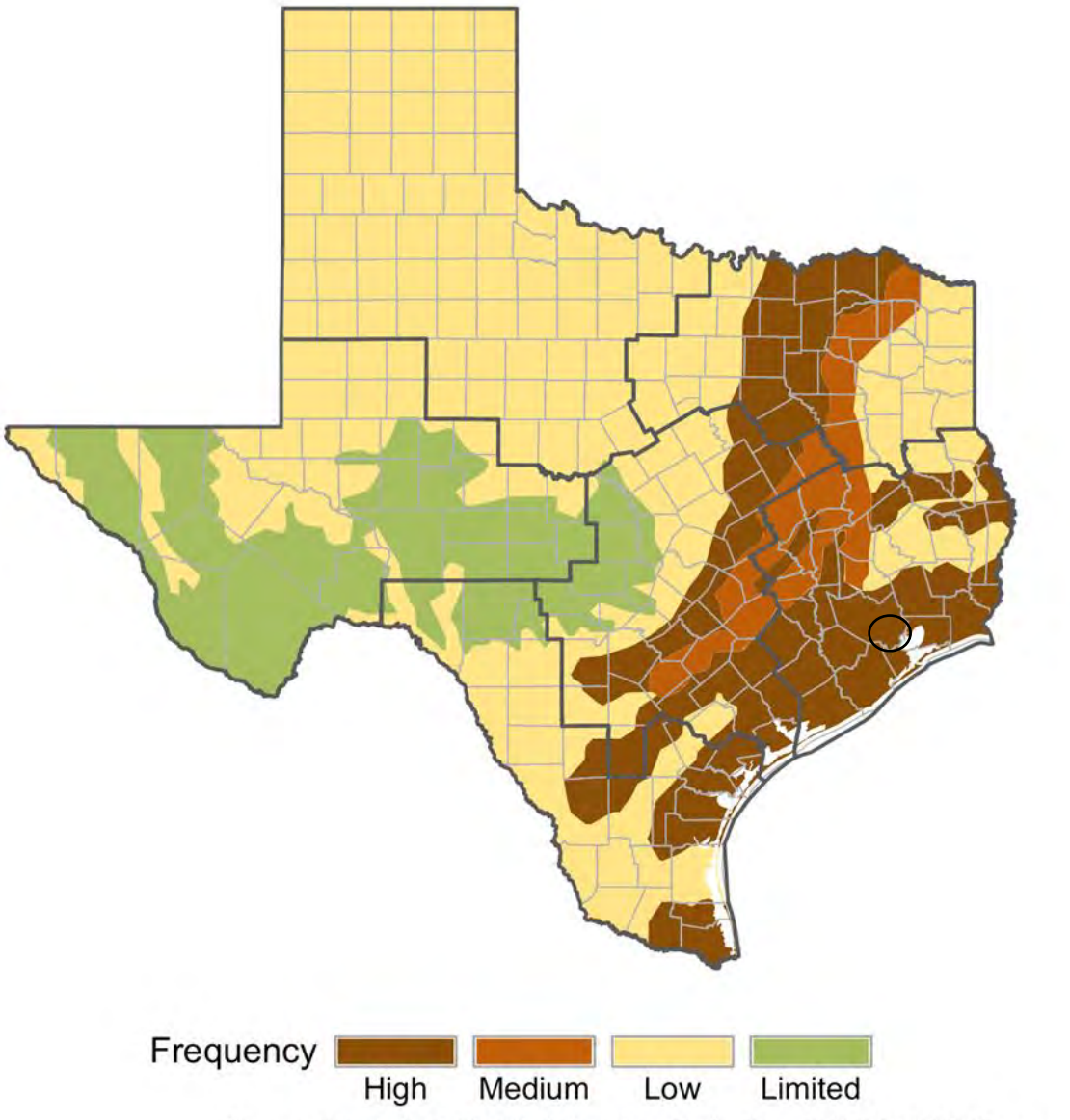
Expansive soils will also lose volume and shrink when they dry. Drought conditions can cause soils to contract in response to a loss of soil moisture. A reduction in soil volume can affect the support to buildings or other structures and result in damage. Fissures in the soil can also develop and facilitate the deep penetration of water when moist conditions or runoff occurs. This produces a cycle of shrinkage and swelling that place repetitive stress on structures. The effect of expansive soil is most prevalent in regions prone to prolonged periods of drought followed by periods of moderate to high precipitation. Expansions in soil of 10 percent or more are not uncommon in the City of Houston planning area.

LOCATION

In Texas the most expansive soils are in a band 200 miles west from the coastline, stretching approximately from Beaumont down to Brownsville. These areas receive the most moisture and are also vulnerable to droughts, which can cause the soil to contract. In the City of Houston planning area, the problems associated with expansive soil typically occur during drought periods. Expansive soils (bentonite, smectite, or other reactive clays) expand when the soil particles attract water and can shrink when the clay dries.

Figure 11-1 shows areas of expansive soil in Texas. All of Harris County falls within the highest risk area, indicated in brown.

Figure 11-1. Location of Expansive Soils in Texas[1]



Source: Tavakoli, E. (2016). Laboratory Evaluation of TX-PROCHEM as an Ionic Liquid Soil Stabilizer. [Master's Thesis].

EXTENT

The extent to which soil expansion is present in an area can be determined using the predominant soil composition and associated permeability. The Soil Survey was developed by the USDA Soils Conservation Service and contains information that can be applied in determining the suitability of soils in the planning area when selecting sites for roads, structures, and infrastructure.[2]

[1] Tavakoli, E. (2016). Laboratory Evaluation of TX-PROCHEM as an Ionic Liquid Soil Stabilizer. [Master's Thesis].
[2] USDA, http://www.nrcs.usda.gov

Table 11-1. Swelling Potential of Soils and Plasticity Index[3]

POTENTIAL EXPANSION	EXPANSION INDEX
Low	0 – 15
Medium	10 – 35
High	20 – 55
Very High	35 and above

The amount and depth of potential swelling that can occur in a clay material are, to some extent, functions of the cyclical moisture content in the soil. In drier climates where the moisture content in the soil near the ground surface is low because of evaporation, there is a greater potential for extensive swelling than in the same soil in wetter climates where the variations of moisture content are not as severe. Volume changes in highly expansive soils range between 7 and 10 percent, however under abnormal conditions, they can reach as high as 25 percent.

The City of Houston is primarily (89%) comprised of 4 major soil types. These soils present an expansion index (plasticity index) from low to moderate ranges as depicted in Table 11-2.

Table 11-2. Primary Soils and Associated Plasticity Index – City of Houston

SOIL TYPE	PLASTICITY INDEX
Lake Charles Urban Land Part	12-20
Bernard Urban Land Part	12-30
Midland Urban Land Part	12-20
Beaumont Urban Land Part	12-30

HISTORICAL OCCURRENCES

Expansive soil is a condition that is native to Texas soil characteristics and cannot be documented as a time-specific event, except when it leads to structural and infrastructure damage. Extreme conditions can damage roads, structures, and infrastructure, including projects still under construction. Damages from expansive soils are typically associated with droughts, previous occurrences for expansive soils can be correlated with previous occurrences of drought, which are typically negligible.

The City of Houston has experienced three known events. During a wet period in the summer of 2012, the ground expanded and led to cracks in streets. Drought conditions in 2011 and 2022 caused the clay soil underground to contract and shift leading to thousands of broken water pipes. In total the City experienced 700 water main breaks a day in the summer of 2011, an increase of

[3] Panjaitan, Surta Ria Nurliana. "The Effects of Lime Content on the Bearing Capacity and Swelling Potential of Expansive Soil". Journal of Civil Engineering Research. 2014.

200 breaks in a typical summer day.[4] Refer to Section 8 Drought for more information on the impacts of past drought events.

PROBABILITY OF FUTURE EVENTS

The Texas Department of Licensing and Regulation requires structures built after 2005 to include soil tests to be conducted for the likelihood of soil expansion, compression or shifting. In such cases, top or subsoils are required to be removed and remaining soils stabilized. Builders must ensure that water drains away from the structure on all sides and building owners notified of the potential for damage if changes in drainage flow occur. These measures significantly reduce the probability of expansive soil impacts on newer and future development. It is considered "Likely" that the high-risk areas in the City of Houston will experience some expansive soil impacts such as problems with foundations, roadways, sidewalks and other structures and infrastructure in the future, especially during times of drought. Older structures will be impacted with greater frequency due to the soil testing and stabilization requirements for newer structures. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT



The effects of expansive soils are most prevalent when periods of moderate to high precipitation are followed by drought and then again by periods of rainfall. Other cases of damage result from increases in moisture volume from such sources as broken or leaking water and sewer lines. Dry clays are capable of absorbing water and will increase in volume in an amount proportional to the amount of water absorbed. Soils capable of changes in volume present a hazard to structures built over them and to the pipelines buried in them. Houses and one-story commercial buildings are more apt to be damaged by the expansion of swelling clays than are multi-story buildings, which are usually heavy enough to counter swelling pressures. However, if constructed on wet clay, multi-story buildings may also be damaged by clay shrinkage when moisture levels are substantially reduced.

Cracked foundations and floors, jammed windows and doors, and ruptured pipelines are typical types of damage resulting from swelling soils. Damage to the upper floors of larger buildings can occur when motion in the structure is significant. While all infrastructure within the City of Houston planning area is minimally vulnerable, slabs on grade structures are more likely to suffer damage from expansive soils. In addition, older structures built to less stringent building codes may also be more susceptible to damage than new construction.

[4] City of Houston, "Houston Climate Impact Assessment 2.0", May 27, 2022. https://storymaps.arcgis.com/stories/ab02f9edd0904f3f83fbf080f41ad3f6

While the number of slabs on grade structures is not available, the U.S. Census data indicates approximately 504,772 of the housing units (51 percent of all housing units) in the planning area were built before 1980 and may be more susceptible to damages.

Table 11-3. Residential Structures at Greatest Risk

JURISDICTION	SFR STRUCTURES BUILT BEFORE 1980
City of Houston	504,772

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by expansive soils.

Table 11-4. Critical Facilities Vulnerable to Expansive Soils

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations 18 Police Stations 64 Hospitals 21 Airports 49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Uneven settling and shifting cause cracks in building foundations impacting the integrity of critical facility structures and lead to doors being unable to open or close properly. ■ Damages and cracks in streets and highway infrastructure may lead to emergency vehicles being unable to access areas increasing the need for airport operations. ■ Ruptured water pipes can lead to loss of function or water pressure impacting drinking water availability and firefighting capabilities. ■ Ruptured sewer lines can create additional public health emergencies. ■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment.

ASSESSMENT OF IMPACTS

Expansive soils are generally influenced by how wet or dry reactive clay types of soils become, so the climate of an area, and more specifically the seasonal precipitation-drought cycle associated with arid or semi-arid regions influences the occurrence and severity of these hazards. Problems associated with expansive soils in the City of Houston typically occur during extended periods of drought.

Expansive soils present a hazard to lightweight buildings and other infrastructure. Uneven settling and shifting in such structures may occur, causing cracks in foundations, walls, streets, driveways, and sidewalks; ruptured pipes; and windows and doors that do not open and close properly. Special provisions are necessary in the construction of footings and slabs resting on expansive soils to minimize damages due to the expansiveness. Homeowners and public agencies that assume they

cannot afford preventative measures such as more costly foundations and floor systems, often incur the largest percentage of damage and costly repairs from expanding soil. No figures are available for the total damage to homes in the planning area from expansive clays. The greatest damage occurs when structures are constructed when clays are dry (such as during a drought) and then subsequent soaking rains swell the clay.

Infrastructure such as pipelines can be damaged, causing increased maintenance and repairs, replacement, or damage to the point of failure. Sewer and water lines are also affected by shrinking and swelling soils as was experienced in the 2011 and 2022 drought events. The movement of the soil can snap water and sewer and water lines, producing a minimum of temporary discomfort, and a maximum of a serious health and welfare risk. Field monitoring and testing should be conducted on a regular basis, especially during extended drought periods, to avoid loss of function or water pressure, which could impact drinking water and firefighting capabilities. In addition, highways (IH-10, IH-45, US-290, US-59, IH-37, and US-83/US-284) and mass transit (METRORail) can be affected by expansive soils and could hinder evacuations if deemed not usable during disasters.

Unlike many other environmental hazards, the effects of expansive soil are deceptive in that they are not revealed suddenly or caused by a single event, but rather become increasingly evident and destructive over time. As such, the vast majority of expansive soil impacts are relatively benign in terms of emergency management and emergency response.

Expansive soil can directly impact infrastructure and as a result indirectly create impacts on residents. The following are a summary of impacts frequently associated with expansive soils:

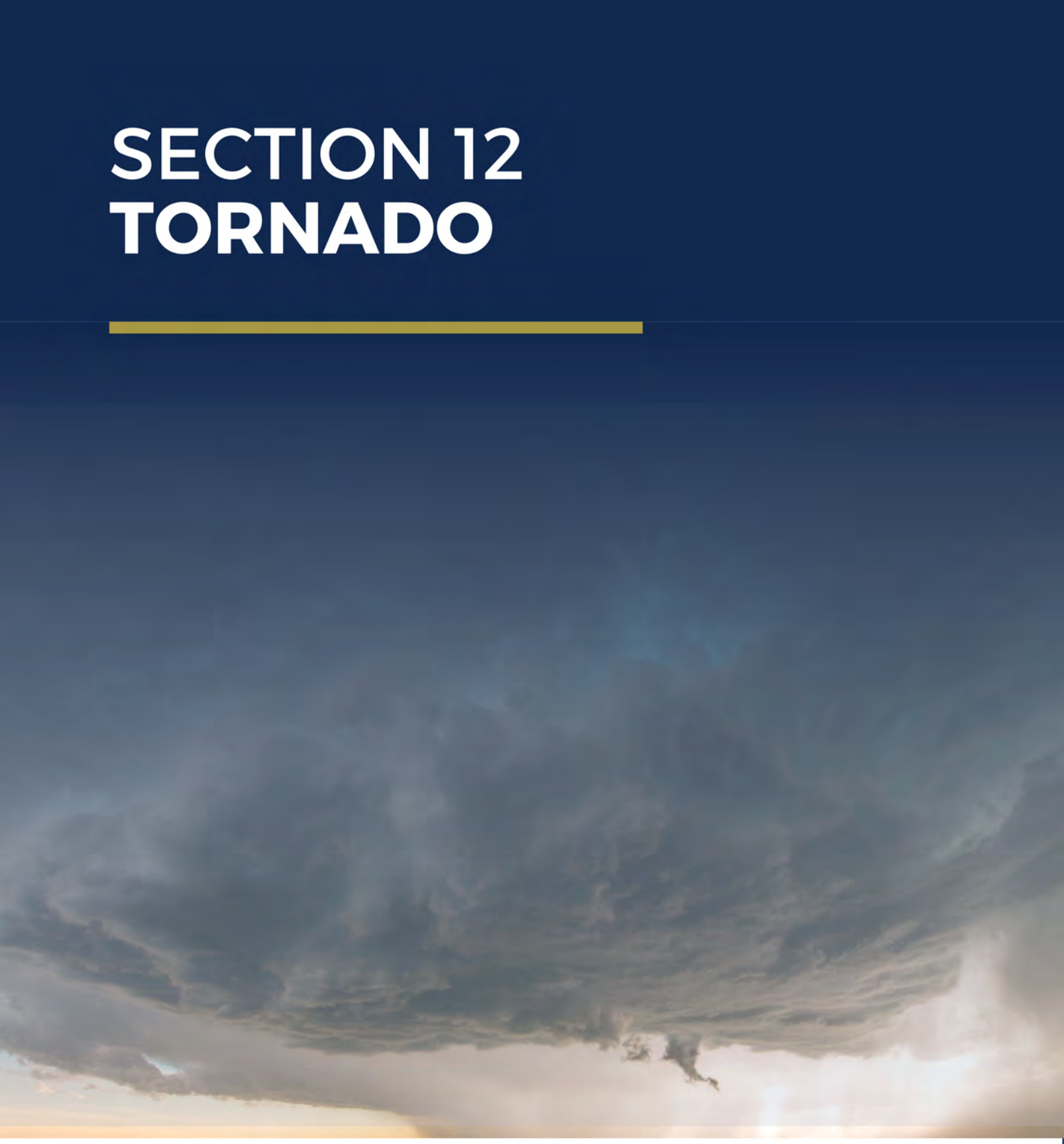
- Expansive soils are influenced by the seasonal precipitation-drought cycle. Most impacts on the City of Houston typically occur during extended periods of drought.
- Impacts to lightweight buildings and other infrastructure are most likely to occur. Impacts include: uneven settling and shifting in structures, cracks in foundations, walls, streets, driveways, and sidewalks; ruptured pipes; and windows and doors that do not open and close properly.
- 51 percent of homes in the City of Houston were built before 1980 leading them to more susceptible to damages from expansive soils. 265 buildings and sites in the City are on the National Register of Historic Places, many of which pre-date modern building codes.
- Highways (IH-10, IH-45, US-290, US-59, IH-37, and US-83/US-284) and mass transit (METRORail) can be affected by expansive soils.
- Economic impacts are limited to uninsured damages.
- Impacts on people are indirect, with impacts related to disruption in city services such as water and sewer.
- As population grows and development increases in the City the potential risk to expansive soils will also increase.
- Limited impact anticipated to the natural environment other than changes in soil characteristics.

The impact of expansive soils experienced in the City of Houston has resulted in no injuries and fatalities, supporting a “limited” severity of impact meaning injuries and/or illnesses are treatable with first aid, shutdown of facilities and services for 24 hours or less, and less than 10 percent of property is destroyed or with major damage.

CLIMATE CHANGE CONSIDERATIONS

Expansive soils are directly connected to drought and flood conditions as they literally swell and shrink with changing moisture conditions. Impacts of climate change on drought and flood events indicate similar changes to expansive soil frequency and impacts. Refer to Probability of Future Events section in Section 5 Flood and Section 8 Drought for more information on those hazards.

SECTION 12
TORNADO



OFFICE OF EMERGENCY MANAGEMENT

SECTION 12: TORNADO

Hazard Description 1
Location 2
Extent 3
Historical Occurrences 6
Significant Events 7
Probability of Future Events 8
Vulnerability and Impact 9
Assessment of Impacts 11
Climate Change Considerations 13

HAZARD DESCRIPTION



Tornadoes are among the most violent storms on the planet. A tornado is a rapidly rotating column of air extending between, and in contact with, a cloud and the surface of the earth. The most violent tornadoes are capable of tremendous destruction and have wind speeds of 250 miles per hour or more. In extreme cases, winds may approach 300 miles per hour. Damage paths can be in excess of one mile wide and 50 miles long.

The most powerful tornadoes are produced by "Supercell Thunderstorms." These thunderstorms are created when horizontal wind shears (winds moving in different directions at different altitudes) begin to rotate the storm. This horizontal rotation can be tilted vertically by violent updrafts, and the rotation radius can shrink, forming a vertical column of very quickly swirling air. This rotating air can eventually reach the ground, forming a tornado.

Table 12-1. Variations among Tornadoes

WEAK TORNADOES	STRONG TORNADOES	VIOLENT TORNADOES
■ 69% of all tornadoes ■ Less than 5% of tornado deaths ■ Lifetime 1-10+ minutes ■ Winds less than 110 mph	■ 29% of all tornadoes ■ Nearly 30% of all tornado deaths ■ May last 20 minutes or longer ■ Winds 110 – 205 mph	■ 2% of all tornadoes ■ 70% of all tornado deaths ■ Lifetime can exceed one hour ■ Winds greater than 205 mph

LOCATION

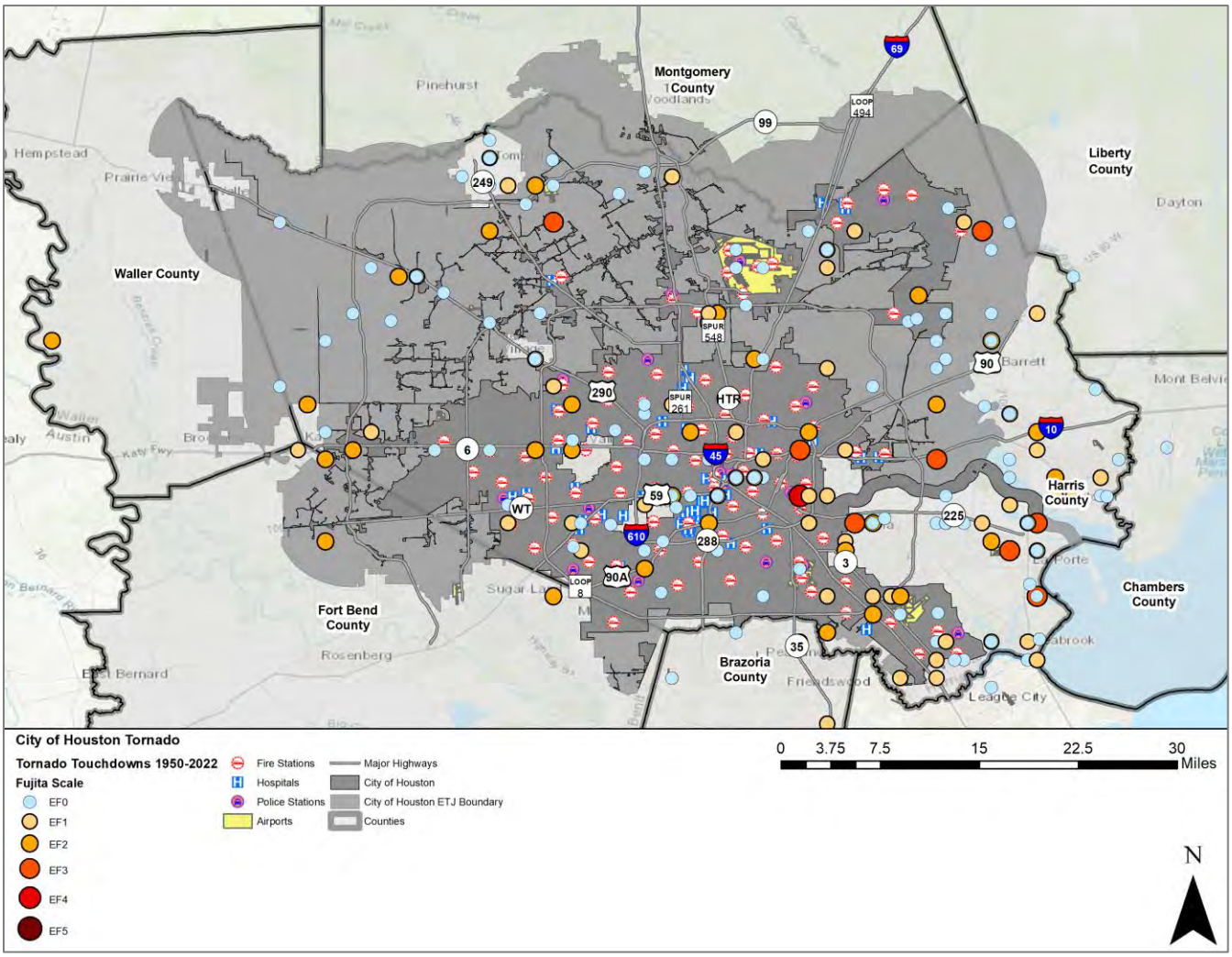
Tornadoes do not have any specific geographic boundary and can occur throughout the City uniformly. It is assumed that the entire City of Houston planning area is susceptible to a potential tornado event. The entire City of Houston planning area is located in Wind Zone III where tornado winds can be as high as 200 mph, refer to Figure 12-1.

Figure 12-1. FEMA Wind Zones in the United States



Figure 12-2 shows the locations of historic tornado events in the City of Houston between 1950 and 2022.

Figure 12-2. Historical Tornado Events in City of Houston



EXTENT

The destruction caused by tornadoes ranges from light to inconceivable, depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, such as residential homes (particularly mobile homes).

Table 12-2. The Fujita Tornado Scale[1]

F-SCALE NUMBER	INTENSITY	WIND SPEED (MPH)	TYPE OF DAMAGE DONE	PERCENT OF APPRAISED STRUCTURE VALUE LOST DUE TO DAMAGE
F0	Gale Tornado	40 – 72	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.	None Estimated
F1	Moderate Tornado	73 – 112	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads; attached garages may be destroyed.	0% – 20%
F2	Significant Tornado	113 – 157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.	50% – 100%
F3	Severe Tornado	158 – 206	Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.	100%
F4	Devastating Tornado	207 – 260	Well-constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.	100%
F5	Incredible Tornado	261 – 318	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles flying through the air in excess of 330 yards; trees debarked; steel reinforced concrete badly damaged.	100%

[1] http://www.tornadoproject.com/fscale/fscale.htm

Tornado magnitudes prior to 2005 were determined using the traditional version of the Fujita Scale (Table 12-2). Since February 2007, the Fujita Scale has been replaced by the Enhanced Fujita Scale (Table 12-3), which retains the same basic design and six strength categories as the previous scale. The newer scale reflects more refined assessments of tornado damage surveys, standardization, and damage consideration to a wider range of structures.

Table 12-3. Enhanced Fujita Scale for Tornadoes

STORM CATEGORY	DAMAGE LEVEL	3 SECOND GUST (MPH)	DESCRIPTION OF DAMAGES	PHOTO EXAMPLE
EF0	Gale	65 – 85	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.	
EF1	Weak	86 – 110	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads; attached garages may be destroyed.	
EF2	Strong	111 – 135	Considerable damage; roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.	
EF3	Severe	136 – 165	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.	
EF4	Devastating	166 – 200	Well-constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.	
EF5	Incredible	200+	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles flying through the air in excess of 330 yards; trees debarked; steel reinforced concrete badly damaged.	

Both the Fujita Scale and Enhanced Fujita Scale should be referenced in reviewing previous occurrences since tornado events prior to 2007 will follow the original Fujita Scale. The largest magnitude reported within the planning area is F4 on the Fujita Scale, a "Devastating Tornado." Based on the planning area's location in Wind Zone III, the planning area could experience anywhere from an EF0 to an EF5 depending on the wind speed. The events in the City of Houston (converted from the Fujita Scale) have been between EF0 and EF5 (Figure 12-2). This is the strongest event the planning area can anticipate in the future.

HISTORICAL OCCURRENCES

Only reported tornadoes were factored into the Risk Assessment. It is likely that a high number of occurrences have gone unreported over the past 72 years. Historical tornado data for the City of Houston is shown on a county-wide basis per the NCEI database.

Figure 12-2, above, identifies the locations of previous occurrences in the City of Houston planning area from 1950 through 2022. A total of 26 events have been recorded by the Storm Prediction Center (NOAA) and National Centers for Environmental Information (NCEI) databases for the City of Houston. The strongest event reported in the City of Houston was an F4 tornado (207 mph – 260 mph) that occurred at the East Houston suburb of Channelview.

Table 12-4. Historical Tornado Events, 1950-2022[2]

JURISDICTION	DATE	TIME	MAGNITUDE	DEATHS	INJURIES	PROPERTY DAMAGE
Clear Lake	2/25/1993	12:10 PM	F0	0	0	$1,034,839
City of Houston	4/7/1993	2:10 PM	F1	0	0	$10,284
City of Houston	11/16/1993	9:49 AM	F1	0	26	$10,156,756
Lake Houston	4/15/1994	4:56 PM	F2	1	20	$100,465
City of Houston	4/20/1995	2:10 PM	F0	0	0	$107,238
City of Houston	10/18/1998	12:00 AM	F0	0	0	$36,118
City of Houston	6/8/1999	11:15 AM	F0	0	0	$44,550
City of Houston	6/29/2001	2:52 PM	Unknown	0	0	$0
City of Houston	10/11/2001	7:15 AM	Unknown	0	0	$0
City of Houston	8/22/2002	2:30 PM	F0	0	0	$16,390
City of Houston	9/1/2003	5:10 PM	Unknown	0	0	$0
(IAH) Houston Intl Airport	11/17/2003	1:00 PM	F0	0	0	$0

[2] Only recorded events with fatalities, injuries or damages are listed. Magnitude is listed when available. Damage values are in 2022 dollars.

JURISDICTION	DATE	TIME	MAGNITUDE	DEATHS	INJURIES	PROPERTY DAMAGE
South Houston	11/17/2003	3:01 PM	F2	0	0	$882,895
Houston Hooks Airport	5/1/2004	8:12 AM	F0	0	0	$0
City of Houston	7/22/2004	11:43 AM	Unknown	0	0	$0
South Houston	11/22/2004	12:45 PM	Unknown	0	0	$0
City of Houston	11/22/2004	3:53 PM	F0	0	0	$23,260
Piney Point	2/10/2006	4:30 PM	F0	0	0	$52,169
City of Houston	5/29/2006	7:05 AM	Unknown	0	0	$0
Almeda	6/21/2008	5:04 PM	EF0	0	0	$148,887
Eureka Springs	6/28/2014	1:25 PM	EF0	0	0	$55,918
Jeannetta	5/24/2015	5:33 AM	EF0	0	4	$249,087
Ellington Field	10/31/2015	4:22 AM	EF0	0	0	$93,395
Ellington Field	10/31/2015	4:47 AM	EF2	0	0	$14,943,163
Lake Houston	4/18/2016	4:12 AM	EF0	0	0	$37,136
Houston Hooks Airport	4/27/2016	3:43 AM	EF0	1	0	$247,571
Houston Weiser Airport	8/26/2017	2:50 PM	EF1	0	0	$603,153
Lake Houston	8/26/2017	3:30 AM	EF0	0	0	$120,631
Clear Lake City	8/26/2017	11:00 PM	EF0	0	0	$60,315
(IAH) Houston Intl Airport	5/7/2019	1:45 PM	Unknown	0	0	$0
(EFD) Ellington Air Force Base	8/28/2020	5:10 PM	Unknown	0	0	$0
TOTAL				2	50	$29,024,220

Based on the list of historical tornado events for the City of Houston planning area (listed above), there have been three recorded events since the 2018 Plan.

SIGNIFICANT EVENTS

November 21, 1992

A total of 14 tornadoes were confirmed in the state on November 21, 1992, the weekend before the Thanksgiving holiday. In total six tornadoes were confirmed in the area, with the greatest magnitude being an F4 in Channelview. In Harris County there were three tornadoes on the

ground simultaneously. Statewide, no fatalities were reported from the events but over 30 individuals suffered injuries. An estimated 2,400 homes were damages and 450 were destroyed from the event resulting in $189 million (2022 dollars) in insured damages.[3]

November 16, 1993
The most significant historical tornado event for the City of Houston planning area in terms of reported injuries occurred on November 16, 1993. This F1 tornado was reported moving northeast across Lake Houston by the Lake Houston dam operator. There were 26 reported injuries and over $8 million (2017) dollars attributed to this event.

April 15, 1994
Another significant historical tornado event for the City of Houston planning area occurred on April 15, 1994. This tornado touched down on the west shore of Lake Houston, crossed the lake to the east shore to Indian Shores Estates. The tornado was reported as a strength of F2, approximately 300 yards wide, and had an approximate length of 2.5 miles. There was 1 reported death, 20 reported injuries, and over $80,000 in damages attributed to this event.

October 31, 2015
The most significant historical tornado event for the City of Houston planning area in terms of reported damage cost occurred on October 31, 2015. This EF2 tornado touched down near the Genoa Red Bluff and Red Bluff intersection and ended near the Spencer Highway and Myrtle Creek Drive intersection in La Porte. There were no reported injuries but the damage estimates exceeded $12 million (2017) dollars. The tornado caused extensive tree, fence and power line damage as well as causing significant roof loss to homes and demolishing an industrial building.

January 24, 2023 – Greater Houston Area
The communities of Pasadena and Deer Park located south of the City of Houston, experienced an EF3 tornado event on January 24, 2023. The estimated maximum path length of the event was 18 miles, and the maximum wind speed was 140 mph. While the event did not directly impact the city limits of Houston, the City was under a Tornado Emergency, a first for the city since the emergency alert was created in 2016. The Tornado Emergency is issued by the National Weather Service when "an exceedingly rare tornado warning is issued when there is a severe threat to human life and catastrophic damage from an imminent or ongoing tornado. This tornado warning is reserved for situations when a reliable source confirms a tornado, or there is clear radar evidence of the existence of a damaging tornado, such as the observation of debris."[4]

PROBABILITY OF FUTURE EVENTS

Tornadoes can occur at any time of year and at any time of day, but they are typically more common in the spring months during the late afternoon and evening hours. A smaller, high frequency period can emerge in the fall during the brief transition between the warm and cold seasons. According to historical records, the City of Houston can experience a tornado touchdown approximately twice every year or 46 percent annual chance of a tornado event. This

[3] Lanza, Matt "Space City Rewind: November 1992 Tornado Outbreak". November 21, 2016. https://spacecityweather.com/november-1992-tornado-outbreak/
[4] KHOU11 'Tornado Emergency' issues in Houston area for first time. https://www.khou.com/article/weather/tornado-emergency-houston/285-972c2dd1-ff1c-47a0-bbca-efee071c1d36

frequency supports a "Highly Likely" probability of future events. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Due to the randomness of tornado events all existing and future buildings, facilities, and infrastructure in the City of Houston planning area are considered to be exposed to this hazard and could potentially be impacted. The damage caused by a tornado is typically a result of high wind velocity and wind-blown debris.

The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. Consequently, vulnerability of humans and property is difficult to evaluate since tornadoes form at different strengths, in random locations, and create relatively narrow paths of destruction. Although tornadoes strike at random, making all buildings vulnerable, three types of structures are more likely to suffer damage:

- Manufactured homes;
- Homes on crawlspaces (more susceptible to lift); and
- Buildings with large spans, such as shopping malls, gymnasiums, and factories.

Tornadoes can cause a significant threat to people as they could be struck by flying debris, falling trees or branches, utility lines, and poles. Blocked roads could prevent first responders to respond to calls. Tornadoes commonly cause power outages which could cause health and safety risks to residents and visitors, as well as to patients in hospitals.

The City of Houston planning area features mobile or manufactured home parks throughout the planning area. These parks are typically more vulnerable to tornado events than typical site-built structures. In addition, manufactured homes are located sporadically throughout the planning area which would also be more vulnerable. U.S. Census data indicates a total of 9,450 (1 percent of total housing stock) manufactured homes located in the City of Houston, a 16 percent increase in this housing type since 2018. Another factor of manufactured homes that may increase vulnerability is the age of installation. Inspection of manufactured home installations changed in 2011 when the process was revised statewide, therefore, manufactured homes installed prior to 2011 may be more vulnerable to damages from tornado events. In addition, 51 percent (approximately 504,772 structures) of the housing structures in the City of Houston were built before 1980. These structures would typically be built to lower or less stringent construction standards than newer construction and may be more susceptible to damage during significant tornado events.

Table 12-6. Structures at Greater Risk to Tornado Events[5]

JURISDICTION	MANUFACTURED HOMES	SFR STRUCTURES BUILT BEFORE 1980	RENTER OCCUPIED UNITS
City of Houston	9,450	504,772	505,745

[5] U.S. Census Bureau American Community Survey Five-Year Estimates, 2017-2021

SECTION 12: TORNADO

While all citizens are at risk to the impacts of a tornado, forced relocation and disaster recovery drastically impacts low-income residents who lack the financial means to travel, afford a long-term stay away from home, and to rebuild or repair their homes. An estimated 19.5 percent of the planning area population live below the poverty level. Renters also tend to be more vulnerable to the impacts of wind events and their ability to recover after an event. Within the city 58 percent of housing units are renter-occupied. While warning times for these type of hazard events should be substantial enough for these individuals to seek shelter, individuals who work and recreate outside are also vulnerable to potential impacts of a tornado event.

Table 12-7. Populations at Greater Risk to Tornado Events[6]

JURISDICTION	POPULATION BELOW POVERTY LEVEL
City of Houston	453,395

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by tornado events.:

Table 12-8. Critical Facilities Vulnerable to Tornado Event

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Emergency vehicles can be damaged by falling trees or flying debris. ■ Power outages could disrupt communications, delaying emergency response times. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Debris/downed trees can impede emergency response vehicle access to areas. ■ Increased number of structure fires due to gas line ruptures and downed power lines, further straining the capacity and resources of emergency personnel. ■ First responders are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions. ■ Extended power outages and evacuations may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.
64 Hospitals	■ Structures can be damaged by falling trees or flying debris. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities. ■ Evacuations may be necessary due to extended power outages, gas line ruptures, or structural damages to facilities.

[6] U.S. Census Bureau American Community Survey Five-Year Estimates, 2017-2021

CRITICAL FACILITIES	POTENTIAL IMPACTS
21 Airports	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications and emergency operations. ■ Temporary break in operations may significantly inhibit post event evacuations. ■ Damaged or destroyed highway infrastructure may substantially increase the need for airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

The average loss estimates of property and crop due to tornado events is $29,124,685 (in 2022 dollars), having an approximate annual loss estimate of $404,510. Based on historic damages, the impact of a tornado event on the City of Houston planning area would be considered “Minor”, with critical facilities and services shutdown for 24 hours or less and less than 10 percent of properties destroyed or with major damage. However, due to the loss of life and number of past injuries, the impact of tornado events for the planning area is considered “Substantial,” with multiple deaths or injuries possible.

ASSESSMENT OF IMPACTS

Tornadoes have the potential to pose a significant risk to the population and can create dangerous situations. Often providing and preserving public health and safety is difficult following a tornado event. More destructive tornado conditions can be frequently associated with a variety of impacts, including:

- Individuals exposed to the storm can be struck by flying debris, falling limbs, or downed trees causing serious injury or death.
- Structures can be damaged or crushed by falling trees, which can result in physical harm to the occupants.
- Manufactured homes may suffer substantial damage as they would be more vulnerable than typical site-built structures.

- Significant debris and downed trees can result in emergency response vehicles being unable to access areas of the community.
- Tornadoes often result in widespread power outages increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outages can result in an increase in structure fires and/or carbon monoxide poisoning as individuals attempt to cook or heat their home with alternate, unsafe cooking or heating devices, such as grills.
- Tornadoes can destroy or make residential structures uninhabitable, requiring shelter or relocation of residents in the aftermath of the event.
- First responders must enter the damage area shortly after the tornado passes to begin rescue operations and to organize cleanup and assessments efforts, therefore they are exposed to downed power lines, unstable and unusual debris, hazardous materials, and generally unsafe conditions, elevating the risk of injury to first responders and potentially diminishing emergency response capabilities.
- Emergency operations and services may be significantly impacted due to damaged facilities, loss of communications, and damaged emergency vehicles and equipment.
- City departments may be damaged or destroyed, delaying response and recovery efforts for the entire community.
- Private sector entities that the City and its residents rely on, such as utility providers, financial institutions, and medical care providers may not be fully operational and may require assistance from neighboring communities until full services can be restored.
- Economic disruption negatively impacts the programs and services provided by the community due to short- and long-term loss in revenue.
- Damage to infrastructure may slow economic recovery since repairs may be extensive and lengthy.
- Some businesses not directly damaged by the tornado may be negatively impacted while roads and utilities are being restored, further slowing economic recovery.
- When the community is affected by significant property damage it is anticipated that funding would be required for infrastructure repair and restoration, temporary services and facilities, overtime pay for responders, and normal day-to-day operating expenses.
- Displaced residents may not be able to immediately return to work, further slowing economic recovery.
- Residential structures destroyed by a tornado may not be rebuilt for years, reducing the tax base for the community.
- Large or intense tornadoes may result in a dramatic population fluctuation, as people are unable to return to their homes or jobs and must seek shelter and/or work outside of the affected area.
- Businesses that are uninsured or underinsured may have difficulty reopening, which results in a net loss of jobs for the community and a potential increase in the unemployment rate.
- Recreation activities may be unavailable, and tourism can be unappealing for years following a large tornado, devastating directly related local businesses.

The economic and financial impacts of a tornado event on the community will depend on the scale of the event, what is damaged, costs of repair or replacement, lost business days in impacted areas, and how quickly repairs to critical components of the economy can be implemented. The level of

preparedness and pre-event planning done by government, businesses, and citizens will contribute to the overall economic and financial conditions in the aftermath of a tornado event.

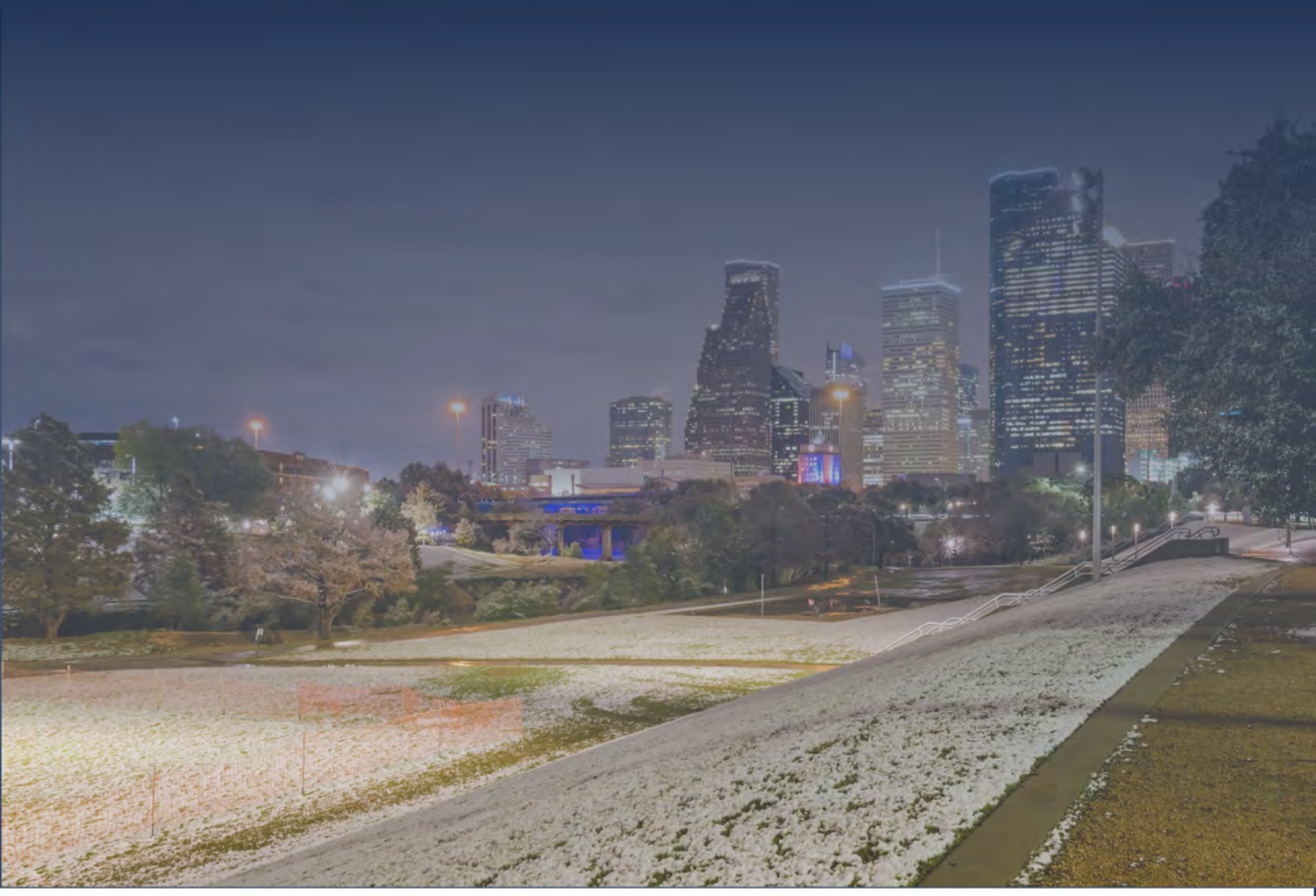
CLIMATE CHANGE CONSIDERATIONS

The impacts on the frequency and severity of tornado events due to climate change are unclear. According to the Texas A&M 2021 Climate Report Update, the most robust trend in tornado activity in Texas is a likelihood for a greater number of tornadoes in large outbreaks, although the factors contributing to this trend are not expected to continue. Tornadoes spawn from less than 10 percent of thunderstorms, usually supercell thunderstorms that are in a wind shear environment that promotes rotation.[7] Based on climate models that are available, the environmental conditions needed for severe thunderstorm events are estimated to become more likely, resulting in an overall increase in the number of days capable of producing a severe thunderstorm event and potential tornadoes to develop from these storms.[8]

[7] Treisman, Rachel. *The exact link between tornadoes and climate change is hard to draw. Here's why.* NPR. December 13, 2021. https://www.npr.org/2021/12/13/1063676832/the-exact-link-between-tornadoes-and-climate-change-is-hard-to-draw-heres-why

[8] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 13
WINTER STORM



OFFICE OF EMERGENCY MANAGEMENT

SECTION 13: WINTER STORM

Hazard Description 1
Location 3
Extent 3
Historical Occurrences 5
Significant Events 6
Probability of Future Events 7
Vulnerability and Impact 7
Assessment of Impacts 9
Climate Change Considerations 10

HAZARD DESCRIPTION



A severe winter storm event is identified as a storm with snow, ice, or freezing rain. This type of storm can cause significant problems for area residents. Winter storms are associated with freezing or frozen precipitation such as freezing rain, sleet, snow, and the combined effects of winter precipitation and strong winds. Wind chill is a function of temperature and wind. Low wind chill is a product of high winds and freezing temperatures.

Winter storms that threaten the City of Houston planning area usually begin as powerful cold fronts that push south from central Canada. Although the City is at risk to ice hazards, extremely cold temperatures, and snow, the effects and frequencies of winter storm events are generally mild and short-lived.

As indicated in Figure 13-1, the City of Houston is located in USDA Hardiness Zone 9a, with annual minimum temperatures between 25°F and 20°F. During times of ice and snow accumulation, response times will increase until public works road crews are able to make major roads passable. Table 13-1 describes the types of winter weather possible to occur in the City of Houston.

Figure 13-1. Annual Minimum Temperature[1]

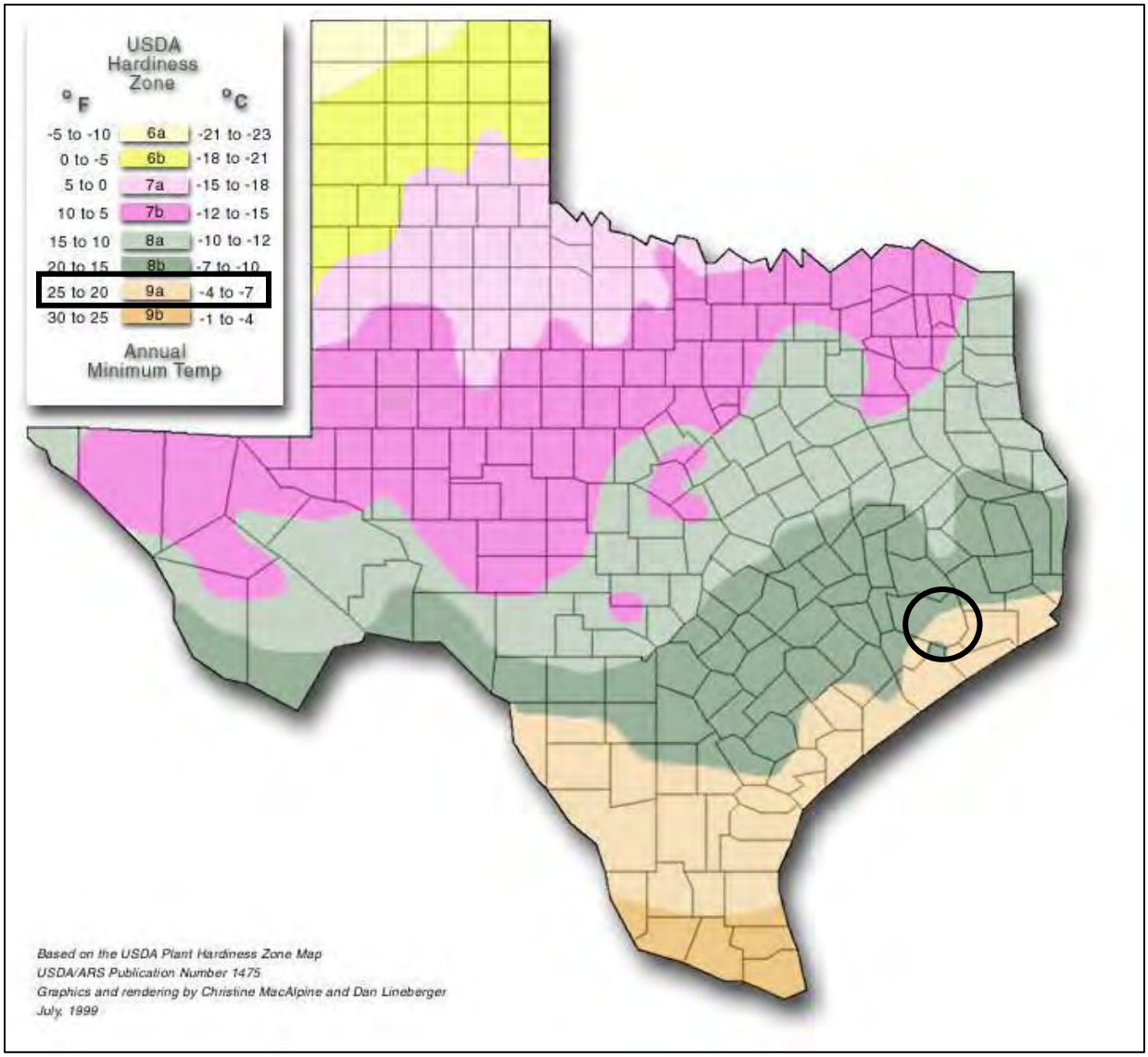


Table 13-1. Types of Winter Weather

TYPE OF WINTER WEATHER	DESCRIPTION
Winter Weather Advisory	This alert may be issued for a variety of severe conditions. Weather advisories may be announced for snow, blowing or drifting snow, freezing drizzle, freezing rain, or a combination of weather events.
Winter Storm Watch	Severe winter weather conditions may affect your area (freezing rain, sleet, or heavy snow may occur separately or in combination).
Winter Storm Warning	Severe winter weather conditions are imminent.

[1] USDA

TYPE OF WINTER WEATHER	DESCRIPTION
Freezing Rain or Freezing Drizzle	Rain or drizzle is likely to freeze upon impact, resulting in a coating of ice glaze on roads and all other exposed objects.
Sleet	Small particles of ice usually mixed with rain. If enough sleet accumulates on the ground, it makes travel hazardous.
Blizzard Warning	Sustained wind speeds of at least 35 mph are accompanied by considerable falling or blowing snow. This alert is the most perilous winter storm with visibility dangerously restricted.
Frost/Freeze Warning	Below freezing temperatures are expected and may cause significant damage to plants, crops, and fruit trees.
Wind Chill	A strong wind combined with a temperature slightly below freezing can have the same chilling effect as a temperature nearly 50 degrees lower in a calm atmosphere. The combined cooling power of the wind and temperature on exposed flesh is called the wind-chill factor.

LOCATION

Winter storm events are not confined to specific geographic boundaries. Therefore, all existing and future buildings, facilities, and populations in the City of Houston are considered to be exposed to a winter storm hazard and could potentially be impacted.

While the entire City of Houston is vulnerable to winter storm events, the areas of the City that reported the highest percentage of damages after Winter Storm Uri in February 2021, were concentrated in the central and eastern areas of the city. The hardest-hit areas tended to be in low-income neighborhoods with older homes built before 1985 and higher shares of renter households.[2]

EXTENT

The extent or magnitude of a severe winter storm is measured in intensity based on the temperature and level of accumulations as shown in Table 13-2. Table 13-2 should be read in conjunction with the wind-chill factor described in Figure 13-2 to determine the intensity of a winter storm. The chart is not applicable when temperatures are over 50°F or winds are calm. This is an index developed by the National Weather Service.

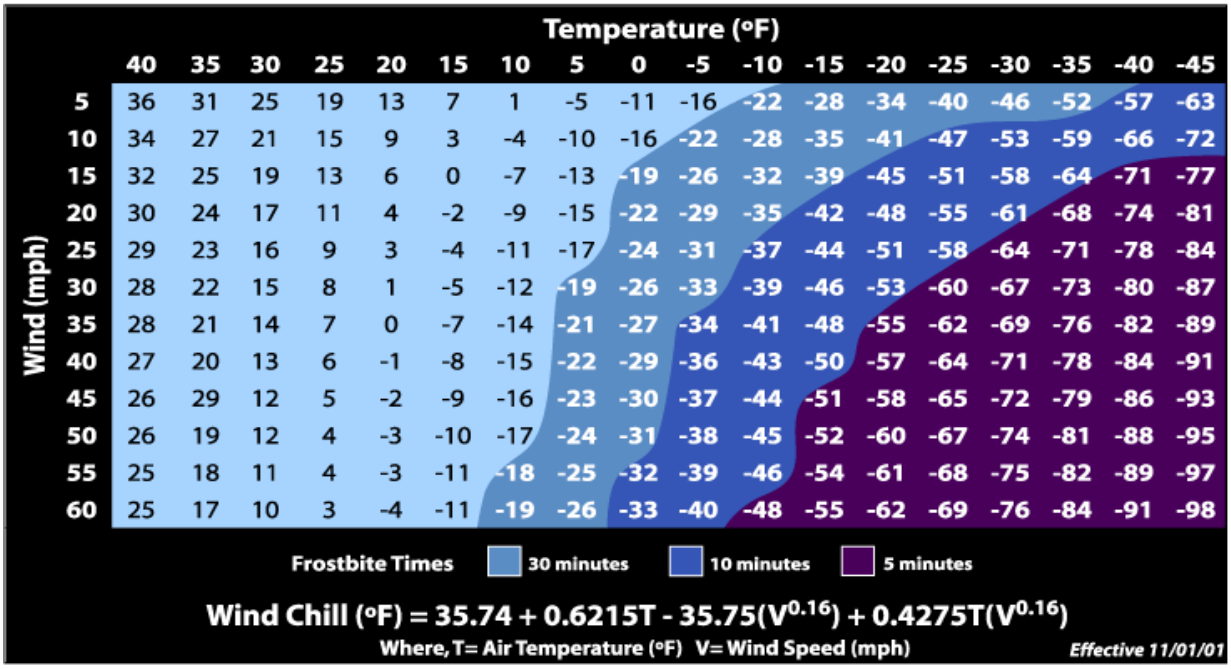
Table 13-2. Magnitude of Severe Winter Storms

INTENSITY	TEMPERATURE RANGE (Fahrenheit)	EXTENT DESCRIPTION
Mild	40° – 50°	Winds less than 10 mph and freezing rain or light snow falling for short durations with little or no accumulations

[2] Rice University's Kinder Institute for Urban Research "Harris County Winter Storm Uri Resilience Assessment" Report. February 2022. https://kinder.rice.edu/research/harris-county-winter-storm-uri-resilience-assessment

INTENSITY	TEMPERATURE RANGE (Fahrenheit)	EXTENT DESCRIPTION
Moderate	30° – 40°	Winds 10 – 15 mph and sleet and/or snow up to 4 inches
Significant	25° – 30°	Intense snow showers accompanied with strong gusty winds between 15 and 20 mph with significant accumulation
Extreme	20° – 25°	Wind driven snow that reduces visibility, heavy winds (between 20 to 30 mph), and sleet or ice up to 5 millimeters in diameter
Severe	Below 20°	Winds of 35 mph or more and snow and sleet greater than 4 inches

Figure 13-2. Wind Chill Chart



Wind chill temperature is a measure of how cold the wind makes real air temperature feel to the human body. Since wind can dramatically accelerate heat loss from the body, a blustery 30 degree day would feel just as cold as a calm day with 0 degree temperatures. The City of Houston has 9 previous occurrences recorded from 1996 through December 2022. The City of Houston has never experienced a blizzard but it has been subject to ice storms, sleet, and winter storms.

The average number of cold days is similar for the entire planning area. Therefore, the intensity or extent of a winter storm event to be mitigated for the area ranges from mild to moderate according to the definitions at Table 13-2. The City of Houston planning area can expect anywhere between

0.1 to 4.0 inches of ice and snow during a winter storm event, and temperatures between 30°F and 50°F with winds ranging from 0 to 15 mph. During Winter Storm Uri in February 2021, the City of Houston experienced record low temperatures including breaking the previous records. On February 15, 2021, the maximum high temperature observed in the City of Houston was 25 degrees breaking the previous record set in 1909 of 32 degrees.[3]

HISTORICAL OCCURRENCES

Table 13-3 shows historical occurrences for the City of Houston from 1996 through December 2022 provided by the NCEI database. Based upon NCEI records, there have been 11 recorded winter storm events within the City of Houston planning area. Historical winter storm information, as provided by the NCEI, identifies winter storm activity across a multi-county forecast area for each event. The appropriate percentage of the total property and crop damage reported for the entire forecast area has been allocated to each county impacted by the event, when appropriate. Historical winter storm data for the City of Houston is provided on a County-wide basis per the NCEI database. Table 13-3 shows historical incident information for the planning area.

Table 13-3. Historical Winter Storm Events, 1996-2022[4]

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
Harris County	1/12/1997	0	0	$0	$0
Harris County	12/24/2004	0	0	$0	$0
Harris County	1/16/2007	0	0	$0	$7,316
Harris County	12/10/2008	0	0	$0	$0
Harris County	1/23/2014	0	0	$0	$0
Harris County	1/28/2014	0	0	$0	$0
Harris County	3/3/2014	0	0	$0	$0
Harris County	12/7/2017	0	0	$0	$0
Harris County	1/16/2018	0	0	$0	$0
Harris County	2/14/2021	0	0	$0	$0
Harris County	2/3/2022	0	0	$0	$0
TOTALS		**0**	**0**	**$7,316**	

Based on the list of historical winter storm events for the City of Houston, two of the events have occurred since the 2018 Plan.

[3] National Weather Service, Houston/Galveston, TX Weather Forecast Office. https://www.weather.gov/hgx/2021ValentineStorm

[4] Values are in 2022 dollars. Database was search for events between 1996 and 2022.

SIGNIFICANT EVENTS

January 16, 2007
A very cold arctic air mass descended upon Texas, combined with southwesterly upper-level disturbances, produced freezing rain across the northern and central regions of southeast Texas. Widespread ice accumulation on roads, bridges, and the roofing of general structures across the northern and central portions of the county, including the City of Houston. US 290 to the Harris-Waller County line and the entry ramps on sections of Beltway 8 were also iced over.

March 3, 2003
An upper-level disturbance moved across the planning area and generated light precipitation within a near freezing air mass. As a result, there was a light glazing of ice with very light sleet accumulations. There were also reports of thunder associated with this precipitation.

February 11 – 20, 2021 – Winter Storm Uri (DR-4586)
Winter Storm Uri was one of the most impactful winter events in the state's history. The winter storm event lasted a week and brought snow, sleet, and freezing rain to the Houston area.[5] The presence of the storm began on February 10, 2021, when a cold front brought a surge of cold air to the Greater Houston Area. The following day a Winter Weather Advisory was issued for the region and was increased on February 12th to a Winter Storm Watch. On February 13th, the winter storm hit the region and Harris County was placed under a Winter Storm Warning. The following day the storm continued, and the City of Houston area was placed under a Hard Freeze Warning and a Wind Chill Warning, the first time issued by the Houston/Galveston National Weather Service (NWS) Office. Between February 15th and 18th, the City of Houston experienced record low temperatures and millions of residents were without power for several days. The last Hard Freeze Warning for the region expired on February 20th, eight days after the initial Winter Weather Advisory for the region was issued on February 11, 2021. [6]

Impacts on infrastructure from the storm included power outages lasting longer than four days, frozen interior and exterior pipes, loss of running water, and impassable road due to snow and ice.[7] The storm took an emotional toll on the City of Houston residents, many who were experiencing a compounding crisis events with the ongoing Covid-19 pandemic and continued impacts felt from Hurricane Harvey.[8]

Fatalities across the state were attributed to hypothermia, vehicle accidents, carbon monoxide poisoning, and chronic medical conditions complicated by a lack of electricity over serval days.[9] Statewide, more than 69 percent of households lost power at some point during the event, with average disruptions lasting 42 hours, 21 of which were consecutive. Water service was also

[5] Houston/Galveston Weather Forecast Office. National Weather Service. "Valentine's Week Winter Outbreak 2021: Snow, Ice, & Record Cold". https://www.weather.gov/hgx/2021ValentineStorm
[6] Zamora-Nipper, Briana. "Timeline: Inside the 2021 winter storm, power crisis". KPRC 2. February 15, 2022. https://www.click2houston.com/features/2022/02/15/timeline-inside-the-2021-winter-storm-power-crisis/
[7] Rice University's Kinder Institute for Urban Research "Harris County Winter Storm Uri Resilience Assessment" Report. February 2022. https://kinder.rice.edu/research/harris-county-winter-storm-uri-resilience-assessment
[8] Rice University's Kinder Institute for Urban Research "Harris County Winter Storm Uri Resilience Assessment" Report. February 2022. https://kinder.rice.edu/research/harris-county-winter-storm-uri-resilience-assessment
[9] Stewart, Shelby. "Remembering Houston's Deep Freeze of 2021". Houstonia Magazine. December 21, 2022. https://www.houstoniamag.com/news-and-city-life/houston-storm-uri-deep-freeze-february-2021

disrupted with 49 percent of households losing running water with an average disruption of 52 hours.[10]

PROBABILITY OF FUTURE EVENTS

According to historical records, the City of Houston has a 42 percent annual chance of experiencing a winter storm event. The probability of a future winter storm event affecting the City of Houston planning area is highly likely, with a winter storm likely to occur within the next year. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

During periods of extreme cold and freezing temperatures, water pipes can freeze and crack, and ice can build up on power lines, causing them to break under the weight or causing tree limbs to fall on the lines. These events can disrupt electric service for long periods.

An economic impact may occur due to increased consumption of heating fuel, which can lead to energy shortages and higher prices. House fires and resulting deaths tend to occur more frequently from increased and improper use of alternate heating sources. Fires during winter storms also present a greater danger because water supplies may freeze and impede firefighting efforts.

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by winter storm events.

Table 13-4. Critical Facilities Vulnerable to Winter Storm Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations, services and response times may be significantly impacted due to power outages, and/or loss of communications. ■ Exposure to extreme cold can cause illnesses in first responders if exposed for a period of time. ■ Roads may become impassable due to snow and/ice impacting response times by emergency services. It may also hinder emergency services personnel's ability to report for duty. ■ Extended power outages due to increased usage may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources. ■ Emergency response apparatus are not designed for cold temperatures or winter storm events and may not be operable during events.
64 Hospitals	■ Power outages due to increased usage could disrupt critical care. ■ Backup power sources could be damaged. ■ Increased number of patients due to exposure to cold temperatures could lead to a strain on staff. ■ Water pipes can freeze and burst leading to flooding within facilities.

[10] Donald, Jess. "Winter Storm Uri. The Economic Impact of the Storm". October 2021. FiscalNotes. Texas Comptroller of Public Accounts. https://comptroller.texas.gov/economy/fiscal-notes/2021/oct/winter-storm-impact.php

CRITICAL FACILITIES	POTENTIAL IMPACTS
21 Airports	■ Facilities, infrastructure, or critical equipment including communications may be damaged, destroyed or otherwise inoperable. ■ Essential supplies like medicines, water, food, and equipment deliveries may be delayed. ■ Economic disruption due to power outages negatively impact airport services as well as area businesses reliant on airport operations. ■ Exposure risks to outdoor workers.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

People and animals are subject to health risks from extended exposure to cold air. Elderly people are at greater risk of death from hypothermia during these events, especially in the neighborhoods with older housing stock. Of all occupied housing units in the city, 65 percent depend on electricity to heat their homes. According to the U.S. Center for Disease Control, every year hypothermia kills about 600 Americans, half of whom are 65 years of age or older. In addition, populations living below the poverty level may not be able to afford to run heat on a regular basis or extend period of time.

Population over 65 in the City of Houston is estimated at 11 percent of the total population or an estimated total of 255,522[11] potentially vulnerable residents in the planning area based on age. An estimated 19.5 percent of the planning area population live below the poverty level.

Older homes tend to be more vulnerable to the impacts of winter storm events. Half of all housing units (51 percent) in the City were built before 1980. Of occupied housing units, 58 percent are renter occupied.[12] Renters can face more challenges with recovery following an event including home repairs or implementing personal mitigation measures before an extreme cold event.

Table 13-5. Structures at Greater Risk of Winter Storm Events

JURISDICTION	HOUSING UNITS BUILT BEFORE 1980	RENTER OCCUPIED UNITS
City of Houston	504,772	505,745

[11] US Census Bureau, American Community Survey Five-Year Estimates 2017-2021
[12] US Census Bureau, American Community Survey Five-Year Estimates 2017-2021

Table 13-6. Populations at Greater Risk of Winter Storm Events

JURISDICTION	YOUTH (UNDER 5)	ELDERLY (OVER 65)	POPULATION BELOW POVERTY LEVEL
City of Houston	164,775	255,522	453,395

Historic loss for the City of Houston planning area are negligible. The potential severity of impact for the City of Houston planning area is "Limited," meaning injuries are treatable with first aid, shutdown of facilities and services for 24 hours or less, and less than 10 percent of property destroyed or with major damage.

Table 13-7. Winter Storm Event Damage Totals, 1996-2022

JURISDICTION	PROPERTY & CROP LOSS	ANNUAL LOSS ESTIMATES
City of Houston	$7,316	$281.38

ASSESSMENT OF IMPACTS

The greatest risk from a winter storm hazard is to public health and safety. The impact of climate change could produce longer, more intense winter storm events, exacerbating the current winter storm impacts. Worsening winter storm conditions can be frequently associated with a variety of impacts, including:

- Vulnerable populations, particularly the elderly (11 percent of total population) and children under 5 (7 percent of total population), can face serious or life-threatening health problems from exposure to extreme cold including hypothermia and frostbite.
- Loss of electric power or other heat source can result in increased potential for fire injuries or hazardous gas inhalation because residents burn candles for light or use fires or generators to stay warm.
- Response personnel, including utility workers, public works personnel, debris removal staff, tow truck operators, and other first responders, are subject to injury or illness resulting from exposure to extreme cold temperatures.
- Response personnel would be required to travel in potentially hazardous conditions, elevating the life safety risk due to accidents and potential contact with downed power lines.
- Operations or service delivery may experience impacts from electricity blackouts due to winter storms.
- Power outages are possible throughout the planning area due to downed trees and power lines and/or rolling blackouts.
- Critical facilities without emergency backup power may not be operational during power outages.
- Emergency response and service operations may be impacted by limitations on access and mobility if roadways are closed, unsafe, or obstructed.

- Hazardous road conditions will likely lead to increases in automobile collisions, further straining emergency response capabilities.
- Depending on the severity and scale of damage caused by ice and snow events, damage to power transmission and distribution infrastructure can require days or weeks to repair.
- A winter storm event could lead to tree, shrub, and plant damage or death.
- Severe cold and ice could significantly damage vegetation in city parks.
- Older structures built to less stringent building codes may suffer greater damage as they are typically more vulnerable to impacts of winter storm events. 51 percent of homes in City were built before 1980. 265 buildings and sites in the City are on the National Register of Historic Places, many of which pre-date modern building codes.
- Schools may be forced to shut early due to treacherous driving conditions.
- Exposed water pipes may be damaged by severe or late season winter storms at both residential and commercial structures, causing significant damages.

The economic and financial impacts of winter weather on the community will depend on the scale of the event, what is damaged, and how quickly repairs to critical components of the economy can be implemented. The level of preparedness and pre-event planning done by businesses and citizens will also contribute to the overall economic and financial conditions in the aftermath of a winter storm event.

CLIMATE CHANGE CONSIDERATIONS

Climate change is expected to reduce the number of extreme cold events statewide but increase in the variability of events.[13] Extreme cold events will continue to be possible but overall winters are becoming milder, and the frequency of extreme winter weather events are decreasing due to the warming of the Arctic and less extreme cold air coming from that region.[14] A trend that is expected to continue with winter extremes estimated to be milder by 2036 compared to extremes in the historic record.[15]

[13] Fourth National Climate Assessment. Chapter 23 Southern Great Plans. U.S. Global Change Program. 2018.
[14] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.
[15] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 14
WILDFIRE



OFFICE OF EMERGENCY MANAGEMENT

SECTION 14: WILDFIRE

Hazard Description 1
Location 1
Extent 2
Historical Occurrences 5
Significant Events 7
Probability of Future Events 7
Vulnerability and Impact 7
Assessment of Impacts 11
Climate Change Considerations 12

HAZARD DESCRIPTION

A wildfire event can rapidly spread out of control and occurs most often in the summer when the brush is dry and flames can move unchecked through a highly vegetative area. Wildfires can start as a slow burning fire along the forest floor, killing and damaging trees. The fires often spread more rapidly as they reach the tops of trees with wind carrying the flames from tree to tree. Usually, dense smoke is the first indication of a wildfire.

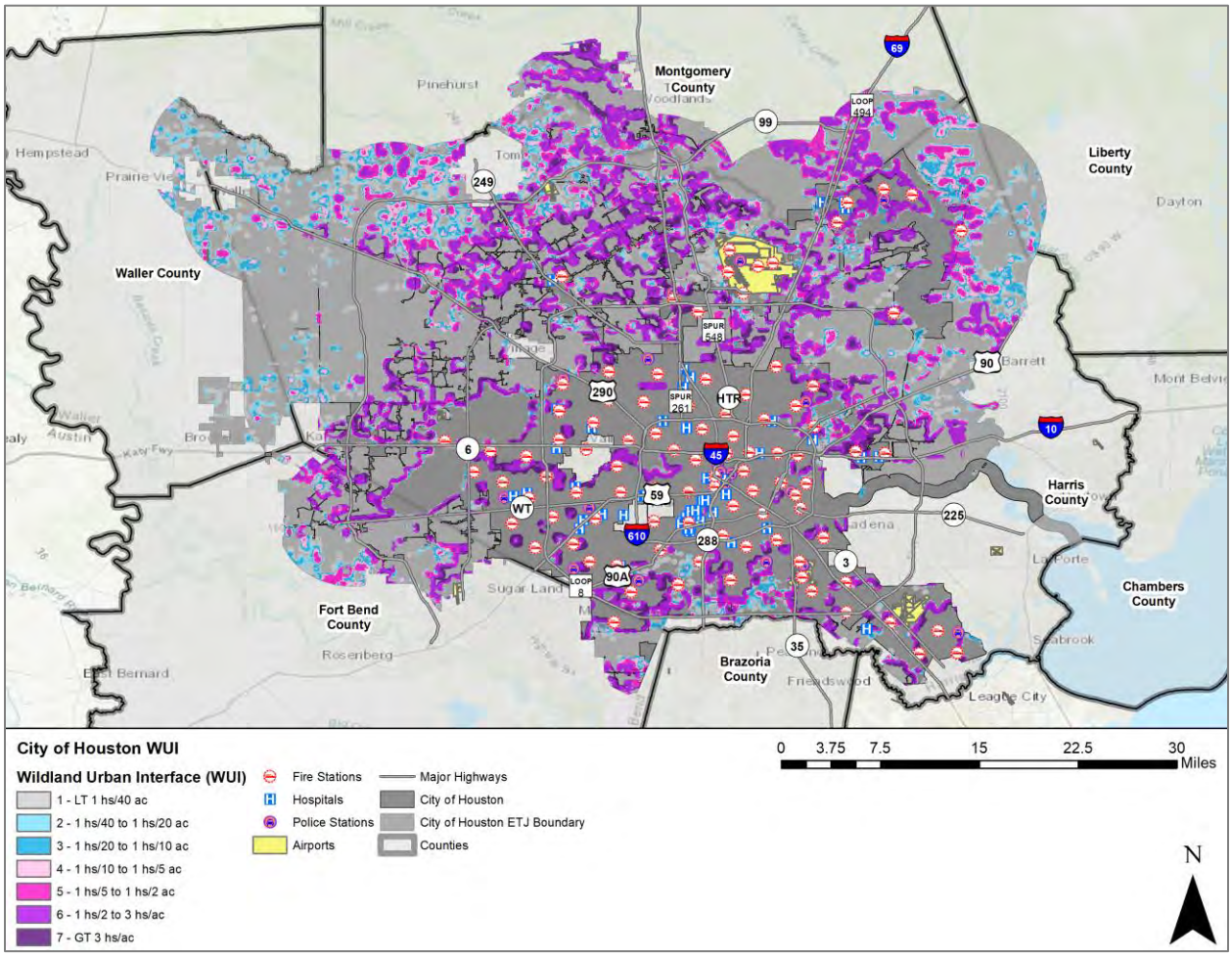
A wildfire event often begins unnoticed and spreads quickly, lighting brush, trees, and homes on fire. For example, a wildfire may be started by a campfire that was not doused properly, a tossed cigarette, burning debris, or arson.

Texas has seen a significant increase in the number of wildfires in the past 30 years, which included wildland, interface, or intermix fires. Wildland fires are fueled almost exclusively by natural vegetation, while interface or intermix fires are urban/wildland fires in which vegetation and the built environment provide the fuel.

LOCATION

A wildfire event can be a potentially damaging consequence of drought conditions, lightning, or wind event, if the conditions allow. Wildfires can vary greatly in terms of size, location, intensity, and duration. While wildfires are not confined to any specific geographic location, they are most likely to occur in open grasslands. The threat to people and property from a wildfire event is greater in the fringe areas where developed areas meet open grass lands, such as the Wildland Urban Interface (WUI) (Figure 14-1). It is estimated that 14.3 percent of the total population in the City of Houston live within the WUI. However, the entire City of Houston planning area is at some risk for wildfires.

Figure 14-1. Wildland Urban Interface Map – City of Houston



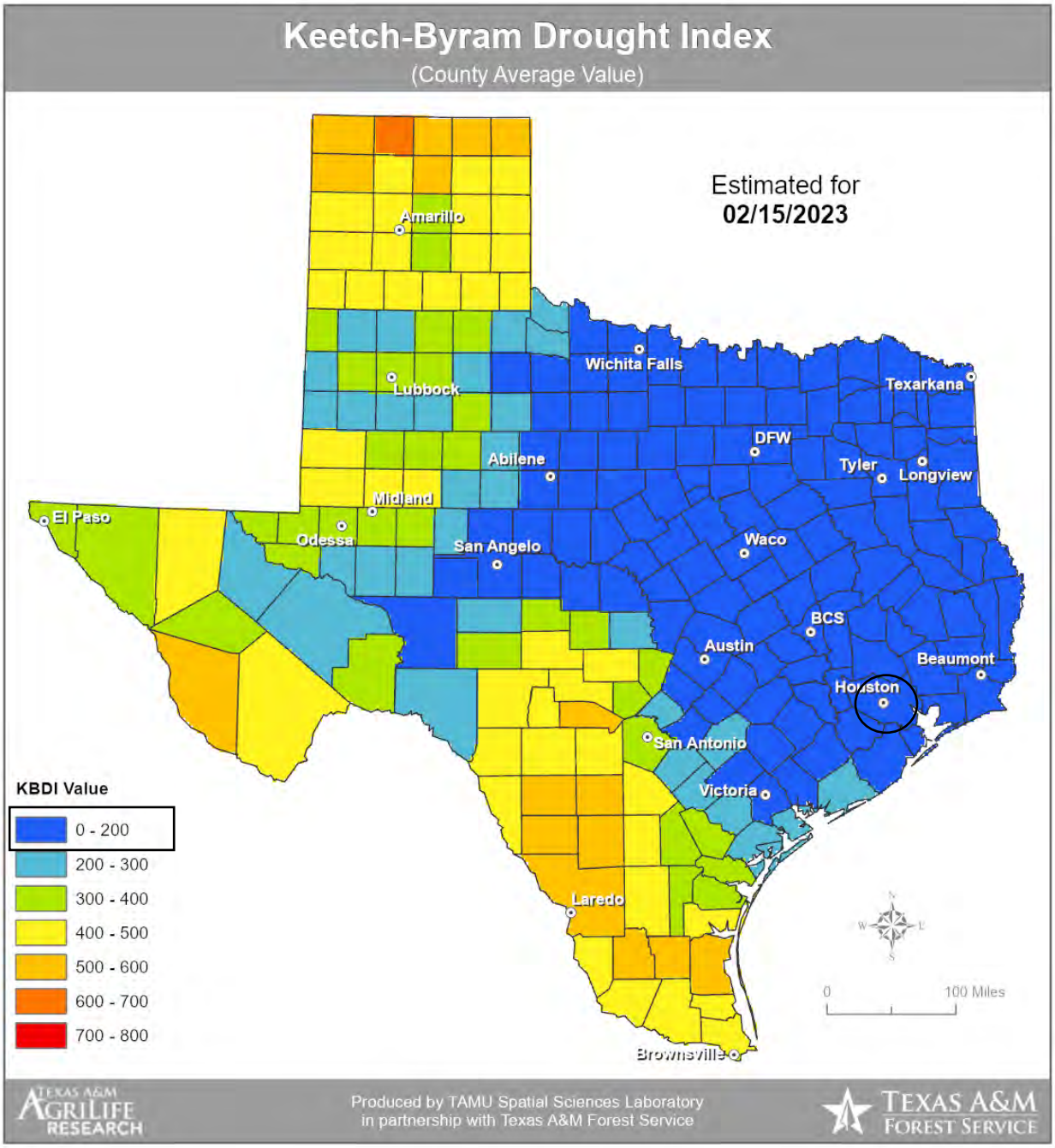
EXTENT



Risk for a wildfire event is measured in terms of magnitude and intensity using the Keetch Byram Drought Index (KBDI), a mathematical system for relating current and recent weather conditions to potential or expected fire behavior. The KBDI determines forest fire potential based on a daily water balance, derived by balancing a drought factor with precipitation and soil moisture (assumed to have a maximum storage capacity of eight inches), and is expressed in hundredths of an inch of soil moisture depletion.

Each color in Figure 14-2 represents the drought index at that location. The drought index ranges from 0 to 800. A drought index of 0 represents no moisture depletion, and a drought index of 800 represents absolutely dry conditions.

Figure 14-2. Keetch-Byram Drought Index (KBDI) for the State of Texas, 2023[1]



Fire behavior can be categorized at four distinct levels on the KBDI:

- **0 -200:** Soil and fuel moisture are high. Most fuels will not readily ignite or burn. However, with sufficient sunlight and wind, cured grasses and some light surface fuels will burn in spots and patches.

[1] City of Houston is located within the black circle.

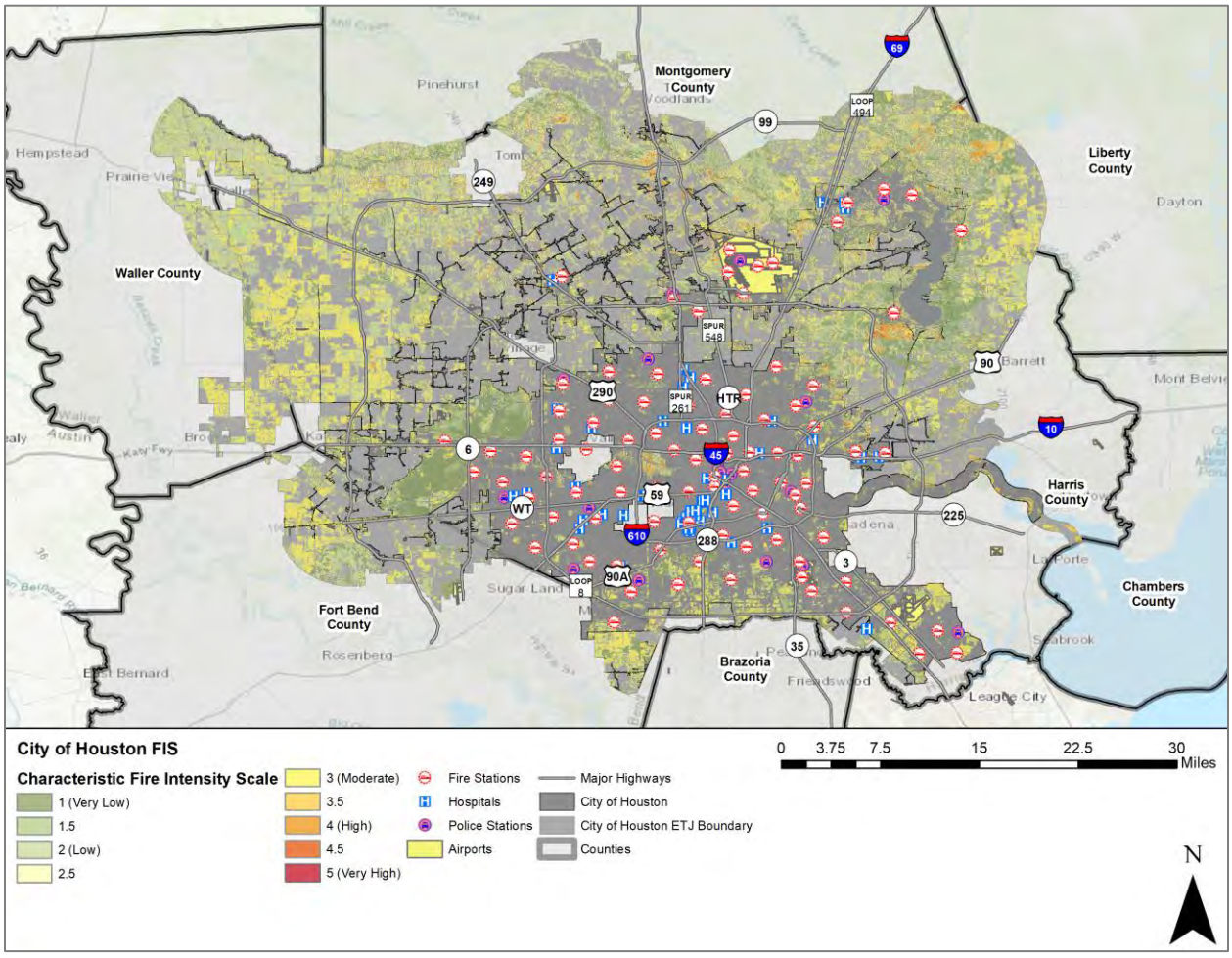
- **200 -400:** Fires more readily burn and will carry across an area with no gaps. Heavier fuels will not readily ignite and burn. Expect smoldering and the resulting smoke to carry into and possibly through the night.
- **400 -600:** Fires intensity begins to significantly increase. Fires will readily burn in all directions exposing mineral soils in some locations. Larger fuels may burn or smolder for several days creating possible smoke and control problems.
- **600 -800:** Fires will burn to mineral soil. Stumps will burn to the end of underground roots and spotting will be a major problem. Fires will burn through the night and heavier fuels will actively burn and contribute to fire intensity.

The KBDI is a good measure of the readiness of fuels for a wildfire event. It should be referenced as the area experiences changes in precipitation and soil moisture, while caution should be exercised in dryer, hotter conditions.

The range of intensity for the City of Houston planning area in a wildfire event is within 161 to 766. The average extent to be mitigated for the City of Houston planning area, is a KBDI of 409. At this level fires intensity begins to significantly increase. Fire will readily burn in all directions exposing mineral soils in some locations. The worst the planning area can anticipate based on historical occurrences and readily available fuel is 200 to 600 as 409 falls within this range. At the high end of this range fires will burn to mineral soil. Stumps will burn to the end of underground roots and spotting will be a major problem. Fires will burn through the night and heavier fuels will actively burn and contribute to fire intensity.

The Texas Forest Service's Fire Intensity Scale identifies areas where significant fuel hazards and associated dangerous fire behavior potential exist based on weighted average of four percentile weather categories. The City of Houston has a potential for limited to moderate wildfire intensities. Figure 14-3 identifies the wildfire intensity for the City of Houston planning area.

Figure 14-3. Fire Intensity Scale Map – City of Houston



HISTORICAL OCCURRENCES

The Texas Forest Service reported 830 wildfire events between 2005 and 2021. The National Centers for Environmental Information (NCEI) did not include any wildfire events from 1996 through 2022. The Texas Forest Service (TFS) started collecting wildfire reported by volunteer fire departments in 2005. Due to a lack of recorded data for wildfire events prior to 2005, frequency calculations are based on a seventeen-year reporting period, using only data from recorded years. The map below shows approximate locations of wildfires, which can be grass or brushfires of any size (Figure 14-4). Tables 14-2 and 14-3 identify the number of wildfires and total acreage burned each year within the City of Houston boundaries.

Figure 14-4. Location and Historic Wildfire Events for the City of Houston

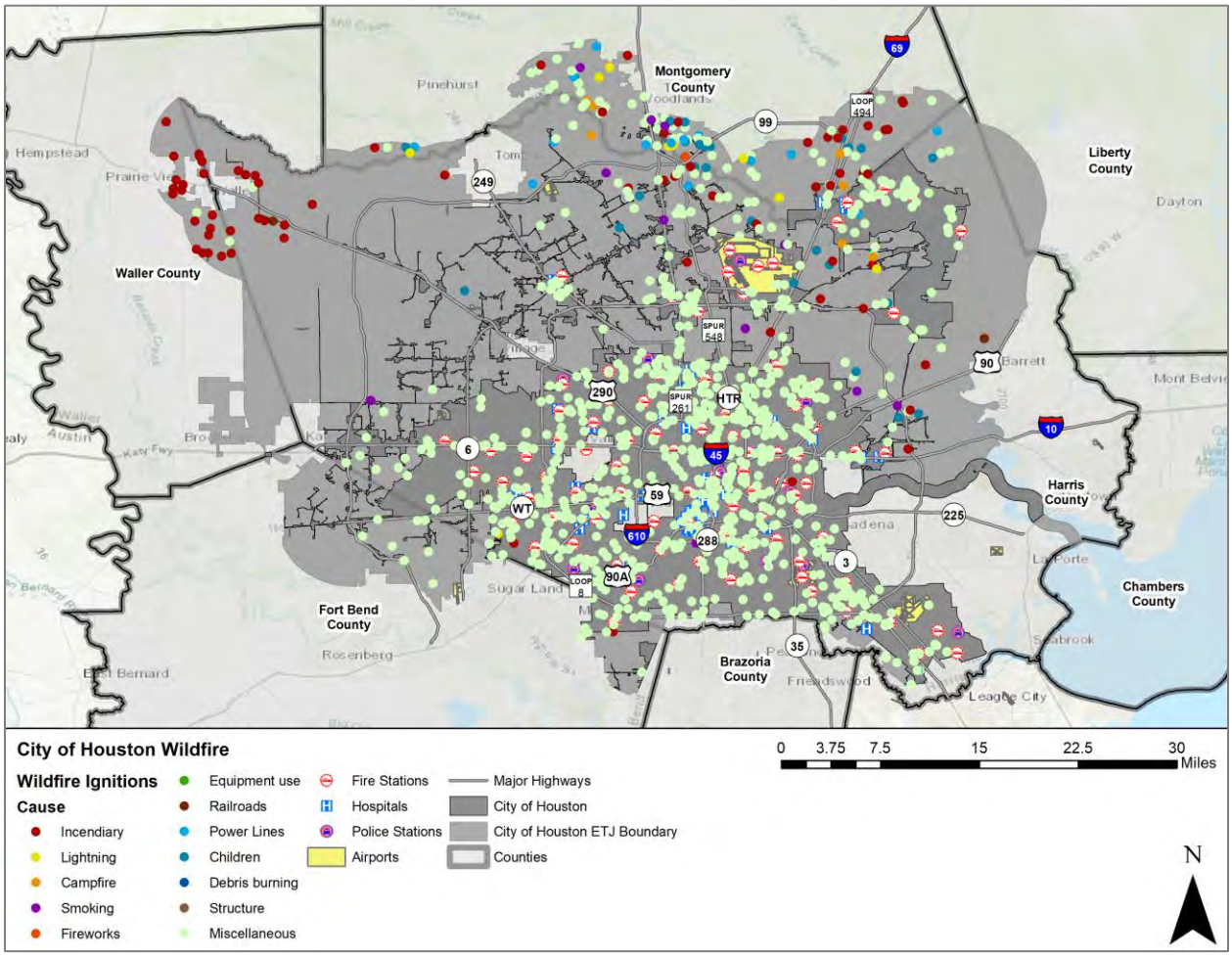


Table 14-1. Historical Wildfire Events Summary, 2005 - 2021

JURISDICTION	NUMBER OF EVENTS	ACRES BURNED
City of Houston	830	2,391

Table 14-2. Historical Wildfire Events by Year

JURISDICTION	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
City of Houston	2	0	1	1	0	1	26	4	3	3	2	0	2	0	265	216	304
																	Total: 830

Table 14-3. Acreage of Suppressed Wildfire by Year

JURISDICTION	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
City of Houston	9	0	1	1	0	0	2110	8	39	3	0	0	23	0	110	44	43
																	Total: 2,391

Based on the list of historical wildfire events for the City of Houston planning area (listed above), 787 events have occurred since the 2018 Plan.

SIGNIFICANT EVENTS

1979 – Woodway Square Apartments Fire – City of Houston
The wide-spread use of wooden shingles and high winds created a firestorm that consumed over 324 apartments and 10 city blocks. The fire resulted in a seven alarm fire with losses of over $34 million. This fire led to a change in building codes and construction materials.

1995 – Houston Distribution Warehouse Fire – City of Houston
This fire did not originate as a wildland fire but required the evacuation of the Pleasantville subdivision for more than 30 hours. The seven alarm fire spread rapidly and involved ten acres of warehouses. Fighting the event required one third of the Houston Fire Department's resources and assistance from Channel Industries Mutual Aid (CIMA) to extinguish.

2011– Houston Distribution Warehouse Fire – City of Houston
A large fire burned about 1,500 acres of land at a west Houston park. Three buildings near the Barker Reservoir in the City of Houston were impacted by the George Bush Park Fire which covered six square miles.

PROBABILITY OF FUTURE EVENTS

Wildfires can occur at any time of the year. As the city moves into wildland, the potential area of occurrence of wildfire increases. With 830 events in a 17-year period, an event within the City of Houston is highly likely, meaning an event is probable within the next year. According to NOAA, research shows that changes in climate create warmer, drier conditions, leading to longer and more active fire seasons, indicating an increase in the frequency and severity of events in the planning area going forward. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Periods of drought, dry conditions, high temperatures, and low humidity are factors that contribute to the occurrence of a wildfire event, as was experienced in 2011. Areas along railroads and people whose homes are in woodland settings have an increased risk of being affected by wildfire.

The heavily populated, urban areas of City of Houston are not likely to experience large, sweeping fires. Unoccupied buildings and open spaces that have not been maintained have the greatest vulnerability to wildfire. The overall level of concern for wildfires is located mostly along the

perimeter of the study area where wildland and urban areas interface. Figure 14-1 illustrates the areas that are the most vulnerable to wildfire throughout the City. Areas along major highways in the City have an increased vulnerability where empty lots and unoccupied areas are located.

Table 14-4 shows the number of structures more vulnerable to wildfire in the City of Houston planning area according to the 2012 Harris County Community Wildfire Protection Plan.

Table 14-4. City of Houston Vulnerable Structures by Type

JURISDICTION	RESIDENTIAL STRUCTURES	COMMERCIAL STRUCTURES	CRITICAL FACILITIES
City of Houston	56,173	3,187	55

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by wildfire events.

Table 14-5. Critical Facilities Vulnerable to Wildfire Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, (14 within WUI) 18 Police Stations (4 within WUI)	■ Emergency services may be disrupted during a wildfire if facilities are impacted, roadways are inaccessible, or personnel are unable to report for duty. ■ First responders are at greater risk of injury when in close proximity to the hazard while extinguishing flames, protecting property, or evacuating residents in the area. ■ Critical city departments may not be able to function and provide necessary services depending on the location of the fire and the structures or personnel impacted. ■ Roadways in or near the WUI could be damaged or closed due to smoke and limited visibility, slowing or preventing access for emergency response vehicles. ■ Fire suppression costs can be substantial, exhausting the financial resources of the community. ■ First responders can experience heart disease, respiratory problems, and other long-term related illnesses from prolonged exposure to smoke, chemicals, and heat. ■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Power outages could disrupt communications, delaying emergency response times. ■ Critical staff may be injured or otherwise unable to report for duty, limiting response capabilities.
64 Hospitals (2 within WUI)	■ Structures can be damaged or destroyed in the path of the wildfire. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Critical staff may be unable to report for duty, limiting capabilities.

CRITICAL FACILITIES	POTENTIAL IMPACTS
	■ Evacuations may be necessary due to wildfire threat, extended power outages, or structural damages to facilities.
21 Airports (x within WUI)	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications, and emergency operations.
49 Ground Water Plants (x within WUI), 40 Wastewater Treatment Plants (x within WUI), 3 Water Purification Plants (x within WUI)	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

Within the City of Houston, a total of 830 fire events were reported from 2005 through 2021. All of these events were suspected wildfires. Historic loss and annualized estimates due to wildfires are presented in Table 14-6 below. The average frequency is approximately 49 events every year.

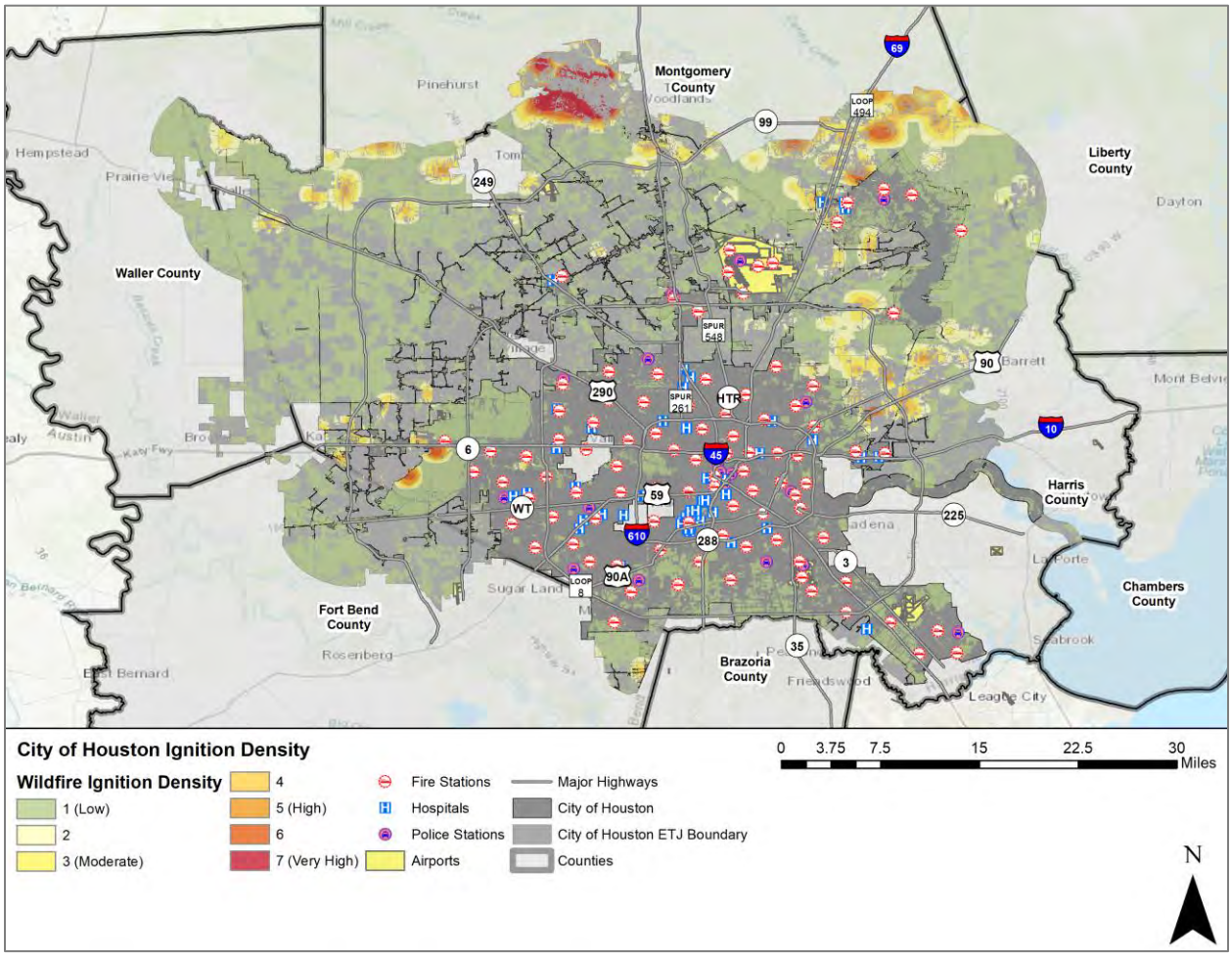
Table 14-6. Potential Annualized Acreage Losses[2]

JURISDICTION	ACRES BURNED	ANNUAL ACRE LOSSES
City of Houston	2,391	140.6

Figure 14-5 shows the threat of wildfire to the City of Houston planning area.

[2] Events divided by 16 years of data.

Figure 14-5. Wildfire Ignition Density – City of Houston



Diminished air quality is an environmental impact that can result from a wildfire event and pose a potential health risk. The smoke plumes from wildfires can contain potentially inhalable carcinogenic matter. Fine particles of invisible soot and ash that are too small for the respiratory system to filter can cause immediate and possibly long-term health effects. The elderly or those individuals with compromised respiratory systems may be more vulnerable to the effects of diminished air quality after a wildfire event.

Climatic conditions such as severe freezes and drought can significantly increase the intensity of wildfires since these conditions kill vegetation, creating a prime fuel source for wildfires. The intensity and rate at which wildfires spread are directly related to wind speed, temperature, and relative humidity.

The severity of impact from major wildfire events can be substantial. Such events can cause multiple deaths, shut down facilities for 30 days or more, and cause more than 50 percent of affected properties to be destroyed or suffer major damage. Severity of impact is gauged by acreage burned, homes and structures lost, and the number of resulting injuries and fatalities.

For the City of Houston planning area, the impact from a wildfire event can be considered “Limited," meaning injuries and/or illnesses are treatable with first aid, shutdown of facilities and

services for 24 hours or less, and less than 10 percent of property is destroyed or with major damage. Severity of impact is gauged by acreage burned, homes and structures lost, injuries and fatalities.

Table 14-7. Impact for City of Houston

JURISDICTION	IMPACT	DESCRIPTION
City of Houston	Limited	City of Houston has an estimated 330,159 people or 14.3% of the total population that live within the Wildland Urban Interface (WUI). Average housing density is most commonly 3 houses per 1 acre. City of Houston citizens may suffer minor injuries that can be treated with first aid. Critical facilities could be shut down for 24 hours or less, and less than 10 percent of total property could be damaged.

ASSESSMENT OF IMPACTS

A Wildfire event poses a potentially significant risk to public health and safety, particularly if the wildfire is initially unnoticed and spreads quickly. The impacts associated with a wildfire are not limited to the direct damages. Significant wildfire events can be frequently associated with a variety of impacts, including:

- The City of Houston's urban parks include 39,501 acres of open space. Community assets including places like Memorial Park or the Armand Bayou Nature Center are vulnerable to the impacts of wildfire events. Recreation and tourism can be unappealing for years following a large wildfire, devastating directly related businesses.
- Recreation activities throughout the City's parks may be unavailable and tourism can be unappealing for years following a large wildfire event, devastating directly related local businesses and negatively impacting economic recovery.
- Persons in the area at the time of the fire are at risk for injury or death from burns and/or smoke inhalation.
- First responders are at greater risk of physical injury when in close proximity to the hazard while extinguishing flames, protecting property, or evacuating residents in the area.
- First responders can experience heart disease, respiratory problems, and other long-term related illnesses from prolonged exposure to smoke, chemicals, and heat.
- Emergency services may be disrupted during a wildfire if facilities are impacted, roadways are inaccessible, or personnel are unable to report for duty.
- Critical City departments may not be able to function and provide necessary services depending on the location of the fire and the structures or personnel impacted.
- Non-critical businesses may be directly damaged, suffer loss of utility services, or be otherwise inaccessible, delaying normal operations and slowing the recovery process.
- Displaced residents may not be able to immediately return to work, further slowing economic recovery.

- Roadways in or near the WUI could be damaged or closed due to smoke and limited visibility.
- Older homes are generally exempt from modern building code requirements, which may require fire suppression equipment in the structure. 51 percent of homes in City were built before 1980. 265 buildings and sites in the City are on the National Register of Historic Places, many of which pre-date modern building codes.
- Vegetation in the City's urban parks may be destroyed in a wildfire, impacting air quality and public health.
- Some high-density neighborhoods feature small lots with structures close together, increasing the potential for fire to spread rapidly.
- Air pollution from smoke may exacerbate respiratory problems of vulnerable residents.
- Charred ground after a wildfire cannot easily absorb rainwater, increasing the risk of flooding and potential mudflows.
- Wildlife may be displaced or destroyed.
- Historical or cultural resources may be damaged or destroyed.
- Tourism can be significantly disrupted, further delaying economic recovery for the area.
- Economic disruption negatively impacts the programs and services provided by the community due to short- and long-term loss in revenue.
- Fire suppression costs can be substantial, exhausting the financial resources of the community.
- Residential structures lost in a wildfire may not be rebuilt for years, reducing the tax base for the community.
- Direct impacts to municipal water supply may occur through contamination of ash and debris during the fire, destruction of aboveground delivery lines, and soil erosion or debris deposits into waterways after the fire.

The economic and financial impacts of a wildfire event on local government will depend on the scale of the event, what is damaged, costs of repair or replacement, lost business days in impacted areas, and how quickly repairs to critical components of the economy can be implemented. The level of preparedness and pre-event planning done by government, businesses, and citizens will contribute to the overall economic and financial conditions in the aftermath of a wildfire event.

CLIMATE CHANGE CONSIDERATIONS

Wildfires require the alignment of a number of factors, including temperature, humidity, and the lack of moisture in fuels, such as trees, shrubs, grasses, and forest debris. All these factors have strong direct or indirect ties to climate variability and climate change. Research shows that changes in climate create warmer, drier conditions, leading to longer and more active fire seasons. Increases in temperatures and the thirst of the atmosphere due to human--caused climate change have increased aridity of forest fuels during the fire season.[3]

Vapor pressure deficit, an indicator of the ability of moisture to evaporate, is projected to increase as temperatures rise and carbon dioxide fertilization reduces transpiration, leading to both lower humidity and increased surface dryness. Overall, increased dryness should extend the wildfire

[3] NOAA Wildfire Climate Connection, August 2022: wildfire-climate-connection.

season in places where the fire season is presently constrained by low levels of aridity, such as eastern Texas.[4]

Extreme heat and extended periods of drought contribute to wildfire risk in the planning area. Extreme temperatures and periods of drought destroy vegetation in the area, contributing to available fuels that spread wildfires. The 2011 drought killed approximately half the trees in Houston's Memorial Park. Additional climate change impacts from drought and extreme heat are discussed in Sections 7 and 8 of this Plan. The projected increases in favorable wildfire conditions, including drought and extreme heat, indicate an increase in favorable wildfire conditions. Additional information and studies are needed to determine the degree and rate of any increased wildfire risk.

[4] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 15
LIGHTNING



OFFICE OF EMERGENCY MANAGEMENT

SECTION 15: LIGHTNING

Hazard Description 1
Location 1
Extent 1
Historical Occurrences 3
Significant Events 5
Probability of Future Events 5
Vulnerability and Impact 5
Assessment of Impacts 8
Climate Change Considerations 9

HAZARD DESCRIPTION

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes the thunder which often accompanies lightning strikes. While most often affiliated with severe thunderstorms, lightning often strikes outside of heavy rain and might occur as far as 10 miles away from any rainfall.

According to the National Weather Service (NWS), the 10-year (2012–2021) average for fatalities is 23 people with an average of 300 injuries in the United States each year by lightning. Lightning can occur as cloud to ground flashes or as intra-cloud lightning flashes. Direct lightning strikes can cause significant damage to buildings, critical facilities, infrastructure, and communication equipment affecting emergency response. Lightning is also responsible for igniting wildfires that can result in widespread damages to property before firefighters have the ability to contain and suppress the resultant fire.

LOCATION

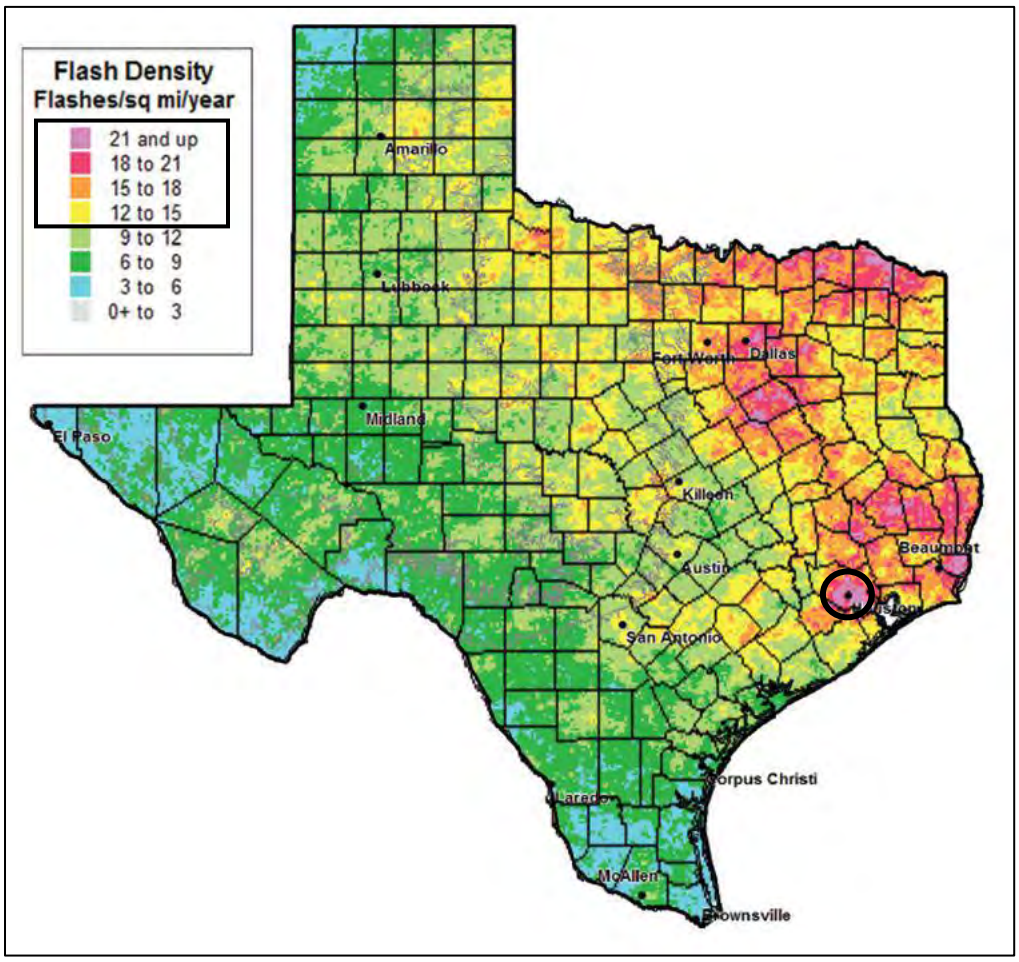
Lightning can strike in any geographic location and is considered a common occurrence in Texas. The City of Houston planning area is in a region of the country that is moderately susceptible to a lightning strike. Therefore, lightning could occur at any location within the entire planning area. It is assumed that the entire City of Houston planning area is uniformly exposed to the threat of lightning.

EXTENT

According to NOAA, the average number of cloud-to-ground flashes for the State of Texas between 2006 and 2016 was 11.3 flashes per square mile. Vaisala's U.S. National Lightning Detection Network lightning flash density map (Figure 15-1) shows a range of twelve to twenty-

one cloud-to-ground lightning flashes per square mile per year for the entire City of Houston planning area. This rate equates to approximately 7,980 to 13,965 flashes per year for the entire planning area.

Figure 15-1. Lightning Flash Density, 2006-2016



The extent for lightning can be expressed in terms of the number of strikes in an interval. NOAA utilizes lightning activity levels (LALs) on a scale from 1-6. LAL rankings reflect the frequency of cloud-to-ground lightning either forecast or observed (Table 15-1).

Table 15-1. NOAA Lightning Activity Levels (LAL)

LAL	CLOUD & STORM DEVELOPMENT	LIGHTNING STRIKES/ 15 MIN
1	No thunderstorms.	-
2	Cumulus clouds are common but only a few reach the towering cumulus stage. A single thunderstorm must be confirmed in the observation area. The clouds produce mainly virga, but light rain will occasionally reach the ground. Lightning is very infrequent.	1-8

LAL	CLOUD & STORM DEVELOPMENT	LIGHTNING STRIKES/ 15 MIN
3	Towering cumulus covers less than two-tenths of the sky. Thunderstorms are few, but two to three must occur within the observation area. Light to moderate rain will reach the ground, and lightning is infrequent.	9-15
4	Towering cumulus covers two to three-tenths of the sky. Thunderstorms are scattered and more than three must occur within the observation area. Moderate rain is common and lightning is frequent.	16-25
5	Towering cumulus and thunderstorms are numerous. They cover more than three-tenths and occasionally obscure the sky. Rain is moderate to heavy and lightning is frequent and intense.	>25
6	Similar to LAL 3 except thunderstorms are dry.	

The NCEI does not include the LAL for historical lightning events, therefore in order to determine the extent of lightning strikes, the yearly average range of estimated number of lightning strikes within the planning area (7,980 to 13,965 flashes) and a cloud-to-ground flash density of twelve to twenty-one per square mile were divided by the number[1] of thunderstorm events that occur annually in the planning area. The City of Houston should expect an average range of nineteen to forty-six lightning strikes within 15 minutes at any given time during a lightning or combined lightning and thunderstorm event, indicating lightning strikes have an average LAL range of 2 to 5. The highest anticipated being a 5 on the LAL for the planning area in the future.

HISTORICAL OCCURRENCES

Since January 1996, there has been twenty-five recorded events for the City of Houston planning area. It is highly likely multiple lightning occurrences have gone unreported before and during the recording period. The NCEI is a national data source organized under the National Oceanic and Atmospheric Administration and considered a reliable resource for hazards. However, the flash density for the planning area along with input from local team members indicates regular lightning occurrences that simply have not been reported.

Table 15-2 Historical Lightning Events, 1996- 2022[2]

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	7/26/1996	0	0	$188,644	$0
City of Houston	3/18/1997	0	0	$138,830	$0

[1] Analysis includes the highest number of events recorded in a given year during the reporting period in order to account for typical under reporting of thunderstorm and lightning events.
[2] Damages are reported in 2022 dollars. Events are reported from January 1996 through October 2022.

SECTION 15: LIGHTNING

JURISDICTION	DATE	DEATHS	INJURIES	PROPERTY DAMAGE	CROP DAMAGE
City of Houston	9/2/1997	0	1	$367,458	$0
City of Houston	3/14/2000	1	0	$0	$0
City of Houston	8/2/2000	0	17	$0	$0
City of Houston	6/17/2004	1	0	$0	$0
City of Houston	8/28/2004	0	1	$31,258	$0
City of Houston	2/1/2005	1	1	$0	$0
City of Houston	2/24/2005	0	1	$0	$0
City of Houston	5/29/2005	0	1	$0	$0
City of Houston	5/29/2005	0	0	$304,703	$0
City of Houston	10/7/2007	0	1	$0	$0
City of Houston	6/18/2008	0	0	$47,373	$0
City of Houston	6/25/2008	0	1	$0	$0
City of Houston	7/19/2012	0	1	$0	$0
City of Houston	5/10/2013	0	1	$0	$0
City of Houston	8/14/2013	0	0	$7,598	$0
City of Houston	6/27/2015	0	0	$18,616	$0
City of Houston	7/4/2015	0	0	$37,230	$0
City of Houston	4/21/2016	1	0	$0	$0
City of Houston	3/29/2017	0	0	$54,666	$0
City of Houston	10/20/2017	0	0	$1,201	$1,201
City of Houston	10/22/2018	1	0	$0	$0
City of Houston	6/24/2019	0	2	$0	$0
City of Houston	8/14/2019	0	0	$28,860	$0
TOTALS		**5**	**28**	**$1,226,437**	**$1,201**

Based on the list of historical lightning events for the City of Houston planning area (listed above), five events have occurred since the 2018 Plan.

SIGNIFICANT EVENTS

September 2, 1997 – City of Houston
Lightning struck the Riverbrook Apartments starting a structure fire. Eighteen units were significantly damaged, and a young boy was taken to the hospital for smoke inhalation.

August 2, 2000 – City of Houston
Lightning struck a tree at Astroworld injuring 17 teenagers. All were treated and quickly released with no permanent injuries.

February 1, 2005 – City of Houston
A lightning strike killed one man and injured another man while walking through a parking lot to their vehicles.

March 29, 2017 – City of Houston
A line of thunderstorms moved across southeast Texas during the morning and afternoon hours and produced several tornadoes, hail, wind damage, lightning and some flooding. Lightning started a fire that caused more than $45,000 in damages to a residential home.

August 10, 2022 – City of Houston
Showers and thunderstorms moved southward across the area, producing wind damage and lightning strikes. A man was hospitalized from a lightning strike in an office parking lot.

PROBABILITY OF FUTURE EVENTS

Based on historical records and input from the planning team the probability of occurrence for future lightning events in the City of Houston planning area is considered highly likely, or an event probable in the next year. The planning team stated that lightning occurs regularly in the area. According to NOAA, the City of Houston planning area is located in an area of the country that experiences approximately twelve to twenty-one lightning flashes per square mile per year (approximately 7,980 to 13,965 flashes per year). Given this estimated probability of events, it can be expected that future lightning events will continue to threaten life and cause minor property damages throughout the planning area. Impacts of climate change are not expected to increase the average frequency of lightning events but may lead to an increase in the intensity of events when they do occur. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Vulnerability is difficult to evaluate since lightning events can occur at different strength levels, in random locations, and can create a broad range of damages depending on the strike location. Due to the randomness of these events, all existing and future structures and facilities in the City of Houston planning area could potentially be impacted and remain vulnerable to possible injury and property loss from lightning strikes. The City of Houston planning area has 25 reported lightning events, since 1996 per the NCEI, however the City is vulnerable and could be impacted by lightning.

The direct and indirect losses associated with these events include injury and loss of life, damage to structures and infrastructure, agricultural losses, utility failure (power outages), and stress on

community resources. The entire population of the City of Houston is considered exposed to the lightning hazard. The peak lightning season in the State of Texas is from June to August; however, the most fatalities occur in July. Fatalities occur most often when people are outdoors and/or participating in some form of recreation. Population located outdoors is considered at risk and more vulnerable to a lightning strike compared to being inside a structure. Moving to a lower risk location will decrease a person's vulnerability.

The entire general building stock and all infrastructure of the City of Houston planning area are considered exposed to the lightning hazard. Lightning can be responsible for damages to buildings, cause electrical, forest and/or wildfires, and damage infrastructure such as power transmission lines and communication towers.

While all citizens are at risk to the impacts of lightning, forced relocation and disaster recovery drastically impacts low-income residents who lack the financial means to travel, afford a long-term stay away from home, and to rebuild or repair their homes. An estimated 19.5 percent of the planning area population live below the poverty level. In addition, renters tend to be more vulnerable to the impacts of lightning events. Their ability to recover after a lightning event is often disproportionally impacted by limited affordable replacement housing, financial constraints, and lack of insurance to cover losses. Within the City 58 percent of housing units are renter-occupied (Table 15-3).

Table 15-3. Populations at Greatest Risk by Jurisdiction[3]

JURISDICTION	POPULATION BELOW POVERTY LEVEL	RENTER OCCUPIED UNITS
City of Houston	63,765	505,745

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by lightning events.

[3] US Census Bureau, American Community Survey Five-Year Estimates, 2021

Table 15-4. Critical Facilities Vulnerable to Lightning Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations and services may be significantly impacted due to power outages, damaged facilities, fires and/or loss of communications as a result of lightning strikes. ■ Emergency vehicles, including critical equipment, can be damaged by lightning strikes or by falling trees damaged by lightning. ■ Power outages could disrupt communications, delaying emergency response times. ■ Downed trees due to lightning strikes can impede emergency response vehicle access to areas. ■ Lightning strikes can be associated with structure fires and wildfires, further straining the capacity and resources of emergency personnel. ■ Extended power outages may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.
64 Hospitals	■ Structures can be damaged by falling trees damaged by lightning. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Evacuations may be necessary due to extended power outages, fires, or other associated damages to facilities.
21 Airports	■ Facilities, infrastructure, or critical equipment including communications may be damaged, destroyed or otherwise inoperable. ■ Essential supplies like medicines, water, food, and equipment deliveries may be delayed. ■ Economic disruption due to power outages and fires negatively impact airport services as well as area businesses reliant on airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

Impact of lightning experienced in the City of Houston planning area has resulted in five injuries and twenty-eight fatalities. The historical injuries and fatalities indicate a “Substantial” impact with multiple fatalities possible. Overall, the average loss estimate for the City of Houston (in 2022 dollars) is $1,229,839 having an approximate annual loss estimate of $45,550 (Table 15-5).

Table 15-5. Potential Annualized Losses by Jurisdiction[4]

JURISDICTION	PROPERTY & CROP LOSS	ANNUAL LOSS ESTIMATE
City of Houston	$1,229,839	$45,550

ASSESSMENT OF IMPACTS

Lightning events have the potential to pose a significant risk to people and can create dangerous and difficult situations for public health and safety officials. Additional impacts to the planning area can include:

- The City of Houston features 39,501 acres of total park space includes 382 developed parks and 167 green spaces. Lightning events could impact recreational activities, placing residents and visitors in imminent danger, potentially requiring emergency services or park evacuation.
- Older structures built to less stringent building codes may suffer greater damage from a lightning strike as they are typically built with less fire resistant materials and often lack any fire mitigation measures such as sprinkler systems. 51 percent of homes in the City were built before 1980. 265 buildings and sites in the City are on the National Register of Historic Places, many of them similarly lack fire mitigation materials or measures.
- Vegetation in the City's urban parks may be destroyed by lightning caused brush fires, impacting air quality and public health.
- Individuals exposed to the storm can be directly struck, posing significant health risks and potential death.
- Structures can be damaged or crushed by falling trees damaged by lightning, which can result in physical harm to the occupants.
- Lightning strikes can result in widespread power outages increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outage often results in an increase in structure fires and carbon monoxide poisoning as individuals attempt to cook or heat their homes with alternate, unsafe cooking or heating devices, such as grills.
- Lightning strikes can be associated with structure fires and wildfires, creating additional risk to residents and first responders.
- Emergency operations and services may be significantly impacted due to power outages and/or loss of communications.
- City departments may be damaged, delaying response and recovery efforts for the entire community.
- Economic disruption due to power outages and fires negatively impacts the programs and services provided by the community due to short and long term loss in revenue.
- Some businesses not directly damaged by lightning events may be negatively impacted while utilities are being restored, further slowing economic recovery.

[4] Damage values are in 2022 dollars.

- Businesses that are more reliant on utility infrastructure than others may suffer greater damages without a backup power source.

The economic and financial impacts of lightning on the area will depend entirely on the scale of the event, what is damaged, and how quickly repairs to critical components of the economy can be implemented. The level of preparedness and pre-event planning done by the City, local businesses, and citizens will also contribute to the overall economic and financial conditions in the aftermath of any significant lightning event.

CLIMATE CHANGE CONSIDERATIONS

As CO_2 increases and the land surface warms, stronger updrafts are more likely to produce lightning. In a climate with double the amount of CO_2, we may see fewer lightning storms overall, but 25 percent stronger storms, with a 5 percent increase in lightning. Lightning damage is also likely to increase because of its role in igniting forest fires, where dry vegetation, also caused by rising temperatures, creates more 'fuel' for fires, so even a small climate change may have huge consequences. While the impact climate change will have on our weather still remains uncertain, researchers agree that implementing simple measures like lightning detection systems and installing grounding systems in buildings could go a long way in avoiding deaths and injuries.[5]

Utilizing historic events in five-year increments, an analysis was completed to estimate the change rate for lightning events for the last three planning cycles. Table 15-6 shows the estimated change rate (+/-) for lightning events for the planning area from one planning cycle to the next.

Table 15-6. Historic Lightning Event Overview by Planning Cycle[6]

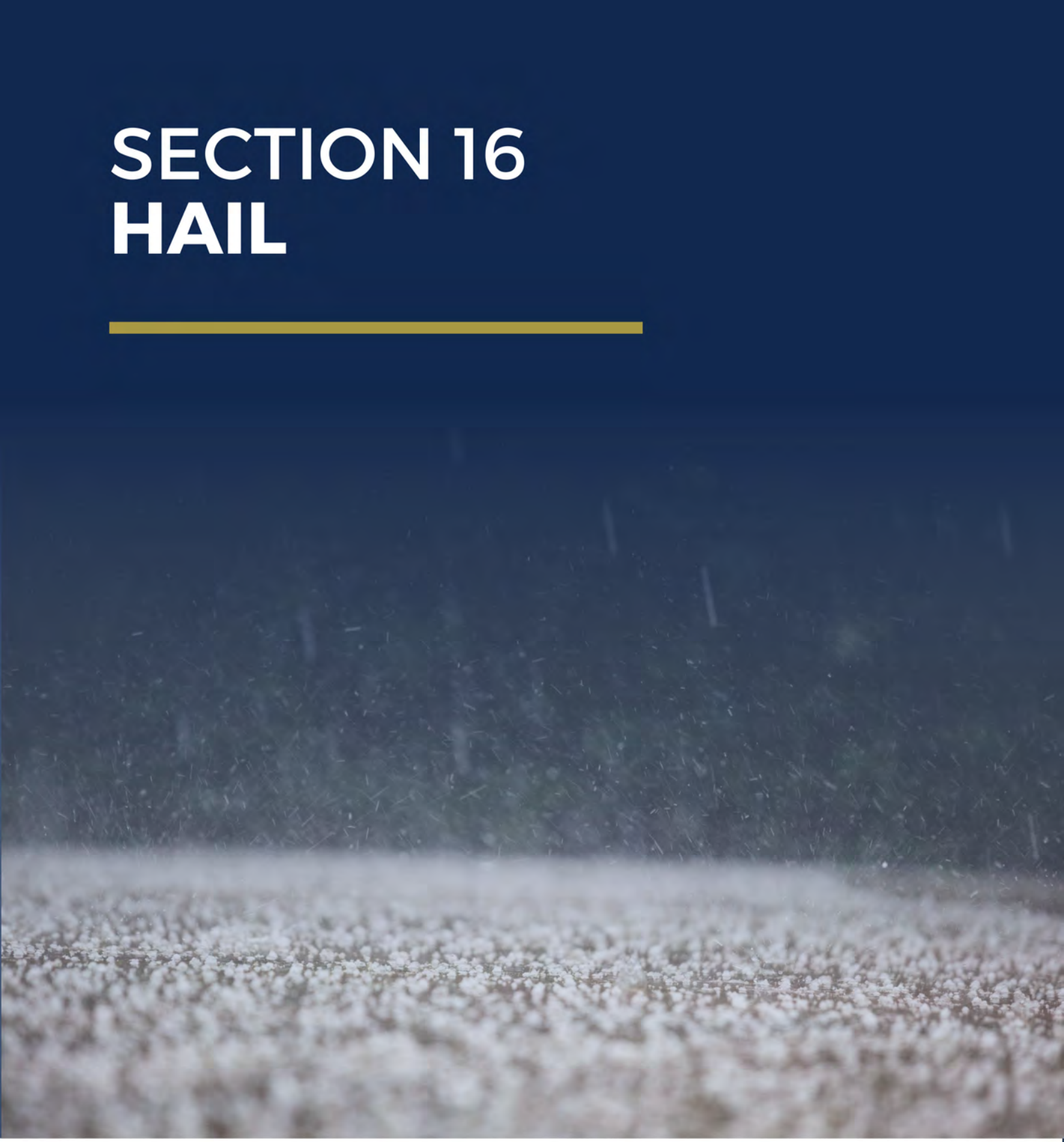
EVENTS 2008-2012	EVENTS 2013-2017	PERCENT CHANGE	EVENTS 2018-2022	PERCENT CHANGE
3	7	+133%	3	-57%

Lightning events have the potential to pose a significant risk to people and property throughout the planning area. The economic and financial impacts of lightning on the area will depend entirely on the scale of the event, what is damaged, and how quickly repairs to critical components of the economy can be implemented. While no increase in the number of hazard events is anticipated, the impact of the hazard may see an increase in losses. As populations grow and urban development continues to rise, the overall vulnerability and impact are expected to increase in the next five years.

[5] Environmental Journal, Nathan Neal, January 11, 2021.

[6] Variations of reported impacts or events from one planning cycle to the next may be the result of changes in event reporting and not an indication of changing weather patterns.

SECTION 16
HAIL



OFFICE OF EMERGENCY MANAGEMENT

SECTION 16: HAIL

Hazard Description 1
Location 2
Extent 2
Historical Occurrences 3
Significant Events 12
Probability of Future Events 12
Vulnerability and Impact 12
Assessment of Impacts 14
Climate Change Considerations 16

HAZARD DESCRIPTION



Hailstorm events are a potentially damaging outgrowth of severe thunderstorms. During the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere, and the subsequent cooling of the air mass. Frozen droplets gradually accumulate into ice crystals until they fall as precipitation that is round or irregularly shaped masses of ice typically greater than 0.75 inches in diameter. The size of hailstones is a direct result of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a by-product of heating on the Earth's surface. Higher temperature gradients above Earth's surface result in increased suspension time and hailstone size.

According to the National Insurance Crime Bureau (NICB), between 2018 and 2020 the State of Texas had the greatest number of hail loss claims in the United States with 605,866 loss claims (23 percent of total hail claims in the U.S.) due to hail events. In this two-year period Texas experienced a total of 584 severe hail days.

In 2021, 6.8 million properties in the U.S. experienced one or more damaging hail events, resulting in a total of $16.5 billion in insured losses. Texas had the highest number of properties affected by hail with over 1.5 million properties or 17 percent of total properties in the state affected; an increase of 80,000 properties affected between 2020 and 2021. Texas hailstorms accounted for almost a quarter of total U.S. properties affected by hail in 2021, with Harris County experiencing the most damages with an estimated 169,579 properties affected by hailstorms.[1]

[1] Samanta, Arindam, "Understanding evolving hail risk, Hail Report 2022" (Verisk, 2022). https://www.verisk.com/insurance/capabilities/weather-risk/hail-and-severe-thunderstorm-risk/

LOCATION

Hailstorms are an extension of severe thunderstorms that could potentially cause severe damage. As a result, they are not confined to any specific geographic location and can vary greatly in size, location, intensity, and duration. Therefore, the entire City of Houston planning area is equally at risk to hail events. Refer to Figure 16-1 for the location of past hail events in the planning area.

EXTENT

The National Weather Service (NWS) classifies a storm as "severe" if there is hail three-quarters of an inch in diameter (approximately the size of a penny) or greater, based on radar intensity or as seen by observers. The intensity category of a hailstorm depends on hail size and the potential damage it could cause, as depicted in the National Centers for Environmental Information (NCEI) Intensity Scale in Table 16-1.

Table 16-1. Hail Intensity and Magnitude[2]

SIZE CODE	INTENSITY CATEGORY	SIZE (Diameter Inches)	DESCRIPTIVE TERM	TYPICAL DAMAGE
H0	Hard Hail	Up to 0.33	Pea	No damage
H1	Potentially Damaging	0.33 – 0.60	Marble	Slight damage to plants and crops
H2	Potentially Damaging	0.60 – 0.80	Dime	Significant damage to plants and crops
H3	Severe	0.80 – 1.20	Nickel	Severe damage to plants and crops
H4	Severe	1.2 – 1.6	Quarter	Widespread glass and auto damage
H5	Destructive	1.6 – 2.0	Half Dollar	Widespread destruction of glass, roofs, and risk of injuries
H6	Destructive	2.0 – 2.4	Ping Pong Ball	Aircraft bodywork dented and brick walls pitted
H7	Very Destructive	2.4 – 3.0	Golf Ball	Severe roof damage and risk of serious injuries
H8	Very Destructive	3.0 – 3.5	Hen Egg	Severe damage to all structures
H9	Super Hailstorms	3.5 – 4.0	Tennis Ball	Extensive structural damage, could cause fatal injuries

[2] NCEI Intensity Scale, based on the TORRO Hailstorm Intensity Scale.

SIZE CODE	INTENSITY CATEGORY	SIZE (Diameter Inches)	DESCRIPTIVE TERM	TYPICAL DAMAGE
H10	Super Hailstorms	4.0 +	Baseball	Extensive structural damage, could cause fatal injuries

The intensity scale in Table 16-1 ranges from H0 to H10, with increments of intensity or damage potential in relation to hail size (distribution and maximum), texture, fall speed, speed of storm translation, and strength of the accompanying wind. Based on available data regarding the previous occurrences for the area, the City of Houston may experience hailstorms ranging from an H0 to an H8. The largest hail event in the City of Houston took place on May 4, 2006 and resulted in hail measuring 3 inches in diameter, or a H8, which is considered a very destructive hailstorm that can cause severe damages to structures. This is likely the greatest extent the planning area can anticipate in the future.

HISTORICAL OCCURRENCES

Historical evidence shown in Figure 16-1 demonstrates that the planning area is vulnerable to hail events overall, which typically result from severe thunderstorm activity. Historical events with reported damages, injuries, or fatalities are shown in Table 16-2. A total of 161 reported historical hail events impacted the City of Houston between 1955 through 2022; these events were reported to NCEI and NOAA databases and may not represent all hail events to have occurred during the past 67 years. Only those events for the City of Houston planning area with latitude and longitude available were plotted (Figure 16-1).

Figure 16-1. Spatial Historical Hail Events, 1955-2022

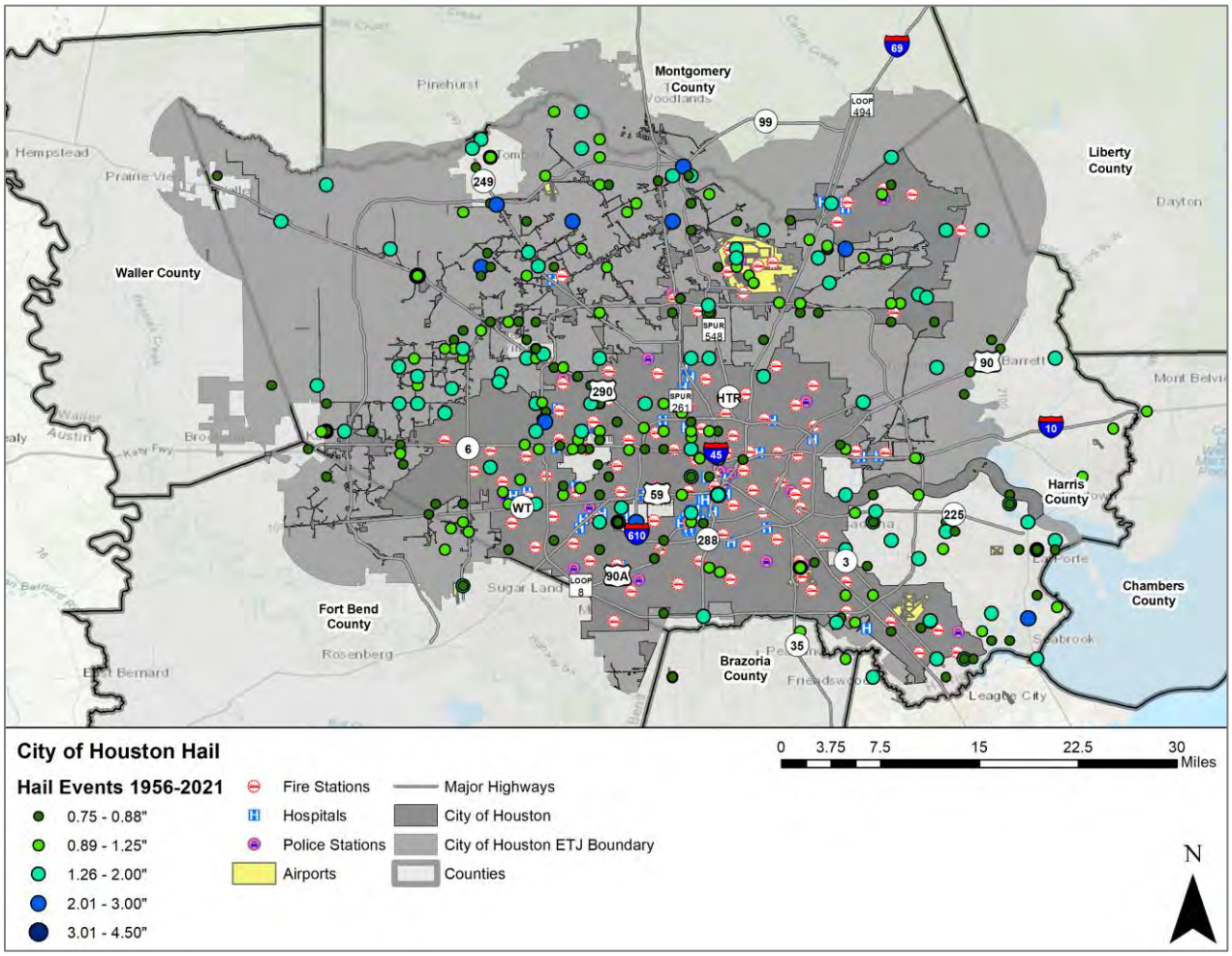


Table 16-2. Historical Hail Events, 1955-2022[3]

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	4/3/1993	0.75	$10,284
City of Houston	4/3/1993	1.75	$102,837
City of Houston	4/3/1993	1.75	$10,284
Clear Lake City	5/28/1994	1	$0
Clear Lake City	1/12/1995	0.75	$0
North West Houston	4/4/1995	1.75	$1,950
City of Houston	4/20/1995	1	$9,749

[3] Only recorded events with damages are listed. No reports of injuries or fatalities were recorded in the NCEI database.

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	4/20/1995	2.75	$9,749
City of Houston	5/18/1995	0.75	$9,730
City of Houston	5/18/1995	0.75	$9,730
City of Houston	11/2/1995	0.75	$9,641
Clear Lake City	11/2/1995	1	$19,282
City of Houston	5/11/1996	0.75	$9,456
City of Houston	5/11/1996	0.75	$9,456
City of Houston	6/2/1996	0.75	$9,450
Almeda	6/2/1996	0.88	$9,450
City of Houston	6/3/1996	0.88	$9,450
Houston Heights	6/4/1996	0.75	$9,450
City of Houston	6/4/1996	0.75	$9,450
City of Houston	6/4/1996	0.75	$47,251
City of Houston	6/13/1996	1	$9,450
City of Houston	6/13/1996	0.75	$9,450
City of Houston	6/18/1996	0.75	$9,450
City of Houston	6/18/1996	0.75	$9,450
Addicks	8/12/1996	0.75	$9,414
City of Houston	8/19/1996	0.75	$9,414
City of Houston	8/26/1996	0.75	$9,414
South Houston	1/27/1997	0.75	$9,308
Addicks	1/27/1997	0.75	$9,308
City of Houston	1/27/1997	0.75	$9,308
City of Houston	1/27/1997	0.75	$9,308
City of Houston	4/11/1997	0.75	$0
City of Houston	4/11/1997	0.75	$0
City of Houston	4/11/1997	0.75	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	4/11/1997	1.75	$0
City of Houston	5/30/1997	0.88	$0
City of Houston	5/31/1997	0.75	$0
City of Houston	6/17/1997	0.75	$0
City of Houston	7/20/1997	0.75	$0
City of Houston	1/21/1998	0.75	$0
City of Houston	1/21/1998	0.75	$0
City of Houston	1/21/1998	1	$0
Clear Lake City	1/21/1998	0.75	$0
City of Houston	7/15/1998	0.75	$0
City of Houston	7/17/1998	0.75	$0
City of Houston	1/1/1999	0.75	$0
City of Houston	1/13/1999	0.75	$0
City of Houston	5/27/1999	0.75	$0
Addicks	5/27/1999	0.75	$0
City of Houston	5/27/1999	0.75	$0
Lake Houston	5/27/1999	1.75	$0
City of Houston	5/30/1999	0.75	$0
City of Houston	5/30/1999	0.75	$0
City of Houston	5/30/1999	0.75	$0
City of Houston	4/2/2000	1	$0
City of Houston	5/3/2000	1	$0
City of Houston	5/3/2000	0.75	$0
City of Houston	5/4/2000	0.75	$0
City of Houston	8/2/2000	0.75	$0
City of Houston	8/2/2000	0.75	$0
City of Houston	3/27/2001	0.75	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	4/16/2001	1.5	$0
City of Houston	5/11/2001	1	$0
City of Houston	5/11/2001	1.75	$0
City of Houston	5/11/2001	0.75	$0
City of Houston	6/26/2001	0.88	$0
City of Houston	6/28/2001	0.88	$0
City of Houston	6/29/2001	0.75	$0
City of Houston	6/29/2001	1	$0
City of Houston	9/21/2001	0.75	$0
(EFD) Ellington Airforce Base	3/30/2002	1	$0
City of Houston	5/30/2002	1	$0
City of Houston	8/3/2002	1	$0
City of Houston	8/23/2002	1	$0
City of Houston	12/23/2002	1	$0
City of Houston	12/23/2002	1	$0
City of Houston	8/8/2003	0.75	$0
City of Houston	8/8/2003	0.75	$0
City of Houston	8/8/2003	0.75	$0
City of Houston	2/14/2003	0.75	$0
City of Houston	2/21/2003	0.75	$0
(HOU) Houston Hobby Airport	4/7/2003	0.75	$0
(HOU) Houston Hobby Airport	4/7/2003	1	$0
South Houston	4/7/2003	1.75	$0
City of Houston	4/7/2003	1.75	$0
(HOU) Houston Hobby Airport	4/7/2003	1	$0
City of Houston	4/24/2003	1.5	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	4/24/2003	0.75	$0
City of Houston	4/24/2003	0.75	$0
City of Houston	4/24/2003	1	$0
City of Houston	4/24/2003	1.75	$0
City of Houston	4/6/2004	1	$0
City of Houston	6/5/2004	1	$0
City of Houston	6/5/2004	1	$0
South Houston	10/4/2004	1	$0
City of Houston	3/7/2005	0.75	$0
City of Houston	3/7/2005	0.75	$0
City of Houston	3/7/2005	1	$0
City of Houston	3/19/2005	1	$0
City of Houston	3/19/2005	1	$0
Houston Heights	3/19/2005	0.75	$0
Addicks	5/8/2005	0.75	$0
Houston Hooks Airport	5/4/2006	1	$0
Houston Hooks Airport	5/4/2006	3	$0
(IAH) Houston Intl Airport	5/4/2006	0.75	$0
Houston Hooks Airport	5/4/2006	1.25	$0
Houston Hooks Airport	5/14/2006	0.88	$0
Houston Heights	3/12/2007	1	$0
Addicks	5/10/2007	1	$0
Addicks	5/10/2007	1	$0
City of Houston	5/14/2007	1.75	$0
City of Houston	5/14/2007	0.75	$0
(IAH) Houston Intl Airport	5/14/2007	0.88	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
City of Houston	5/30/2007	2	$0
City of Houston	5/30/2007	1.75	$0
City of Houston	5/30/2007	1.75	$0
City of Houston	5/30/2007	0.88	$0
City of Houston	5/30/2007	2	$0
Houston Heights	6/18/2008	1.25	$0
Houston Heights	6/18/2008	0.88	$0
Houston Heights	6/18/2008	0.88	$0
Houston Heights	6/18/2008	1	$0
(IAH) Houston Intl Airport	3/27/2009	1.75	$0
(HOU) Houston Hobby Airport	3/27/2009	0.75	$0
Houston Lakeside Airport	4/12/2009	1	$0
White Oak Acres	4/17/2009	1	$0
Hermossey	8/21/2009	0.88	$0
Jeannetta	5/28/2010	0.75	$0
Piney Point	5/28/2010	1	$0
(IAH) Houston Intl Airport	4/2/2012	1	$0
Houston Heights	4/20/2012	1	$0
Hermossey	5/11/2012	1	$0
(IAH) Houston Intl Airport	6/12/2012	1	$0
Houston Weiser Airport	6/26/2012	0.75	$0
Houston Heights	4/27/2013	1	$0
Houston Lakeside Airport	6/6/2013	1.75	$0
Hermossey	4/16/2015	1	$0
White Oak Acres	4/19/2015	1	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
Ellington Field	5/26/2015	0.75	$0
Houston Heights	1/8/2016	1	$6,251
City of Houston	3/18/2016	1.5	$0
White Oak Acres	6/18/2016	0.75	$0
Hermossey	1/20/2017	0.75	$0
Lake Houston Dam	3/29/2017	0.75	$0
(IAH) Houston Intl Airport	5/26/2018	1	$0
Addicks	5/9/2019	1.75	$0
Hermossey	5/9/2019	2	$0
Hermossey	5/9/2019	2.5	$0
Ellington Field	5/9/2019	1.5	$0
Ellington Field	5/9/2019	1.5	$0
Clear Lake City	7/30/2019	0.75	$0
Lake Houston	4/18/2020	1.75	$0
Lake Houston	4/18/2020	1.25	$0
Lake Houston	4/18/2020	1.25	$0
Houston Weiser Airport	4/19/2020	0.75	$0
Houston Lakeside Airport	4/19/2020	1.5	$0
Houston Lakeside Airport	4/19/2020	1.5	$0
Houston Hooks Airport	4/24/2020	1	$0
Houston Hooks Airport	4/15/2021	1	$0
Houston Hooks Airport	4/15/2021	1.5	$0
Englewood	6/15/2021	1	$0
White Oak Acres	4/19/2015	1	$0
Ellington Field	5/26/2015	0.75	$0

SECTION 16: HAIL

LOCATION	DATE	MAGNITUDE (inches)	PROPERTY DAMAGE
Houston Heights	1/8/2016	1	$6,251
City of Houston	3/18/2016	1.5	$0
White Oak Acres	6/18/2016	0.75	$0
Hermossey	1/20/2017	0.75	$0
Lake Houston Dam	3/29/2017	0.75	$0
(IAH) Houston Intl Airport	5/26/2018	1	$0
Addicks	5/9/2019	1.75	$0
Hermossey	5/9/2019	2	$0
Hermossey	5/9/2019	2.5	$0
Ellington Field	5/9/2019	1.5	$0
Ellington Field	5/9/2019	1.5	$0
Clear Lake City	7/30/2019	0.75	$0
Lake Houston	4/18/2020	1.75	$0
Lake Houston	4/18/2020	1.25	$0
Lake Houston	4/18/2020	1.25	$0
Houston Weiser Airport	4/19/2020	0.75	$0
Houston Lakeside Airport	4/19/2020	1.5	$0
Houston Lakeside Airport	4/19/2020	1.5	$0
Houston Hooks Airport	4/24/2020	1	$0
Houston Hooks Airport	4/15/2021	1	$0
Houston Hooks Airport	4/15/2021	1.5	$0
Englewood	6/15/2021	1	$0
		Total	**$35,431,998**

Based on the list of historical hail events for the City of Houston planning area (listed above), 21 of the events have occurred since the 2018 Plan according to reports in the NCEI database.

SIGNIFICANT EVENTS

April 16, 2001
Numerous reports of hail were reported on the west side of the City of Houston the afternoon of April 16, 2001. Hail sizes from 0.75 inch to 1.5 inches were reported along I-10 between Hunters Creek Village and the West Loop. Hail measures 1 to 1.5 inches near South Braeswood and Fondren Road and accumulated up to several inches deep. The hail was still on the ground 24 hours after the storm. There were numerous reports of windows broken and trees and shrubs stripped of their leaves. Damage estimates exceeded $27 million (2017) dollars.

May 4, 2006
Large hail - up to 3 inches (the size of teacups) fell in the Champions Forest Subdivision near Houston Hooks Airport.

May 9, 2019
A severe thunderstorm produced severe hail causing widespread damage across Harris County. The City of Houston area was struck by baseball sized hail in the evening hours.

PROBABILITY OF FUTURE EVENTS

Based on available records of historic events, 161 events in a 67-year reporting period for City of Houston provides a probability of one to 2.4 events per year. This frequency supports a highly likely probability of future events for the City of Houston planning area. See additional information on climate change at the end of this section.

VULNERABILITY AND IMPACT

Much of the damage inflicted by hail is to crops. Even relatively small hail can shred plants to ribbons in a matter of minutes. Vehicles, roofs of buildings and homes, and landscaping are most commonly damaged by hail.

Utility systems on roofs of City buildings and critical facilities would be vulnerable and could be damaged. Hail could cause a significant threat to people as they could be struck by hail and falling trees and branches. Outdoor activities and events may elevate the risk to residents and visitors when a hailstorm strikes with little warning. Portable buildings typically utilized by schools and commercial sites such as construction areas would be more vulnerable to hail events than the typical site-built structures.

The City of Houston planning area features mobile or manufactured home parks throughout the planning area. These parks are typically more vulnerable to hail events than typical site-built structures. In addition, manufactured homes are located sporadically throughout the planning area which would also be more vulnerable. The U.S. Census data indicates a total of 9,450 (1 percent of total housing stock) manufactured homes located in the City of Houston planning area, a 16 percent increase in this housing type since 2018. Another factor of manufactured homes that may increase vulnerability is the age of installation. Inspection of manufactured home installations changed in 2011 when the process was revised statewide, therefore manufactured homes installed prior to 2011 may be more vulnerable to damages from hail events. In addition, 51 percent (approximately 504,772 structures) of the housing structures in the City of Houston

planning area were built before 1980. These structures would typically be built to lower or less stringent construction standards than newer construction and may be more susceptible to damages during significant hail events.

Table 16-3. Structures at Greater Risk to Hail Events

JURISDICTION	MANUFACTURED HOMES	SFR STRUCTURES BUILT BEFORE 1980	RENTER OCCUPIED UNITS
City of Houston	9,450	504,772	505,745

While all citizens are at risk to the impacts of a hail event, forced relocation and disaster recovery drastically impacts low-income residents who lack the financial means to travel, afford a long-term stay away from home, and to rebuild or repair their homes. An estimated 19.5 percent of the planning area population live below the poverty level. Renters also tend to be more vulnerable to the impacts of wind events and their ability to recover after an event. Within the City 58 percent of housing units are renter-occupied. While warning times for these type of hazard events should be substantial enough for these individuals to seek shelter, individuals who work and recreate outside are also vulnerable to potential impacts of a hail event.

Table 16-4. Populations at Greater Risk to Hail Events

JURISDICTION	POPULATION BELOW POVERTY LEVEL
City of Houston	453,395

The City of Houston identified the following critical facilities as assets that are considered the most important to the planning area and are susceptible to a range of impacts caused by hail events.

Table 16-5. Critical Facilities Vulnerable to Hail Events

CRITICAL FACILITIES	POTENTIAL IMPACTS
94 Fire Stations, 18 Police Stations	■ Emergency operations and services may be significantly impacted due to damaged facilities and/or loss of communications. ■ Emergency vehicles can be damaged by hailstones. ■ Power outages could disrupt communications, delaying emergency response times. ■ Accumulated hail on the streets may impede emergency response vehicle access to areas. ■ Extended power outages and evacuations may lead to possible looting, destruction of property, and theft, further burdening law enforcement resources.
64 Hospitals	■ Structures can be damaged by hailstones. ■ Power outages could disrupt critical care. ■ Backup power sources could be damaged. ■ Evacuations may be necessary due to extended power outages, gas line ruptures, or structural damages to facilities.

CRITICAL FACILITIES	POTENTIAL IMPACTS
21 Airports	■ Facilities or infrastructure may be damaged, destroyed or otherwise inaccessible. ■ Essential supplies like medicines, water, food, and equipment deliveries may be significantly delayed. ■ Additional emergency responders and critical aid workers may not be able to reach the area for days. ■ Power outages and infrastructure damage may prevent larger airports from acting as temporary command centers for logistics, communications and emergency operations. ■ Temporary break in operations may significantly inhibit post event evacuations. ■ Damaged or destroyed highway infrastructure may substantially increase the need for airport operations.
49 Ground Water Plants, 40 Wastewater Treatment Plants, 3 Water Purification Plants	■ Wastewater and drinking water facilities and infrastructure may be damaged or destroyed resulting in service disruption or outage for multiple days or weeks. ■ Disruptions and outages impact public welfare as safe drinking water is critical. ■ A break in essential and effective wastewater collection and treatment is a health concern, potentially spreading disease. ■ Exposure to untreated wastewater is harmful to people and the environment. ■ Any service disruptions can negatively impact or delay emergency management operations.

Hail has been known to cause injury to humans and occasionally has been fatal. Overall, the average loss estimate of property and crops in the planning area is considered $35,431,998 with an average annualized loss of $528,836. Based on historic loss and damages, the impact of hail damages on the City of Houston planning area can be considered “Limited” severity of impact, meaning minor quality of life lost, critical facilities and services shut down for 24 hours or less, and less than 10 percent of property destroyed or with major damage.

ASSESSMENT OF IMPACTS

Hail events have the potential to pose a significant risk to people and can create dangerous situations. The impact of climate change could produce larger, more severe hail events, exacerbating the current hail impacts. Worsening hail conditions can be frequently associated with a variety of impacts, including:

- Hail may create hazardous road conditions during and immediately following an event, delaying first responders from providing for or preserving public health and safety.
- Individuals and first responders who are exposed to the storm may be struck by hail or falling branches resulting in injuries or possible fatalities.
- Residential structures can be damaged by falling trees, which can result in physical harm to occupants.

- Large hail events will likely cause extensive roof damage to residential structures along with siding damage and broken windows, creating a spike in insurance claims and a rise in premiums.
- Automobile damage may be extensive depending on the size of the hail and length of the storm.
- Hail events can result in power outages over widespread areas increasing the risk to more vulnerable portions of the population who rely on power for health and/or life safety.
- Extended power outage can result in an increase in structure fires and/or carbon monoxide poisoning, as individuals attempt to cook or heat their home with alternate, unsafe cooking or heating devices, such as grills.
- First responders are exposed to downed power lines, damaged structures, hazardous spills, and debris that often accompany hail events, elevating the risk of injury to first responders and potentially diminishing emergency response capabilities.
- Downed power lines and large debris can result in the inability of emergency response vehicles to access areas of the community.
- Economic disruption negatively impacts the programs and services provided by the community due to short- and long-term loss in revenue.
- Some businesses not directly damaged by the hail event may be negatively impacted while roads are cleared and utilities are being restored, further slowing economic recovery.
- Businesses that are more reliant on utility infrastructure than others may suffer greater damages without a backup power source.
- Hazardous road conditions will likely lead to increases in automobile collisions, further straining emergency response capabilities.
- Depending on the severity and scale of damage caused by large hail events, damage to power transmission and distribution infrastructure can require days or weeks to repair.
- A significant hail event could significantly damage agricultural crops, resulting in extensive economic losses for the community and surrounding area.
- Hail events may injure or kill livestock and wildlife.
- A large hail event could impact the accessibility of recreational areas and parks due to extended power outages or debris clogged access roads.

The economic and financial impacts of hail will depend entirely on the scale of the event, what is damaged, and how quickly repairs to critical components of the economy can be implemented. The level of preparedness and pre-event planning conducted by the community, local businesses, and citizens will contribute to the overall economic and financial conditions in the aftermath of any hail event.

CLIMATE CHANGE CONSIDERATIONS

While the impact of climate change on the frequency and severity hailstorm events is unclear, the increase of warmer temperatures will likely lead to less hail events during the summer months but is expected to increase the risk of large hailstones during the spring season.[4]

[4] Assessment of Historic and Future Trends of Extreme Weather in Texas, 1900-2036, Texas A&M University Office of the Texas State Climatologist, 2021 update.

SECTION 17
MITIGATION STRATEGY



OFFICE OF EMERGENCY MANAGEMENT

SECTION 17: MITIGATION STRATEGY

Mitigation Goals **1**
Goal 1 1
Goal 2 2
Goal 3 2
Goal 4 2
Goal 5 3
Goal 6 3

MITIGATION GOALS

Based on the results of the risk and capability assessments, the Planning Team developed and prioritized the mitigation strategy. This involved utilizing the results of both assessments and reviewing the goals and objectives that were included in the previous 2018 Plan Update.

At the Mitigation Workshop in February 2023, Planning Team members reviewed the mitigation strategy from the previous 2018 Plan Update. The consensus among all members present was that the strategy developed for the 2018 Plan did not require changes, as it identified overall improvements to be sought in the Plan Update. The Mitigation Goal Statement is "It is the goal of the City of Houston to protect public health, safety, and welfare and to reduce losses due to hazards by identifying hazards, by minimizing exposure of citizens and property to hazards, and by increasing public awareness and involvement."

GOAL 1

Protect public health and safety.

Objective 1.1

Advise the public about health and safety precautions to guard against injury and loss of life from hazards.

Objective 1.2

Maximize utilization of the latest technology to provide adequate warning, communication, and mitigation of hazard events.

Objective 1.3

Reduce the danger to, and enhance protection of, high risk areas during hazard events.

Objective 1.4

Protect critical facilities and services.

Objective 1.5

Reduce the long-term vulnerabilities from high hazard potential dams that pose an unacceptable risk to the public.

GOAL 2



Build and support local capacity and commitment to continuously become less vulnerable to hazards.

Objective 2.1

Build and support local partnerships to continuously become less vulnerable to hazards.

Objective 2.2

Build a cadre of committed volunteers to safeguard the community before, during, and after a disaster.

Objective 2.3

Build hazard mitigation concerns into City planning and budgeting processes.

GOAL 3

Increase public understanding, support, and demand for hazard mitigation.

Objective 3.1

Heighten public awareness regarding the full range of natural and man-made hazards the public may face.

Objective 3.2

Educate the public on actions they can take to prevent or reduce the loss of life or property from all hazards and increase individual efforts to respond to potential hazards.

Objective 3.3

Publicize and encourage the adoption of appropriate hazard mitigation measures.

GOAL 4

Protect new and existing properties.

Objective 4.1

Reduce repetitive losses to the National Flood Insurance Program (NFIP).

Objective 4.2

Use the most cost-effective approach to protect existing buildings and public infrastructure from hazards.

Objective 4.3

Enact and enforce regulatory measures to ensure that future development will not put people in harm's way or increase threats to existing properties.

GOAL 5

Maximize the resources for investment in hazard mitigation.

Objective 5.1

Maximize the use of outside sources of funding.

Objective 5.2

Maximize participation of property owners in protecting their properties.

Objective 5.3

Maximize insurance coverage to provide financial protection against hazard events.

Objective 5.4

Prioritize mitigation projects, based on cost-effectiveness and sites facing the greatest threat to life, health, and property.

GOAL 6

Promote growth in a sustainable manner.

Objective 6.1

Incorporate hazard mitigation activities into long-range planning and development activities.

Objective 6.2

Promote beneficial uses of hazardous areas while expanding open space and recreational opportunities.

Objective 6.3

Utilize regulatory approaches to prevent creation of future hazards to life and property.

SECTION 18
PREVIOUS ACTIONS



OFFICE OF EMERGENCY MANAGEMENT

SECTION 18: PREVIOUS ACTIONS

Summary **1**

City of Houston **2**

SUMMARY

Executive and Advisory Planning Team members were given copies of the previous mitigation actions submitted in the 2018 Plan at the mitigation workshop. The Executive and Advisory Team personnel reviewed the previous actions and provided an analysis as to whether the action had been completed, should be deferred as an ongoing activity, or be deleted from the City of Houston Plan Update. The actions from the 2018 Plan are included in this section as they were written in 2018, with the exception of the "2023 Analysis" section.

CITY OF HOUSTON

	City of Houston - Previous Action #1
Proposed Action:	Implement flood risk reduction projects identified through the Harris County Flood Control District's (HCFCD) ongoing Capital Improvement Program (CIP). Flood control measures will include cost-effective structural drainage improvements as well as acquisition/demolition projects.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City of Houston Buyouts in 24 Areas of Investment High flood-risk areas
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce risk to structures and infrastructure through drainage improvements, reduction of floodplains, and removal of high-risk structures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$5,000,000
Potential Funding Sources:	Local tax base, FEMA, USACE, HUD
Lead Agency/ Department Responsible:	Project Management Department (structural), Property Acquisition Department (buyouts)
Implementation Schedule:	Within 12-24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #2
Proposed Action:	Implement a community outreach and awareness program, including community event activations, social media campaigns, e-mail communications, website blogs, inclusion in Disaster Guides, update preparedness website and other methods as deemed appropriate to educate citizens of hazards that may threaten the community and provide mitigation measures to reduce potential damages and injuries.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of all hazards through education outreach programs throughout the city.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Extreme Heat, Thunderstorm Wind, Lightning, Tornado, Expansive Soils, Hail, Wildfire, Drought, Dam Failure, Winter Storm
Priority (High, Moderate, Low):	High
Estimated Cost:	$500-$6,000
Potential Funding Sources:	HMGP, Corporate Grants
Lead Agency/ Department Responsible:	OEM
Implementation Schedule:	Within 12 months of plan adoption

2023 ANALYSIS:
Completed and Defer to Plan Update. Update action to include STEAR and SB-968 expectation. Update implementation schedule to reoccurre annually. Update estimated cost to $50,000 - $100,000 annually.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #3
Proposed Action:	Storm Water Action Team projects. Provide flood relief to neighborhoods on improvements such as: ditch widening; driveway culvert replacement; inlet replacement; side lot swales; and storm sewer line improvements as identified in the Storm Water Action Team Project Log (See Appendix G).
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of structure and infrastructure flooding through various drainage improvements.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$10,000,000
Potential Funding Sources:	ReBuild Houston, General Fund, Grants
Lead Agency/ Department Responsible:	Public Works and Engineering
Implementation Schedule:	Within 12-48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #4
Proposed Action:	Implement a community outreach and awareness program notifying homebuyers of the areas that have had flooding in the past. Notify them of the damages caused by floods and the challenges homeowners face after a disaster. Discuss the importance of flood insurance and pre-disaster preparations.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide flood-prone areas
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of flood devastation through education outreach programs and increase participation in the NFIP.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants
Lead Agency/ Department Responsible:	Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #5
Proposed Action:	Create and Implement reconstruction program to bring buildings up to code and protect from hazardous events.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide flood-prone areas
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of hazards and possible loss of life through improved construction.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind, Lightning, Tornado, Hail, Wildfire
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000,000
Potential Funding Sources:	HMGP, Corporate Grants, CDBG
Lead Agency/ Department Responsible:	Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #6
Proposed Action:	Adopt an ordinance to require retention ponds in all new developments and to validate retention ponds in existing high-risk flood areas.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of flooding through development requirements.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #7
Proposed Action:	Develop and implement programs to clean and clear ditches in existing neighborhoods to improve drainage capacity.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of flooding by maintaining drainage capacity.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Public Works
Implementation Schedule:	Within 24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #8
Proposed Action:	Purchase and Provide backup generators with permanent hard-wired quick connections to all grant-funded critical facilities throughout the planning area.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide critical facilities
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce risk through continuity of services.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Extreme Heat, Thunderstorm Wind, Lightning, Tornado, Hail, Wildfire, Dam Failure, Winter Storm
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Housing and Community Development Department
Implementation Schedule:	Within 24-36 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #9
Proposed Action:	Develop and implement an ordinance to require engineering techniques for infrastructures to mitigate the effects of expansive soils.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce risk to new development through improved construction methods.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Houston Building Code Compliance
Implementation Schedule:	Within 48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #10
Proposed Action:	Develop and implement a program to regularly water the foundation of public buildings.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of expansive soils on public buildings through the implementation of protective measures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Houston Building Code Compliance
Implementation Schedule:	Within 48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #11
Proposed Action:	Replace water fixtures in public buildings with low-flow fixtures.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of drought impacts through water reduction measures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Drought
Priority (High, Moderate, Low):	Low
Estimated Cost:	$100,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Houston Public Works
Implementation Schedule:	Within 48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update. Update lead agency to include General Service Department (GSD).

	City of Houston - Previous Action #12
Proposed Action:	Adopt an ordinance to require drought-resistant landscaping (xeriscaping) at public facilities.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of drought impacts through water reduction measures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Drought
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	HMGP, Corporate Grants, General Funding
Lead Agency/ Department Responsible:	Houston Building Code Compliance
Implementation Schedule:	Within 48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update. Update description to include new construction.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #13
Proposed Action:	Pre-Positioned Contingency Contract services to Mobilize, Collect, Characterize, and Package Household Hazardous Waste after a disaster. Currently Advertised through SPD.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Hazardous substances are toxic, flammable, corrosive, explosive, or even radioactive; they can be dangerous when disposed of improperly (source: CDC.gov). Avoided Injuries are respiratory irritation, dizziness or other central nervous system symptoms, eye irritation, and burns (source: CDC.gov).
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$10,000,000
Potential Funding Sources:	General Fund, Grants
Lead Agency/ Department Responsible:	Solid Waste Management Department
Implementation Schedule:	Within 12 months of plan adoption

2023 ANALYSIS:
Completed. Contract is currently in place and is also a part of our debris management and collection contractor.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #14
Proposed Action:	Pre-Positioned Contract to Monitor Disaster Debris. Secure Extension of the Pre-Positioned Contract services to monitor disaster debris after Disaster Declaration. Currently advertised through SPD.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Ensure lawful disposal of all debris (Source: COH SPD BID #t26183).
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$37,265,500 (Source: SAP DOC 4600011786)
Potential Funding Sources:	General Funds, Grants
Lead Agency/ Department Responsible:	Solid Waste Management Department
Implementation Schedule:	Within 12 months of plan adoption

2023 ANALYSIS:
Completed. The City has 6 pre-positioned contractors that will be activated upon a declared emergency.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #15
Proposed Action:	Extension of the Grant Funded Zika Abatement Contract from CDC including proposed continued grant funding; propose extension of the M.O.U. between SWMD, HHD, and OSPHP, as it will expire on July 2018.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Protect large segments of the population from mosquitoes known health risks after an extreme event: 1. Serous birth defects during pregnancy (Source: CDC.gov) Guillain-Barre syndrome (GBS), an uncommon sickness of the nervous system (Source: CDC.gov).
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Tornado, Extreme Heat, Hail, Wildfire, Dam Failure
Priority (High, Moderate, Low):	High
Estimated Cost:	$500,000
Potential Funding Sources:	CDBG
Lead Agency/ Department Responsible:	Solid Waste Management Department
Implementation Schedule:	Within 12 months of plan adoption

2023 ANALYSIS:
Delete Action. City no longer deems action a priority.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #16
Proposed Action:	Prioritize and harden critical facilities throughout the city.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of damages to critical facilities and ensure continuity of critical services.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Tornado, Extreme Heat, Thunderstorm Wind, Lightning, Hail, Wildfire, Dam Failure
Priority (High, Moderate, Low):	High
Estimated Cost:	$500,000
Potential Funding Sources:	CDBG, HMGP, PDM
Lead Agency/ Department Responsible:	OEM / PW&E
Implementation Schedule:	Within 12-24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 18: PREVIOUS ACTIONS

	City of Houston - Previous Action #17
Proposed Action:	Improve the data collection capabilities of expansive soils incidents. This may include using the City's 3-1-1 helpline to maintain a database of reports called in regarding cracked slabs and other evidence of expansive soils. A database would be compiled with the information then the most vulnerable facilities could then be identified.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Improve future risk assessment information and data that is needed; protect critical facilities and the general population of the city.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Priority (High, Moderate, Low):	Low
Estimated Cost:	$100,000
Potential Funding Sources:	HMGP, OEM budget
Lead Agency/ Department Responsible:	OEM
Implementation Schedule:	Within 48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #18
Proposed Action:	Install lightning rods and surge protectors on critical facilities located throughout the city.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide critical facilities
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Protection of critical facilities from the effects of lightning, such as fire, and ensure continuity of services.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Lightning
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$15,000
Potential Funding Sources:	HMGP, Local Taxes
Lead Agency/ Department Responsible:	OEM / PW&E
Implementation Schedule:	Within 24 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #19
Proposed Action:	Analyze the current storm sewer system, then design and implement an improved storm sewer system that will convey the current contributing drainage areas runoff flows adequately to the discharge point. Storm sewers will be increased in size to adequately convey the minimum City design storm event (2-year event). In addition, an analysis of sheet flow will be performed to assess what design measures are necessary to adequately convey a more significant (i.e., 100-year) storm event to the discharge point in a manner that minimizes structural flooding.
BACKGROUND INFORMATION	
Jurisdiction/Location:	Various Neighborhoods City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Improved drainage and less critical facilities impacted by the effects of floods. Various storm sewer systems shall be prioritized to justify this action based on project cost over a comparison of structures impacted in 100-year event pre-project vs. post-project.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,000,000 - $30,000,000
Potential Funding Sources:	City of Houston Capital Improvement Program funding and available federal grant funding
Lead Agency/ Department Responsible:	Houston Department of Public Works and Engineering
Implementation Schedule:	Within 12-28 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #20
Proposed Action:	Improve/enhance flood vulnerability data, including alternative analysis and Benefit-Cost Analysis. Enhance planning using surveys to more accurately define flood vulnerability.
BACKGROUND INFORMATION	
Jurisdiction/Location:	Various Neighborhoods City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)***:**	Provide additional data to enhance risk assessment, planning of flood mitigation projects, and for public education.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storms
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,500,000
Potential Funding Sources:	City of Houston Capital Improvement Program funding and available federal grant funding
Lead Agency/ Department Responsible:	City of Houston Department of Public Works and Engineering
Implementation Schedule:	Within 24-36 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #21
Proposed Action:	Map Enhancement – Storm Surge Vulnerability: Elevation data obtained by field survey, in addition to data collected from existing plans and records, would be compiled into a database, and the most vulnerable facilities and transportation links may be identified for mitigation actions.
BACKGROUND INFORMATION	
Jurisdiction/Location:	Various Neighborhoods City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Provide additional data to enhance the planning of flood mitigation projects and for public education.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storms
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,500,000
Potential Funding Sources:	City of Houston Capital Improvement Program funding and available federal grant funding
Lead Agency/ Department Responsible:	City of Houston Department of Public Works and Engineering
Implementation Schedule:	Within 24-36 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #22
Proposed Action:	Utilize existing GIS data to identify large facilities to serve as potential refuges of last resort, either during or after a disaster. Develop vulnerability assessment for identified facilities. Conduct site visits to evaluate structural capabilities and resistance to identified hazards. Develop prioritized implementation procedures for use of these facilities during or after disaster events. Identify and implement required retrofit enhancements needed for each facility identified. Identify the capacity of each facility to house refugees.
BACKGROUND INFORMATION	
Jurisdiction/Location:	Various Locations City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	During and after Hurricanes Katrina, Rita, and Ike, the City of Houston was tasked with sheltering a large number of its own residents and residents from other states and areas for extended periods of time. It is imperative that the city identify, prioritize, and develop vulnerability assessments for potential facilities to be used as refuges of last resort or as hosts to evacuees from other areas.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	High
Priority (High, Moderate, Low):	$1,000,000 - $30,000,000
Estimated Cost:	HMGP, CDBG, PDM
Potential Funding Sources:	OEM / PW&E
Lead Agency/ Department Responsible:	Within 12-36 months of plan adoption
Implementation Schedule:	High

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #23
Proposed Action:	Damage Identification Tracking and Mitigation Alternative Development Tool – Develop a GIS-based damage-tracking tool. Once this tool is complete, the City of Houston will be capable of developing effective mitigation actions, measures, or strategies based on actual documented disaster data.
BACKGROUND INFORMATION	
Jurisdiction/Location:	City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	The City has a need for improvements to its damage identification and tracking tool, or Disaster Recovery Plan. The "Disaster Recovery Plan" will incorporate GIS-based damage assessment and reporting. The initial idea and much of the initial planning began during the development of our Mitigation Action Plan, assuring the fast-track development of this plan.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$50,000
Potential Funding Sources:	HMGP, Operational budgets, Other Federal Grants
Lead Agency/ Department Responsible:	OEM / PW&E
Implementation Schedule:	Within 24-36 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

	City of Houston - Previous Action #24
Proposed Action:	Elevation or Mitigation Reconstruction of Flood-prone Structures.
BACKGROUND INFORMATION	
Jurisdiction/Location:	Various Neighborhoods City-wide
Risk Reduction Benefit *(Current Cost/ Losses Avoided)*:	Reduce the risk of flooding to repetitive loss of buildings by completing elevation or mitigation reconstruction projects.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,000,000 - $50,000,000
Potential Funding Sources:	HMGP, PDM, and Other Federal Grant funding
Lead Agency/ Department Responsible:	City of Houston Department of Public Works and Engineering
Implementation Schedule:	Within 12-48 months of plan adoption

2023 ANALYSIS:
Defer to Plan Update.

SECTION 19
MITIGATION ACTIONS



OFFICE OF EMERGENCY MANAGEMENT

SECTION 19: MITIGATION ACTIONS

Summary **1**

City of Houston **3**

SUMMARY

As discussed in Section 2, at the mitigation workshop the planning team and stakeholders met to develop mitigation actions for each of the natural hazards included in the Plan Update. Each of the actions in this section were prioritized based on FEMA's Social, Technical, Administrative, Political, Legal, Economic, and Environmental (STAPLEE) criteria necessary for the implementation of each action.

As part of the economic evaluation of the STAPLEE analysis, jurisdictions analyzed each action in terms of the overall costs, measuring whether the potential benefit to be gained from the action outweighed costs associated with it. As a result of this exercise, priority was assigned to each mitigation action by marking them as High (H), Moderate (M), or Low (L). An action that is ranked as "High" indicates that the action will be implemented as soon as funding is received. A "Moderate" action is one that may not be implemented right away depending on the cost and number of citizens served by the action. Actions ranked as "Low" indicate that they will not be implemented without first seeking grant funding and after "High" and "Moderate" actions have been completed. Timeframes may be general and there will be short-, medium-, and long-term goals for implementation; these goals will be based on prioritization of each action as identified on individual Hazard Mitigation Action worksheets included in the Plan Update for the City of Houston. Short-term goals are defined as less than a year; medium-term goals are defined as between 1 and 3 years; and long-term goals are defined as between 3 and 5 years.

Within each mitigation action worksheet, the Planning Team considered all potential funding sources that could be utilized to implement the proposed project. To ensure all potential funding resources are considered and are not limited to those sources identified within the action worksheet, please see appendix J for a list of all available State and Federal grant programs as of 2023. The Planning Team will continue to seek out other available funding sources during the 5-year cycle as notices of funding opportunity (NOFO) are released.

All mitigation actions created by Planning Team members are presented in this section in the form of Mitigation Action Worksheets. More than one hazard is sometimes listed for an action, if appropriate. Actions presented in this section represent a comprehensive range of mitigation actions per current State and FEMA Guidelines, including two actions, per hazard, and of two different types for the City of Houston.

SECTION 19: MITIGATION ACTIONS

Table 19-1. City of Houston Mitigation Action Matrix

TYPE OF ACTION	
Action #1 – Plans/Regulations (Blue)	Action #4 – Structural (Orange)
Action #2 – Education/Awareness (Red)	Action #5 – Preparedness/Response (Black)
Action #3 – Natural Systems Protections (Green)	

Jurisdiction	Flood	Hurricane/Tropical Storm	Extreme Heat	Drought	Thunderstorm Wind	Dam Failure	Expansive Soils	Tornado	Winter Storm	Wildfire	Lightning	Hail
City of Houston	XXXXX	XXXX	XXXX	XXXXX	XXX	XXXX	XXX	XXX	XXX	XXXX	XXX	XXX

CITY OF HOUSTON

	City of Houston – Action #1
Proposed Action:	Harden/retrofit critical facilities and infrastructures to hazard-resistant levels.
BACKGROUND INFORMATION	
Site and Location:	City-wide critical facilities including SWD facilities/infrastructure
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages at critical facilities; Ensure continuity of critical services during and after event; Reduce risk of injury to emergency and critical personnel.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to existing structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$5,000,000
Potential Funding Sources:	Local Funds (staff time), Local Department Budget, Tax Revenue; State and Federal Grants: FEMA HMA, BRIC, CDBG, PA Section 406 Funds
Lead Agency/Department Responsible:	Houston OEM; Solid Waste Department
Implementation Schedule:	Within 12-60 months of plan adoption
Incorporation into Existing Plans:	Emergency Management Plan; Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #2
Proposed Action:	Acquire and install generators with hard wired quick connections at all critical facilities and infrastructure.
BACKGROUND INFORMATION	
Site and Location:	City-wide critical facilities including HFD and SWD facilities/infrastructure
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Provide power for critical facilities during power outages and ensure continuity of critical services.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Energy (Power/Fuel)
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	High
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Funds (staff time), Local Department Budget, Tax Revenue; State and Federal Grants: HMGP- 5% Initiative Grant, BRIC, CDBG
Lead Agency/Department Responsible:	Houston OEM; Solid Waste Department; Housing and Community Development Department; Houston Fire Department
Implementation Schedule:	Within 12-60 months of plan adoption
Incorporation into Existing Plans:	Emergency Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Helps ensure critical facilities continue to provide services during a power outage caused by unforeseen events.

	City of Houston – Action #3
Proposed Action:	Restrict future development in high-risk areas.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of damages to new structures and infrastructure through building restrictions in high-risk areas.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures and infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,500
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston OEM; Building Code Compliance
Implementation Schedule:	Within 12 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #4
Proposed Action:	Incorporate higher standards for hazard resistance in local application of the building code.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of damages to structures through improved construction techniques; Reduce recovery efforts for the community after an event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston OEM; Building Code Compliance
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #5
Proposed Action:	Prohibit animal shelters in known hazard areas. Educate residents on shelters that will offer care and assistance during extreme hazards events.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk to structures and animals by requiring development outside of hazardous areas; reduce burden on emergency response during hazardous events.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures and infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,500
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston OEM; Building Code Compliance; Local Animal Shelters
Implementation Schedule:	Within 12 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injuries and fatalities.

	City of Houston – Action #6
Proposed Action:	Establish, adopt, and implement a "green infrastructure" program for parks, nature preserves, greenbelts, etc.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce impacts of flood through expanded greenspace and restoration of floodplains and wetlands; Reduce impacts of drought through green infrastructure that works to replenish groundwater reserves; Reduce impacts of Urban Island Heat effect in densely populated areas through tree planting.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Natural Systems Protection Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Drought, Extreme Heat
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$10,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, NRCS Conservation Programs, TWDB Planning Assistance to States, WaterSMART – Drought Response Program
Lead Agency/Department Responsible:	Houston OEM; Building Code Compliance; Parks and Recreation Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #7
Proposed Action:	Acquire and preserve open spaces adjacent to floodplain areas.
BACKGROUND INFORMATION	
Site and Location:	City-wide flood risk fringe areas.
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flood risk to structures and infrastructure in and near the floodplain; Reduce downstream impacts associated with development in the floodplain; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Natural Systems Protection

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, Emergency Watershed Protection (EWP), TWDB National Wildlife Wetland Refuge System
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Floodplain Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #8
Proposed Action:	Require standards for burial of electrical, telephone, cable lines and other utilities in new developments.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages to infrastructure; Ensure continuity of critical services during and after event; Reduce damages associated with power outages; Reduce risk of injuries or fatalities to vulnerable populations.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hail, Hurricane/Tropical Storm, Lightning, Tornado, Thunderstorm Wind, Winter Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Energy (Power/Fuel)
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$3,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston OEM; Building Code Compliance
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #9
Proposed Action:	Bury existing utility lines.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages to infrastructure; Ensure continuity of critical services during and after event; Reduce damages associated with power outages; Reduce risk of injuries or fatalities to vulnerable populations.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Winter Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Energy (Power/Fuel)
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$10,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: BRIC, CDBG, FEMA HMA, PA Section 406 Funds, Economic Development Administration Grants and Investments
Lead Agency/Department Responsible:	Houston OEM; Local Utility Company
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #10
Proposed Action:	Adopt and implement a routine tree trimming program that clears tree limbs near power lines and/or hanging in right-of-way; Remove dead trees from right-of way and drainage systems on a scheduled basis.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages to infrastructure; Ensure continuity of services during and after event; Reduce damages associated with power outages; Reduce risk of injuries or fatalities to vulnerable populations.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Winter Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Energy (Power/Fuel)
Effect on New/Existing Buildings:	Reduce risk to new and existing structures
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$100,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, USDOT / TXDOT, GLO
Lead Agency/Department Responsible:	Houston OEM; Houston Public Works
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Maintenance Plan; Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents. Helps ensure critical facilities continue to provide services during a power outage caused by unforeseen events.

	City of Houston – Action #11
Proposed Action:	Complete drainage plan for Spring Shadows and Nuens Road. Implement feasible alternatives for flood reduction.
BACKGROUND INFORMATION	
Site and Location:	Spring Shadows and Nuens Road
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Improve risk assessment; Reduce risk of damages or injuries through drainage improvements; Reduce risk of damages and injuries.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication, Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: Silver Jackets, Small Flood Control Projects (USACE Section 205), Emergency Management Performance Grant
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24-36 months of plan adoption
Incorporation into Existing Plans:	Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #12
Proposed Action:	Adopt and implement a program for clearing debris from bridges, drains, and culverts as well as roadside ditches.
BACKGROUND INFORMATION	
Site and Location:	City-wide including the following areas: Kashemere Gardens/East Houston areas Eastex Jensen area, Greater Inwood and Independence Heights areas Hiram Clark and Fondren Gardens areas
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$50,000 (annually)
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Pre-Disaster Mitigation Loan Program, Silver Jackets
Lead Agency/Department Responsible:	Houston OEM; Houston Public Works
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #13
Proposed Action:	Adopt and implement a retrofitting and maintenance program for city wide dams, bayous, rivers, and streams, including but not limited to installing gates to allow floodwaters to travel downstream.
BACKGROUND INFORMATION	
Site and Location:	City-wide focusing on Addicks Dam, Barker Dam, Cypress Dam, Buffalo Bayou and San Jacinto River
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Dam Failure
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$50,000 (annually)
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: HHPD, FEMA HMA, USACE, TWDB
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes/Ordinances

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #14
Proposed Action:	Upgrade undersized stormwater drains and culverts.
BACKGROUND INFORMATION	
Site and Location:	City-wide drainage system
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood damages through improved drainage capacity; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$3,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, BRIC, PA Section 406 Funds, TWDB Flood Infrastructure Fund (FIF)
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Floodplain Management Plan; Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #15
Proposed Action:	Increase drainage capacity; add stormwater detention and/or retention basins as deemed necessary to reduce flood risk.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flood risk through improved drainage capacity; Reduce risk of damages and injuries; Reduce emergency response demands.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$10,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, BRIC, PA Section 406 Funds, TWDB Flood Infrastructure Fund (FIF), Silver Jackets, Small Flood Control Projects (USACE Section 205), Texas Infrastructure Resiliency Fund (TIRF)
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24-48 months of plan adoption
Incorporation into Existing Plans:	Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #16
Proposed Action:	Improve drainage systems as deemed necessary to reduce flood risk.
BACKGROUND INFORMATION	
Site and Location:	Granville Drive Maplewood and Meyerland areas Kashemere Gardens/East Houston areas Eastex Jensen area, Greater Inwood and Independence Heights areas Hiram Clark and Fondren Gardens areas
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flood risk through improved drainage capacity; Reduce risk of damages and injuries; Reduce emergency response demands.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$10,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, BRIC, PA Section 406 Funds, Small Flood Control Projects (USACE Section 205), TWDB Flood Infrastructure Fund (FIF)
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24-48 months of plan adoption
Incorporation into Existing Plans:	Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #17
Proposed Action:	Retain and maintain natural vegetation in stormwater channels.
BACKGROUND INFORMATION	
Site and Location:	City-wide with focus on Buffalo Bayou
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood damages due to erosion or scour during flood events.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Natural Systems Protection

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Agricultural Management Assistant (AMA, Emergency Watershed Protection (EWP), NRCS Conservation Programs
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 12 months of plan adoption
Incorporation into Existing Plans:	Flood Damage Prevention Ordinance; Local Ordinance

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #18
Proposed Action:	Implement restoration/channelization program to ensure adequate drainage/diversion of stormwater.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood damages through improved drainage capacity/stormwater diversion; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$3,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Emergency Watershed Protection (EWP), NRCS Conservation Programs
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Drainage Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #19
Proposed Action:	Undertake an initiative to increase the number of flood insurance policies.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flood risk and build resiliency; Increase flood risk awareness; Reduce damage impact on residents after a flood event; Reduce the burden on state and federal resources.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 12 months of plan adoption
Incorporation into Existing Plans:	Floodplain Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #20
Proposed Action:	Evaluate access and road conditions for evacuation and response vehicles. Develop and implement options to improve access and/or add redundant access routes in high-risk areas.
BACKGROUND INFORMATION	
Site and Location:	City-wide with focus on: Maplewood and Meyerland areas Kashemere Gardens/East Houston areas Eastex Jensen area, Greater Inwood and Independence Heights areas Hiram Clark and Fondren Gardens areas Allen Parkway at Waugh & Waugh north of the Bayou
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Improve response time for emergency services; Reduce risk of injury or damages; Provide additional ingress/egress routes through high-risk areas to prevent loss of life and avoid rescue efforts.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new or existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,00,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, BRIC, CDBG, Emergency Relief (ER) Program, Transportation Enhancement Program
Lead Agency/Department Responsible:	Houston OEM; Houston Public Works
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #21
Proposed Action:	Raise electrical components of sewage lift stations above the Base Flood Elevation (BFE).
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood water contamination; Reduce risk of surface water infiltration and sewage backup; Ensure continuity of critical services.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Energy (Power/Fuel)
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$250,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, EPA American Recovery and Reinvestment Act (ARRA), Clean Water State Revolving Fund, Community Assistance Program (CAP), TWDB DFund
Lead Agency/Department Responsible:	Houston Solid Waste Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Wastewater Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #22
Proposed Action:	Flood-proof sewage treatment plants in flood hazard/low-lying areas.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood water contamination; Reduce risk of surface water infiltration and sewage backup; Ensure continuity of critical services.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$250,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, EPA American Recovery and Reinvestment Act (ARRA), Clean Water State Revolving Fund, Community Assistance Program (CAP), TWDB DFund
Lead Agency/Department Responsible:	Houston Solid Waste Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Wastewater Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #23
Proposed Action:	Workorder Management System: Upgrade existing route management software to install and integrate a system to track the flow of service requests during extreme weather events.
BACKGROUND INFORMATION	
Site and Location:	City-wide Solid Waste Service Area
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Promotes risk assessment. Facilitates debris collection response and recovery efforts. Reduce risk of damage. Ensures continuity of critical services.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind, Tornado
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Clean Water State Revolving Fund, Community Assistance Program (CAP), TWDB DFund
Lead Agency/Department Responsible:	Houston Solid Waste Department
Implementation Schedule:	Within 24-48 months of plan adoption
Incorporation into Existing Plans:	Stormwater Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #24
Proposed Action:	Adopt and implement a debris removal program that clears roadways and impact of critical facilities on a scheduled basis. Ensure city has accessible to necessary equipment to maintain debris removal.
BACKGROUND INFORMATION	
Site and Location:	Solid Waste Service Area
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages to infrastructure; Ensure continuity of services during and after event; Reduce damages associated with power outages; Reduce risk of injuries or fatalities to vulnerable populations.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Winter Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDGB, Pre-Disaster Mitigation Loan Program
Lead Agency/Department Responsible:	Houston OEM; Solid Waste Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Stormwater Management Plan

COMMENTS:
City of Houston would look to establish an MOU and/or pre-proposed contract for accessibility to additional equipment needs during severe weather events.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents. Helps ensure critical facilities continue to provide services during a power outage caused by unforeseen events.

	City of Houston – Action #25
Proposed Action:	Improvements along Frey Rd within the Edgebrook neighborhood: Assessment of street condition which includes replacement and/or upgrades of storm inlets, in addition to damaged curbs and sidewalks deemed as necessary to ensure proper storm water drainage. New pavement markings will be implemented at various levels depending on the extent of roadway surface rehabilitation.
BACKGROUND INFORMATION	
Site and Location:	Edgebrook – Frey Rd along the major roadway within the limits of the project
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood damages through improved drainage capacity; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Emergency Relief (ER) Program, BRIC, Transportation Enhancement Program, Public Assistance Section 406 Funds
Lead Agency/Department Responsible:	Houston Public Works; Planning Department
Implementation Schedule:	Within 3-5 years of plan adoption
Incorporation into Existing Plans:	Edgebrook Neighborhood Resilience Plan; [1]CIP

COMMENTS:
Project is programmed in the Capital Improvement Plan (CIP). Construction to begin FY2023. Freeway manner N and South currently programmed.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

[1]https://www.letstalkhouston.org/edgebrook

	City of Houston – Action #26
Proposed Action:	Replace asphalt and concrete pavement sections and base material depending along Frey Rd within the Edgebrook neighborhood. New pavement markings will be implemented at various levels depending on the extent of roadway surface rehabilitation.
BACKGROUND INFORMATION	
Site and Location:	Edgebrook – Frey Rd along the major roadway within the limits of the project
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk residents through improved condition to allow for emergency response and evacuation. Reduce burden on emergency services during and after a flood event. Reduce risk of flood damages through improved drainage capacity;
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure - Preparedness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hurricane/Tropical Storm, Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Emergency Relief (ER) Program, BRIC, Transportation Enhancement Program, Public Assistance Section 406 Funds
Lead Agency/Department Responsible:	Houston Public Works; Houston Planning Department
Implementation Schedule:	Within 3-5 years of plan adoption
Incorporation into Existing Plans:	Edgebrook Neighborhood Resilience Plan; CIP

COMMENTS:
Project is programmed in the Capital Improvement Plan (CIP). Construction to begin FY2023. Freeway manner N and South currently programmed.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety. Protects communities and reduces risk of flooding.

	City of Houston – Action #27
Proposed Action:	Improve Intersection safety at various locations in the Edgebrook Super Neighborhood: Conduct feasibility analysis for intersection improvements and install protected turn lanes with use of green infrastructure such as bioretention planters.
BACKGROUND INFORMATION	
Site and Location:	Protected turn lanes at Edgebrook @ Theta Frey @ Edgebrook (HIN 6%); Hartstook @ Frey; Install 3-way stop Hartsook @ Theta (Garfield Elementary)
Risk Reduction Benefit (Current Cost/Losses Avoided)**:**	Reduce impacts of flood through expanded greenspace and restoration of floodplains and wetlands; Reduce impacts of drought through green infrastructure that works to replenish groundwater reserves; Reduce impacts of Urban Island Heat effect in densely populated areas through tree planting.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Emergency Relief (ER) Program, BRIC, Transportation Enhancement Program, Public Assistance Section 406 Funds
Lead Agency/Department Responsible:	Houston Public Works; Planning Department
Implementation Schedule:	Within 6+ years of plan adoption (long-term)
Incorporation into Existing Plans:	Edgebrook Neighborhood Resilience Plan; CIP; Transportation Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #28
Proposed Action:	Improve sidewalks to connect gaps at various locations.
BACKGROUND INFORMATION	
Site and Location:	Minnesota St. N. of Hinds; Rodney St. between Gilpin and Hinds; Theta St between Gilpin and Hinds
Risk Reduction Benefit (Current Cost/Losses Avoided)**:**	Reduce damages to critical infrastructure. Reduces risk of injury to residents and vulnerable populations.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Preparedness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Drought, Expansive Soils, Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$500,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue;
Lead Agency/Department Responsible:	Super Neighborhood, Residents, Planning Department
Implementation Schedule:	Within 1-2 years of plan adoption
Incorporation into Existing Plans:	Neighborhood Resilience Plans[2]; CIP

COMMENTS:
Community to apply for traffic/sidewalk safety projects
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

[2] https://www.houstonpublicworks.org/sites/g/files/nwywnm456/files/doc/004-ntmp_faq_2022.pdf

	City of Houston – Action #29
Proposed Action:	Improve stormwater drainage within the Edgebrook Neighborhood.
BACKGROUND INFORMATION	
Site and Location:	Edgebrook Ave between I-45 and Old Galveston Rd (Hwy 3)
Risk Reduction Benefit (Current Cost/Losses Avoided)**:**	Reduce risk of flood damages through improved drainage capacity; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structure and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, BRIC, PA Section 406 Funds, Flood Infrastructure Fund (FIF), Silver Jackets, Small Flood Control Projects (USACE Section 205), Texas Infrastructure Resiliency Fund (TIRF)
Lead Agency/Department Responsible:	Houston Public Works; Houston Planning Department
Implementation Schedule:	Within 6+ years of plan adoption (long-term)
Incorporation into Existing Plans:	Edgebrook Neighborhood Resilience Plan; CIP

COMMENTS:
Discuss feasibility of a stormwater assessment with HPW. Review M02 Freeway Manor Pre-Engineering Report. Evaluate the appropriate options that align with CIP and other city plans and studies.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #30
Proposed Action:	Improve Flood Resilience with Halls Bayou improvements: Assess and implement necessary improvement to correct the erosion along the banks and removing the sediment that builds up on the bottom to allow better water flow.
BACKGROUND INFORMATION	
Site and Location:	East Houston Neighborhood – Halls Bayou
Risk Reduction Benefit (Current Cost/Losses Avoided)**:**	Reduce risk of flood damages due to erosion or scour during flood events.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structure and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,000,000
Potential Funding Sources:	2018 bond initiative
Lead Agency/Department Responsible:	HCFCD (P118-02-00-X001)
Implementation Schedule:	Within 6+ years of plan adoption (long-term)
Incorporation into Existing Plans:	East Houston Neighborhood Resilience Plan[3]; CIP

COMMENTS:
Harness Halls Bayou as a flood management tool that includes a greenway for improvement of ecological health, increase in natural cooling, and addition of a multiuse path along the bayou that would serve as a spine creating connections within the neighborhood. Amenities such as trees and trails along Harris County Flood Control District Rights-of-Way require a Citizen's Request Service found at https://www.hcfcd.org/Community/Contact-Us/General-Inquiries.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

[3] https://www.letstalkhouston.org/easthouston

	City of Houston – Action #31
Proposed Action:	Yale Stormwater Detention Basin: Construct additional stormwater detention facilities to reduce flooding during future events in the Independence Heights neighborhood which will increase flood resiliency.
BACKGROUND INFORMATION	
Site and Location:	Yale Stormwater Detention Basin - Little White Oak Bayou
Risk Reduction Benefit (Current Cost/Losses Avoided)**:**	Reduce flood risk through improved drainage capacity; Reduce risk of damages and injuries; Reduce emergency response demands.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structure and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000,000
Potential Funding Sources:	HCFCD Bond
Lead Agency/Department Responsible:	HCFCD, Planning Department
Implementation Schedule:	Within 6+ years of plan adoption (long-term)
Incorporation into Existing Plans:	Independence Heights Neighborhood Resilience Plan[4]; CIP

COMMENTS:
The Flood Control District has newly completed a feasibility study for Little White Oak Bayou sub watershed, and it includes a recommended plan to guide future decisions by the Flood Control District in this area. The recommended plan is considerate of two ongoing efforts for the sub watershed separate from the feasibility analysis, the Rigs Stormwater Detention Basin and the Yale Stormwater Detention Basin which were approaching construction at the time of this feasibility study.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

[4] https://www.letstalkhouston.org/independenceheights

	City of Houston – Action #32
Proposed Action:	Promote and Incorporate community health rooms in fire stations.
BACKGROUND INFORMATION	
Site and Location:	City-wide fire stations
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Promotes hazard awareness through direct public safety education. Reduces risk of injury or fatalities by providing direct community health services onsite.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Drought, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Communication, Health/Medical
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$400,000 per station
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: Public Health Emergency Preparedness, CDC, HHS, DSHS
Lead Agency/Department Responsible:	Houston Fire Department, Houston Department of Health Services
Implementation Schedule:	Within 12-60 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Projects and Resilient Houston

COMMENTS:
Community rooms built into new and renovated stations allow Houston Fire Department provide direct interaction with the public either for rendering care or providing education.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #33
Proposed Action:	Installing flood level signs for bridges and overpasses.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of property damage and loss of life when flood levels are underestimated. Reduces demands of emergency response and risk to emergency response personnel.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Communication, Transportation
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$850,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, TDEM, GLO, TWDB
Lead Agency/Department Responsible:	Houston Public Works
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Resilient Houston

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #34
Proposed Action:	Implementing an education and awareness campaign to educate residents and businesses of hazards that threaten the area and mitigation measures they can take to reduce risk.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Capacity building for the community to reduce exposure to risk and mitigate its impacts.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Drought, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Communication, Health/Medical
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$250,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, NOAA, NWS, TDEM
Lead Agency/Department Responsible:	Houston OEM; Houston Fire Department; Other departments
Implementation Schedule:	Within 12-24 months of plan adoption
Incorporation into Existing Plans:	Resilient Houston

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #35
Proposed Action:	Relocating fire stations from the flood plain. Harden/retrofit critical facilities to hazard-resistant levels.
BACKGROUND INFORMATION	
Site and Location:	Kingwood area
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of property damage and prevention of loss due to flooding. Ensure continuity of critical services and maintaining response capabilities. Improves energy and water efficiency.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to existing structure and infrastructure by upgrading facilities to improve functionality for operation and public use
Priority (High, Moderate, Low):	High
Estimated Cost:	$22,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, BRIC, CDBG, NFIP, Community Assistance Program (CAP), TWDB Flood Infrastructure Fund (FIF)
Lead Agency/Department Responsible:	Houston Fire Department
Implementation Schedule:	2027-2028
Incorporation into Existing Plans:	Capital Improvement Projects and Resilient Houston

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents and emergency response personnel.

		City of Houston – Action #36
	Proposed Action:	Relocating fire stations from the flood plain. Harden/retrofit critical facilities to hazard-resistant levels.
	BACKGROUND INFORMATION	
	Site and Location:	Station 26 - 7111 Dixie Dr, Houston, TX 77087
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of property damage and prevention of loss due to flooding. Ensure continuity of critical services and maintaining response capabilities. Improves energy and water efficiency.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to existing structure and infrastructure by upgrading facilities to improve functionality for operation and public use
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$22,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: HMGP, FMA, BRIC, CDBG, NFIP, Community Assistance Program (CAP), TWDB Flood Infrastructure Fund (FIF)
Lead Agency/Department Responsible:	Houston Fire Department
Implementation Schedule:	Within 36-60 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Projects and Resilient Houston

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents and emergency response personnel.

	City of Houston – Action #37
Proposed Action:	Assessing wildland-urban interface to determine areas where mitigation plans are needed.
BACKGROUND INFORMATION	
Site and Location:	City-wide with focus on Kingwood, Clear Lake, and park areas
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Improve risk assessment. An assessment would be the first step in determining potential mitigation plans to protect lives and property. Reduce risk of property damage and loss of life.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Wildfire
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Communication, Food/Water/Shelter
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$150,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: CNCS AmeriCorps, FEMA Assistance to Firefighters program – Fire Prevention & Safety (FP&S Grants), USDA Community Fire Protection Program, USFS Community Wildfire Defense Grant, FEMA Fire Management Assistance Grants (FMAG), TAMFS Prescribed Fire Grants
Lead Agency/Department Responsible:	Houston Fire Department
Implementation Schedule:	2025
Incorporation into Existing Plans:	Resilient Houston

COMMENTS:

		City of Houston – Action #38
	Proposed Action:	Create a post-disaster program / protocol to follow-up with residents, learn where resources are still needed and recovery may be slowing, and to provide an ongoing pipeline for sharing information about recovery efforts, potential funding and social support opportunities, and other such recovery information directly with the public. Program would be integrated with regular social media platforms, providing regular notifications to users whose geolocation places them in the Houston area and its outlying counties. The platforms will not be hosting this effort but be promoting this effort. Consider development of an app or website where users can provide information which can be shared with data analysts and processes can be put into place to help collect, aggregate, and disseminate data in real-time to rescue efforts, local leaders, and others who are in a position to provide help.
	BACKGROUND INFORMATION	
	Site and Location:	City-wide with assistance from Rice University (Kinder Institute for Urban Research), UT School of Public Health, University of Houston.
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Promotes hazard awareness. Increases the ability for vulnerable populations to connect with critical or emergency response personnel during extreme hazard events.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

SECTION 19: MITIGATION ACTIONS

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Drought, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	High
Estimated Cost:	$500,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: Emergency Management Performance Grant (EMPG), NOAA, FEMA HMA, TDEM, GLO
Lead Agency/Department Responsible:	Rice University; Houston OEM; City/County/Regional/State Leaders
Implementation Schedule:	Within 12-24 months of plan adoption
Incorporation into Existing Plans:	N/A

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #39
Proposed Action:	Improve data collection by creating a system that addresses incoming data in real time. Create a program / protocol to disseminate information during a disaster, and in the recovery period following a disaster.
BACKGROUND INFORMATION	
Site and Location:	City-wide with assistance from Rice University (Kinder Institute for Urban Research), UT School of Public Health, University of Houston.
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Promotes hazard awareness. Ensures information is shared informing residents and vulnerable populations of shelters, high-risk areas, and resource availability.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Drought, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	High
Estimated Cost:	$20,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: Emergency Management Performance Grant (EMPG), NOAA, FEMA HMA, TDEM, GLO
Lead Agency/Department Responsible:	Rice University; Houston OEM; City/County/Regional/State Leaders
Implementation Schedule:	Within 12-24 months of plan adoption
Incorporation into Existing Plans:	N/A

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

	City of Houston – Action #40
Proposed Action:	Kingwood Diversion Channel Improvements: Expansion of the channel to increase capacity and protect the community from flooding.
BACKGROUND INFORMATION	
Site and Location:	Kingwood Diversion Channel from Montgomery County and routes to Lake Houston
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduces risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$10,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, BRIC, TDEM, GLO, TWDB
Lead Agency/Department Responsible:	Houston OEM, Houston Public Works
Implementation Schedule:	Within 12-24 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #41
Proposed Action:	Develop and conduct retrofitting projects at the Lake Houston Dam.
BACKGROUND INFORMATION	
Site and Location:	Lake Houston Dam in Magnolia Gardens, TX
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity. Retrofit and resilience at Lake Houston Dam to strengthen and mitigate a breach or overflow event
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hurricane/Tropical Storm, Thunderstorm Wind
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Energy
Effect on New/Existing Buildings:	Reduces risk to existing structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,000,000
Potential Funding Sources:	General Funds; Grant Funds: HMGP, L-PDM
Lead Agency/Department Responsible:	Houston Public Works, Coastal Water Authority
Implementation Schedule:	Within 36 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Capital Improvement Plan, Local Building Codes/Ordinances, Disaster Recovery Plan, Stormwater Management Plan, Emergency Operations Plan

COMMENTS:
The City has a phased HMGP grant for mitigation at Lake Houston Dam and pursuing legislative funding under the L-PDM program
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #42
Proposed Action:	Conduct diversion and bridge and channel improvements at North Canal.
BACKGROUND INFORMATION	
Site and Location:	North Canal is located at the confluence of White Oak and Buffalo Bayous with South overflow channel downstream. The bridge and channel improvements provide conveyance capacity to areas along White Oak Bayou, including I-10 west of downtown Houston
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity. Provide flood damage reduction to upstream areas along White Oak and Buffalo Bayous
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hurricane/Tropical Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Transportation
Effect on New/Existing Buildings:	Reduces risk to new and existing residential and nonresidential structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$150,000,000
Potential Funding Sources:	General Funds; Grant Funds: HMGP
Lead Agency/Department Responsible:	Houston Public Works, Harris County Flood Control District
Implementation Schedule:	Within 36 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Disaster Recovery Plan, Stormwater Management Plan

COMMENTS:
The City was awarded Phase I of the North Canal project in 2019 and will begin Phase II once awarded.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #43
Proposed Action:	Develop flood detention at the Inwood Forest Golf Course.
BACKGROUND INFORMATION	
Site and Location:	Northwest Houston in the Greater Inwood neighborhood, along the White Oak Bayou, just north of its confluence with Vogel Creek.
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages caused by flooding by maintaining or restoring drainage capacity. Provide flood reduction benefits to thousands of homes within the community
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Transportation
Effect on New/Existing Buildings:	Reduces risk to new and existing residential and nonresidential structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$90,000,000
Potential Funding Sources:	General Funds; Grant Funds: HMGP
Lead Agency/Department Responsible:	Houston Public Works, Harris County Flood Control District
Implementation Schedule:	Within 36 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Disaster Recovery Plan, Stormwater Management Plan

COMMENTS:
The former golf course was acquired in 2011 and encompasses 12 interconnected stormwater detention basins. Phase I of the grant has been completed for design and Phase II was awarded in October 2022
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #44
Proposed Action:	Develop detention basin and conduct storm sewer improvements for Tax Increment Reinvestment Zone (TIRZ) 17.
BACKGROUND INFORMATION	
Site and Location:	TIRZ 17 encompasses approximately 1,000 acres of land, bounded by Beltway 8 and Gessner Road, both north and south of I-10.
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flooding in high-impact areas. Reduce risk of property damage, injuries, and fatalities.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Transportation
Effect on New/Existing Buildings:	Reduces risk to new and existing residential and nonresidential structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$60,000,000
Potential Funding Sources:	General Funds; Grant Funds: HMGP
Lead Agency/Department Responsible:	Houston Public Works, TIRZ 17
Implementation Schedule:	Within 36 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Disaster Recovery Plan, Stormwater Management Plan

COMMENTS:
The city was awarded Phase I of grant in 202
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #45
Proposed Action:	Consolidate and decommission wastewater facilities and develop offsite mitigation projects, such as detention basins and elevation, for flood mitigation.
BACKGROUND INFORMATION	
Site and Location:	Wastewater Treatment Plants (WWTP), lift stations, and facilities throughout the city
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce flooding in high-impact areas. Reduce risk of property damage, injuries, and fatalities.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Transportation, Energy, Food/Water/Shelter
Effect on New/Existing Buildings:	Reduces risk to new and existing residential and nonresidential structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$2.5 billion
Potential Funding Sources:	General Funds; Grant Funds: 406 Hazard Mitigation Funds, BRIC, and HMGP
Lead Agency/Department Responsible:	Houston Public Works
Implementation Schedule:	Within 36-48 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Stormwater Management Plan, Disaster Recovery Plan, Emergency Operations Plan, Local Building Codes/Ordinances

COMMENTS:
The City is seeking 406 Hazard Mitigation funds, in addition to BRIC and HMGP funding for multiple detention/retention and other offsite flood reduction mitigation projects for WWTPs throughout the City to consolidate and decommission plants in the event of severe flooding.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #46
Proposed Action:	Conduct Keegans Bayou channel improvements and develop detention pond at the Ruffino Hills landfill.
BACKGROUND INFORMATION	
Site and Location:	The Ruffino Hills landfill/Keegans Bayou in southwest Houston
Risk Reduction Benefit: (Current Cost/Losses Avoided)	The project proposes drainage, channelization, and a detention pond to reduce or eliminate flooding to residential and industrial areas near Keegans Bayou.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm, Thunderstorm Wind
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Transportation
Effect on New/Existing Buildings:	Reduces risk to new and existing residential and nonresidential structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$100,000,000
Potential Funding Sources:	General Funds; Grant Funds: HMGP
Lead Agency/Department Responsible:	Houston Public Works, Harris County Flood Control District
Implementation Schedule:	Within 36-48 months of implementation based on grant schedule period of performance per grant
Incorporation into Existing Plans:	Stormwater Management Plan, Local Building Codes/Ordinances

COMMENTS:
The proposed project would be phased for the completion of design and environmental prior to construction.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #47
Proposed Action:	Implement flood risk reduction projects identified through the Harris County Flood Control District's (HCFCD) ongoing Capital Improvement Program (CIP). Flood control measures will include cost-effective structural drainage improvements as well as acquisition/demolition projects.
BACKGROUND INFORMATION	
Site and Location:	City of Houston high flood risk areas Buyouts in 24 Areas of Investment Allen Field, Little York and Tidwell areas
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Eliminates risk of flood damages to high-risk structures and prevent future losses in high-risk flood hazard areas; Reduce downstream impacts associated with development in the floodplain; Reduce risk to structures and infrastructure through drainage improvements; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure Natural Systems Protection

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to new and existing structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$5,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, BRIC, CDBG, USACE
Lead Agency/Department Responsible:	Project Management Department (structural), Property Acquisition Department (buyouts)
Implementation Schedule:	Within 12 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan; Floodplain Management / Ordinance

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

		City of Houston – Action #48
	Proposed Action:	Implement a community outreach and awareness program, including State of Texas Emergency Assistance Registry (STEAR) program, Senate Bill (SB)-968, community event activations, social media campaigns, e-mail communications, website blogs, inclusion in Disaster Guides, update preparedness website and other to educate citizens of hazards that may threaten the community and provide mitigation measures to reduce potential damages and injuries.
	BACKGROUND INFORMATION	
	Site and Location:	City-wide
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Promotes hazard awareness. Reduces the risk of all hazards through education outreach programs.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Drought, Expansive Soils, Extreme Heat, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication, Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$50,000 - $100,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, Emergency Management Performance Grant, NOAA
Lead Agency/Department Responsible:	Houston OEM; Houston Fire Department
Implementation Schedule:	Annually
Incorporation into Existing Plans:	Emergency Operations Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

		City of Houston – Action #49
	Proposed Action:	Storm Water Action Team projects. Provide flood relief to neighborhoods on improvements such as: ditch widening; driveway culvert replacement; inlet replacement; side lot swales; and storm sewer line improvements.
	BACKGROUND INFORMATION	
	Site and Location:	City-wide
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of structure and infrastructure flooding through various drainage improvements.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures
Priority (High, Moderate, Low):	High
Estimated Cost:	$10,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: ReBuild Houston, FEMA HMA, CDBG, BRIC, PA Section 406 Funds, TWDB Flood Infrastructure Fund (FIF), Silver Jackets, Small Flood Control Projects (USACE Section 205), TWDB Texas Infrastructure Resiliency Fund (TIRF)
Lead Agency/Department Responsible:	Houston Public Works and Engineering
Implementation Schedule:	Within 12-48 months of plan adoption
Incorporation into Existing Plans:	Stormwater Management Plan

COMMENTS:
The Storm Water Action Team Project Log can be seen in Appendix G
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #50
Proposed Action:	Analyze the current storm sewer system, then design and implement an improved storm sewer system that will convey the current contributing drainage areas runoff flows adequately to the discharge point. Storm sewers will be increased in size to adequately convey the minimum City design storm event (2-year event). In addition, an analysis of sheet flow will be performed to assess what design measures are necessary to adequately convey a more significant (i.e., 100-year) storm event to the discharge point in a manner that minimizes structural flooding.
BACKGROUND INFORMATION	
Site and Location:	Various Neighborhoods City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk of flood damages through improved drainage capacity/stormwater diversion; Reduce risk of injuries to citizens; Reduce burden on emergency services during and after a flood event.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$2,000,000 - $30,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, EPA American Recovery and Reinvestment Act (ARRA), TWDB DFund
Lead Agency/Department Responsible:	Houston Public Works and Engineering
Implementation Schedule:	Within 12-28 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
Various storm sewer systems shall be prioritized to justify this action based on project cost over a comparison of structures impacted in 100-year event pre-project vs. post-project.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #51
Proposed Action:	Utilize existing GIS data to identify large facilities to serve as potential refuges of last resort, either during or after a disaster. Develop vulnerability assessment for identified facilities. Conduct site visits to evaluate structural capabilities and resistance to identified hazards. Develop prioritized implementation procedures for use of these facilities during or after disaster events. Identify and implement required retrofit enhancements needed for each facility identified. Identify the capacity of each facility to house refugees.
BACKGROUND INFORMATION	
Site and Location:	Eight identified facilities
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce damages at city facilities; Reduce risk of injury to vulnerable populations. Provides alternative shelter for residents.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hurricane/Tropical Storm, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$1,000,000 - $30,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, CDBG, BRIC, NFIP
Lead Agency/Department Responsible:	Houston OEM / PW&E; Houston ISD
Implementation Schedule:	Within 12-36 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan; Emergency Operations Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

		City of Houston – Action #52
	Proposed Action:	Elevation and/or Mitigation Reconstruction of Flood-prone Structures.
	BACKGROUND INFORMATION	
	Site and Location:	City-wide, including 2 fire stations
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of flooding to repetitive loss of buildings by completing elevation or mitigation reconstruction projects. Reduce risk of injury. Ensure continuity of emergency response services. Reduces relocation of residents.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Flood, Hurricane/Tropical Storm, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security, Health/Medical
Effect on New/Existing Buildings:	Reduce risk to existing infrastructure
Priority (High, Moderate, Low):	High
Estimated Cost:	$300,000 per home or as set by the respective grant program $20,000,000 per fire station
Potential Funding Sources:	General Funds, Grant Funds: FMA, CDBG
Lead Agency/Department Responsible:	Houston Department of Public Works and Engineering; HFD
Implementation Schedule:	Continual as city submits each year under the annual grant program
Incorporation into Existing Plans:	Capital Improvement Plan; Emergency Operations Plan, Disaster Recovery Plan, Stormwater Management Plan, Local Building Codes/Ordinance

COMMENTS:
HPW is currently managing grants for home elevations with the Texas Water Development Board (TWDB) for 2015, 2016, 2018, 2019, and 2020 grant cycles. The city has submitted grant applications for FY 2021 and 2022.
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #53
Proposed Action:	Implement a community outreach and awareness program notifying homebuyers of the areas that have had flooding in the past. Notify them of the damages caused by floods and the challenges homeowners face after a disaster. Discuss the importance of flood insurance and pre-disaster preparations.
BACKGROUND INFORMATION	
Site and Location:	City-wide flood-prone areas
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of flood devastation through education outreach programs and increase participation in the NFIP. Increase flood insurance coverage.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication, Safety/Security
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, FEMA Emergency Management Performance Grant (EMPG), NOAA, TDEM
Lead Agency/Department Responsible:	Houston Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	N/A

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #54
Proposed Action:	Create and Implement reconstruction program to bring buildings up to code and protect from hazardous events.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of hazards and loss of life through improved construction.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Dam Failure, Expansive Soils, Flood, Hail, Hurricane/Tropical Storm, Lightning, Thunderstorm Wind, Tornado, Wildfire, Winter Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMAHMA, BRIC, CDBG, HUD, TDEM, GLO
Lead Agency/Department Responsible:	Houston Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects infrastructure, reduces cost of reparation, and prevents injury to residents.

	City of Houston – Action #55
Proposed Action:	Adopt an ordinance to require retention ponds in all new developments and to validate retention ponds in existing high-risk flood areas.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of flooding through development requirements. Requiring developers to implement on-site retention basin for new developments will prevent downstream impacts, reduce impacts to floodplain and provide additional potential water sources for firefighting uses.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, GLO, TWDB, USACE / Silver Jackets
Lead Agency/Department Responsible:	Houston Housing and Community Development Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Stormwater Management Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #56
Proposed Action:	Install lightning rods and surge protectors on critical facilities located throughout the city.
BACKGROUND INFORMATION	
Site and Location:	City-wide critical facilities
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Protection of critical facilities from the effects of lightning, such as fire, and ensure continuity of services.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Lightning
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$30,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, US DOC / EDA – Economic Development Administration Grant
Lead Agency/Department Responsible:	Houston OEM / PW&E; Houston Fire Department
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:

	City of Houston – Action #57
Proposed Action:	Improve/enhance flood vulnerability data, including CTP status, updating of H&H study, alternative analysis and Benefit-Cost Analysis. Enhance planning using surveys to more accurately define flood vulnerability.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Improve risk assessment; reduce risk of damages or injuries through planning of flood mitigation projects, and for public education.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructures
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,500,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA Emergency Management Performance Grant (EMPG), NOAA Hydrologic Research Grant
Lead Agency/Department Responsible:	Houston Public Works and Engineering
Implementation Schedule:	Within 24- 36 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #58
Proposed Action:	Map Enhancement – Storm Surge Vulnerability: Elevation data obtained by field survey, in addition to data collected from existing plans and records, would be compiled into a database, and the most vulnerable facilities and transportation links may be identified for mitigation actions
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Provide additional data to enhance the planning of flood mitigation projects and for public education.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$1,500,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA Emergency Management Performance Grant (EMPG), TWDB
Lead Agency/Department Responsible:	Houston Public Works and Engineering
Implementation Schedule:	Within 24- 36 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Protects communities and reduces risk of flooding.

	City of Houston – Action #59
Proposed Action:	Damage Identification Tracking and Mitigation Alternative Development Tool – Develop a GIS-based damage-tracking tool. With use of this tool and Houston 1-2-3 will allow the City of Houston the capabilities to develop effective mitigation actions, measures, or strategies based on actual documented disaster data.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of flood devastation through education outreach programs and increase participation in the NFIP. Increase flood insurance coverage.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flood, Hurricane/Tropical Storm
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Communication, Safety/Security
Effect on New/Existing Buildings:	N/A
Priority (High, Moderate, Low):	Moderate
Estimated Cost:	$50,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA
Lead Agency/Department Responsible:	Houston OEM / PW&E
Implementation Schedule:	Within 24 months of plan adoption
Incorporation into Existing Plans:	Disaster Recovery Plan

COMMENTS:
CRS REQUIREMENT & WHY MITIGATION ACTION IS APPROPRIATE:
Promotes public safety.

		City of Houston – Action #60
	Proposed Action:	Develop and implement an ordinance to require engineering techniques for infrastructures to mitigate the effects of expansive soils.
	BACKGROUND INFORMATION	
	Site and Location:	City-wide
	Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce risk to new development through improved construction methods.
	Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures and infrastructure
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: HMGP
Lead Agency/Department Responsible:	Houston Building Code Compliance
Implementation Schedule:	Within 48 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes / Ordinances

COMMENTS:

	City of Houston – Action #61
Proposed Action:	Develop and implement a program to regularly water the foundation of public buildings.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of expansive soils on public buildings through the implementation of protective measures.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures and infrastructure
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston Building Code Compliance; Houston Fire Department
Implementation Schedule:	Within 48 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes / Ordinances

COMMENTS:

	City of Houston – Action #62
Proposed Action:	Replace water fixtures in public buildings with low-flow fixtures.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of drought impacts through water reduction measures.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Structure and Infrastructure

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Drought
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Low
Estimated Cost:	$100,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA, US DOC/EDA Economic Development Administration Grants and Investments
Lead Agency/Department Responsible:	Houston Public Works; General Services Department (GSD)
Implementation Schedule:	Within 48 months of plan adoption
Incorporation into Existing Plans:	Capital Improvement Plan

COMMENTS:

	City of Houston – Action #63
Proposed Action:	Adopt an ordinance to require drought-resistant landscaping (xeriscaping) for new public facilities.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Reduce the risk of drought impacts through water reduction measures.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Local Plans and Regulations

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Drought
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new structures and infrastructure
Priority (High, Moderate, Low):	Low
Estimated Cost:	$5,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue
Lead Agency/Department Responsible:	Houston Building Code Compliance
Implementation Schedule:	Within 48 months of plan adoption
Incorporation into Existing Plans:	Local Codes / Ordinances

COMMENTS:

	City of Houston – Action #64
Proposed Action:	Improve the data collection capabilities of expansive soils incidents. A database would be compiled with the information then the most vulnerable facilities could then be identified.
BACKGROUND INFORMATION	
Site and Location:	City-wide
Risk Reduction Benefit: (Current Cost/Losses Avoided)	Improve future risk assessment information and data that is needed; Protects critical facilities and the general population of the city.
Type of Action: (Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, or Education and Awareness)	Education and Awareness

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Expansive Soils
Community Lifeline: (Safety/Security, Food, Water Shelter, Health/Medical, Energy (Power/Fuel), Communication, Transportation, Hazardous Materials)	Safety/Security
Effect on New/Existing Buildings:	Reduce risk to new and existing structures and infrastructure
Priority (High, Moderate, Low):	Low
Estimated Cost:	$100,000
Potential Funding Sources:	Local Department Budget, Staff time, Bonds, Tax Revenue; State and Federal Grants: FEMA HMA Emergency Management Performance Grant
Lead Agency/Department Responsible:	Houston OEM
Implementation Schedule:	Within 48 months of plan adoption
Incorporation into Existing Plans:	Local Building Codes / Ordinances

COMMENTS:
The City's 3-1-1 helpline may have reports called in regarding cracked slabs and other evidence of expansive soils to enhance data collection.

SECTION 20
PLAN MAINTENANCE



OFFICE OF EMERGENCY MANAGEMENT

SECTION 20: PLAN MAINTENANCE

Plan Maintenance Procedures **1**

Incorporation **1**

Process of Incorporation 1

Monitoring and Evaluation **4**

Monitoring 4

Evaluation 5

Updating **5**

Plan Revisions 5

Five (5) Year Review 5

Continued Public Involvement **6**

PLAN MAINTENANCE PROCEDURES

The following is an explanation of how the City of Houston, and the general public will be involved in implementing, evaluating, and enhancing the Plan over time. When the plan is discussed in all maintenance procedures it includes mitigation actions and hazard assessments. The sustained hazard mitigation planning process consists of four main parts:

- Incorporation
- Monitoring and Evaluation
- Updating
- Continued Public Involvement

INCORPORATION

The City of Houston will be responsible for further development and implementation of mitigation actions. Each action has been assigned to a specific department within the City. The following describes the process by which the City of Houston will incorporate elements of the mitigation plan into other planning mechanisms.

PROCESS OF INCORPORATION

Once the Plan Update is adopted, the City of Houston will implement actions based on priority and the availability of funding. The City currently implements policies and programs to reduce loss to life and property from hazards. The mitigation actions developed for this Plan Update enhance this ongoing effort and will be implemented through other program mechanisms where possible.

The potential funding sources listed for each identified action may be used when the City seeks funds to implement actions. An implementation time period or a specific implementation date has been assigned to each action as an incentive for completing each task and gauging whether actions are implemented in a timely manner.

SECTION 20: PLAN MAINTENANCE

The City of Houston will integrate implementation of their mitigation actions with other plans and policies such as construction standards and emergency management plans, and ensure that these actions, or proposed projects, are reflected in other planning efforts. Coordinating and integrating components of other plans and policies into goals and objectives of the Plan Update will further maximize funding and provide possible cost-sharing of key projects, thereby reducing loss of lives and property and mitigating hazards affecting the area.

Upon formal adoption of the Plan Update, planning team members from each City department will work to integrate the hazard mitigation strategies into other plans and codes as they are developed. Participating team members will conduct periodic reviews of plans and policies, once per year at a minimum, and analyze the need for revisions in light of the approved Plan Update. The planning team will review all comprehensive land use plans, capital improvement plans, annual budget reviews, emergency operations or management plans, and transportation plans to guide and control development. Departments will ensure that capital improvement planning in the future will also contribute to the goals of this hazard mitigation Plan Update to reduce the long-term risk to life and property from all hazards. Within one year of formal adoption of the hazard mitigation Plan Update, existing planning mechanisms will be reviewed.

The City of Houston will review and revise, as necessary, the long-range goals and objectives in strategic plan and budgets to ensure that they are consistent with this mitigation action plan. Additionally, the City will work to advance the goals of this hazard mitigation plan through its routine, ongoing, long-range planning, budgeting, and work processes.

Table 20-1 identifies types of planning mechanisms and examples of methods for incorporating the Plan Update into other planning efforts. The team members, listed in Table 20-2 below, will be responsible for the review of these planning mechanisms and their incorporation of the plan, with the exception of the Floodplain Management Plan; the Floodplain Administrator on staff will be responsible for incorporating the plan when floodplain management plans are updated or new plans are developed.

Table 20-1. Methods of Incorporation of the Plan

PLANNING MECHANISM	DEPARTMENT / TITLE RESPONSIBLE	INCORPORATION OF PLAN
Annual Budget Review	OEM Deputy Emergency Management Coordinator	Various departments and key personnel that participated in the planning process will review the Plan and mitigation actions therein when conducting their annual budget review. Allowances will be made in accordance with grant applications sought, and mitigation actions that will be undertaken, according to the implementation schedule of the specific action.

PLANNING MECHANISM	DEPARTMENT / TITLE RESPONSIBLE	INCORPORATION OF PLAN
Capital Improvement Plans	OEM Deputy Emergency Management Coordinator	Prior to any revisions to the Capital Improvement Plan (CIP), City departments will review the risk assessment and mitigation strategy sections of the HMAP, as limiting public spending in hazardous zones is one of the most effective long-term mitigation actions available to local governments.
General Plan	OEM Deputy Emergency Management Coordinator	The City of Houston adopted Plan Houston, the City's General Plan, in 2015. In future revisions and updates to the General Plan, the mitigation vision and goals of this Plan will be reviewed.
Floodplain Management Plans	Floodplain Administrator	Floodplain management plans include preventative and corrective actions to address the flood hazard. Therefore, the actions for flooding and information found in Section 5 of this Plan Update discussing the people and property at risk of flooding will be reviewed and revised when updating the flood management plans or developing new plans.
Grant Applications	OEM Deputy Emergency Management Coordinator	The Plan will be evaluated when grant funding is sought for mitigation projects. If a project is not in the Plan Update, a Plan Revision may be necessary to include the action in the Plan.
Regulatory Plans	OEM Deputy Emergency Management Coordinator	Currently, the City of Houston has regulatory plans in place, such as Emergency Management Plans, Continuity of Operations Plans, Land Use Plans, and Evacuation Plans. The Plan Update will be consulted when City departments review or revise their current regulatory planning mechanisms or in the development of regulatory plans that are not currently in place.

MONITORING AND EVALUATION

Periodic revisions of the Plan are required to ensure that goals, objectives, and mitigation actions are kept current. When the plan is discussed in these sections it includes the risk assessment and mitigation actions as a part of the monitoring, evaluating, updating and review process. Revisions may be required to ensure the Plan is in compliance with federal and state statutes and regulations. This section outlines the procedures for completing Plan revisions, updates, and review. Table 20-2 indicates the department and title of the party responsible for Plan monitoring, evaluating, updating, and review of the Plan.

Table 20-2. Team Members Responsible for Plan Monitoring, Evaluating, Updating, and Review of the Plan

DEPARTMENT	TITLE
Office of Emergency Management	Administrative Specialist
Office of Emergency Management	Community Outreach
Office of Emergency Management	Deputy Emergency Management Coordinator
Office of Emergency Management	Emergency Management Coordinator
Office of Emergency Management	Mass Care Coordinator
Office of Emergency Management	Planner I
Office of Emergency Management	Planner II

MONITORING

Designated Planning Team members are responsible for monitoring, evaluating, updating, and reviewing the Plan, as shown in Table 20-2. Individuals holding the title listed in Table 20-2 will be responsible for monitoring the Plan on an annual basis. Plan monitoring includes reviewing and incorporating into the Plan other existing planning mechanisms that relate or support goals and objectives of the Plan; monitoring the incorporation of the Plan into future updates of other existing planning mechanisms as appropriate; reviewing mitigation actions submitted and coordinating with various City departments to determine if mitigation actions need to be re-evaluated and updated; evaluating and updating the Plan as necessary; and monitoring plan maintenance to ensure that the process described is being followed, on an annual basis, throughout the planning process. The Planning Team will develop a brief report that identifies policies and actions in the plan that have been successfully implemented and any changes in the implementation process needed for continued success. A summary of meeting notes will report the particulars involved in developing an action into a project. In addition to the annual monitoring, the Plan will be similarly reviewed immediately after extreme weather events include but not limited to state and federally declared disasters.

EVALUATION

As part of the evaluation process, the Planning Team will assess changes in risk; determine whether the implementation of mitigation actions is on schedule; determine whether there are any implementation problems, such as technical, political, legal, or coordination issues; and identify changes in land development or programs that affect mitigation priorities for each respective department or organization.

The Planning Team will meet on an annual basis to evaluate the Plan and identify any needed changes and assess the effectiveness of the plan achieving its stated purpose and goals. The team will evaluate the number of mitigation actions implemented along with the loss-reduction associated with each action. Actions that have not been implemented will be evaluated to determine if any social, political, or financial barriers are impeding implementation and if any changes are necessary to improve the viability of an action. The team will evaluate changes in land development and/or programs that affect mitigation priorities in their respective jurisdictions. The annual evaluation process will help to determine if any changes are necessary. In addition, the Plan will be similarly evaluated immediately after extreme weather events including but not limited to state and federally declared disasters.

UPDATING

PLAN REVISIONS

At any time, minor technical changes may be made to update the City of Houston Hazard Mitigation Action Plan Update 2023. Material changes to mitigation actions or major changes in the overall direction of the Plan or the policies contained within it, must be subject to formal adoption by the City.

The City will review proposed revisions and vote to accept, reject, or amend the proposed change. Upon ratification, the Revision will be transmitted to TDEM.

In determining whether to recommend approval or denial of a Plan Revision request, the City will consider the following factors:

- Errors or omissions made in the identification of issues or needs during the preparation of the Plan Update;
- New issues or needs that were not adequately addressed in the Plan Update; and
- Changes in information, data, or assumptions from those on which the Plan Update was based.

FIVE (5) YEAR REVIEW

The Plan will be thoroughly reviewed by the Planning Team at the end of three years from the approval date, to determine whether there have been significant changes in the planning area that necessitate changes in the types of mitigation actions proposed. Factors that may affect the content of the Plan include new development in identified hazard areas, increased exposure to

hazards, disaster declarations, increase or decrease in capability to address hazards, and changes to federal or state legislation.

The Plan review process provides the City an opportunity to evaluate mitigation actions that have been successful, identify losses avoided due to the implementation of specific mitigation measures, and address mitigation actions that may not have been successfully implemented as assigned.

It is recommended that the full Executive and Advisory Planning Team (Section 2, Tables 2-1 and 2-2) meet to review the Plan at the end of three years because grant funds may be necessary for the development of a five-year update. Reviewing planning grant options in advance of the five-year Plan update deadline is recommended considering the timelines for grant and planning cycles can be in excess of a year.

Following the Plan review, any revisions deemed necessary will be summarized and implemented according to the reporting procedures and Plan Revision process outlined herein. Upon completion of the review, update, and revision process the revised Plan will be submitted to TDEM for final review and approval in coordination with FEMA.

CONTINUED PUBLIC INVOLVEMENT

Public input was an integral part of the preparation of this Plan and will continue to be essential for Plan updates. The Public will be directly involved in the annual evaluation, monitoring, reviews and cyclical updates. Changes or suggestions to improve or update the Plan will provide opportunities for additional public input.

The public can review the Plan on the City of Houston's Office of Emergency Management website, where officials and the public are invited to provide ongoing feedback, via email. Notification that the Plan Update is available for review and comment will be made via social media outlets.

The Planning Team may also designate voluntary citizens from the City or willing stakeholder members from the private sector businesses that were involved in the Plan's development to provide feedback on an annual basis. It is important that stakeholders and the immediate community maintain a vested interest in preserving the functionality of the planning area as it pertains to the overall goals of the mitigation plan. The Planning team is responsible for notifying stakeholders and community members on an annual basis and maintaining the Plan.

Media, including local newspaper and radio stations, will be used to notify the public of any maintenance or periodic review activities during the implementation, monitoring, and evaluation phases. Additionally, local news media will be contacted to cover information regarding Plan updates, status of grant applications, and project implementation. Local and social media outlets, such as Facebook and Twitter, will keep the public and stakeholders apprised of potential opportunities to fund and implement mitigation projects identified in the Plan Update. Social media outlets have been successful in communicating in the past and will continue to be utilized to not only inform the public of progress but utilized to create public awareness of activities and the need for their involvement going forward.

APPENDIX A
PLANNING TEAM



CITY OF HOUSTON
TEXAS

OEM
OFFICE OF EMERGENCY MANAGEMENT

APPENDIX A: PLANNING TEAM

Planning Team Members 1
Stakeholders 3

PLANNING TEAM MEMBERS

The City of Houston Hazard Mitigation Action Plan 2023 was organized using a direct representative model. An Executive Planning Team from the City of Houston, shown in Table A-1, was formed to coordinate planning efforts and request input and participation in the planning process. Table A-2 reflects the Advisory Planning Team, consisting of area organizations and departments that participated throughout the planning process. Table A-3 is comprised of stakeholders who were invited to provide Plan input. Public outreach efforts and meeting documentation is provided in Appendix E.

Table A-1. Executive Planning Team

ORGANIZATION / DEPARTMENT	TITLE
Office of Emergency Management	Administrative Specialist
Office of Emergency Management	Community Outreach
Office of Emergency Management	Deputy Emergency Management Coordinator
Office of Emergency Management	Emergency Management Coordinator
Office of Emergency Management	Mass Care Coordinator
Office of Emergency Management	Planner I
Office of Emergency Management	Planner II

Table A-2. Advisory Planning Team

ORGANIZATION / DEPARTMENT	TITLE
Finance Department	Assistant Director
Finance Department	Deputy Director
Finance Department	Division Manager
Finance Department	Financial Analyst
Finance Department	Financial Analyst IV
Housing and Community Development Department	Deputy Assistant Director
Housing and Community Development Department	Deputy Assistant Director Planning and Grants Reporting

APPENDIX A: PLANNING TEAM

ORGANIZATION / DEPARTMENT	TITLE
Housing and Community Development Department	Deputy Director
Housing and Community Development Department	Director
Housing and Community Development Department	Division Manager
Housing and Community Development Department	Grants Analyst
Housing and Community Development Department	Planner
Housing and Community Development Department	Planning and Grants Reporting
Houston Fire Department	Accreditation Manager / Management Analyst IV
Houston Fire Department	Executive Assistant Chief
Houston Fire Department	Assistant Fire Chief / Fire Marshal
Houston Office of the Mayor	Mayor
Houston Police Department	Sergeant / Planning
Houston Public Works	Administrative Assistant
Houston Public Works	Assistant Director
Houston Public Works	Chief of Staff
Houston Public Works	Community Rating System Coordinator
Houston Public Works	Emergency Management Coordinator
Houston Public Works	Deputy Emergency Management Coordinator
Houston Public Works	Employee Engagement Coordinator
Houston Public Works	Floodplain Administrator
Houston Public Works	Planner Manager / Urban Designer
Houston Public Works	Senior Assistant Director
Houston Public Works	Senior Staff Analyst
Houston Public Works	Staff Analyst
Parks and Recreation Department	City Forester
Parks and Recreation Department	Deputy Director of Management and Finance

ORGANIZATION / DEPARTMENT	TITLE
Parks and Recreation Department	Director of Greenspace Management Division
Parks and Recreation Department	Division Manager
Parks and Recreation Department	Director
Parks and Recreation Department	Superintendent
Planning and Development Department	Community and Regional Planning
Planning and Development Department	Director
Planning and Development Department	Division Manager
Planning and Development Department	Planner for Sunnyside and Acres Home
Solid Waste Management Department	Deputy Director
Solid Waste Management Department	Director

STAKEHOLDERS

The following groups listed in Table A-3 represent a list of organizations invited to stakeholder meetings, public meetings, and workshops throughout the planning process and include non-profit organizations, private businesses, neighboring counties, and legislators. The public were also invited to participate via e-mail throughout the planning process. Many of the invited organizations and stakeholders participated and were integral to providing comments and data for the Plan. For a list of attendees at meetings, please see Appendix E[1].

Table A-3. Stakeholders

AGENCY	TITLE	STAKEHOLDER TYPE
AARP	Director of Programs	Nonprofit/Community-Based Organization
American Red Cross	Disaster Program Manager	Nonprofit/Community-Based Organization
American Red Cross	Regional Disaster Officer	Nonprofit/Community-Based Organization
Catholic Charities	Manager	Nonprofit/Community-Based Organization
Chinese Community Center	Chief Executive Officer	Nonprofit/Community-Based Organization
City of Houston	Chief of Staff for At-Large 1	Authority To Regulate Development/Involved In Hazard Mitigation Activities

[1] Information contained in Appendix E is exempt from public release under the Freedom of Information Act (FOIA).

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
City of Houston	Chief of Staff for District A	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District C	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District E	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District F	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District G	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District H	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District J	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Chief of Staff for District K	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Council Member for At-Large 3	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Council Member for District B	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Council Member for District D	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Council Member for District H	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Council Member for District I	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Deputy Chief of Staff for At-Large 2	Authority To Regulate Development/Involved In Hazard Mitigation Activities

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
City of Houston	Deputy Chief of Staff for At-Large 4	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Deputy Chief of Staff for At-Large 5	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Deputy Chief of Staff for District G	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Director of Constituent Services & Housing Research Assistant for District F	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Director of Department of Neighborhoods	Authority To Regulate Development/Involved In Hazard Mitigation Activities
City of Houston	Director of General Services Department	Involved In Hazard Mitigation Activities
City of Houston	Permitting Center Managing Engineer	Involved In Hazard Mitigation Activities
Consulate of Argentina	Consul General	
Consulate of France	Press & Communications Officer	
Consulate of Colombia	Consul General	
Consulate of Colombia	Consul General	
Consulate of Guatemala	Consul General	
Consulate of Mexico	Consul of Prevention	
Consulate of Salvador	Consul General	
Consulate of Spain	Consul General	
Consulate of Qatar	Vice Consul	
Consulate of Vietnam	Citizens Protection	
Department of Neighborhoods	Director	
FEMA	Community Planner	Involved In Hazard Mitigation Activities
Greater Houston Flood Mitigation Consortium	Vice President / Director of Planner	Nonprofit/Involved In Hazard Mitigation Activities

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
Harris County Engineering Department	Project Manager	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Engineering Department	Team Lead Project Manager for Recovery and Resiliency Division	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Flood Control District	Planning Division Director	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Flood Control District	Resilience Division Manager	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Office of Homeland Security and Emergency Management	Emergency Management Coordinator	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Office of Homeland Security and Emergency Management	Flood Control Risk Manager	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Office of Homeland Security and Emergency Management	Mitigation Planner	Neighboring Community/Involved In Hazard Mitigation Activities
Harris County Office of Homeland Security and Emergency Management	Planning Section Chief	Neighboring Community/Involved In Hazard Mitigation Activities
Houston Airport System	Division Manager	Involved In Hazard Mitigation Activities
Houston County SPC / Harris County Disaster Animal Task Force	Director of Emergency Management	Neighboring Community/Involved In Hazard Mitigation Activities
Houston Food Bank	Coordinator	Nonprofit/Community-Based Organization
Houston Food Bank	Lead Associate / Manager	Nonprofit/Community-Based Organization
Houston – Galveston Area Council	Director of Communications and Outreach	Neighboring Community/Involved In Hazard Mitigation Activities
Houston – Galveston Area Council	Emergency Preparedness/Homeland Security Planner	Neighboring Community/Involved In Hazard Mitigation Activities
Houston – Galveston Area Council	Manager of Hurricane Evacuation and Evacuation Zones	Neighboring Community/Involved In Hazard Mitigation Activities

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
Houston Health Department	Public Health Preparedness Bureau Chief	Community-Based Organization
Houston Health Department	Staff Analyst	Community-Based Organization
Houston Hispanic Chamber of Commerce	President / CEO	Nonprofit/Community-Based Organization
Houston Independent School District (ISD)	Receptionist	Academia
Houston Independent School District (ISD)	Senior Manager for Nutrition Services	Academia
Houston Independent School District (ISD)	Senior Manager for Risk Management	Academia
Houston Office of the Mayor	Chief Resilience and Recovery Officer	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Chief Resilience and Sustainability Officer	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Deputy Assistant Director of Internal Operations for Complete Communities Division	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Director of Complete Communities Division	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Community Liaison for People with Disabilities Division	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Director of People with Disabilities Division	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Director of Public Safety and Homeland Security	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Staff Analyst of Resiliency and Sustainability Division	Involved In Hazard Mitigation Activities
Houston Office of the Mayor	Staff Representative of Complete Communities Division	Involved In Hazard Mitigation Activities
Houston Parks Board	Interim Director of Capital Improvements	Authority To Regulate Development/Involved In Hazard Mitigation Activities
Houston Parks Board	Director of Conservation and Maintenance	Authority To Regulate Development/Involved In Hazard Mitigation Activities
Houston Police Department	Disaster Management / Catastrophic Planning	Involved In Hazard Mitigation Activities

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
Jewish Community Center	Chief Executive Officer	Nonprofit/Community-Based Organization
KHOU	Managing Editor	Private Organization/Involved In Hazard Mitigation Activities
KPRC	Assignment Editor	Private Organization/Involved In Hazard Mitigation Activities
KRIV	Representative	Private Organization/Involved In Hazard Mitigation Activities
KTRK	Assignments Manager	Private Organization/Involved In Hazard Mitigation Activities
Lockwood, Andrews, & Newnam, Inc. (LAN)	CRS/Floodplain Mitigation Manager	Private Organization
Lone Star College – Kingwood	President	Academia
METRO	Chief of Safety Officer	Involved In Hazard Mitigation Activities
METRO	Director of Risk Management	Involved In Hazard Mitigation Activities
METRO	Emergency Management Coordinator	Involved In Hazard Mitigation Activities
METRO	Risk Manager	Involved In Hazard Mitigation Activities
National Weather Service	Warning Coordination Meteorologist	Involved In Hazard Mitigation Activities
Partnership Lake Houston	Chief Economic Development Officer	Nonprofit/Community-Based Organization
Partnership Lake Houston	Interim President / CEO	Nonprofit/Community-Based Organization
Port of Houston	Director of Community Relations	Private Organization
Port of Houston	Emergency Preparedness Coordinator	Private Organization
Region IV Education Service Center	Director of Emergency Management & School Safety	Academia
Region IV Education Service Center	Executive Director	Academia
Rice University Kinder Institute	Senior Director of Research	Academia/Involved In Hazard Mitigation Activities

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
Rice University Kinder Institute	Staff Representative	Academia/Involved In Hazard Mitigation Activities
San Jacinto College	Executive Director	Academia
South East Texas Regional Advisory Council (SETRAC)	Chief Executive Officer	Authority To Regulate Development/Involved In Hazard Mitigation Activities
Texas Children's Hospital (TCH)	Emergency Management Coordinator	Private Organization
TEEX Community Watershed	Infrastructure Training & Safety Representative	Nonprofit
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Specialist	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	District Coordinator	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Coordinator for Region 2	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Specialist for Region 2	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Hazard Mitigation Unit Chief for Region 2	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Recovery Coordinator	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Regional Mitigation Coordinator for Region 2	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	Regional Preparedness Coordinator / Planner for Region 2	Involved In Hazard Mitigation Activities
Texas Division of Emergency Management (TDEM)	STEAR Program Manager	Involved In Hazard Mitigation Activities
Texas Medical Center (TMC)	Emergency Management Coordinator	Private Organization
Texas Medical Center (TMC)	Director of Strategy	Private Organization
Texas Medical Center (TMC)	Vice President of Planning	Private Organization
Texas State Legislature	District 29	Involved In Hazard Mitigation Activities
Transtar	Director	Private Organization
Transtar	Executive Director	Private Organization
UTHealth and Safety	Governmental Relations Director	Academia

APPENDIX A: PLANNING TEAM

AGENCY	TITLE	STAKEHOLDER TYPE
United Way	211 Senior Manager of Information and Referral	Nonprofit
United Way	Disaster and Outreach Coordinator	Nonprofit
United Way	Information Referral Specialist	Nonprofit
University of Houston	Director of OEM	Academia
University of Houston	Risk & Emergency Program Manager II	Academia
Work for Solutions	Career Office Manager	Nonprofit
Work for Solutions	Senior Manager	Nonprofit

APPENDIX B
PUBLIC SURVEY RESULTS



OFFICE OF EMERGENCY MANAGEMENT

APPENDIX B: PUBLIC SURVEY RESULTS

Overview **1**

Public Survey Results **2**

Paper Survey **11**

English Paper Survey 11

Spanish Paper Survey 13

OVERVIEW

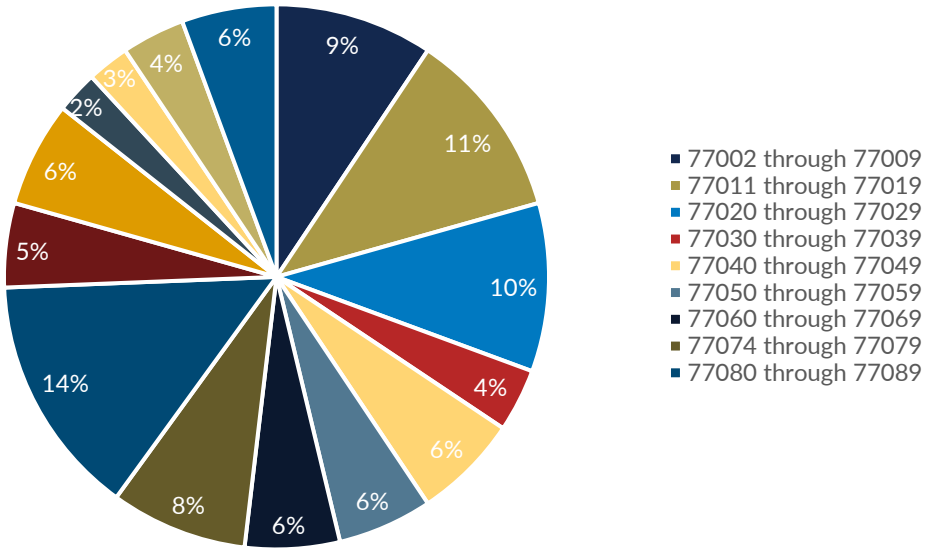
The City of Houston prepared a public survey that requested public opinion on a wide range of questions relating to natural hazards. The survey was made available via the City's websites. This survey link, along with hard copies, were also distributed at public meetings and stakeholder events throughout the planning process. The City of Houston offered the survey in both English and Spanish versions.

A total of 489 surveys were collected, the results of which are analyzed in Appendix B. The purpose of the survey was twofold: 1) to solicit public input during the planning process, and 2) to help the jurisdictions identify any potential actions or problem areas.

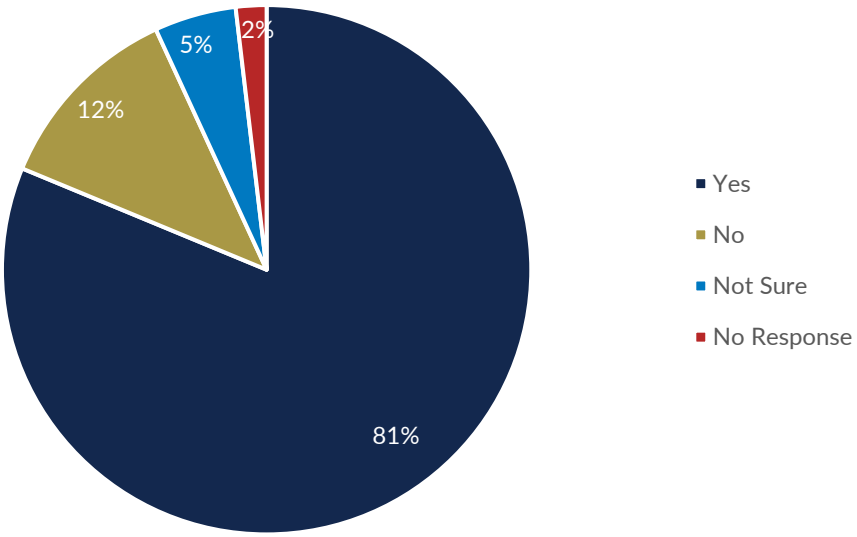
The following survey results depict the percentage of responses for each answer. Similar responses have been summarized for questions that did not provide a multiple-choice answer or that required an explanation.

PUBLIC SURVEY RESULTS

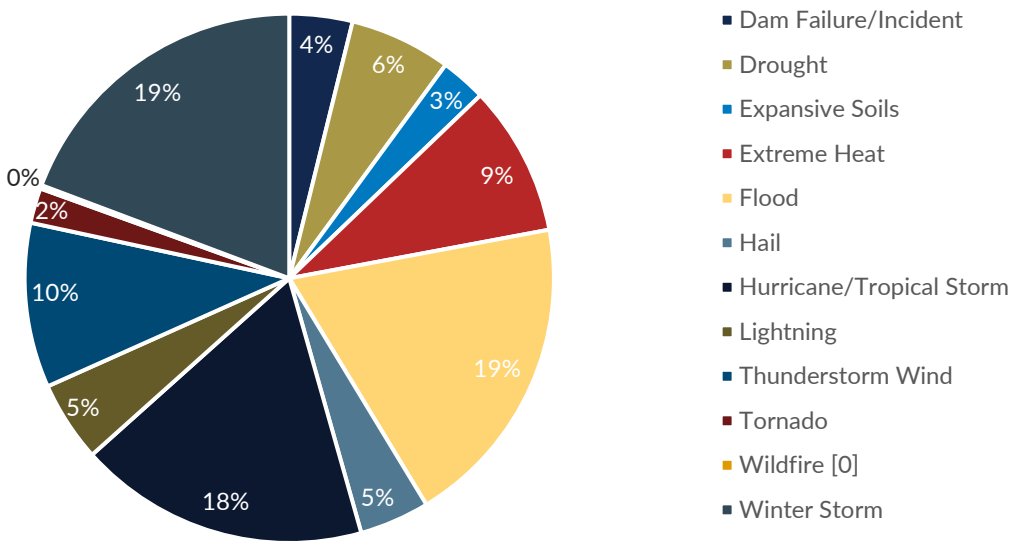
1. In what zip code do you reside?



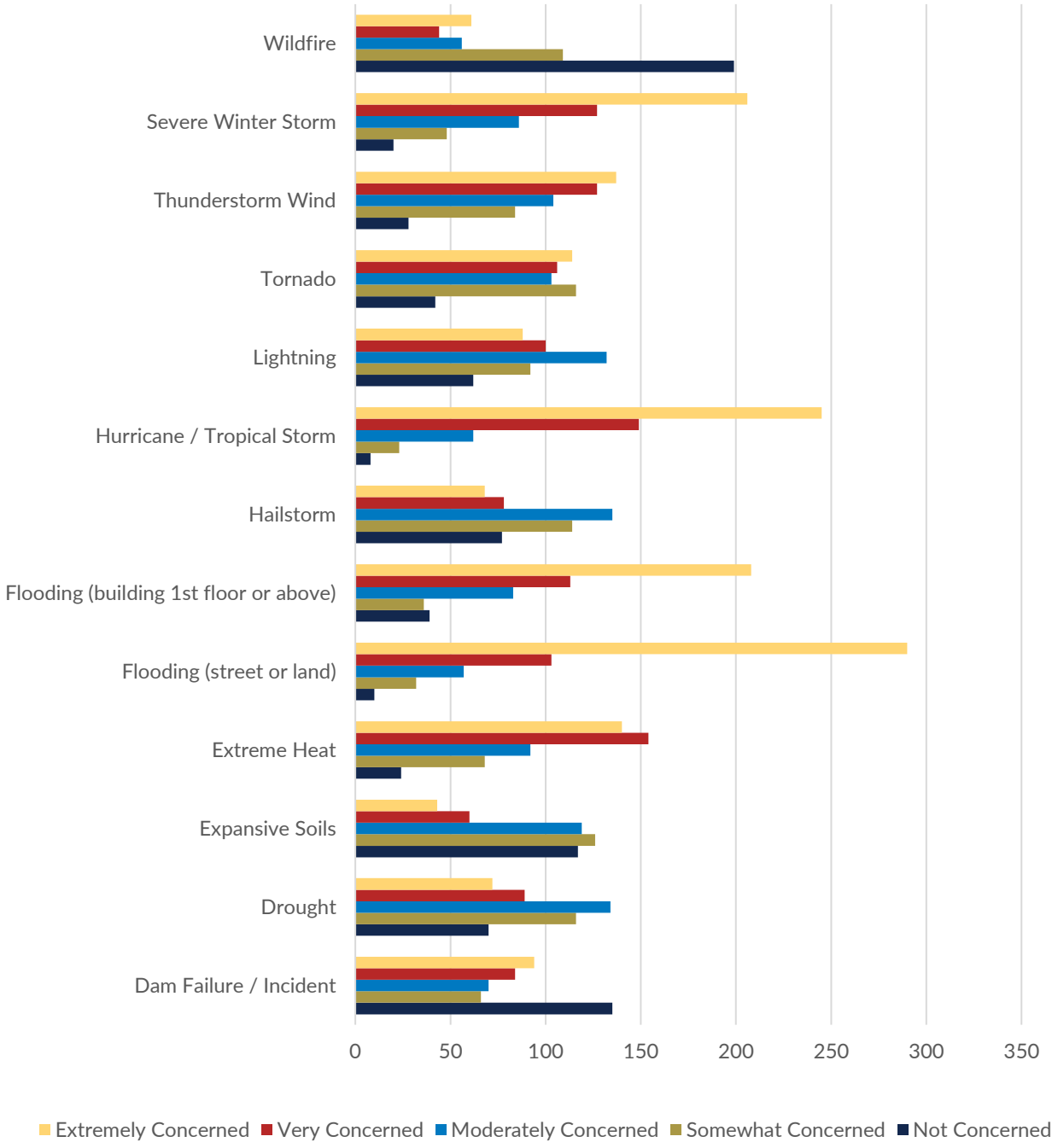
2. A “disaster” is an event that could threaten lives, disrupt services like water and power, or damage property. Have you or your community experienced the impacts of a disaster?



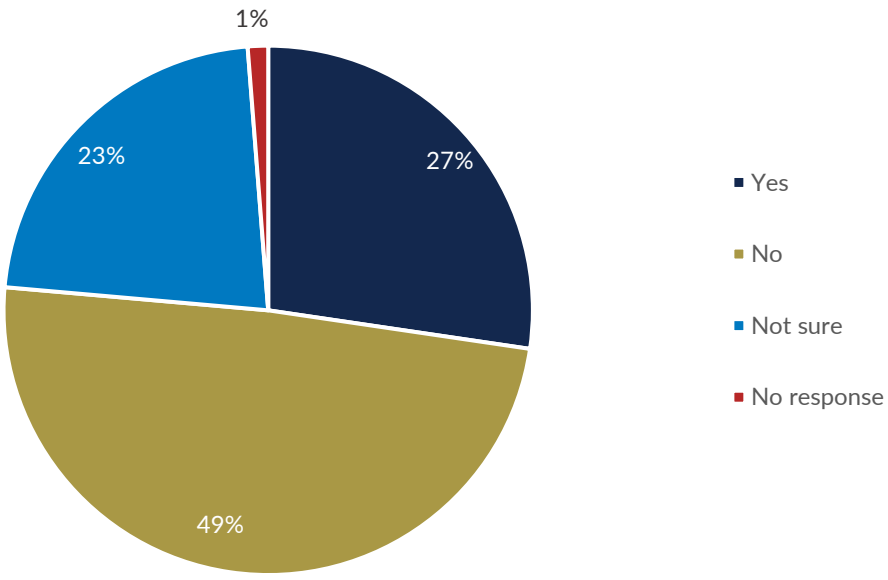
3. If yes, which of the following natural hazards have impacted you?



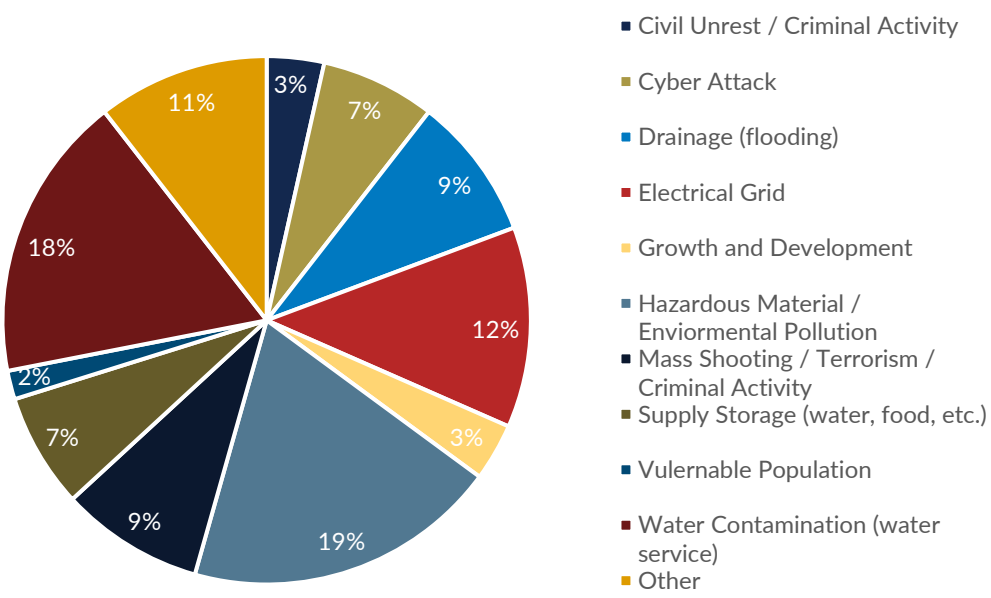
4. How concerned are you about the hazards listed below impacting you or your community?



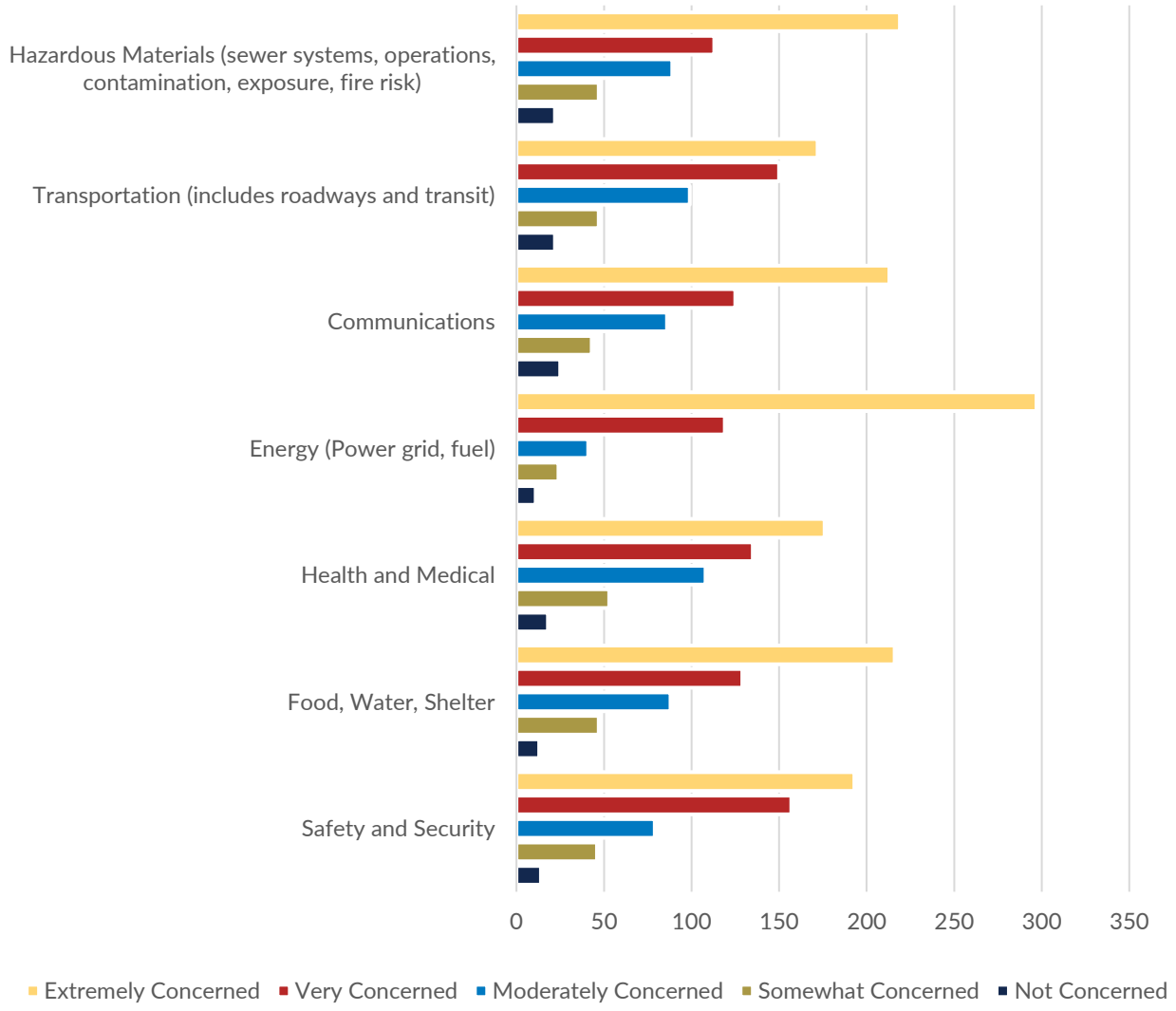
5. Are there any hazards not listed above that you think can have a wide-scale impact to your community:



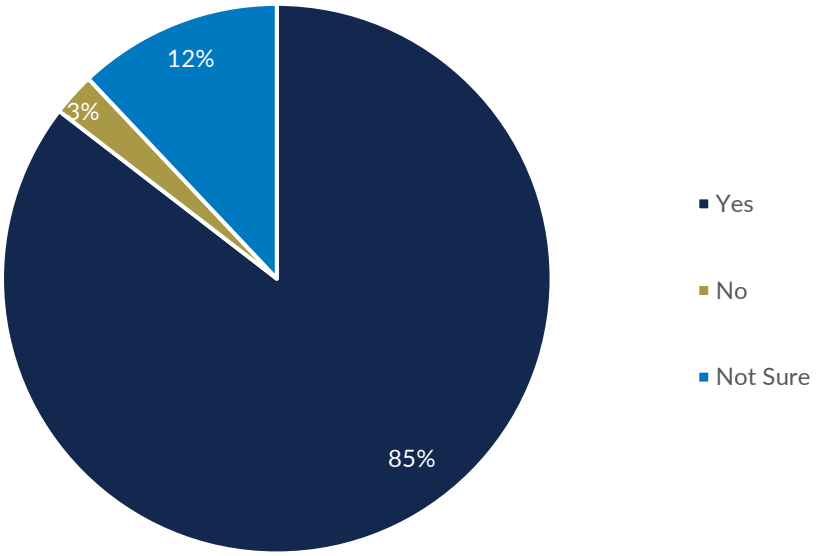
6. If yes, please explain.



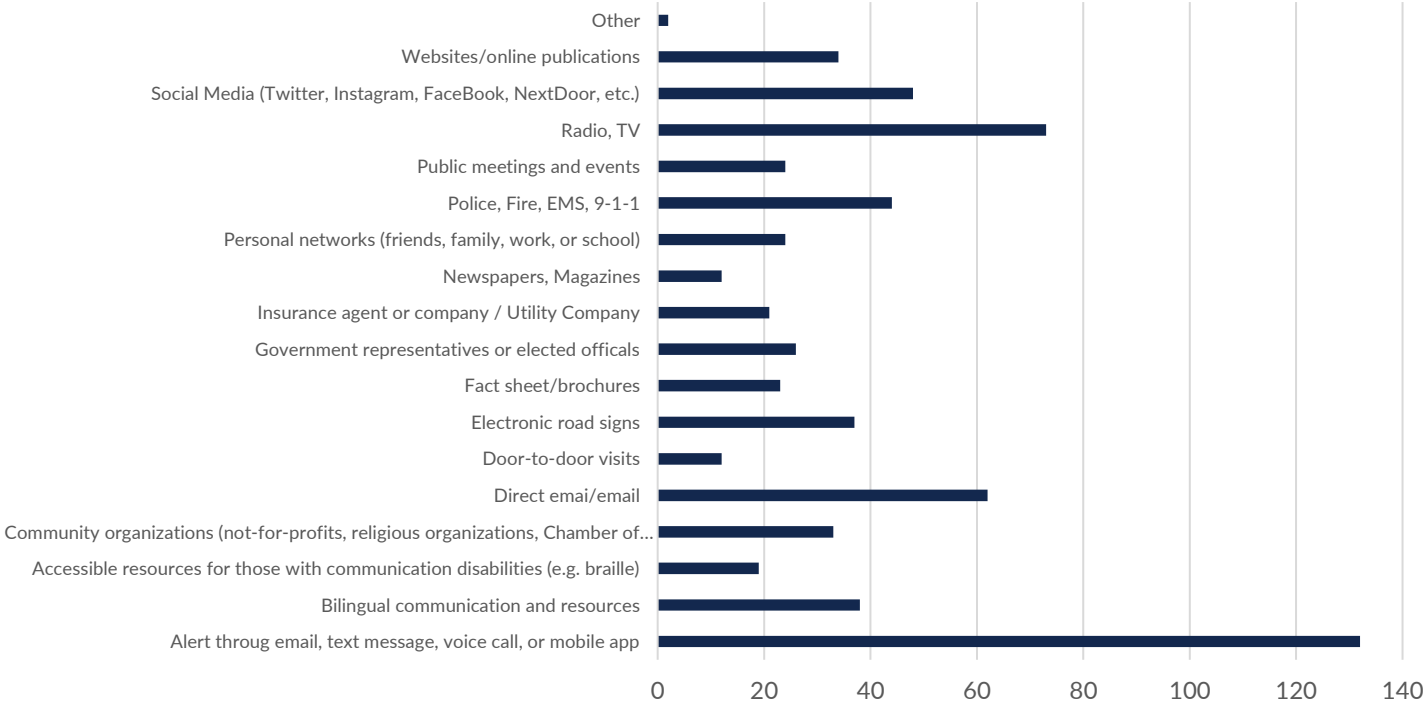
7. Community lifelines are the basic services that enable all other aspects of your community to function. In the event of a disaster, how concerns are you about impacts to the following community lifelines?



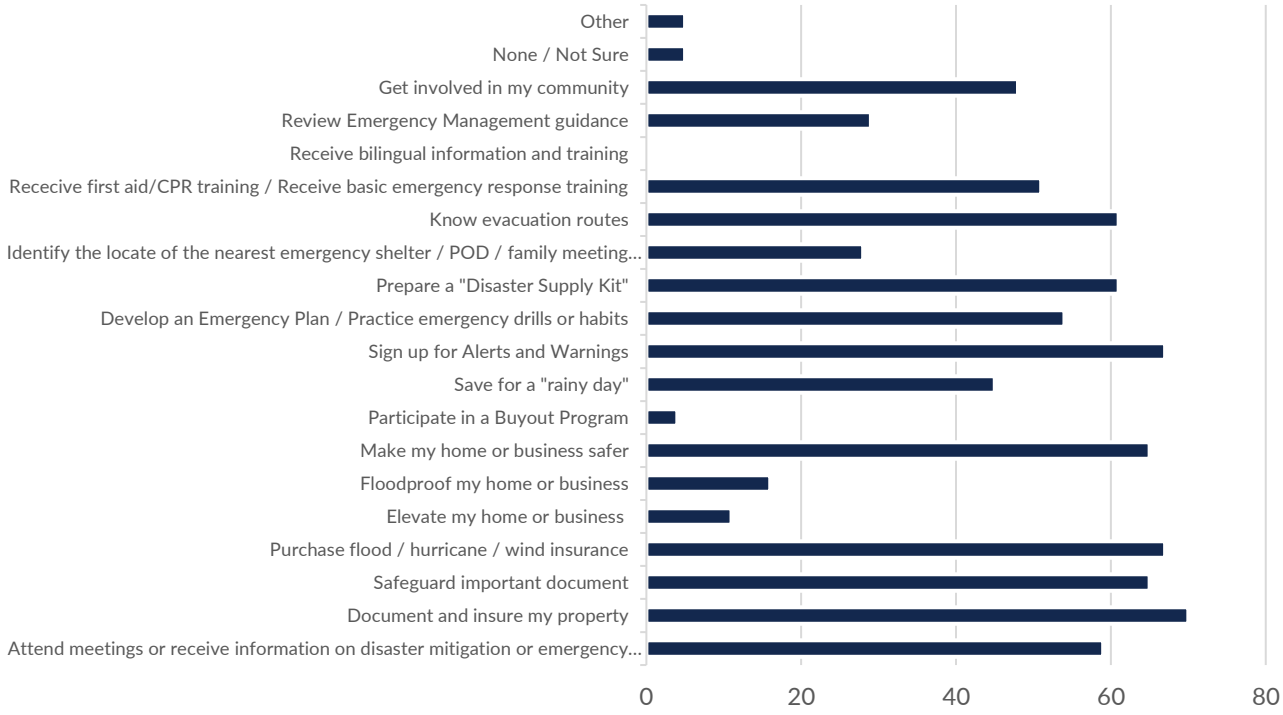
8. Are you interested in making your home or community resilient to hazards?



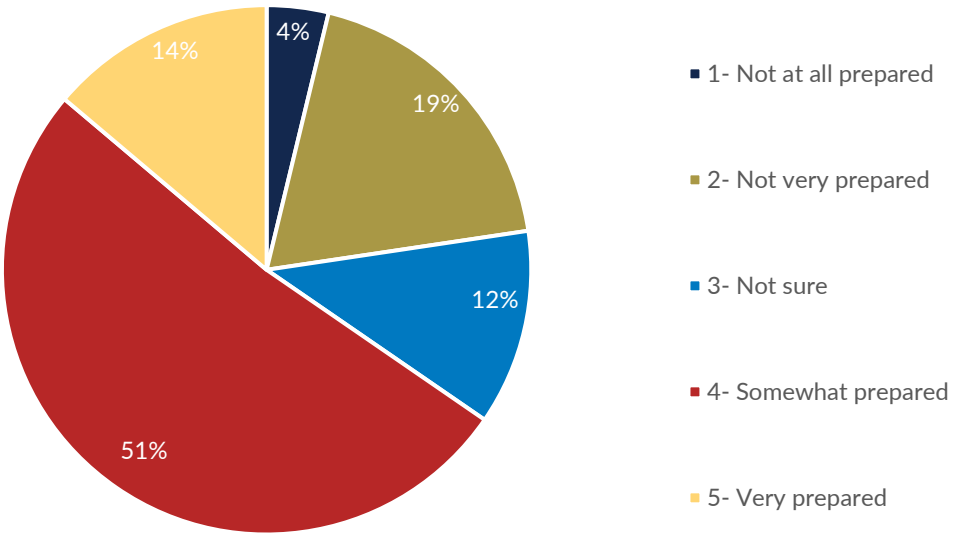
9. What are the top five best ways to receive information about how to make your home or business safer from hazards?



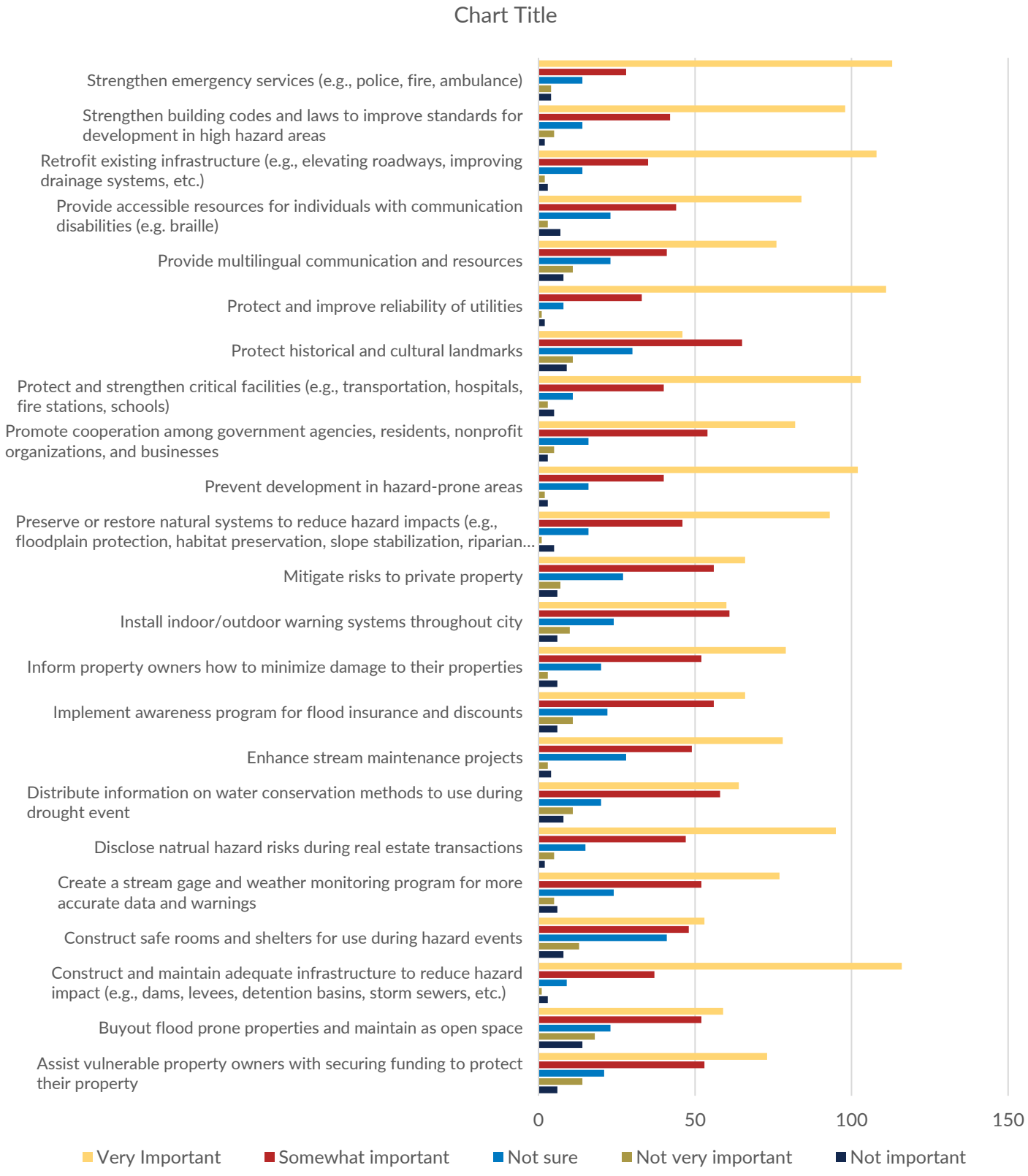
10. Which activities have you done or would be willing to do to minimize the impacts of natural hazards?



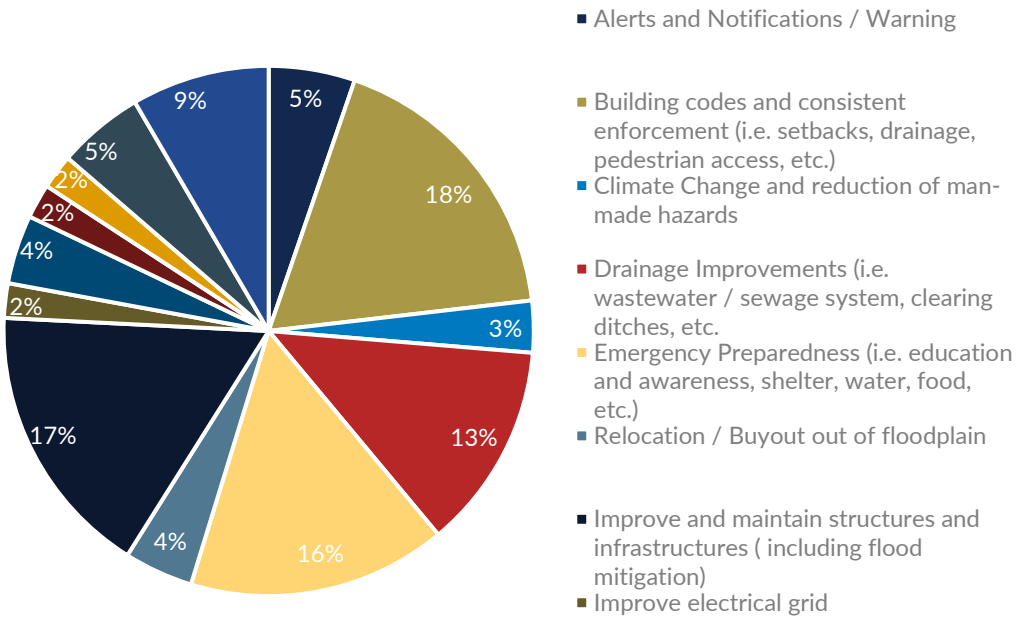
11. Please rank how prepared you are for natural hazards likely to occur in your community?



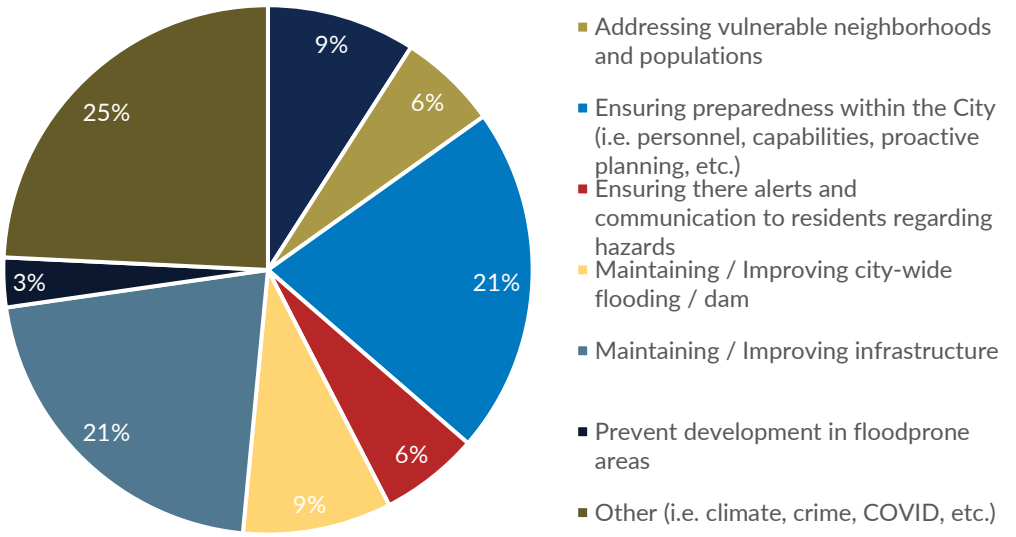
12. Natural hazards can have a significant impact on a community. Listed below are strategies that could minimize impacts in Houston. Please tell us how important each one is to you.



13. If you could choose one action to reduce the impacts of natural hazards, what would it be?

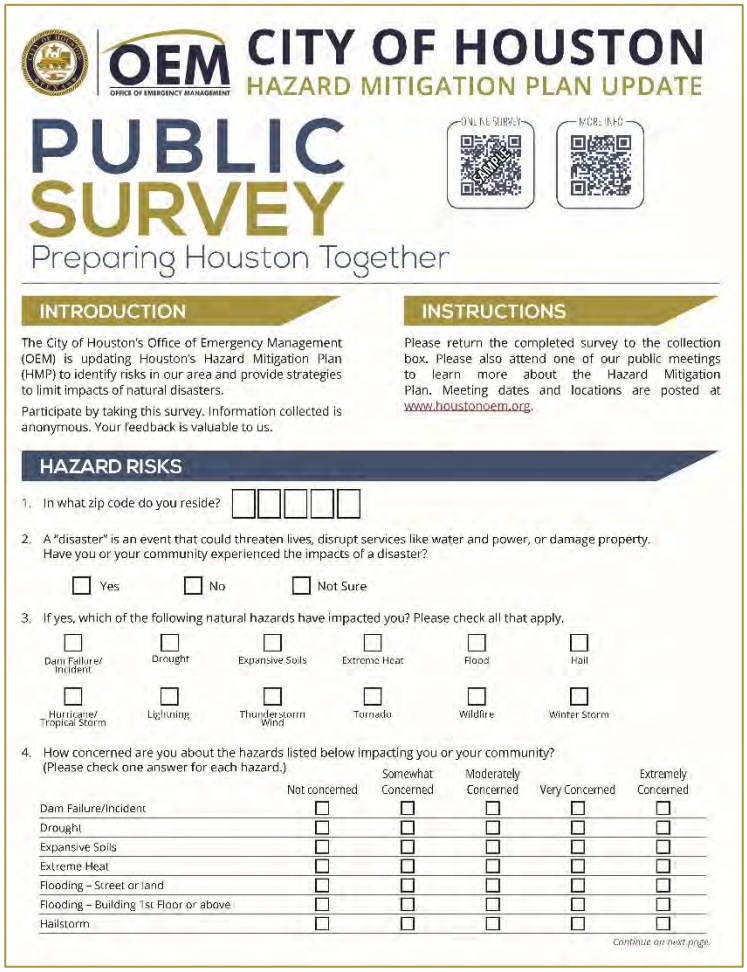


14. Provide any additional comments below.



PAPER SURVEY

ENGLISH PAPER SURVEY



CITY OF HOUSTON
HAZARD MITIGATION PLAN UPDATE

PUBLIC SURVEY

Preparing Houston Together

ONLINE SURVEY

MORE INFO

INTRODUCTION

The City of Houston's Office of Emergency Management (OEM) is updating Houston's Hazard Mitigation Plan (HMP) to identify risks in our area and provide strategies to limit impacts of natural disasters.

Participate by taking this survey. Information collected is anonymous. Your feedback is valuable to us.

INSTRUCTIONS

Please return the completed survey to the collection box. Please also attend one of our public meetings to learn more about the Hazard Mitigation Plan. Meeting dates and locations are posted at www.houstonoem.org.

HAZARD RISKS

1. In what zip code do you reside? ☐☐☐☐☐

2. A "disaster" is an event that could threaten lives, disrupt services like water and power, or damage property. Have you or your community experienced the impacts of a disaster?

☐ Yes ☐ No ☐ Not Sure

3. If yes, which of the following natural hazards have impacted you? Please check all that apply.

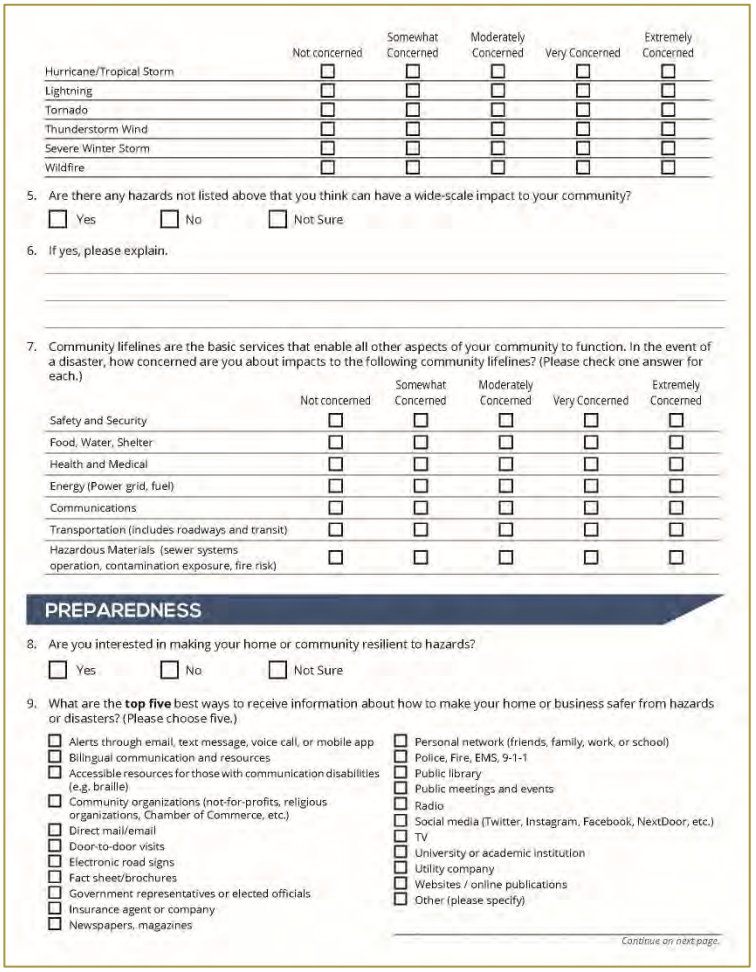
☐ Dam Failure/ Incident ☐ Drought ☐ Expansive Soils ☐ Extreme Heat ☐ Flood ☐ Hail

☐ Hurricane/ Tropical Storm ☐ Lightning ☐ Thunderstorm Wind ☐ Tornado ☐ Wildfire ☐ Winter Storm

4. How concerned are you about the hazards listed below impacting you or your community? (Please check one answer for each hazard.)

	Not concerned	Somewhat Concerned	Moderately Concerned	Very Concerned	Extremely Concerned
Dam Failure/Incident	☐	☐	☐	☐	☐
Drought	☐	☐	☐	☐	☐
Expansive Soils	☐	☐	☐	☐	☐
Extreme Heat	☐	☐	☐	☐	☐
Flooding – Street or land	☐	☐	☐	☐	☐
Flooding – Building 1st Floor or above	☐	☐	☐	☐	☐
Hailstorm	☐	☐	☐	☐	☐
Hurricane/Tropical Storm	☐	☐	☐	☐	☐
Lightning	☐	☐	☐	☐	☐
Tornado	☐	☐	☐	☐	☐
Thunderstorm Wind	☐	☐	☐	☐	☐
Severe Winter Storm	☐	☐	☐	☐	☐
Wildfire	☐	☐	☐	☐	☐

Continue on next page.



5. Are there any hazards not listed above that you think can have a wide-scale impact to your community?

☐ Yes ☐ No ☐ Not Sure

6. If yes, please explain.

7. Community lifelines are the basic services that enable all other aspects of your community to function. In the event of a disaster, how concerned are you about impacts to the following community lifelines? (Please check one answer for each.)

	Not concerned	Somewhat Concerned	Moderately Concerned	Very Concerned	Extremely Concerned
Safety and Security	☐	☐	☐	☐	☐
Food, Water, Shelter	☐	☐	☐	☐	☐
Health and Medical	☐	☐	☐	☐	☐
Energy (Power grid, fuel)	☐	☐	☐	☐	☐
Communications	☐	☐	☐	☐	☐
Transportation (includes roadways and transit)	☐	☐	☐	☐	☐
Hazardous Materials (sewer systems operation, contamination exposure, fire risk)	☐	☐	☐	☐	☐

PREPAREDNESS

8. Are you interested in making your home or community resilient to hazards?

☐ Yes ☐ No ☐ Not Sure

9. What are the **top five** best ways to receive information about how to make your home or business safer from hazards or disasters? (Please choose five.)

☐ Alerts through email, text message, voice call, or mobile app
☐ Bilingual communication and resources
☐ Accessible resources for those with communication disabilities (e.g. braille)
☐ Community organizations (not-for-profits, religious organizations, Chamber of Commerce, etc.)
☐ Direct mail/email
☐ Door-to-door visits
☐ Electronic road signs
☐ Fact sheet/brochures
☐ Government representatives or elected officials
☐ Insurance agent or company
☐ Newspapers, magazines
☐ Personal network (friends, family, work, or school)
☐ Police, Fire, EMS, 9-1-1
☐ Public library
☐ Public meetings and events
☐ Radio
☐ Social media (Twitter, Instagram, Facebook, NextDoor, etc.)
☐ TV
☐ University or academic institution
☐ Utility company
☐ Websites / online publications
☐ Other (please specify)

Continue on next page.

APPENDIX B: PUBLIC SURVEY RESULTS

10. Which activities have you done or would be willing to do to minimize the impacts of natural hazards? (Check all that apply.)

- ☐ Attend meetings or receive written information on disaster mitigation or emergency preparedness
- ☐ Document and insure my property
- ☐ Safeguard important documents
- ☐ Purchase flood insurance
- ☐ Purchase hurricane or wind insurance
- ☐ Elevate my home or business to reduce flood damage
- ☐ Floodproof my home or business to reduce flood damage
- ☐ Participate in a Buyout Program
- ☐ Save for a "rainy day"
- ☐ Sign up for Alerts and Warnings
- ☐ Make my home or business safer (e.g., smoke detectors and fire extinguishers)
- ☐ Develop an Emergency Plan for my family, home, or business in case of disaster
- ☐ Prepare a "Disaster Supply Kit" (extra food, water, batteries, medicine, or emergency supplies)
- ☐ Identify the location of the nearest emergency shelter, point of supply distribution (POD), and/or family meeting point
- ☐ Know evacuation routes
- ☐ Receive first aid/CPR training
- ☐ Receive basic emergency response training
- ☐ Review emergency management guidelines
- ☐ Receive bilingual information and training
- ☐ Practice emergency drills or habits
- ☐ Get involved in my community
- ☐ None
- ☐ Not sure
- ☐ Other (please specify) _____

11. Please rank how prepared you are for natural hazards likely to occur in your community. Rank on a scale of 1 to 5, with 5 representing the most prepared.

1	2	3	4	5
Not At All Prepared	Not Very Prepared	Not Sure	Somewhat Prepared	Very Prepared
☐	☐	☐	☐	☐

HAZARD MITIGATION STRATEGIES

12. Natural hazards can have a significant impact on a community. Listed below are strategies that could minimize impacts in Houston. Please tell us how important each one is to you.

	Not Important	Not Very Important	Not Sure	Somewhat Important	Very Important
Assist vulnerable property owners with securing funding to protect their property	☐	☐	☐	☐	☐
Buyout flood prone properties and maintain as open space	☐	☐	☐	☐	☐
Construct and maintain adequate infrastructure to reduce hazard impact (e.g., dams, levees, detention basins, storm sewers, etc.)	☐	☐	☐	☐	☐
Construct safe rooms and shelters for use during hazard events	☐	☐	☐	☐	☐
Create a stream gage and weather monitoring program for more accurate data and warnings	☐	☐	☐	☐	☐
Disclose natural hazard risks during real estate transactions	☐	☐	☐	☐	☐
Distribute information on water conservation methods to use during drought event	☐	☐	☐	☐	☐
Enhance stream maintenance projects	☐	☐	☐	☐	☐
Implement awareness program for flood insurance and discounts	☐	☐	☐	☐	☐
Inform property owners how to minimize damage to their properties	☐	☐	☐	☐	☐
Install Indoor/outdoor warning systems throughout city	☐	☐	☐	☐	☐
Mitigate risks to private property	☐	☐	☐	☐	☐

Continue on next page

	Not Important	Not Very Important	Not Sure	Somewhat Important	Very Important
Preserve or restore natural systems to reduce hazard impacts (e.g., floodplain protection, habitat preservation, slope stabilization, riparian buffers, and forest management)	☐	☐	☐	☐	☐
Prevent development in hazard-prone areas	☐	☐	☐	☐	☐
Promote cooperation among government agencies, residents, non-profit organizations, and businesses	☐	☐	☐	☐	☐
Protect and strengthen critical facilities (e.g., transportation, hospitals, fire stations, schools)	☐	☐	☐	☐	☐
Protect historical and cultural landmarks	☐	☐	☐	☐	☐
Protect and improve reliability of utilities	☐	☐	☐	☐	☐
Provide bilingual communication and resources	☐	☐	☐	☐	☐
Provide accessible resources for individuals with communication disabilities (e.g. braille)	☐	☐	☐	☐	☐
Retrofit existing infrastructure (e.g., elevating roadways, improving drainage systems, etc.)	☐	☐	☐	☐	☐
Strengthen building codes and laws to improve standards for development in high hazard areas	☐	☐	☐	☐	☐
Strengthen emergency services (e.g., police, fire, ambulance)	☐	☐	☐	☐	☐

13. If you could choose one action to reduce the impacts of natural hazards, what would it be?

_____

_____

_____

14. Provide any additional comments below.

_____

_____

_____

STAY INFORMED (OPTIONAL)

Please provide your contact information if you are interested in receiving information from OEM.

Name _____ Email _____

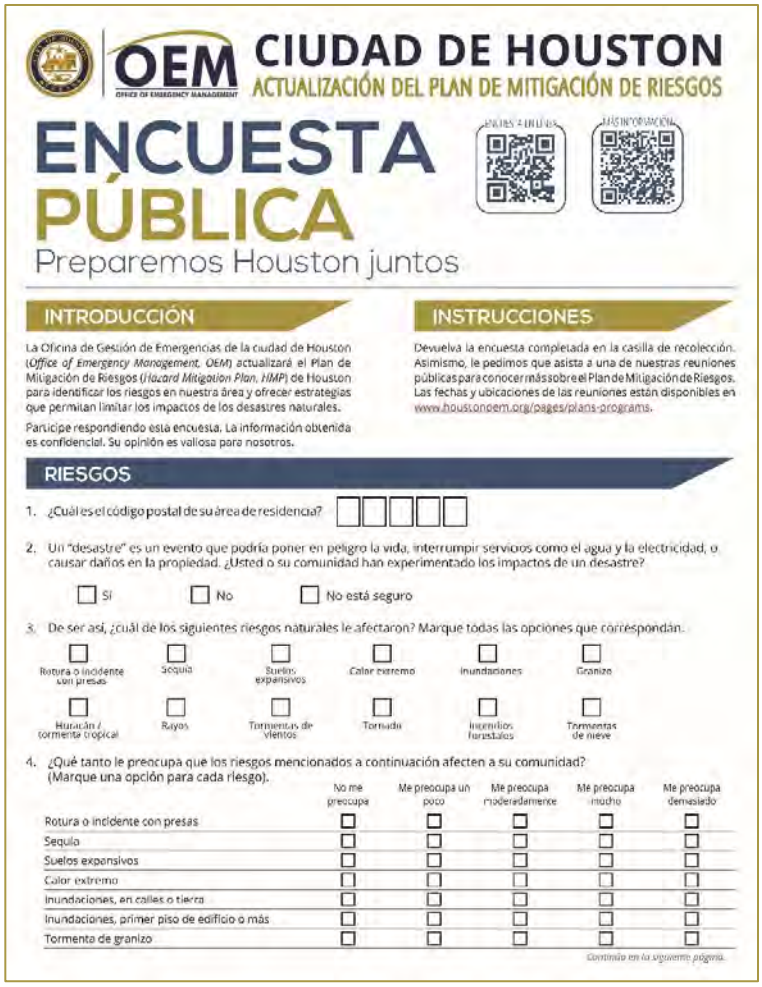
Mobile Phone (optional) _____ Home Phone (optional) _____

Thank you for your time and input

OEM

APPENDIX B: PUBLIC SURVEY RESULTS

SPANISH PAPER SURVEY



CIUDAD DE HOUSTON
ACTUALIZACIÓN DEL PLAN DE MITIGACIÓN DE RIESGOS

ENCUESTA PÚBLICA

Preparemos Houston juntos

INTRODUCCIÓN

La Oficina de Gestión de Emergencias de la ciudad de Houston (*Office of Emergency Management, OEM*) actualizará el Plan de Mitigación de Riesgos (*Hazard Mitigation Plan, HMP*) de Houston para identificar los riesgos en nuestra área y ofrecer estrategias que permitan limitar los impactos de los desastres naturales.

Participe respondiendo esta encuesta. La información obtenida es confidencial. Su opinión es valiosa para nosotros.

INSTRUCCIONES

Devuelva la encuesta completada en la casilla de recolección. Asimismo, le pedimos que asista a una de nuestras reuniones públicas para conocer más sobre el Plan de Mitigación de Riesgos. Las fechas y ubicaciones de las reuniones están disponibles en www.houstonem.org/pages/plans-programs.

RIESGOS

1. ¿Cuál es el código postal de su área de residencia? ☐☐☐☐☐

2. Un "desastre" es un evento que podría poner en peligro la vida, interrumpir servicios como el agua y la electricidad, o causar daños en la propiedad. ¿Usted o su comunidad han experimentado los impactos de un desastre?

☐ Sí ☐ No ☐ No está seguro

3. De ser así, ¿cuál de los siguientes riesgos naturales le afectaron? Marque todas las opciones que correspondan.

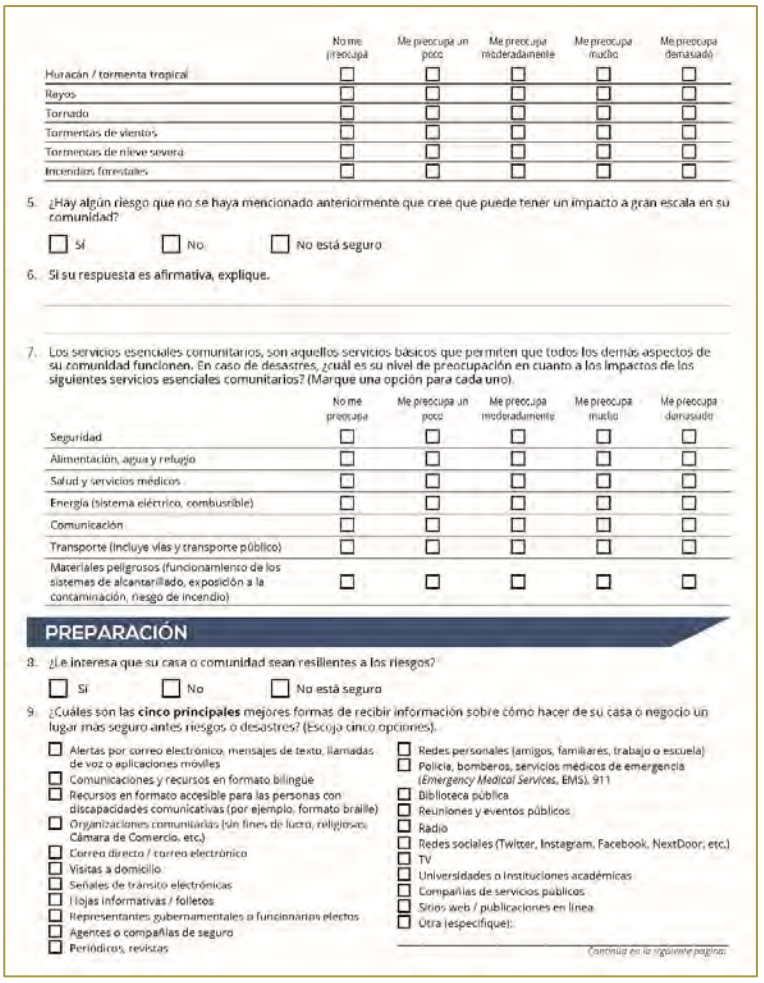
☐ Rotura o incidente con presas ☐ Sequía ☐ Suelos expansivos ☐ Calor extremo ☐ Inundaciones ☐ Granizo

☐ Huracán / tormenta tropical ☐ Rayos ☐ Tormentas de vientos ☐ Tornado ☐ Incendios forestales ☐ Tormentas de nieve

4. ¿Qué tanto le preocupa que los riesgos mencionados a continuación afecten a su comunidad? (Marque una opción para cada riesgo).

	No me preocupa	Me preocupa un poco	Me preocupa moderadamente	Me preocupa mucho	Me preocupa demasiado
Rotura o incidente con presas	☐	☐	☐	☐	☐
Sequía	☐	☐	☐	☐	☐
Suelos expansivos	☐	☐	☐	☐	☐
Calor extremo	☐	☐	☐	☐	☐
Inundaciones, en calles o tierra	☐	☐	☐	☐	☐
Inundaciones, primer piso de edificio o más	☐	☐	☐	☐	☐
Tormenta de granizo	☐	☐	☐	☐	☐

Continúa en la siguiente página.



	No me preocupa	Me preocupa un poco	Me preocupa moderadamente	Me preocupa mucho	Me preocupa demasiado
Huracán / tormenta tropical	☐	☐	☐	☐	☐
Rayos	☐	☐	☐	☐	☐
Tornado	☐	☐	☐	☐	☐
Tormentas de vientos	☐	☐	☐	☐	☐
Tormentas de nieve severa	☐	☐	☐	☐	☐
Incendios forestales	☐	☐	☐	☐	☐

5. ¿Hay algún riesgo que no se haya mencionado anteriormente que crea que puede tener un impacto a gran escala en su comunidad?

☐ Sí ☐ No ☐ No está seguro

6. Si su respuesta es afirmativa, explique.

7. Los servicios esenciales comunitarios, son aquellos servicios básicos que permiten que todos los demás aspectos de su comunidad funcionen. En caso de desastres, ¿cuál es su nivel de preocupación en cuanto a los impactos de los siguientes servicios esenciales comunitarios? (Marque una opción para cada uno).

	No me preocupa	Me preocupa un poco	Me preocupa moderadamente	Me preocupa mucho	Me preocupa demasiado
Seguridad	☐	☐	☐	☐	☐
Alimentación, agua y refugio	☐	☐	☐	☐	☐
Salud y servicios médicos	☐	☐	☐	☐	☐
Energía (sistema eléctrico, combustible)	☐	☐	☐	☐	☐
Comunicación	☐	☐	☐	☐	☐
Transporte (incluye vías y transporte público)	☐	☐	☐	☐	☐
Materiales peligrosos (funcionamiento de los sistemas de alcantarillado, exposición a la contaminación, riesgo de incendio)	☐	☐	☐	☐	☐

PREPARACIÓN

8. ¿Le interesa que su casa o comunidad sean resilientes a los riesgos?

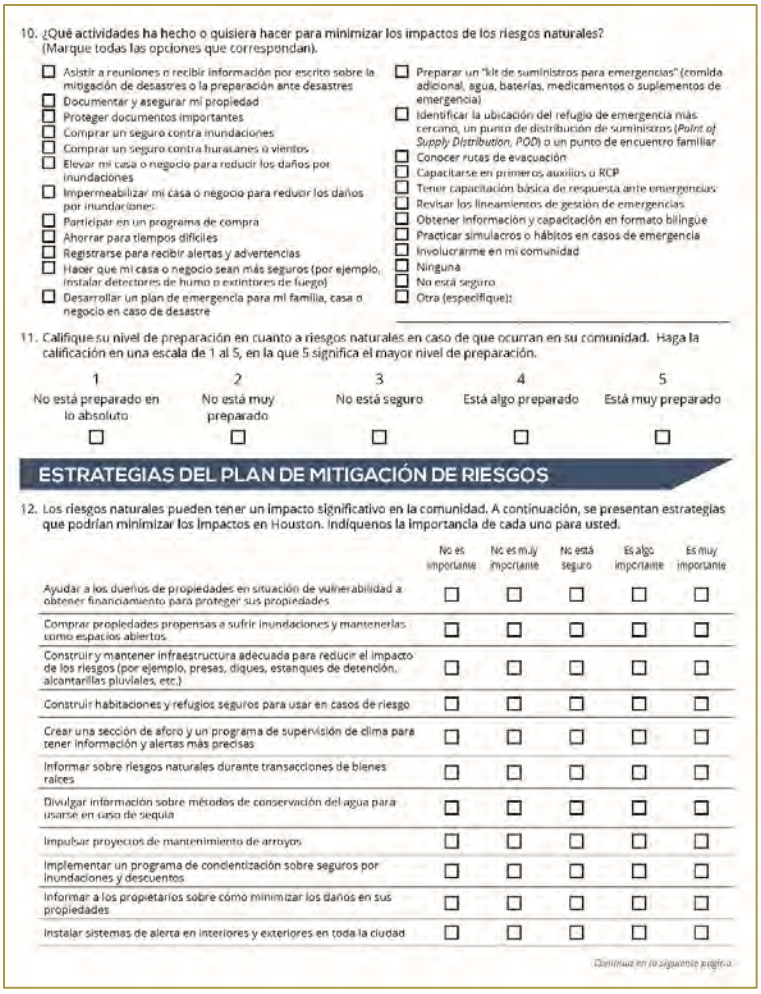
☐ Sí ☐ No ☐ No está seguro

9. ¿Cuáles son las **cinco principales** mejores formas de recibir información sobre cómo hacer de su casa o negocio un lugar más seguro antes riesgos o desastres? (Escoja cinco opciones).

☐ Alertas por correo electrónico, mensajes de texto, llamadas de voz o aplicaciones móviles
☐ Comunicaciones y recursos en formato bilingüe
☐ Recursos en formato accesible para las personas con discapacidades comunicativas (por ejemplo, formato braille)
☐ Organizaciones comunitarias (sin fines de lucro, religiosas, Cámara de Comercio, etc.)
☐ Correo directo / correo electrónico
☐ Visitas a domicilio
☐ Señales de tránsito electrónicas
☐ Hojas informativas / folletos
☐ Representantes gubernamentales o funcionarios electos
☐ Agentes o compañías de seguro
☐ Periódicos, revistas
☐ Redes personales (amigos, familiares, trabajo o escuela)
☐ Policía, bomberos, servicios médicos de emergencia (*Emergency Medical Services*, EMS), 911
☐ Biblioteca pública
☐ Reuniones y eventos públicos
☐ Radio
☐ Redes sociales (Twitter, Instagram, Facebook, NextDoor, etc.)
☐ TV
☐ Universidades o instituciones académicas
☐ Compañías de servicios públicos
☐ Sitios web / publicaciones en línea
☐ Otra (especifique):

Continúa en la siguiente página.

APPENDIX B: PUBLIC SURVEY RESULTS



10. ¿Qué actividades ha hecho o quisiera hacer para minimizar los impactos de los riesgos naturales? (Marque todas las opciones que correspondan).

- ☐ Asistir a reuniones o recibir información por escrito sobre la mitigación de desastres o la preparación ante desastres
- ☐ Documentar y asegurar mi propiedad
- ☐ Proteger documentos importantes
- ☐ Comprar un seguro contra inundaciones
- ☐ Comprar un seguro contra huracanes o vientos
- ☐ Elevar mi casa o negocio para reducir los daños por inundaciones
- ☐ Impermeabilizar mi casa o negocio para reducir los daños por inundaciones
- ☐ Participar en un programa de compra
- ☐ Ahorrar para tiempos difíciles
- ☐ Registrarse para recibir alertas y advertencias
- ☐ Hacer que mi casa o negocio sean más seguros (por ejemplo, instalar detectores de humo o extintores de fuego)
- ☐ Desarrollar un plan de emergencia para mi familia, casa o negocio en caso de desastre
- ☐ Preparar un "kit de suministros para emergencias" (comida adicional, agua, baterías, medicamentos o suplementos de emergencia)
- ☐ Identificar la ubicación del refugio de emergencia más cercano, un punto de distribución de suministros (*Point of Supply Distribution, POD*) o un punto de encuentro familiar
- ☐ Conocer rutas de evacuación
- ☐ Capacitarse en primeros auxilios o RCP
- ☐ Tener capacitación básica de respuesta ante emergencias
- ☐ Revisar los lineamientos de gestión de emergencias
- ☐ Obtener información y capacitación en formato bilingüe
- ☐ Practicar simulacros o hábitos en casos de emergencia
- ☐ Involucrarme en mi comunidad
- ☐ Ninguna
- ☐ No está seguro
- ☐ Otra (especifique): _____

11. Califique su nivel de preparación en cuanto a riesgos naturales en caso de que ocurran en su comunidad. Haga la calificación en una escala de 1 al 5, en la que 5 significa el mayor nivel de preparación.

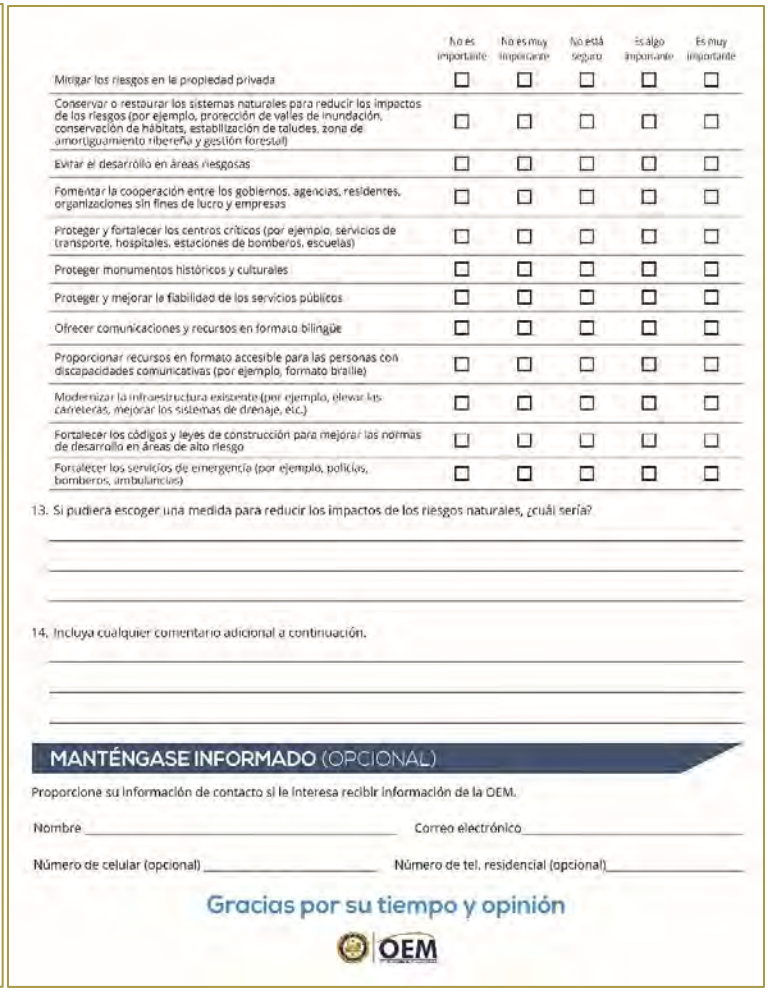
1	2	3	4	5
No está preparado en lo absoluto	No está muy preparado	No está seguro	Está algo preparado	Está muy preparado
☐	☐	☐	☐	☐

ESTRATEGIAS DEL PLAN DE MITIGACIÓN DE RIESGOS

12. Los riesgos naturales pueden tener un impacto significativo en la comunidad. A continuación, se presentan estrategias que podrían minimizar los impactos en Houston. Indíquenos la importancia de cada uno para usted.

	No es importante	No es muy importante	No está seguro	Es algo importante	Es muy importante
Ayudar a los dueños de propiedades en situación de vulnerabilidad a obtener financiamiento para proteger sus propiedades	☐	☐	☐	☐	☐
Comprar propiedades propensas a sufrir inundaciones y mantenerlas como espacios abiertos	☐	☐	☐	☐	☐
Construir y mantener infraestructura adecuada para reducir el impacto de los riesgos (por ejemplo, presas, diques, estanques de detención, alcantarillas pluviales, etc.)	☐	☐	☐	☐	☐
Construir habitaciones y refugios seguros para usar en casos de riesgo	☐	☐	☐	☐	☐
Crear una sección de aforo y un programa de supervisión de clima para tener información y alertas más precisas	☐	☐	☐	☐	☐
Informar sobre riesgos naturales durante transacciones de bienes raíces	☐	☐	☐	☐	☐
Divulgar información sobre métodos de conservación del agua para usarse en caso de sequía	☐	☐	☐	☐	☐
Impulsar proyectos de mantenimiento de arroyos	☐	☐	☐	☐	☐
Implementar un programa de concientización sobre seguros por inundaciones y descuentos	☐	☐	☐	☐	☐
Informar a los propietarios sobre cómo minimizar los daños en sus propiedades	☐	☐	☐	☐	☐
Instalar sistemas de alerta en interiores y exteriores en toda la ciudad	☐	☐	☐	☐	☐

Continúa en la siguiente página



	No es importante	No es muy importante	No está seguro	Es algo importante	Es muy importante
Mitigar los riesgos en la propiedad privada	☐	☐	☐	☐	☐
Conservar o restaurar los sistemas naturales para reducir los impactos de los riesgos (por ejemplo, protección de valles de inundación, conservación de hábitats, estabilización de taludes, zona de amortiguamiento ribereña y gestión forestal)	☐	☐	☐	☐	☐
Evitar el desarrollo en áreas riesgosas	☐	☐	☐	☐	☐
Fomentar la cooperación entre los gobiernos, agencias, residentes, organizaciones sin fines de lucro y empresas	☐	☐	☐	☐	☐
Proteger y fortalecer los centros críticos (por ejemplo, servicios de transporte, hospitales, estaciones de bomberos, escuelas)	☐	☐	☐	☐	☐
Proteger monumentos históricos y culturales	☐	☐	☐	☐	☐
Proteger y mejorar la fiabilidad de los servicios públicos	☐	☐	☐	☐	☐
Ofrecer comunicaciones y recursos en formato bilingüe	☐	☐	☐	☐	☐
Proporcionar recursos en formato accesible para las personas con discapacidades comunicativas (por ejemplo, formato braille)	☐	☐	☐	☐	☐
Modernizar la infraestructura existente (por ejemplo, elevar las carreteras, mejorar los sistemas de drenaje, etc.)	☐	☐	☐	☐	☐
Fortalecer los códigos y leyes de construcción para mejorar las normas de desarrollo en áreas de alto riesgo	☐	☐	☐	☐	☐
Fortalecer los servicios de emergencia (por ejemplo, policías, bomberos, ambulancias)	☐	☐	☐	☐	☐

13. Si pudiera escoger una medida para reducir los impactos de los riesgos naturales, ¿cuál sería?

_____

_____

_____

14. Incluya cualquier comentario adicional a continuación.

_____

_____

_____

MANTÉNGASE INFORMADO (OPCIONAL)

Proporcione su información de contacto si le interesa recibir información de la OEM.

Nombre _____ Correo electrónico _____

Número de celular (opcional) _____ Número de tel. residencial (opcional) _____

Gracias por su tiempo y opinión

OEM

APPENDIX C
CRITICAL FACILITIES

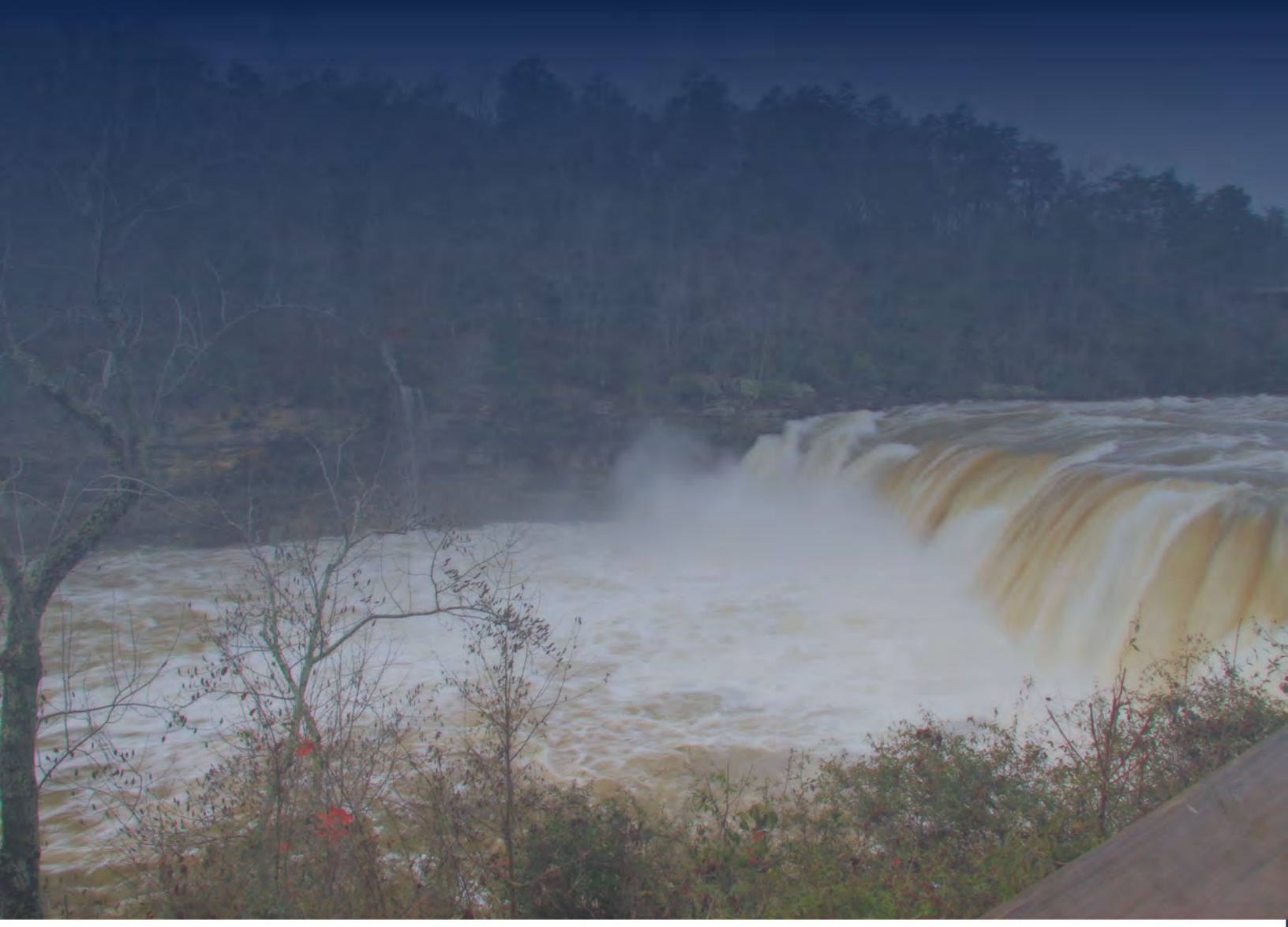


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APPENDIX C: CRITICAL FACILITIES

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APPENDIX D
DAM LOCATIONS



OFFICE OF EMERGENCY MANAGEMENT

APPENDIX D: DAM LOCATIONS

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APPENDIX E
MEETING DOCUMENTATION



CITY OF HOUSTON TEXAS

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APPENDIX E: MEETING DOCUMENTATION

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APPENDIX F
CAPABILITY ASSESSMENT



OFFICE OF EMERGENCY MANAGEMENT

APPENDIX F: CAPABILITY ASSESSMENT

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APPENDIX G
SWAT PROJECT LOG



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APPENDIX G: STORM WATER ACTION TEAM PROJECT LOG

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APPENDIX H
PUBLIC ENGAGEMENT AND OUTREACH PLAN & SUMMARY REPORT



CITY OF HOUSTON TEXAS

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APPENDIX H: PUBLIC ENGAGEMENT AND OUTREACH PLAN & SUMMARY REPORT

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APPENDIX I
CRS REQUIREMENTS



OFFICE OF EMERGENCY MANAGEMENT

APPENDIX I: CRS REQUIREMENTS

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APPENDIX J
STATE AND FEDERAL FUNDING OPPORTUNITIES



OFFICE OF EMERGENCY MANAGEMENT

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

Overview.....1

OVERVIEW

Texas utilizes state funds to improve statewide hazard mitigation capabilities and advance their hazard mitigation goals to help identify, understand, and manage various risks associated with natural hazards. State funds also provide funding for state facility and infrastructure upgrades, hazard mapping, mitigation planning, and other mitigation programmatic activities. Table J-1 describes a varied loan and grant programs offered by state agencies for which mitigation activities may be eligible.

Table G-1. Summary of State Funded Mitigation Programs

AGENCY	FUNDING PROGRAM
TDA	■ Community Development Block Grant for Rural Texas
TDEM	■ Hazard Mitigation Planning Grants Program
TXDOT	■ Bridge Preventative Maintenance Program ■ Safe Rest Stops Program
TAMFS	■ The Urban Tree Canopy Project ■ The FireAdapted Communities Program ■ Resilient Landscapes Program ■ The Firewise USA Program ■ Mitigation Project Support Fund ■ Prescribed Fire Grants ■ SFAM Mechanical Fuel Reduction Grants ■ SFAM Vegetative Fuel Break Grant ■ The Texas Longleaf Conservation Assistance Program
GLO	■ Hazard Mitigation Grant Program Supplemental ■ Beach Maintenance Reimbursement Fund ■ Beach Grants ■ Coastal Erosion Planning and Response Act ■ Gulf of Mexico Energy Security Act (GOMESA)
TWDB	■ Research and Planning Fund and Fund Development program ■ Flood Protection Planning Program ■ Drinking Water State Revolving Fund ■ Rural Water Assistance Fund ■ State Participation Program – Regional Water and Wastewater Facilities ■ State Water Implementation Fund for Texas (SWIFT)

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

AGENCY	FUNDING PROGRAM
	■ Texas Water Development Fund ■ Economically Distressed Areas Program ■ Agricultural Water Conservation Grants ■ Agricultural Water Conservation Loans ■ Groundwater Conservation District Loan Program ■ Regional Water Planning Group Grants ■ Regional Facility Planning Grant Program ■ Water Research Grant Program ■ Flood Infrastructure Fund (FIF) ■ Texas Infrastructure Resiliency Fund (TIRF) ■ Clean Water State Revolving Fund (CWSRF)
TDHCA	■ Texas HOME Disaster Relief
TCEQ	■ High Hazard Potential Dams Grant Program ■ Nonpoint Source Grant Program
TPWD	■ Texas Farm and Ranch Lands Conservation Program ■ Wildlife Habitat Incentive Program (WHIP) ■ Natural Resources Damage Assessment (NRDA)

In addition to State funded programs, many local jurisdictions benefit from federal mitigation funding opportunities. FEMA'S Hazard Mitigation Assistance is a primary source for the implementation of mitigation projects throughout the Nation. Table J-2 described additional Federal, State, Local, and Non-Profit mitigation funding sources specifically within the State of Texas.

Table J-2. Federal, State, Local and Non-Profit Mitigation Funding Sources in Texas

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Agricultural Management Assistance (AMA)	Federal	USDA, NRCS	TDA	Provides financial and technical assistance to agricultural producers to voluntarily address issues such as water management, water quality, and erosion control by incorporating conservation methods into their farming operations.
Agricultural Water Enhancement Program (AWEP)	Federal	USDA, NRCS	TDA	Voluntary conservation initiative that provides financial and technical assistance to agricultural producers to implement water enhancement activities on agricultural land to conserve surface and ground water and improve water quality.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Agricultural Water Conservation Grants	State	TWDB	TWDB	Provided to state agencies and political subdivisions for projects that support the implementation of conservation of water management strategies identified in state and regional water plans. Yearly applications. Up to $1.2 million available annually. Grant categories vary from year to year.
Agricultural Water Conservation Loans	State	TWDB	TWDB	Agricultural water conservation loans to use either for improvements on facilities or as loan to individuals. Low-interest, fixed rates. Up to 10-year repayment terms. U.S. Iron and Steel requirements apply to certain projects. Eligible Loan applicants include political subdivisions.
AmeriCorps	Federal	Corporation for National & Community Service		Provides funding for volunteers to serve communities, including disaster prevention. AmeriCorps/Vista has assisted local communities with wildfire mitigation projects.
American Recovery and Reinvestment Act (ARRA)	Federal	EPA		Provided significant funding for states to finance high priority water infrastructure projects through a $2 billion appropriation to the DWSRF (see below) program and a $4 billion appropriation to the CWSRF (see below) program.
Assistance to Firefighters program - Fire Prevention & Safety (FP&S) Grants	Federal	FEMA		Fire Prevention & Safety (FP&S) Grants support projects that enhance the safety of the public and firefighters from fire and related hazards.
Beach Maintenance Reimbursement Fund	State	GLO	GLO	Allocates approximately $750,000 per year to help communities keep their beaches maintained. Applications are distributed to eligible participants in early fall and are due within a specified amount of time, no less than 30 days. Contracts are renewable annually.

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Bridge Preventative Maintenance Program	State	TXDOT	TXDOT	A planned, cost-effective treatment that preserves, improves, or delays future deterioration of the condition of a bridge. To be eligible for the BMIP a bridge must have a condition rating of 5 or 6 for at least one of the following: deck, superstructure, substructure, culvert or channel. Safety and improvement to the physical conditions of the State's on-system bridges are TxDOT's main goals in the prioritization of the bridges using BMIP funds. The Bridge Division develops an initial list each FY of eligible bridges in each district and distribute to the districts for the annual program call.
Building Resilient Infrastructure & Communities (BRIC)	Federal	FEMA	TDEM	Pre-disaster/annual cycle addressing all natural hazards, emphasis on infrastructure & lifelines.
Clean Water Act Section 319 Grants	Federal	EPA	TCEQ and TSSWCB	Provides grants for a wide variety of activities related to non-point source pollution runoff mitigation.
Clean Water State Revolving Fund	Federal	EPA	TWDB	Providing low-cost financing for a wide range of wastewater, stormwater, reuse, and other pollution control projects.
Coastal Erosion Planning and Response Act	State	GLO	GLO	Since 2000, the Texas General Land Office's Coastal Erosion Planning and Response Program has received more than $62 million in state funding and more than $62 million in matching funds, completing more than 200 coastal erosion projects and studies. The application process for non-emergency project funding requests opens every even year in February and closes in early June of that same year.
Coastal and Estuarine Land Conservation Program (CELCP)	Federal	NOAA	GLO	When NOAA provides funding for CELCP, the GLO provides coastal communities an opportunity to apply for up to three projects per

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
				year, with federal grants for any single project not to exceed $3 million.
Coastal Management Program (CMP)	Federal	NOAA	GLO	Texas receives approximately $2 million annually in grants from National Oceanic and Atmospheric Administration (NOAA) and 90% of the funds are passed through to local governments and entities to address environmental needs and promote sustainable economic development along the coast. Projects must improve the management of the state's coastal resources and ensure long-term ecological and economic productivity. Section 306 administrative funds can be used for non- construction, coastal planning and education, and research. Section 306A improvement funds can be utilized for construction and land acquisition projects and preservation and restoration. CMP funding categories include Coastal Natural Hazards Response, Critical Areas Enhancement, Public Access, Water/Sediment Quantity and Quality Improvements, Waterfront Revitalization and Ecotourism Development, Permit Streamlining/ Assistance, Governmental Coordination and Local Government Planning Assistance.
Community Assistance Program (CAP)	Federal	FEMA, NFIP	TWDB	Product-oriented financial assistance program directly related to the flood loss reduction objectives of the NFIP.
Community Development Block Grant	Federal	HUD	TDA	The primary objective is to develop viable communities by providing decent housing and suitable living environments and expanding economic opportunities principally for persons of low- to moderate- income. Eligible applicants are non-entitlement cities under 50,000 in population and non-entitlement counties that have a non-metropolitan population under 200,000 and are not eligible for direct CDBG funding from HUD may apply for funding through any of the Texas CDBG programs.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Community Development Block Grant for Rural Texas	State	TDA	TDA	TDA administers the Community Development Block Grant for Rural Texas. The primary objective of the CDBG is to develop viable communities by providing decent housing and suitable living environments and expanding economic opportunities principally for persons of low- to moderate-income. Eligible applicants are non-entitlement cities under 50,000 in population and non-entitlement counties that have a non-metropolitan population under 200,000 and are not eligible for direct CDBG funding from HUD may apply for funding through any of the Texas CDBG programs.
Community Development Block Grant – Disaster Recovery (CDBG-DR)	Federal	HUD	GLO	Often following a disaster, the state may receive a CDBG-DR Supplement intended for mitigation and disaster recovery projects in the affected areas. Funding can be used to acquire properties in hazard prone areas. Since CDBG funds lose their federal identify they can also be used to supplement state or local match requirements on other funds such as FEMA HMA grants. Funding also supports public facilities including water and wastewater.
Community Development Block Grant – Mitigation (CDBG-MIT)	Federal	HUD	GLO	Eligible grantees to use this assistance in areas impacted by recent disasters to carry out strategic and high-impact activities to mitigate disaster risks and reduce future losses. In February of 2018, Congress appropriated $12 billion dollars in Community Development Block Grant (CDBG) funds specifically for mitigation activities for qualifying disasters in 2015, 2016, and 2017. HUD was able to allocate an additional $3.9 billion, bringing the amount available for mitigation to nearly $16 billion.
Community Fire Protection Program	Federal	USDA	TAMFS	Mitigation delivered via USDA Forest Service and Private Forestry Coop Fire Program.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Community Wildfire Defense Gran	Federal	USFS	TAMFS	Offers financial assistance to at-risk local communities with planning for and mitigating against the risk of catastrophic wildfire. This program is authorized in Public Law 117-58, the Infrastructure Investment and Jobs Act. Two primary objectives: The development and revision of Community Wildfire Protection Plans (CWPP), and the implementation of projects described in a CWPP that is less than ten years old. Prioritizes at-risk communities that are in an area identified as having high or very high wildfire hazard potential, are low-income, and/or have been impacted by a severe disaster. No minimum federal funding limit for projects.
Conservation Innovation Grants (CIG)	Federal	USDA, NRCS	TDA	Voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production.
Drinking Water State Revolving Fund (DWSRF)	Federal	EPA	TWDB	Makes funds available to drinking water systems to finance infrastructure improvements. The program also emphasizes providing funds to small and disadvantaged communities and to programs that encourage pollution prevention as a tool for ensuring safe drinking water.
Economic Development Administration Grants and Investments	Federal	U.S. DOC, EDA		Invests and provides grants for community construction projects, including mitigation activities.
Economically Distressed Areas Program	State	TWDB	TWDB	Provides financial assistance for projects serving economically distressed areas where water or sewer services do not exist, or systems do not meet minimum state standards. Eligible EDAP applicants include cities, counties, water districts, nonprofit water supply corporations, and all other

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				political subdivisions. The city or county where the project is located must adopt and enforce Model Subdivision Rules for the regulation of subdivisions prior to application for financial assistance. Projects must also be located in an economically distressed area where the median household income is not greater than 75 percent of the median state household income.
Emergency Community Water Assistance Grants	Federal	USDA	TWDB	$150,000 to $500,000 available to rural communities with populations over 10,000 people with a median household income less than $65,900. Provides assistance to communities who have experienced a decline in quantity or quality of drinking water as a result of an emergency including drought.
Emergency Management Performance Grant (EMPG)	Federal	FEMA	TDEM	The EMPG program provides a yearly allocation of funding to support state and local emergency management programs. This has included providing some funding for local mitigation plans, mitigation-oriented studies, and related activities.
Emergency Relief (ER) Program	Federal	US DOT - FHWA		Provides funds for roads and bridges on Federal-aid highways that are damaged as a direct result of a natural disaster or catastrophic failure from an external cause.
Emergency Watershed Protection (EWP)	Federal	USDA, NRCS		Provides funding and technical assistance for emergency measures such as floodplain easements in impaired watersheds. Funding available through the Simplified Acquisition Procedures (SAP) ranges from $25K to $100K. Funded through contracts between project sponsors and the NRCS. There are no grants. The NRCS pays 75% of the costs.
Environmental Quality Incentives Program (EQUIP)	Federal	USDA, NRCS	TDA	Provides funding and technical assistance to farmers and ranchers to promote agricultural production and environmental quality as compatible goals.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Fire Management Assistance Grants (FMAG)	Federal	FEMA	TDEM	Provides fire suppression support to states when loss of life and property are imminent. Wildfire mitigation is also eligible under emergency protection if life is in imminent danger.
Flood Mitigation Assistance (FMA) Program	Federal	FEMA	TWDB	Repetitive flood loss property reduction and projects that mitigate losses to NFIP insured properties.
Flood Infrastructure Fund (FIF)	State	TWDB	TWDB	Enacted through Senate Bill 7 to address needs identified following the flood disasters of 2015, 2016, and 2017. Senate Bill 500 appropriated $793 million. Purpose is to provide loans and grants for flood activities and projects. Once the State Flood Plan is adopted, the account may only be used for projects included in the plan. The SWIFT Advisory Committee is the oversight entity.
Forest Land Enhancement Program	Federal	USDA, NRCS	TAMFS	Provides educational, technical, and financial assistance to help landowners implement sustainable forestry management objectives.
Forest Legacy Program	Federal	USFS	TAMFS	Program providing funding to protect private forest lands that are environmentally, economically, and socially critical. This program reduces development in the wildland-urban interface.
Hazard Mitigation Grant Program (HMGP)	Federal	FEMA	TDEM	Post-disaster multi-hazard mitigation funding for federally declared disasters. HMGP Post Fire funds are available for FMAG declarations.
High Hazard Potential Dam Program (HHPD)	Federal	FEMA	TCEQ	Pre-disaster/annual cycle, for non-federal high hazard dams rated Unsatisfactory. Local match is 35% for each of the four grant periods.
Highway Bridge Replacement and Rehabilitation Program	Federal	FHWA	TXDOT	Provides funding to enable states to improve the condition of highway bridges through replacement, rehabilitation and systematic preventive maintenance. Also includes the National Historic Covered Bridge Preservation Program.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
HOME Disaster Relief	Federal	TDHCA	TDHCA	The Texas HOME Disaster Relief Program is a long-term housing program designed to help eligible organizations serve income eligible households impacted by disasters. Funds are available to assist with federal or state declared disasters, or other natural or man-made disasters that may occur. The Department's practice is to maintain a HOME Disaster Relief Fund balance of $1 million whenever possible. These funds can be accessed to support impacted households not located in communities that receive HOME funds directly from the U.S. Department of Housing and Urban Development (HUD).
Homeland Security Grant Program (HSGP)	Federal	Department of Homeland Security	TDEM	Homeland security activities identified in the state and local strategic plans. Funding supports threat & hazard and risk identification for natural, technological, and human-caused hazards. Some prevention activities may be considered mitigation.
Hospital Preparedness Program (HPP) Cooperative Agreement	Federal	HHS	DSHS	HPP is the primary source of federal funding for health care system preparedness and response and, in collaboration with public health, prepares health care delivery systems to save lives through the development of health care coalitions (HCCs). Under the direction of the HPP providers, the HCCs develop plans and provide training, and coordinate regional exercises.
Hydrologic Research Grants	Federal	NOAA		Up to $125,000 to conduct joint research and development on pressing surface water hydrology issues common to national, regional, local operational offices. Eligible applicants are federally recognized agencies of state or local governments, quasi-public institutions such as water supply or power companies, hydrologic consultants and companies involved in using and developing hydrologic forecasts.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Groundwater Conservation District Loan Program	State	TWDB	TWDB	Provides short-term loans to finance the start-up costs of Groundwater Conservation Districts. Funding is available for any Groundwater District or Authority with the authority to regulate the spacing of water wells, the production from water wells, or both. The program is authorized under Texas Water Code Chap. 36, Subchap. L, and governed by TWDB rules in 31 Tex. Admin. Code Chap. 363, Subchap. H.
Gulf of Mexico Energy Security Act (GOMESA)	Federal	DOI	GLO	GOMESA significantly enhances oil and gas leasing activities and creates revenue sharing provisions for the oil- and gas-producing states of Alabama, Louisiana, Mississippi, and Texas, and their coastal political subdivisions (CPSs). GOMESA funds are used for coastal conservation, restoration and hurricane protection. The second phase of GOMESA revenue sharing began in Fiscal Year 2017 and expands the definition of qualified Outer Continental Shelf revenues to include receipts from Gulf of Mexico leases subject to withdrawal or moratoria restrictions. A revenue-sharing cap of $500 million per year for the four Gulf producing states, their CPSs and the Land and Water Conservation Fund applies from fiscal years 2016 through 2055.
Individual Assistance (IA)	Federal	FEMA	TDEM	Following a disaster, funds can be used to mitigate hazards when repairing individual and family homes.
In-Lieu Fee Program Mitigation Projects	Federal	USACE	Community Applicants	Restoration, establishment, enhancement, and/or preservation of aquatic resources through funds paid to a governmental or non-profit natural resources management entity to satisfy compensatory mitigation requirements for Department of the Army permits.
Mitigation Banks	Federal	USACE	Community Applicants	Mitigation Banks are sites approved by the Corps to sell compensatory mitigation credits for projects resulting in unavoidable impacts to

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
				waters of the U.S. When a permit is issued that requires compensatory mitigation, the permit will specify how many credits are required to be purchased at an approved mitigation bank.
National Earthquake Hazards Reduction Program (NEHRP)	Federal	FEMA	TDEM	Provides money to support enhanced earthquake risk assessments in local hazard mitigation plans and other earthquake hazard mitigation and preparedness activities.
National Weather Service (NWS)	Federal	NOAA - NWS		NWS offers storm spotter training, along with weather and flooding safety guides. They can also sometimes provide funding to support severe weather signage in parks or other public places.
National Wildlife Wetland Refuge System	Federal	USFWS	TPWD	Provides funding for the acquisition of lands into the federal wildlife refuge system.
North American Wetland Conservation Fund	Federal	USFWS	TPWD	Provides funding for wetland conservation projects.
NRCS Conservation Programs	Federal	USDA, NRCS	Community Applicants	Provides funding through a number of programs for the conservation of natural resources.
Partners for Fish and Wildlife	Federal	USFWS	TPWD	Provides financial and technical assistance to landowners for wetland restoration projects in “Focus Areas” of the state.
Planning Assistance to States	Federal	USACE	TWDB	Provides assistance to states in planning for the development, utilization, and conservation of water and related land resources.
Pre-Disaster Mitigation Loan Program	Federal	SBA		Provides low-interest loans to small businesses for mitigation projects.

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Prescribed Fire Grants	State	TAMFS	TAMFS	TAMFS's Mitigation & Prevention Department annually implements 4 prescribed fire grants intended to protect local communities and restore ecosystems. (1) SFAM Plains Prescribed Fire Grant – provides assistance to communities that have been or may be threatened by wildland fire by funding prescribed burning to reduce hazardous fuels in or around communities. Treatment areas will be located adjacent to priority communities in Texas that are at highest risk for loss during a Southern Plains Wildfire Outbreak event. (2) The Community Protection Program Grant provides assistance to reduce the hazard of high-risk fuels on private lands through the use of prescribed burning. The treatment area will be within 10 miles of a National Forest boundary. The grant's goal is to protect high-risk communities and associated forest resources by reducing the risk of catastrophic wildfire on private and public lands. (3) The State Fire Assistance for Mitigation Central & East Texas Grant provides assistance to communities that have been or may be threatened by wildfire by funding prescribed burning to reduce hazardous fuels in and around communities. Treatment areas will be private property in the 43 Counties in Central and East Texas that have a Community Wildfire Protection Plan within the county. The goal is to protect high-risk communities and aid in ecosystem restoration by utilizing prescribed fire to consume excess vegetation before it contributes to catastrophic wildfire. Priority will be given to treatments sites that are within a CWPP, located near a Firewise community, located near homes based on Texas Wildfire Risk Assessment Portal and contain ecosystems that will benefit from prescribed fire. (4) Neches River and Cypress Basin Watershed Restoration Program - Prescribed Fire Grant provides assistance to landowners in utilizing

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
				prescribed fire for ecological improvement to the Neches River and Cypress Basin watersheds. This program will benefit the public and natural resources through improvement of water quality and quantity, control of invasive species and enhancement of wildlife habitat. Treatment areas will be private property in the Neches River and Cypress Basin Watersheds. Priority will be given to prescribed burn treatments that promote native ecosystem restoration, are in priority watershed protection zones and near public land.
Public Assistance (PA) Section 406 funds	Federal	FEMA	TDEM	Following a disaster, funds can be used to mitigate hazards when repairing damages to a public structure or infrastructure. Wildfire mitigation is also eligible under emergency protection if life is in imminent danger.
Public Health Emergency Preparedness (PHEP) Cooperative Agreement	Federal	CDC	DSHS	Helps health departments build and strengthen their abilities to effectively respond to a range of public health threats, including infectious diseases, natural disasters, and biological, chemical, nuclear, and radiological events. Preparedness activities funded by the PHEP cooperative agreement specifically target the development of emergency-ready public health departments that are flexible and adaptable.
Research and Planning Fund and Fund Development program	State	TWDB	TWDB	Offers grants to eligible applicants for the development or revision of regional water plans. The proposed planning must be a plan, an amendment to an approved regional water plan developed by the regional water planning group for a regional water planning area pursuant to the Texas Water Code, §16.053 and Chapter 357, or other special studies approved by the TWDB which will enhance water planning efforts in the region. Activities eligible for funding are those related to

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
				the development, revision, or improvement of regional water plans including public meetings, hearings, and special studies.
Risk MAP Program	Federal	FEMA, NFIP	TWDB	Establishes or updates floodplain mapping and multi-hazard risk products.
Rural Development Grants	Federal	USDA-Rural Development	TWDB	Provides grants and loans for infrastructure and public safety development and enhancement in rural areas. Provides $100,000 or 75% of the total project, whichever is less.
Rural Fire Assistance Grant	Federal	NIFC	TAMFS	Funds fire mitigation activities in rural communities.
Rural Utilities Service (RUS)	Federal	USDA-Rural Development		RUS administers programs that provide much-needed infrastructure or infrastructure improvements to rural communities. These include water and waste treatment, electric power and telecommunications services.
Rural Water Assistance Fund	State	TWDB	TWDB	Designed to assist small rural utilities to obtain low-cost financing for water and wastewater projects. The RWAF offers tax-exempt equivalent interest rate loans with long-term finance options.
State Fire Assistance for Mitigation (SFAM) - Mechanical Fuels Grants	State	TAMFS	TAMFS	Provides financial assistance to reduce the hazard of high-risk fuels on private lands through the use of hazardous fuel reduction. The grant's goal is protected high risk communities within the 32 high risk counties in Central Texas identified by Texas A&M Forest Service Mitigation and Prevention Department. Priority will be given to landowners that live with in the 32 high risk counties, are in a county or city that has an active Community Wildfire Protection plan or live with in a Firewise USA Site.
SFAM Vegetative Fuel Break Grant	State	TAMFS	TAMFS	Provides financial assistance for the creation of vegetative fuel breaks on private lands in Texas. Vegetative fuel breaks are trees and shrubs systematically planted adjacent to fields, homesteads, or feedlots to reduce or redirect the

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				wind. Projects will be located in the Texas High Plains. The goal of the grant is to protect high-risk communities by reducing the risk of catastrophic wildfire on private and public lands. Grant recipients will be reimbursed up to $2,500 for actual costs associated with creating a green, vegetative fuel break, consisting of a minimum of 3 rows of trees and 400 feet in length.
Silver Jackets	Federal	USACE	TWDB	Can provide funding for flood related studies, public awareness, risk analysis, and flood response plans. Construction of small flood control projects.
Small Flood Control Projects (USACE Section 205)	Federal	USACE	TWDB	Authorizes use of USACE to do feasibility and construction of small flood control projects.
State Water Implementation Fund for Texas (SWIFT)	State	TWDB	TWDB	Passed by the Legislature and approved by Texas voters through a constitutional amendment, the SWIFT program helps communities develop and optimize water supplies at cost-effective rates. The program provides low-interest loans, extended repayment terms, deferral of loan repayments, and incremental repurchase terms for projects with state ownership aspects.
State Water Resources Research Act Program	Federal	USGS	TWDB	USGS in cooperation with the National Institutes for Water Resources supports an annual call for proposals to focus on water problems and issues that are of a regional or interstate nature or relate to a specific program priority identified by the Secretary of the Interior and the Institutes.
Texas Farm and Ranch Lands Conservation Program (TFRLCP)	State	TPWD	TPWD	Maintains and enhances the ecological and agricultural productivity of these lands through Agricultural Conservation Easements. The TFRLCP supports responsible stewardship and conservation of working lands, water, fish and wildlife, and agricultural production through:

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
				■ Generating interest and awareness in easement programs and other options for conserving working lands. ■ Leveraging available monies to fund as many high-quality projects as possible. ■ Highlighting the ecological and economic value of working lands and the opportunities to conserve working lands for the future.
The Texas Longleaf Conservation Assistance Program	Federal	National Fish and Wildlife Foundation (NFWF)	TAMFS	Provides eligible landowners with financial and technical assistance for establishing, enhancing, and managing longleaf pine. Landowners with property within ten East Texas counties which include Angelina, Hardin, Jasper, Nacogdoches, Newton, Polk, San Augustine, Sabine, San Jacinto, Trinity, and Tyler are eligible to apply. Approved participants may receive up to 50% payment not to exceed a standard cap rate for implementing approved conservation practices. Approved conservation practices include prescribed burning, reforestation, site preparation, and forest stand improvement.
Texas Infrastructure Resiliency Fund (TIRF)	State	TWDB	TWDB	Enacted through Senate Bill 7 to address needs identified following the flood disasters of 2015, 2016, and 2017. Senate Bill 500 appropriated $685 million. Purpose is to provide loans, grants, and matching funds for flood projects through four separate accounts. Each account has different purposes. The oversight entity is the TIRF Advisory Board (SWIFT Advisory Committee and TDEM Director as non-voting member).
Texas Water Development Fund (DFund)	State	TWDB	TWDB	State funded loan program The DFund enables the Board to fund multiple eligible components in one loan to our borrowers, e.g., an application for funding of water and wastewater components can be processed in a single loan. Provide financial assistance for water supply projects, wastewater projects, and flood control projects (including structural and nonstructural flood protection improvements).

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Transportation Enhancement program	Federal	FHWA	TXDOT	Provides opportunities for non-traditional transportation related activities. Projects should go above and beyond standard transportation activities and be integrated into the surrounding environment in a sensitive and creative manner that contributes to the livelihood of the communities, promotes the quality of our environment, and enhances the aesthetics of our roadways. Projects undertaken with enhancement funds are eligible for reimbursement of up to 80 percent of allowable costs.
United States Geological Survey (USGS)	Federal	USGS		USGS issues competitive grants and cooperative agreements to support research in earthquake hazards, the physics of earthquakes, earthquake occurrence, and earthquake safety policy.
U.S.-Mexico Border Water Infrastructure Program	Federal	EPA	TCEQ	Provides grant assistance to U.S. and Mexican communities located within 60 miles of the border for the development and construction of high- priority drinking water and wastewater facilities. The program furthers EPA's mission of protecting human health and the environment by providing critical resources for what is often an area's first drinking water and basic sanitation services.
Water Conservation Field Services Program	Federal	HUD		Provides a number of grants related to safe housing initiatives.
Water2025 Challenge Grant Program for Western States	Federal	Bureau of Reclamation		Up to $25,000 for projects that improve water use efficiency and improve water management practices.
Watershed Processes and Water Resources	Federal	Bureau of Reclamation		Up to $250,000 for projects that can be completed within 24 months and that reduce conflicts through water conservation, efficiency, and markets.

APPENDIX J: STATE AND FEDERAL FUNDING OPPORTUNITIES

NAME	LEVEL	SOURCE AGENCY	MANAGING STATE AGENCY	PURPOSE OF FUNDING
Watershed Processes and Water Resources – National Research Initiative Standard Research (Part T)	Federal	USDA		$100,000 available. Sponsors research that addresses two areas: (1) understanding fundamental watershed processes; and (2) developing appropriate technology and management practices for improving the effective use of water (consumptive and nonconsumptive) and protecting or improving water quality for agriculture and forestry production.
WaterSMART – Drought Response Program	Federal	USDA	TWDB	$500,000 available. Innovative research in understanding fundamental processes that affect the quality and quantity of water resources at diverse spatial and temporal scales, ways on improving water resource management in agriculture, forested, and rangeland watersheds, and developing appropriate technology to reach those goals.
Wildlife Habitat Incentive Program (WHIP)	Federal	USDA, NRCS	TPW	Voluntary program for conservation-minded landowners who want to develop and improve wildlife habitat on agricultural land, nonindustrial private forest land, and tribal land.