# City of Houston

## Floodplain Management Plan

## 2016

*Photo Courtesy of HCFCD*

# Table of Contents

# Introduction

The City of Houston is currently the fourth largest city in the United States with a reported population of 2,099,451 in 2010 (U.S. Census Bureau) which represents a growth of 7.5% from the figure of 1,953,631 reported by the Bureau for 2000. Due to continuing growth and development of the urban and suburban areas within the city, coupled with the susceptibility of the area to flooding related to extreme rainfall events, Houston places a high priority on floodplain management and its participation in the Community Rating System (CRS) under the National Flood Insurance Program (NFIP).

The City of Houston (City) enrolled in the Emergency Phase of the NFIP on September 14, 1973, and entered the Regular Phase of the NFIP on December 11, 1979. The City's Flood Hazard Boundary Map was published by the Federal Insurance Administration (FIA) on December 27, 1974. FEMA published the initial countywide Flood Insurance Rate Map (FIRM) for Harris County and all incorporated communities in Harris County on September 28, 1990. The Harris County FIRM was revised on September 30, 1992, November 11, 1996, April 20, 2000, and June 18, 2007.

Flooding and flood insurance claims in the City are not confined to the Special Flood Hazard Areas (SFHAs), or 1% annual chance floodplain, as depicted on the Repetitive Loss Map included in Appendix C. Flooding can happen anywhere in Houston, and all citizens live in a flood zone even if they are not located in a SFHA, or high-risk flood zone. Approximately two-thirds of all flood losses from Tropical Storm Allison occurred outside the mapped 1% annual chance flood, or 100-year floodplain, and nationally, approximately one-third of all flood losses occur outside the mapped 1% annual chance floodplain. *[Source: Harris County Flood Control District]*

There are more than 2 million residents living in the City of Houston. Given Houston's flat terrain, proximity to the coast, and historical flooding record, all Houstonians need to be protected by federal flood insurance. With less than 121,000 total number of flood policies in force in the City of Houston, the entire community is considered "needs improvement" to increase flood coverage in the high-risk flood zone, areas outside the SFHA in high-need areas , areas with low policy count, and community-wide. Relative to its location, and large, growing population, City of Houston officials recognize the need to promote flood insurance in an effort to increase the policy count, protect property, and save lives.

In conjunction with the 2016 CRS reverification, the City prepared a 'Coverage Improvement Plan' (CP) and developed outreach projects in an effort to track and increase the current flood policy count, city-wide. A 'Floodplain Management Committee' (FMPC) met on two separate dates to make recommendations for projects. These include, but are not limited to:

- Increase policy count for nonresidential and commercial property owners to protect both building and contents;
- Increase outreach in high-need areas outside the SFHA in areas prone to drainage issues, minor flooding, and low policy count areas;
- Increase policy count for contents coverage;
- Increase purchase of flood insurance for residents living behind dams, lakes, levees, or reservoirs

Since flood insurance claims and repetitive loss properties (two or more claim payments of more than $1,000 within a 10-year period) are distributed across the city, the entire city may be considered a Repetitive Loss Area. The Floodplain Management Office (FMO) of the City's Department of Public Works and Engineering currently identifies 4,020 unmitigated repetitive loss properties within the City limits. In previous years, there were additional structures in the City considered by FEMA to be repetitive loss structures; however, the City, along with the Harris County Flood Control District (HCFCD) has worked with property owners to undertake flood mitigation measures such as buyout, relocation, elevation, or otherwise improving the structures so they are no longer subject to repetitive flood damage.

The City is classified as a Category C community (10 or more unmitigated repetitive loss properties) under the CRS. Among other requirements under the CRS, category C communities must prepare a Floodplain Management Plan, Repetitive Loss Area Analysis, or similar natural hazard mitigation planning document, and update the document(s) on a periodic basis. This 2016 'City of Houston Floodplain Management Plan' is prepared in conformance with the requirements of Section 510, Floodplain Management Planning of the *"National Flood Insurance Program Community Rating System Coordinator's Manual"*, 2013 (FIA-15/2013, OMB No. 1660-0022.) The FMP also serves to enhance floodplain management planning and practices in the City.

The CRS program was created to recognize communities where floodplain management standards and practices exceed the minimum federal requirements and, in exchange, policyholders receive discounts on their flood insurance premiums. Participating communities are awarded class ratings ranging from 10 (lowest) to 1 (highest) based on their degree of compliance and documentation with CRS recommended activities. As a community's class rating improves, the amount of the flood insurance premium discount available to policyholders also improves. Due to the stringent requirements of the CRS, many communities are unable to progress beyond a Class 8 rating.

The 'City of Houston Floodplain Management Plan', dated July 2001, was prepared as part of the City's original application to the CRS. This application resulted in the City being awarded a CRS class 8 rating effective May 2002. At that time, Houston was the largest City in the nation to be awarded a class 8. Due to improvements in the City's building code enforcement program, along with other enhancements to floodplain management standards, the City was awarded a class 7 rating effective May 2006.

The 'City of Houston Local Hazard Mitigation Plan' was published in June 2006 to meet the planning requirements of the CRS and FEMA's hazard mitigation grant programs. The City's 2012 'Floodplain Management Plan' officially replaced the City's local Hazard Mitigation plan to further address flood risk reduction in the community. FEMA's review of the local Hazard Mitigation Plan, and development of the 2012 'Floodplain Management Plan' by City Council, along with the City's improvement on floodplain management standards, as recognized during the five-year program reverification conducted in 2006, resulted in the City being awarded with a class 6 rating effective October 2007. This achievement placed Houston in the upper 11% of all communities participating in the CRS nationwide.

The City of Houston improved its CRS rating to a Class 5 effective October 2009. This increase in rating was based on enhanced floodplain management practices including improvements to

public outreach programs, flood protection assistance, storm water quality management practices, and drainage system maintenance. The City's class 5 rating affords flood insurance customers in the 1% annual chance floodplain, and floodway, a 25% discount on flood insurance premiums. Flood insurance customers in more moderate risk areas or with standard rated policies save up to 10% on flood insurance premiums. As a result of the City's class 5 rating, property owners in Houston save in excess of $10,588,000 per year on flood insurance premiums.

## Section 1 – Organize to prepare the plan update

The 2016 FMP and its underlying planning process are the creation of the City of Houston Floodplain Management Plan Committee (FMPC) to serve the following purposes:

- Reduce flood losses and impacts from flooding
- Improve protection of the floodplain's natural and beneficial functions
- Support flood mitigation activities
- Promote awareness and attention to the City's flooding problems
- Fulfill the requirements of a category C community in the CRS

(a) Composition of Successor Floodplain Management Plan Committee

The 2016 FMPC Committee members include representatives from the Public Works/Engineering Department, Floodplain Management office and Public Information office, as well as citizens and private-sector businesses and organizations. The 2016 Committee is the successor committee with a similar membership that was created to replace the 2012 FMPC Planning Committee.

The 2016 FMPC met on two separate dates in 2015 to assist with the evaluation and revision of the FMP. This included reviewing and analyzing the 2014 Floodplain Management Progress Report prepared by the City's Floodplain Management Office to document the status of mitigation actions and floodplain management planning in the City of Houston. The 2016 FMPC reviewed, analyzed and made recommendations to include in the 2016 FMP update.

| Meeting Dates | Topics |
|---|---|
| November 10, 2015 | Evaluation and Plan Revisions of the 2012 Floodplain Management Plan; review status of mitigation projects in 2014 report |
| November 16, 2015 | Review new studies, plans, and mitigation actions to incorporate into 2016 Plan; evaluate any flood related issues to address and incorporate; City staff to provide update on pertinent flood issues and previous flood disasters affecting development |

The 2016 FMPC is also tasked with monitoring and evaluating implementation of the 2016 FMP. They will meet at least twice each year to make recommendations and revisions to the FMP as needed. These recommendations will be compiled into an annual evaluation report, submitted to the governing body, released to the media, and made available to the public.

## Section 2 – Involvement with the public

The 2012 FMPC made involvement of the public a priority in the planning process for the initial FMP. The public was given the opportunity to provide input in the FMP throughout the process. The public was engaged through participation in the FMPC, through public meetings during the planning process, prior to the adoption of the plan, and through coordination with agencies and professional societies.

The 2016 FMP update will be submitted to the governing body and released to the media, and posted on the City's flood information webpage for public review and comment.

## Section 3 – Coordination with other agencies and organizations

(a) Review of existing studies, reports, and technical information

In developing this plan update, the FMPC reviewed a variety of existing studies, reports, and technical information that provided insight into Houston's needs, goals, and plans that impact floodplain management. The "City of Houston Floodplain Management Plan" (July 2001), submitted in support of the City's initial application to the CRS, was reviewed to establish a baseline for subsequent planning activities and mitigation actions.

The City of Houston Local Hazard Mitigation Plan "Planning for a Disaster Resistant Community" (June 2006) was reviewed in depth to evaluate the planning methodology employed during Houston's first effort to consolidate planning and mitigation efforts for all natural hazards of concern to the community. The process of analyzing hazards, determining vulnerabilities to those hazards, establishing goals and objectives to mitigate those hazards, and evaluating and prioritizing potential mitigation actions was employed in the development of this FMP. In addition, the FMPC reviewed the draft 2014 FMP Progress Report to assess any modifications that may have been developed for the processes and recommendations established in the 2014 report. No changes were noted.

Numerous other sources of information were consulted during this planning process including CRS documents developed in 2016. These included 'Program for Public Information' (PPI) which serves as a planning tool to support the City's outreach efforts and increase CRS points in an effort to maintain a Class 5 program rating, a 'Flood Insurance Assessment' (FIA), 'Coverage Improvement Plan' (CP), 'Flood Response Projects' (FRP), and current reports of NFIP flood insurance claims and repetitive loss properties, which were integral to the planning process.

(1) The known flood hazards in the City of Houston are identified in the "Flood Insurance Study for Harris County, Texas and Incorporated Area", revised June 18, 2007, FEMA FIS No. 48201CV00, Volumes 1A through 8A, and FIRM panels issued for that FIS with the same effective date. The City of Houston is assigned NFIP Community Number 480296 and FIRM panel numbers for the City are identified with this number. The FIS and FIRM panels are available for viewing at the City of Houston Floodplain Management Office and City libraries. The documents may also be viewed and downloaded from the FEMA Map Service Center: https://msc.fema.gov. HCFCD maintains data on revisions (planned or actual) to information contained in the 2007 FIS. This information is available to the public upon request.

A map of the regulatory floodplain within the city identifying current repetitive loss properties is included in Appendix C. As stated in the Introduction to this FMP, all areas of the city have the potential for flooding and are considered to be located in a "needs improvement" area.

(2) Description of the flood hazard

Houston's unique in that its flat terrain, large amounts of impervious cover (concrete), slowly-absorbing soil, and potential for thunderstorms, tropical storms, and hurricanes all combine to form ideal conditions for flooding. Due to its humid-subtropical climate and proximity to the coast, Houston is susceptible to large amount of rainfall that is often too great for its infrastructure and bayous to handle. Once the City's ditch and storm sewer networks are inundated with storm water runoff, streets become secondary drainage facilities.

Houston area residents are subject to a tremendous amount of rainfall, which often occurs over an extremely short period of time. The extent of flooding in the city can be measured in water depths from between one and ten feet deep in structures located in the identified flood hazard area. Floods are a natural and recurrent event, and can take place every year and in all seasons. Flooding events are usually broken into three categories: flash floods, riverine floods, and tidal floods. Given the present knowledge, the size, time, and place of floods cannot be predicted more than a few hours in advance. Flooding events can cause damage to homes and businesses in any and every area of Houston. A map showing the 22 major watersheds in Houston is located in Appendix D. Maps identifying the 100-year and 500-year floodplains are included in Appendix G. It is important to note that flooding can affect any area, and even a small rain event can cause local flooding in homes and/or businesses.

Harris County maintains a Flood Warning System (FWS) that measures rainfall amounts and monitors water levels in bayous and major streams on a real-time basis (data may be delayed up to five minutes) to inform citizens of dangerous weather conditions. The system relies on 133 gage stations strategically placed throughout Harris County bayous and their tributaries. The stations contain sensors that transmit valuable data during times of heavy rainfall and during tropical storms and hurricanes. Some gages also measure wind speed and direction, barometric pressure, air temperature, road temperature, and humidity. The FWS is available over the Internet at http://www.harriscountyfws.org/

The FWS is used by HCFCD and by Harris County's Office of Homeland Security and Emergency Management to inform citizens of imminent and current flooding conditions along bayous. It also is used by the National Weather Service to assist in the issuing of flood watches and warnings. Accurate rainfall and bayou/stream level data assists the public and emergency management officials to make critical decisions that ultimately can reduce the risk of property damage, injuries and loss of life. The Harris County FWS also provides information on historical rainfall and flooding events.

As required by the FEMA-approved 2006 local Hazard Mitigation Plan, specifically the Hazard Identification and Risk Estimation table included in this FMP in Appendix F, floods are prioritized as the number one natural hazard threat to the city. This prioritization is based on several key risk factors including: 1) area impacted; 2) probability of occurrence; 3) health and safety consequences; 4) consequences to property; 5) consequences to environmental resources; and 6) economic consequences. Each of these key risk factors is discussed in further detail in Appendix F. The extent (i.e., magnitude or severity) for flood is considered to be substantial. The frequency and severity of these events cause flooding to be a hazard of concern for the city of Houston.

(3) Discussion of past floods

(a) Assessment of the flood hazard

Houston is subject to intense local thunderstorms of short duration, general storms extending over periods of several days, and torrential rainfall associated with hurricanes and other tropical disturbances. Flooding results from tidal surges along Galveston Bay that are caused by hurricanes, tropical storms, and stream overflow.

After experiencing devastating floods in 1929 and 1935, the City issued a plea to Congress and secured a commitment for federal flood control assistance. In 1937, the Texas Legislature created the HCFCD and designated the Harris County Commissioners Court as the governing body. Throughout the past 75 years, HCFCD has acted as the local sponsor for many federal flood control projects to protect the lives and property of local citizens. The City is an active partner with the HCFCD and the USACE. The result has been numerous multi-objective projects that have provided flood protection and maximized the use of public lands.

\

The following table lists major storm and flooding affecting the Houston area since 2012 that caused flooding in Houston and Harris County. This data is also shown in Appendix E along with previous annual historical flood data.

Flooding Events 2012-2016

| Event | Date |
|---|---|
| Severe Storms/Flooding | March 16, 2016 |
| Severe Storms/Flooding | October 22, 2015 |
| Severe Storms/Flooding | May 29, 2015 |
| Severe Storms/Flooding | May 04, 2015 |

b. Other natural hazards

The following pages include brief summaries of natural hazards, in addition to flooding, that have been evaluated during the development of hazard mitigation action plans for the City by the FMPC. Maps demonstrating risk potential, where applicable, are also included for reference in this section. Maps for the risk potential for hurricane storm surge and wind are included in Appendix G. The generic discussion of the characteristics of these hazards is contained in the hazard mitigation plans and is not repeated in this FMP. Magnitude and frequency of occurrence were evaluated in the risk assessment process detailed in Section 5 in this FMP. Tables included with Appendix G demonstrate the frequency and severity of these events in the Houston area.

***Hurricanes***

Since the effects of a hurricane can be widespread and devastating, a hurricane is considered a hazard of concern to the city of Houston and is considered the second highest natural hazard of concern behind flooding.

***Tropical Storms***

The thunderstorm activity in a tropical storm can create significant rainfall. Bayous may flood and roads become impassable as a result of the sometimes substantial precipitation. Inland areas are particularly vulnerable to freshwater flooding, due to residents not preparing adequately. Any time the city receives intense precipitation within a short duration, flooding will be a problem. It is impossible to quantify the specific amount of precipitation required to produce flooding, due to the numerous varying contributing factors (i.e., location, ground elevations, proximity to bayous, storm sewer conditions, etc.).

Tropical storms that make landfall in the Houston area can vary in severity and magnitude. Some cause little to no damage and some produce extraordinary damage to property and lives. The

destructive power of tropical storms can mimic that of hurricanes when areas receive either prolonged or intense precipitation, high winds, significant thunderstorm activity, and tornadoes. As is the case for hurricanes, a tropical storm is a natural hazard of concern for the city of Houston and is ranked third after hurricanes.

***Extreme heat***

People living in southeast Texas are no strangers to high temperatures and high humidity during the summer. It is normal for Houston to experience high humidity levels combined with elevated temperatures producing a heat index above 100 degrees. This heat creates the need for residents to implement extreme caution. Houston also suffers from what is known as the "urban heat island effect." This phenomenon occurs in areas where large amounts of asphalt and concrete are located. Asphalt and concrete store heat for extended periods and slowly release heat at night, which can produce higher nighttime temperatures. The stagnant atmospheric conditions of the heat wave trap pollutants in urban areas and add the stresses of severe pollution to the already dangerous stresses of hot weather, creating a health problem of undetermined dimensions. Extreme heat is prioritized as the fourth highest natural hazard threat to the city.

***Tornado***

The warm, moist air coming up from the Gulf of Mexico contributes to the formation of tornadoes. Tornadoes can and have occurred within the city of Houston making it a hazard of concern and are prioritized as the fifth highest natural hazard threat to the city.

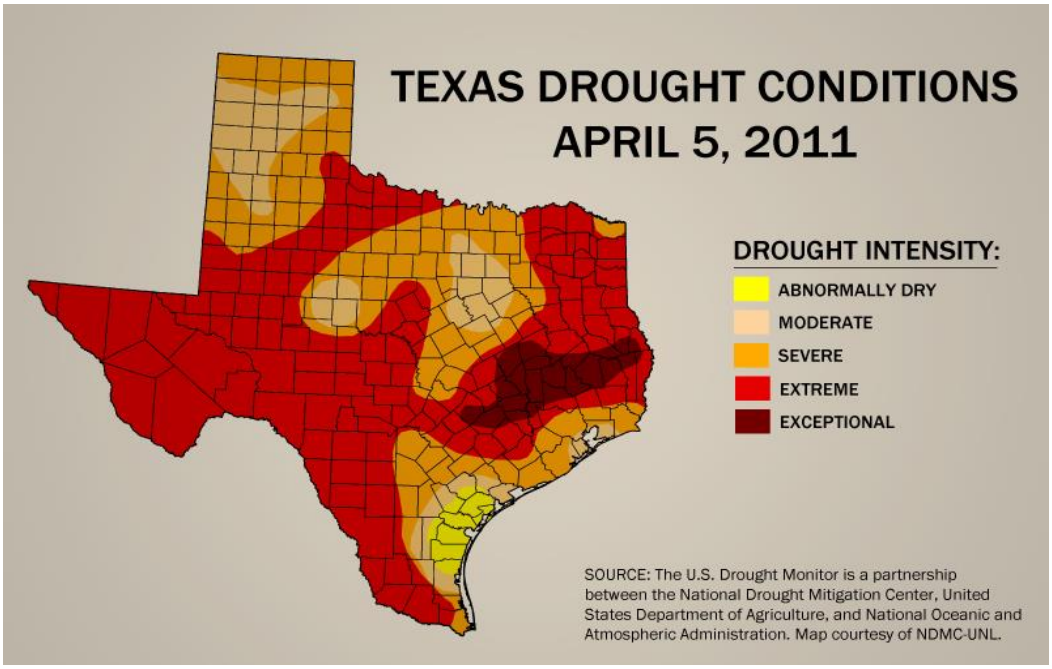
***Severe winter storm***

A winter storm can range from a mild snow over a period of a few hours to blizzard conditions with blinding snow that lasts for several days. Winter storms may include snow, sleet, freezing rain, or a mix of freezing precipitation. Based upon previous occurrences, the severity of winter storms in the area is relatively low due to the infrequency and lack of substantial damage created by these events. Houston is generally spared from dealing with severe winter weather; however, when the city has experienced freezing or below freezing temperatures, severe winter storms become a hazard of concern. Severe winter storms are ranked sixth out of the 10 possible natural hazard threats to the city.

***Drought***

Some consequences of drought in the Houston area are wildfires, lack of water for agriculture and irrigation, cracking foundations and water main breaks linked to issues with expansive soils, and loss of urban forest due to lack of rainfall. Typically, the severity of drought within Houston could be described as mild, in that (based on the National Weather Service historical data) there have been no recorded incidents of loss of life as a result of drought. Hot and dry conditions can and have occurred within the city of Houston, as recently as the summer of 2011, making drought a hazard of concern for the entire area as a whole.

According to the Hazard Identification and Risk Estimation table in Appendix F, drought is ranked seventh out of the 10 possible natural hazard threats to the city. The map below is a snapshot of the risk of the state of Texas to the conditions and dangers of drought.




***Hailstorm***

Hailstorms are most common in the middle United States, and most often accompany a thunderstorm. Hail is also most likely to occur in late afternoon. Because of the unpredictability and likelihood of the city of Houston receiving a hailstorm, it is a hazard of concern.

Hailstorms are ranked eighth out of the 10 possible natural hazard threats to the city. This prioritization is based on several previously mentioned key risk factors discussed in further detail near the end of this section. The extent for hailstorm is minor and is explained further in this section.

***Lightning***

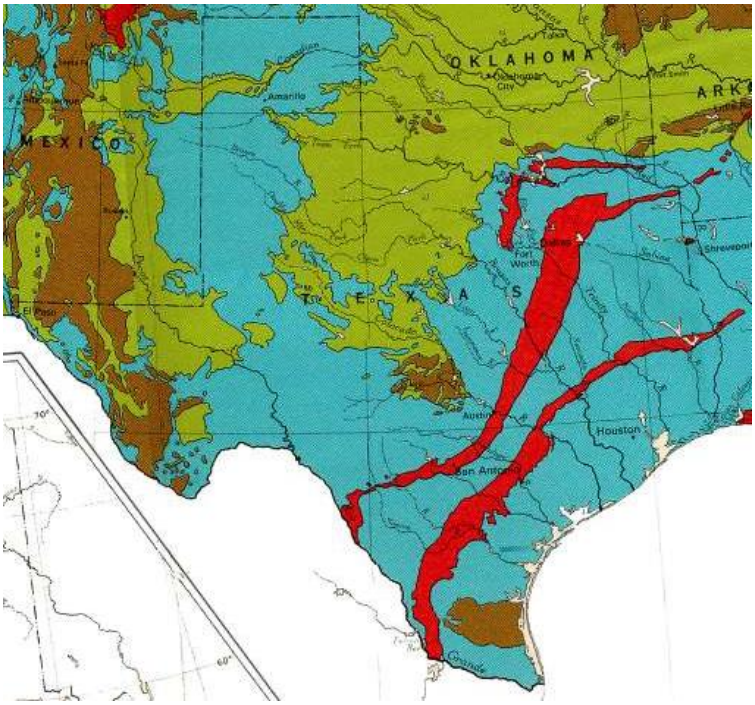
The severity of damage due to lightning within Houston could be described as moderate to high. Based upon historical data from the National Weather Service (included in Appendix E), there have been two recorded deaths and 21 injuries as a result of lightning within Houston. In addition, there have also been recorded incidents of property damage. Lightning is a common occurrence in the city of Houston, making it a natural hazard of concern.

Lightning is ranked ninth out of the 10 possible natural hazard threats to the city. This prioritization is based on several previously mentioned key risk factors discussed in further detail near the end of this section. The extent of damage due to lightning is minor.

***Expansive soils***

The climatic conditions in southeast Texas play a significant role in making expansive soils a nuisance to the area. Houston's average climatic conditions are based on cycles of wet and dry weather. During dry periods, shrinkage of soils occurs, and during wet periods, swelling occurs. The expansion and contraction of the soil can produce damage to foundations on homes and cracks in streets and highways. No record of expansive soils is maintained at this time so it is difficult to track. However, there is a mitigation action item that addresses this need.

According to the USGS Swelling Clays Map displayed below, the city of Houston is located in an area described as "consisting of clay with a high swelling potential." The blue shading in the map, which covers Houston, demonstrates clay that has a high swelling potential. Much of the risk to structures being built on expansive soils can be eliminated provided that good design, good construction, and good maintenance are implemented. Expansive soils become more than just a hazard when it causes damage to structures and infrastructure. The severity of expansive soils within Houston could be described as low. There is no threat to life. The only real threat is damage to property and infrastructure. Since Houston is located in an area of "high swelling potential" in relation to the soil, expansive soil is a hazard of concern.




Based on the Hazard Identification and Risk Estimation table in Appendix F, expansive soils is ranked last out of the 10 possible natural hazard threats to the city. This prioritization is based on several previously mentioned key risk factors discussed in further detail near the end of this section. The extent for expansive soils is minor.

***Coastal Storm – Not a hazard of concern***

A coastal storm is defined as any type of storm that moves inland from off the coast and is not cyclonic (having a counter-clockwise rotation) in nature. With Houston's close proximity to the coast, coastal storms can and do push through the city. These storms usually produce showers and may sometimes be accompanied with thunderstorms. The adverse impacts of coastal storms are reported with other hazards such as severe weather, thunderstorms or flooding when examining federal databases.

***Dam Failure – Not a hazard of concern***

According to the Texas Commission on Environmental Quality (TCEQ), the City of Houston has three "high hazard" dams within its jurisdiction. The State Hazards Analysis defines high hazard as a "dam failure [that] would probably result in loss of life and major damage to property." Furthermore, "the hazard rating has nothing to do with whether the dam is about to collapse immediately or will last forever. It does not relate to the condition or structure of the dam. Basically, it has to do with whether there are people living downstream in the floodplain area which would be endangered in the event of dam failure." Since the probability of a dam failure is low for Houston, dam failure is not a hazard of concern to the City. Note that no risk areas or specific dams have been identified within this report due to the sensitivity of this information.

***Coastal and Riverine Erosion – Not a hazard of concern***

Coastal erosion is a natural hazard that threatens the southeast Texas coast; however, the city of Houston has no coastline within its jurisdiction. Riverine erosion is the natural removal of river banks by flowing water. It is not easy to determine what the "normal" natural rate is for this type of erosion, as it may be accelerated through man-made processes such as storm sewer outfalls. Floods increase the velocity of the water within a river which produces the most powerful form of natural riverine erosion. Certainly, there is some degree of riverine erosion which occurs naturally, and is increased by man-made development within the bayous and streams of the City of Houston; however, there are no indications that this erosion creates a significant concern.

***"Natural" Land Subsidence – Not a hazard of concern***

Land subsidence is a gradual settling or sudden sinking of the Earth's surface due to naturally occurring subsurface movement of earth materials. There is no indication that the City of Houston has experienced this natural process.

***Volcanic Activity – Not a hazard of concern***

The state of Texas has no active volcanoes, and it is highly unlikely that there will ever be any active volcanoes due to the distance the area is from any of the currently known sources of magma.

***Wildland Fire – Not a hazard of concern***

Wildland fires are highly dependent upon climatic conditions. They are most likely to occur during dry and hot periods in undeveloped and wooded areas. The National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center has no reported history of wildand fires within the City of Houston from 1950 to the present. Thus, wildland fire was determined to pose no significant threat to the area.

***Tsunami – Not a hazard of concern***
Tsunamis are a series of very long waves generated by any rapid, large-scale disturbance of the sea (normally large earthquakes under the ocean). Because of the geographic location of the City of Houston, tsunamis are not a threat to the city.

***Earthquake – Not a hazard of concern***
Peak gravitational acceleration (PGA) is the deciding factor in labeling an area as being prone to earthquakes. PGA is a measure of the strength of ground movements. The City of Houston is in the PGA zone of 0 to 2.0, which implies a relatively low seismic risk.

***Landslide – Not a hazard of concern***
Houston is not prone to earthquakes or extreme rain incidents, which are the major causes of landslides. Also, the geology and topography of the city does not offer much in terms of hillside slopes or embankments, which is where landslides and mudslides take place. According to the United States Geological Survey (USGS), the City of Houston lies in the low incidence zone for landslides. Thus, landslides are determined to be of no significant threat to the city of Houston.

***Avalanche – Not a hazard of concern***
An avalanche is caused when a buildup of snow and ice is released down a slope. Houston is not prone to substantial snowfall and the topology of the city is relatively flat. An avalanche is not considered to be a hazard of concern.

***Windstorm – Not a hazard of concern***
Windstorms are usually associated with tropical storms or hurricanes, thunderstorms, and tornadoes; however, they can occur independently of these events. There are no known incidents of an independent windstorm (a windstorm not accompanied by a tropical storm, hurricane, thunderstorm, or tornado) within the City of Houston. Thus, windstorms are not considered to be a hazard of concern.

An important indication of the hazards threatening the community is the actual occurrence of disaster events and the level of impact these events have on the community. Assessment of past disasters can also be very informative regarding the types, locations, or scope of mitigation initiatives that would be needed to prevent similar damages from future events of the same type.

# Section 5 – Assess the problem

Much of the information presented in this Section was produced as part of the City's hazard mitigation action planning activities. The methodology employed by the FMPC to evaluate hazards, assess risk, and estimate vulnerability is included in Appendix F of the FMP. In some cases, additional information directly related to the flood hazard has been compiled for the FMP.

(a) Summary of community's vulnerability to all the hazards

Of the hazards of concern identified in Section 4, three are more likely to occur in predictable areas of the City within defined areas of risk. The remaining seven hazards do not have defined areas of risk and can generally occur anywhere within the city. The list below separates these two categories.

| Hazards with defined areas of risk | Hazards without defined areas of risk | |
|---|---|---|
| Floods | Extreme heat | Hailstorm |
| Tropical storm | Tornado | Lightning |
| Hurricanes | Severe winter storm | Expansive soils |
| | Drought | |

The City of Houston Geographic Information System (CoH-GIS) was used to estimate vulnerability for hazards with defined areas of risk: floods, storm surge, and hurricane wind. Dollar values, counts, and types of structures at risk within these hazard areas have been obtained, where possible, from the GIS databases. Maps that display the risk areas for these hazards also include tables that provide estimates of vulnerability for high risk areas and city-wide for five categories of structures: residential, commercial, critical, special, and hazmat (see Appendix G).

The vulnerability of the community to the seven listed hazards without defined risk areas is difficult to quantify; however, the impact of the drought of 2011, coupled with the expansive soils present in the area, created an environment where thousands of mature pine and oak trees in the city's Memorial Park alone were lost to a lack of water and aging water mains across the City burst from stresses created by the shrinkage of expansive soils.

(b) Description of impact

(1) Life, safety, and health

The potential impacts of the hazards of concern for life, safety, and health have been evaluated and the results are displayed on the "Hazard Identification and Risk Estimation" table included in Appendix F. The City and Harris County have a variety of mechanisms available (see discussion in Section 4 (a)(2)) to inform citizens of the potential for impacts from natural hazards and to advise them precautions that should be employed. The media, including television, internet, and wireless communications, are utilized to disseminate information to the public with great effect. Lessons learned by city, county, and state emergency management officials during Hurricane Rita in 2005 were used effectively in preparation for Hurricane Ike in 2008. The evacuation of area residents most at risk from the approaching storm proceeded in an orderly manner, while those

residents whose safety was best assured by sheltering in place were encouraged to remain in their own homes and off the streets, highways, and major evacuation routes. Emergency management agencies and first responders within the greater Houston area are continually striving to raise the level of preparedness and response capability to meet the needs of future hazard events.

(2) Critical facilities

Some facilities and systems in the community are crucial to the health, safety, and welfare of the community. Therefore, high priority is given to assessing their vulnerabilities to future disasters and proposing mitigation initiatives to address identified vulnerabilities. For purposes of this FMP, these facilities are considered to be "critical facilities." A critical facility is a structure that, if impacted by an event, would present an immediate threat to life, public health, and safety. Critical facilities include hospitals, emergency operations centers, fire department services, and nursing homes. For hazards where a definable risk area could be developed geographically using GIS, a numerical value showing the number of critical facilities potentially at risk to the given hazard represented was generated.

It must be emphasized that the fundamental reason for undertaking the hazard identification and vulnerability assessment process was to highlight vulnerabilities that needed to be addressed by the development of proposed mitigation initiatives for incorporation into the FMP. This component of the planning process is expected to be continued in future updates of the plan until all necessary vulnerabilities have been assessed and their mitigation needs addressed.

The City of Houston maintains a list and map of all critical facilities within not only the Houston area, but also all of Harris County. This list identifies vulnerabilities and estimates risks of all hazards that have a defined area of vulnerability. The critical facility list and map are not included in this plan due to the sensitivity of the nature of the facilities. This list is updated on an ongoing basis and maintained by the City of Houston Office of Emergency Management.

Tables that include the numbers of critical facilities at risk from flooding, storm surge, and hurricane wind are displayed on maps included with Appendix G.

(3) Economy and Tax Base

An assessment of the impact of the ten hazards of concern for the city's economy and tax base is incorporated into the Hazard Identification and Risk Estimation table included in Appendix F.

(c) Number and types of buildings

The tabular data provided on the hazard risk area maps located in provides information on the number of structures by five category types and the associated value of those buildings located within each of the flooding, storm surge, and hurricane wind risk areas. These tables also display the total number and value of all buildings in the city by category.

(d) Review of policy data and Coverage in Force

Based on information provided by FEMA for general policy data, the vast majority of flood insurance policies are for Zone X properties. The number of flood policies for properties in the low- to moderate flood risk zones are more than double the number of policies for properties located in the Special Flood Hazard Area. Non-residential flood policies total less than 6,000, an indication that the vast majority of businesses and commercial properties are unprotected.

There are almost three times more Zone X flood policies for Post-FIRM structures than there are for Post-FIRM properties located in Zone A and AE. This may be an indication that City of Houston community officials, the Harris County Flood Control District, social media, and other Stakeholders have done a good job educating residents regarding flood risk outside identified Special Flood Hazard Areas. It may also be an indication that many homeowners in the SFHA have paid off their mortgage and are no longer required by the lender to carry flood insurance under NFIP's 'Mandatory Purchase of Flood Insurance' provision.

There are more than 2 million residents living in the City of Houston. Given Houston's flat terrain, proximity to the coast, and historical flooding record, all Houstonians need to be protected by federal flood insurance. With less than 121,000 total number of flood policies in force in the City of Houston, the entire community is considered "needs improvement" to increase flood coverage in the high-risk flood zone, areas outside the SFHA in high-need areas , areas with low policy count, and community-wide. As part of the City's CRS program, a 'Coverage Improvement' (CP) Plan was developed as a key outreach program to improve and increase the flood insurance policy count city-wide. CP efforts will be tracked annually and adjustments made as needed based on number of policies, city-wide and in targeted areas. Both Building and Contents coverage will be reviewed.

(e) Natural and beneficial functions

The City of Houston, Harris County, and the USACE cooperatively endeavor to preserve and enhance areas that provide natural and beneficial functions within, and adjacent to, floodplain areas in Houston.

Buffalo Bayou serves as a major channel draining much of west and central Houston to the Houston Ship Channel and Galveston Bay. Located upstream of the western portion of the Buffalo Bayou Watershed and completed by the USACE in the 1940s as flood protection measures for the city of Houston, Addicks and Barker dams, and the reservoir areas formed upstream of the dams, provide an excellent natural resource for the Houston area. Portions of the reservoir areas are leased to Harris County and Fort Bend County, among others, to provide recreational facilities, while vast areas of the reservoirs remain in a natural state providing wetlands and other habitat for a wide range of plants and wildlife. Buffalo Bayou is a natural channel for much of its length, and the City, County, and public interest groups such as the Bayou Preservation Association (http://www.bayoupreservation.org) strive to preserve this asset in such a condition. For more information, visit http://www.addicksandbarker.info/.

Developed and maintained by HCFCD, and located at the confluence of Garners and Greens Bayous northeast of Houston, the Greens Bayou Wetlands Mitigation Bank project combines

wetland creation, mitigation, and natural stormwater runoff treatment in a unique and highly beneficial manner. The Bank project provides a unique convergence of multiple ecosystems - a situation that makes the restoration and preservation of the area extremely valuable from both human and natural resource perspectives, while the stormwater surge basin optimizes the ability to capture large volumes of runoff during major storm events. For more information, please visit http://www.hcfcd.org/greensbayou_wmb.html.

The City and HCFCD have integrated the enhancement of natural and beneficial functions into their infrastructure design criteria for stormwater detention storage and water quality (pollution prevention). The design requirements have recently been augmented with requirements and recommendations for low impact development, including provisions for the design and construction of bio-retention facilities, infiltration trenches, porous pavement, and vegetative swales, among other practices and innovations. More information is provided at these two links:
http://documents.publicworks.houstontx.gov/documents/design_manuals/idm.pdf
http://www.hcfcd.org/downloads/manuals/2011-FINAL_LID_GIDC.pdf.

A map featuring open space in the SFHA has been included in Appendix H.

(f) Land use trends and potential vulnerability

In 2010, the total land area within the city of Houston's incorporated boundaries was 617.5 square miles (395,200 acres). Between 1990 and 2010, the City annexed 36.02 square miles, which is a 6% increase in area (23,053 acres). The largest portion of this annexation is the Kingwood area; other large annexations occurred near Clear Lake and the Addicks Reservoir. Land uses within the city of Houston are classified according to the following land-use categories: vacant, single-family, multi-family, commercial, office, industrial, agricultural, parks and open space, public and institutional, transportation, roads, and water.

While the city does not have zoning restrictions, some regulation of land use does exist in City ordinances. The FMPC recognizes that the way in which land is utilized, especially land within known hazard-prone areas, is a key measure of community vulnerability because some land uses, such as for residential or industrial development, can be more susceptible to disaster-related damages than others.

# Section 6 – Goals and objectives

Natural hazards cannot be eliminated, but with effective mitigation, their detrimental effects can be reduced. FEMA and the State of Texas encourage local governments to take action in order to protect citizens from the devastating effects of natural hazards and to maintain their communities' sustainable growth. Mitigation actions provide a way for communities to protect themselves from the potentially devastating effects of a natural hazard. FEMA defines mitigation as "any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards." The State of Texas established the following mitigation goals as part of its State of Texas Mitigation Plan (approved by FEMA on October 27, 2004), and these goals are also the foundation of the FMP for the City of Houston:

- Reduce/eliminate hazardous conditions that inflict injuries or cause loss of life.
- Reduce/eliminate hazardous conditions that cause property damage.
- Reduce/eliminate hazardous conditions that degrade important natural resources.

Concurrently, the City also follows the goals listed below that were established by the NFIP:

- Reduce loss of life and property caused by flooding.
- Reduce rising disaster relief costs caused by flooding.
- Make affordable federally backed insurance coverage available to property owners.

The City is responsible for developing goals, objectives, and mitigation actions that are consistent with the State's goals and those of the NFIP. Goals and objectives identified by the FMPC are also aligned with outreach projects in the City's CRS program. According to the State of Texas Local Mitigation Planning Handbook, the procedures below should be followed in order to align the FMP with the State plan.

- Goals to reduce hazard vulnerability and risk should always be coordinated with the City's Capital Improvement Plan.
- The FMP reflects what the City would like to see happen in the future, and guides other local measures such as capital improvements, and subdivision ordinances.
- The FMP incorporates mitigation strategies identified to regulate new development in hazard-prone areas, and encourages practices that are consistent with disaster-resistant community goals.

Following the establishment of goals for the FMP, the FMPC developed objectives as a bridge from the goals to mitigation actions. The objectives on the following page break down the goals into more concrete ideas and tie in to concepts that can help achieve the mitigation actions set forth by the FMPC. The mitigation actions in Section 8 include reference to these specific objectives.

**1.0 Protect existing properties.**

*Objectives:*

1.1 Use the most effective approaches to protect buildings from flooding, including acquisition or relocation where warranted.

1.2 Enact and enforce regulatory measures that ensure new development will not increase flood threats to existing properties.

1.3 Use appropriate actions to mitigate against the danger and damage posed by other hazards.

**2.0 Protect health and safety.**

*Objectives:*

2.1 Advise public of safety/health precautions to take against flooding and other hazards.

2.2 Improve traffic circulation during floods and at other times.

2.3 Improve water quality and habitat.

**3.0 Improve the quality of life in the community.**

*Objectives:*

3.1 Preserve and improve the downtown core of businesses and services.

3.2 Ensure that current owners can maintain and improve their properties.

3.3 Use acquisition programs to expand open space and recreational opportunities.

3.4 Maintain attractive public open spaces.

**4.0 Reduce the impact of natural disasters on people and property.**

*Objectives:*

4.1 Promote studies and projects that support natural resource protection.

4.2 Develop and implement programs that remove or relocate residential structures from highly vulnerable areas.

4.3 Enforce measures that regulate new development in high hazard areas.

**5.0 Improve communication and coordination with other relevant organizations.**

*Objectives:*

5.1 Establish and maintain lasting partnerships and mutual aid agreements.

5.2 Encourage capability to perform hazard risk assessments and track mitigation activities.

5.3 Improve quantity and quality of information on hazard identification and vulnerable assets and populations.

The goals established by the FMPC are considered broad, general guidance that define the long-term direction of the planning. The objectives define actions or results that can be placed into measurable terms by the committee, and translated into specific assignments for implementation by the participants and associated agencies and organizations.

## Section 7 – Review possible activities

Coinciding with the development of mitigation actions, the FMPC first reviewed possible activities to consider what actions could be a result of existing mechanisms and what activities could be achieved with future modifications to those mechanisms.

(a) Preventative activities

**Planning –** The City developed drainage criteria manuals and guidance for flood loss mitigation such as the "Minimum Requirements for Internal (Site) Drainage" (published in 2000). Through Chapter 42 of Houston's Code of Ordnances, the City regulates certain standards on new development or redevelopment based upon the applicant's proposed land uses in subdivision plat applications. The subdivision review process provides a comment opportunity for departments and agencies to ensure compliance with regulatory requirements prior to plat recordation.

**Open space preservation –** Recognizing the always increasing development rates within the City, the FMPC realizes the importance of open space preservation in an attempt to offset the amount of impervious cover and restore the city's open areas. Along the same lines is a project spearheaded by the HCFCD called the Vegetation Management Program. This project restores natural landscapes around the city, and offers stormwater drainage while also protecting the environment.

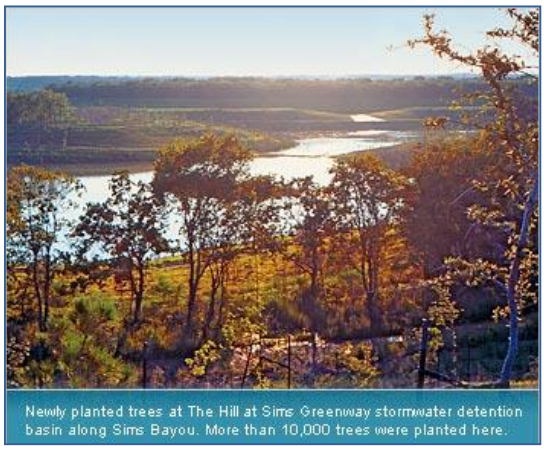


*Photo Courtesy of HCFCD*

Vacant tracts adjacent to existing streams, channels, and bayous are not permitted to develop within the proposed ultimate right of way of the stream, channel, or bayou. HCFCD reviews plans for development adjacent to HCFCD-maintained drainage facilities as part of the City of Houston building permit process. During this review, HCFCD ensures that open space is maintained adjacent to their facilities.

The City's special flood hazard area includes 26,555 acres of park land and 8,814 acres of HCFCD right of way, and 164 acres of other open space for a total of 35,533 acres of open space within the floodplain of the City of Houston. Open space in the SFHA is shown on a map in Appendix H. The City is committed to maintaining these open spaces.

**Floodplain regulations –** The City has adopted Chapter 19 of the Code or Ordinances that require higher standards for floodplain regulations than the NFIP minimum. The City requires the lowest floor of new or substantially improved structures located within the floodplain to be elevated so that it is a minimum of 2.0' above the base flood elevation. Development within areas designated as floodways can occur only if a registered professional engineer licensed in the State of Texas submits supporting documentation or an engineering analysis certifying that the bottom of the lowest horizontal structural member of a structure, excluding pilings or columns, will be elevated at least 18 inches above base flood elevation. The engineer must also confirm that the cumulative

effect of the proposed development will result in a zero increase in flood levels at any point within the City during the occurrence of the base flood discharge. Also, the construction may not impede the flow of floodwaters and the construction will not result in an adverse effect on the carrying capacity of the 100-year floodplain during the occurrence of the base flood discharge (Section 19-43, Houston Code of Ordinances). Critical facilities are afforded additional protection; if located within the 0.2% probability flood zone and the special flood hazard area, the lowest floor must be elevated 12 inches above the 500-year flood elevation. Chapter 19 also provides that no net fill be placed below base flood elevation in the special flood hazard area. The City Engineer and staff are empowered to enforce the provisions of the Chapter with citations and stop work orders. The City also published Guidelines to assist in the understanding of the floodplain ordinance. Chapter 19 was last updated in February 2009. The latest version of the Guidelines was published in May 2009. Chapter 19 is administered by qualified staff. The City of Houston Floodplain Management Office is staffed by twelve certified floodplain managers (CFMs). City staff includes a total of 32 CFMs.

**Building codes –** The City of Houston adopted the 2012 International Building Code and City of Houston Amendments effective November 10, 2015. The City's Building Code Effectiveness Grade Schedule Classification is 4 based the last review in 2010. The Building Code Effectiveness Grading Schedule (BCEGS®) assesses the building codes in effect in a particular community and how the community enforces its building codes, with special emphasis on mitigation of losses from natural hazards.

**Stormwater management –** The City's stormwater management regulations are codified in Chapter 47 of the City of Houston Code of Ordinances and are in Chapters 9 and 13 of the City's Infrastructure Design Manual. The City's stormwater management regulations address Low Impact Development design criteria, best management practices for storm water quality and criteria for the management of stormwater quantity including detention requirements and internal subsurface drainage requirements. Chapter 47 of the Code of Ordinances was last updated in 2006. Infrastructure Design Manual Chapters 9 and 13 were last updated in 2015.

**Drainage system maintenance** – The City of Houston inspects its drainage system, removes debris, and evaluates and takes steps to correct drainage problem sites either through CIP maintenance projects or regular maintenance activities. The City's drainage system consists of all natural and human-made watercourses, conduits, and storage basins that must be maintained in order to prevent flood damage to buildings from smaller, more frequent storms. In the City, this includes streets, roadside ditches, underground storm sewers, and inlets, as well as open channels and detention basins. The majority of the major open channel systems and detention basins within the City limits are operated and maintained by HCFCD. For all City-maintained portions of the drainage system, the system is inspected annually, after storms, and after other events that could cause damage and in response to complaints. Action is taken if an inspection identifies a need for maintenance or cleaning in accordance with the City's drainage maintenance procedures. Maintenance records are data points for needs analysis for storm sewer project development.

(b) Property protection activities

**Acquisition/relocation –** The City of Houston works cooperatively with the HCFCD to mitigate the vulnerability of flood prone (repetitive loss) properties within the city limits through the voluntary acquisition program conducted by HCFCD under FEMA guidelines. The HCFCD also conducts a Right-of-Way acquisition program to acquire properties when property is needed for capital projects such as channel widening and regional detention construction (Section 7(e)). Right-of Way acquisition may also serve to eliminate flood-prone properties, but that is not the intent of this acquisition program.

Voluntary home buyout is used by HCFCD and the City to reduce damage and losses caused by flooding from bayous, creeks and smaller waterways that feed into the bayous in areas where a structural flood damage reduction project, such as widening the channel or constructing a stormwater detention basin, is not considered to be cost effective or beneficial. When elevation or modification of a building located in a special flood hazard area is not practical, purchase and removal may be the most effective and efficient way to prevent future losses.

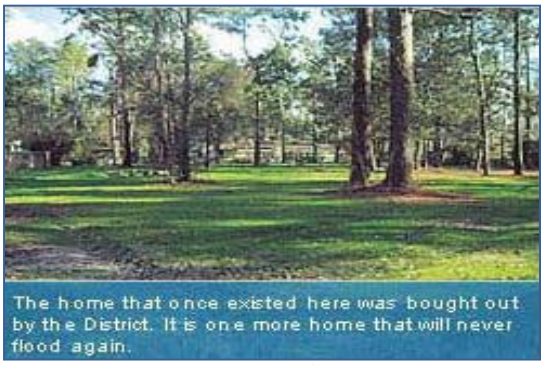


*Photo Courtesy of HCFCD*

In order for a property to meet FEMA's eligibility requirements for a grant-funded voluntary buyout, it must meet the following criteria:

- The property's purchase must be cost beneficial. In simplest terms, a property is considered cost beneficial if the cost of acquiring and demolishing the property is less than the cost of the estimated future flood damages to the property.
- The property must have a current flood insurance policy for certain FEMA mitigation grant programs (Severe Repetitive Loss (SRL) and Flood Mitigation Assistance (FMA)).

In order for a property to meet the HCFCD eligibility requirements, it must meet one or more of the following criteria:

- The property's source of the flooding must be from a bayou, creek, or smaller waterway that feeds into the bayou system.
- The property must be located in a mapped floodplain and subject to repetitive flooding.
- Voluntary buyout must be the most cost-effective and beneficial solution to the property's flooding problem (as opposed to a structural solution, such as a channel improvement or detention basin).
- The property must be strategically located for potential or future flood damage reduction projects and/or floodplain preservation.
- The property must help prevent or decrease the "checker-boarding" effect within neighborhoods where other voluntary buyouts have occurred.

Properties that meet both the FEMA and HCFCD criteria are selected for the voluntary acquisition program based on the benefit/cost ratio (BCR). The greater the BCR associated with a property, the higher the priority for acquisition. On occasion, a specific property or properties may be targeted for acquisition with a lower BCR if acquisition benefits another flood reduction measure; however, the property must still meet all FEMA and HCFCD eligibility requirements. Properties with low BCRs (<1.0) may also be bundled with higher scoring properties to form a project with an overall favorable BCR (≥1.0).

More information on both HCFCD acquisition programs (SRL and FMA) is available at: http://www.hcfcd.org/acquisition/

(c) Natural resource protection

**Wetlands protection** – The Greens Bayou Wetlands Mitigation Bank is a project administered through the HCFCD that also benefits the city of Houston. The project focuses on mitigation banking, a concept that provides sustainable ecological benefits and wetlands restoration activities to an area that would otherwise be susceptible to adverse impacts from human activity. Mitigation credits are offered to developers such that the builders can pay a one-time fee to meet the wetlands mitigation requirement. The project is described in more detail including a virtual tour at www.hcfcd.org/greensbayou_wmb.html.

(d) Emergency services

**Hazard warning and response –** The City of Houston Office of Emergency Management has enhanced its emergency services activities in recent years, putting more emphasis on preparedness as well as recovery. The "Hurricane and Disaster Preparedness Guide" revised in June 2015 (available for download on the OEM website at http://www.houstonoem.net) provides helpful information to citizens including how to build an emergency kit, transportation assistance for hurricanes, evacuation zones and maps, preparedness tips for people with functional support needs, how to get involved with the Community Emergency Response Team (CERT), a directory of helpful telephone numbers, and descriptions and tips for other hazard events besides flooding such as extreme heat, lightning, and winter storms. The guide is published in six languages to appeal to all citizens in the area.

HCFCD also maintains a Flood Warning System (FWS) that measures rainfall amounts and monitors water levels in bayous and major streams on a real-time basis (data may be delayed up to five minutes) to inform citizens of dangerous weather conditions. The system relies on 133 gage stations strategically placed throughout Harris County bayous and their tributaries. The stations contain sensors that transmit valuable data during times of heavy rainfall and during tropical storms and hurricanes. Some gages also measure wind speed and direction, barometric pressure, air temperature, road temperature and humidity. The FWS is used by HCFCD and by Harris County's Office of Homeland Security and Emergency Management to inform citizens of imminent and current flooding conditions along bayous. It also is used by the National Weather Service to assist in the issuing of flood watches and warnings. Accurate rainfall and bayou/stream level data assists the public and emergency management officials to make critical decisions that ultimately can reduce the risk of property damage, injuries and loss of life.

The City of Houston is one of four members in the Transtar partnership that provides transportation information and emergency management services to the city. In addition to providing real-time information on traffic situations, Transtar also offers state-of-the-art technology to convey emergency conditions to the public. The Doppler Radar Imagery, Satellite Weather Maps, Automated Flood Warning System, Road Flood Warning Systems, and the Regional Incident Management System comprise some of the tools used to address the emergency. For more information, please visit http://www.houstontranstar.org/about_transtar/.

(e) Structural projects

The City of Houston, Harris County, and the USACE work cooperatively to reduce the vulnerability of persons and property in the city of Houston to the impacts of flooding through structural improvement projects.

**Major Channel Improvements and Regional Detention Facilities –** Typically, HCFCD and the USACE conduct improvement projects for main channels in Harris County. In addition, HCFCD constructs major regional detention basins to store peak stormwater volume during severe rainfall events. Recently, HCFCD has initiated comprehensive Watershed Master Plans for each of the major watersheds in Harris County. The Watershed Master plans will address the current and anticipated needs for new or improved stormwater and flood damage reduction infrastructure for each watershed. HCFCD implements flood damage reduction plans by taking elements of the plans and defining projects from those elements, programming each project in an annual Active Projects (CIP), and executing each project. Harris County Commissioners Court approves projects and funding for the HCFCD five-year CIP. Major channel improvement projects for Brays Bayou and Sims Bayou that are ongoing and will result in a reduction in the flood hazard along these channels provide examples of these types of projects. A thorough explanation of HCFCD project funding, CIP development, and major project status is available at: http://www.hcfcd.org/cip.html.

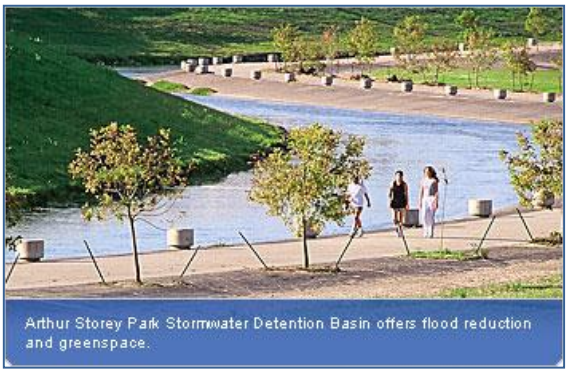


*Photo Courtesy of HCFCD*

**Storm Drainage System Improvements and Sub-Regional Detention Facilities –** Through the Rebuild Houston initiative, the City of Houston Department of Public Works and Engineering identifies, evaluates, programs, and constructs capital improvement projects for stormwater drainage system upstream of the main HCFCD channels. These projects involve both large scale and localized improvements to storm sewer systems and may also involve construction of some detention facilities. Project programming in the five-year CIP is limited by funding availability and is based on the criteria and process described in the following narrative.

Storm drainage systems include infrastructure to handle both the Design Event (more common) and the Extreme Event. These are designed as coordinated systems: the Design Event system is utilized during every rainfall event and the Extreme Event system is used for larger, less frequent

rain events. Storm drainage needs are determined for the existing storm drainage systems across the city.

The Design Event is the smaller rain event, typically one to two inches of rain over the course of an hour. The Design Event is the rainfall event that storm sewer pipes and roadside ditches are designed to carry. Specific criteria for Design Event Level of Service are:

- Curb and gutter: 2-year hydraulic grade line (HGL) below gutter line
- Roadside ditch: 2-year HGL 6" below edge of pavement
- For local streets (residential): width of one lane passable during the 2-year storm

The Extreme Event is the higher volume, but less frequent, event (100-year rainfall event) and is defined as approximately 12 to 13 inches of rainfall over 24 hours. During the Extreme Event, the pipes or roadside ditches are overwhelmed, and the road or overland system carry the excess water to the bayou. This runoff should be carried within the public right-of-way. Houston's streets constructed since the mid-1980s are designed to convey stormwater when more rain falls than the design system can carry. Streets constructed prior to that time were not specifically designed to address the Extreme Event Level of Service, which is established with the 100-year water surface elevation below the maximum ponding elevation. The maximum ponding elevation is established to prevent structural flooding and is the lowest of the following:

- Natural ground at the right-of-way line,
- Curb and gutter: 6" above top-of-curb at pavement high points,
- Curb and gutter: 18" above top-of-curb at pavement low points, or
- Roadside ditch: below slab or finished floor elevation of any adjacent structure.

Need is assessed for each infrastructure component as the first step in identifying areas in need of infrastructure improvement, and the need is determined based on the defined or acceptable level of service established for each component. Areas which do not meet the defined level of service standards have a need for infrastructure improvement.

The existing infrastructure is evaluated against these levels of service to identify need. The design event drainage system has not been analyzed citywide. The City's Comprehensive Drainage Plan analyzed most of the city currently served by pipes. Areas that had interconnected pipe systems, or that were served by roadside ditches, were not analyzed for capacity. For these areas, other observations such as documented structural flooding and streets that must pond to more than two feet of depth (currently based on LiDAR information) before flowing toward the bayou are used to determine adequacy that is used to indicate a need.

The City has developed and is now utilizing a GIS-based tool to identify and prioritize problem areas citywide in need of drainage improvement. The tool, called Storm Water Enhanced Evaluation Tool (SWEET), uses objective criteria to develop a ranked list of the highest priority needs areas across the city, and is also used to prioritize candidate storm drainage projects. The projects selected for program funding have the highest need for drainage improvements. Each project will be designed to contain the standard design rainfall runoff in the underground storm pipe or roadside ditch. Each project has the objective of reducing the potential for structural

flooding by containing the rainfall runoff from the extreme event in the public right-of-way to protect adjacent properties.

Storm drainage need is prioritized by a combination of factors that indicate an inability of infrastructure to address storm drainage needs – primarily resulting in structural flooding. SWEET allows the weighting of specific parameters to prioritize need areas citywide. These parameters are combined within a uniform grid system to allow comparison citywide. The grid system utilized is the Lambert map system or grid that is also used by the Harris County Appraisal District. There is not currently a citywide analysis of the design event and extreme event drainage systems. Since there is not a single analysis to compare citywide, the SWEET utilizes several citywide databases to allow for comparison.

These databases include existing storm drainage analyses, other city databases that represent the capacity of the existing storm infrastructure, surface flow data derived from LiDAR, existence of structural flooding and drainage impacts to mobility. These include documented flooding (structural and non-structural), flood insurance claims and repetitive losses, flooding that makes streets impassable and underpasses with documented flooding.

The SWEET evaluates parameters related to the need for drainage improvements and creates a need score for each Lambert grid. Weighting factors for each parameter are reviewed each year based on input from stakeholders and the evolution of drainage priorities, and then is revised if appropriate. The SWEET calculates a score for storm drainage needs and then allows for ranking those need areas across the city. Higher scores indicate greater need. The following table illustrates the Storm Drainage Need Prioritization Weighting Factors.

| Parameter | Percent |
|---|---|
| **Capacity of Existing Storm Drainage System** | **38%** |
| Design Event System Adequacy | 40% |
| Extreme Event System Adequacy | 20% |
| Reported Non-Structural Flooding | 40% |
| **Existence of Structural Flooding** | **38%** |
| Reported Structural Flooding | 65% |
| Flood Insurance Claims | 35% |
| **Drainage Impacts to Mobility** | **24%** |
| Reported Street Impassable Flooding | 100% |

Properties adjacent to HCFCD channels or located in a special flood hazard area are susceptible to riverine flooding. Riverine flooding is most commonly attributable to channels with a low level of service that reach capacity and flood waters spill over the top of bank. The Storm Drainage Program may not protect properties from the adverse impacts of overbank flooding until the HCFCD completes complementary channel capacity improvement projects.

Sub-regional detention projects are identified in response to solution development of prioritized storm drainage needs or in coordination with other agencies and infrastructure improvement projects. The SWEET programming tool is not currently used to prioritize and rank regional detention projects.

Once the areas of highest need have been prioritized, solutions to address those needs can be developed into a specific project. Pre-engineering is the tool for defining the problem, finding the source of the problem (even if outside the identified Need Area) and evaluating possible solutions. Extent of surface drainage impacting the Need Area will be a high priority to determine.

During pre-engineering, priority areas of need for street and drainage improvements will be compared to priority areas of need for water and wastewater upgrades. In addition, coordination with entities such as Harris County, HCFCD, other drainage districts, TxDOT, and METRO will be required to coordinate regional planning efforts and to incorporate priority and/or scheduling considerations for infrastructure improvements which meet the needs of or support critical regional transportation or flood control efforts. For example, structural flooding may be the result of inadequate bayou or stream capacity and require the involvement of HCFCD to resolve the identified need.

Additionally, mitigation needs are determined for each solution as required to address potential for impacts, particularly to storm drainage. As individual drainage projects are implemented across the city, improved conveyance may lead to increased discharges to receiving streams or bayous. To maintain the existing level of protection as defined by the designated special flood hazard area as shown in the effective FIRMs and supporting models and studies, it may be necessary to mitigate impacts to receiving streams or bayous. While this may be accomplished on a project by project basis, this can also be accomplished through the construction of regional or sub-regional mitigation.

The pre-engineering process results in the creation of candidate projects which will be considered for inclusion in the CIP during the programming phase. When a candidate project is identified, it is referred for programming. During the programming phase, candidate projects are ranked and prioritized based on the candidate project priority score for programming into the CIP. A complete explanation of the storm drainage CIP process can be found in a document titled "Capital Improvement Plan Process Manual for Infrastructure Programs" (July 18, 2012) at http://www.rebuildhouston.org/projects/capital-improvement-plan-process-manual-for-infrastructure-programs.html.

A map illustrating storm drainage needs as indicated by the SWEET process is included in Appendix I.

(f) Public information activities

**Map information –** The City publicizes a great deal of map information on its website (http://www.houstontx.gov/) and through the website for the Storm Water Management Program (SWMP) (http://www.swmp.org).

On the SWMP site, any user is able to access the GIS-based flood maps online and can find address-specific information such as floodplain and floodway boundaries, base flood elevations,

contours, Harris County Appraisal District records, overland flow paths, CIP project areas, aerial photography, and FIRM attributes such as panel numbers and Letters of Map Changes.
The City's Floodplain Management Office (FMO) also updated their Home Page as part of the 2016 CRS Reverification. The link is user-friendly and provides residents comprehensive flood information on a variety of topics including, but not limited to, flood risk, flood insurance, flood mitigation options, and warning and disaster preparedness. The FMO page may be accessed at https://www.publicworks.houstontx.gov/floodplain.html

**Outreach projects –** City staff regularly commits to conducting presentations to local groups in order to provide awareness and education about flooding hazards. In accordance with the CRS activity for outreach, the City has been sending letters annually to property owners both in and out of the floodplain and including information on development requirements, flood insurance, drainage system maintenance information, safety tips, and other City matters relating to floodplain management. A number of new outreach projects as part of the CRS program have been identified in the 2016 'Program for Public Information' (PPI). These projects will be implemented in 2016-2017.

**Library –** The downtown branch of the Houston Public Library is home to a multitude of flood damage reduction resources including FEMA publications on floodproofing and retrofitting, as well as the effective FIRMs and FIS documents. FIRMs have been distributed to all library branches and future revisions will be distributed to each branch and made available to the public upon receipt from FEMA.

**Environmental education –** The "ReadyHouston" campaign (www.readyhoustontx.gov) is another example of how involved the City is with getting information to the public. "ReadyHouston" targets people of all ages in Houston who need to be prepared for disaster events through making a plan, building a kit, and staying informed. The website includes information on how to order the free 15-minute DVD (available in four languages and a captioned version), and also links viewers to educational materials for kids such as coloring books, posters, teaching curriculum, songs, and filmed and live performances of the Ready Super Heroes. All of these materials are free.

# Section 8 – Draft an action plan

This section of the FMP provides information on proposed and ongoing mitigation actions for the five-year time horizon covered by this document. Additional activities that do not appear in this current list will be identified and initiated during that time frame. Those actions are identified in the 2014 Progress Report discussed in Section 10. Status of mitigation actions were updated in the 2016 FMP.

Each activity has been assigned a priority ranking of high, medium, or low. Only one of the proposed activities is assigned a low priority and only one is considered a medium priority. In the current and expected economic environment, low and medium priority actions rarely receive consideration for implementation.

Capital projects conducted by the City of Houston and HCFCD are all high priority. The City has over a billion dollars in identified and needed storm drainage infrastructure improvements. Any project that makes it to the five-year Storm Drainage CIP is a high priority project. Likewise, channel improvement capital improvement projects funded by the HCFCD and USACE have a high priority, as these measures serve to reduce the risk of flooding in areas such as the Texas Medical Center, an extremely valuable asset for the city, nation, and global community. Project Brays is reducing the risk of flooding in the Texas Medical Center where severe flooding occurred during Tropical Strom Allison in 2001.

Mitigation actions financed through FEMA grant funding are high priority. These federal funds must be used for the purpose for which they were applied and cannot be diverted to some other action that may appear at some future time to be a higher priority without the express consent of FEMA. With that explanation, the FMPC offers the following mitigation actions corresponding to the specified goals and objectives, and addressing the mitigation categories identified in Section 7 of this plan.

| Mitigation Action | |
|---|---|
| **Title** | **Improvements to Floodplain Management Regulations** |
| **Category** | Preventative - Flooding |
| **Objective(s)** | 1.2; 4.3 |
| **Description** | Project provides for the evaluation and revision of Chapter 19, the City of Houston Floodplain Management Ordinance and Guidelines as needed. The process will determine if the implementation of additional higher standards and/or changes to administrative procedures are warranted. |
| **Department** | Public Works and Engineering; Floodplain Management Office |
| **Timeframe** | 2015 |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | High |
| **Benefit** | Improved mitigation of flood damage and loss. Additionally, implementation of additional higher standards could result in an improvement of the City's CRS score and an increased discount to NFIP policyholders in Houston. |

**Status as of April 2016**

Ongoing updates to coincide with CRS program to increase Class Rating

| Mitigation Action | |
|---|---|
| **Title** | **Improvements to Storm Water Management Regulations** |
| **Category** | Preventative - Flooding |
| **Objective(s)** | 1.2; 4.3 |
| **Description** | Project provides for the evaluation and revision of Chapter 9, Storm Water Design Requirements, and Chapter 13, Storm Water Quality Design Requirements of the City's Infrastructure Design Manual (IDM). All of the chapters of IDM are reviewed and revised on a rotating five-year cycle to ensure that the manual's design criteria incorporate changes in technology, construction practices, related regulations, and the goals of the community. |
| **Department** | Public Works and Engineering; Office of City Engineer; Standards Review Section |
| **Timeframe** | 2014 |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | High |
| **Benefit** | Improved storm water management regulations will improve drainage in the City related to new private and public projects. Improved drainage will reduce the likelihood and frequency of street and structural flooding. Additionally, implementation of changes to storm water management regulations could result in improvement of the City's CRS score and an increased discount to NFIP policy holders in the City of Houston. |

**Status as of April 2016**

Chapter 9, Storm Water Design, and Chapter 13 Storm Water Quality drafts pending final adoption by the City. The draft of Chapter 9 is available for review at http://edocs.publicworks.houstontx.gov/engineering-and-construction/standards-review-committee/2013-stormwater-revisions/chapter-9.html.

| Mitigation Action | |
|---|---|
| **Title** | **Arbor Oaks Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 244 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 155 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Glenburnie/Cashiola Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 134 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 34 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Wood Shadows, Section 2 Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 127 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 45 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Lake Forest Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 71 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 22 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Lakewood Estates Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 70 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 13 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Home Owned Estates Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 55 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 39 acquisitions in this area were made in 2014. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Braeburn Glen Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 47 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | HCFCD's capital project funds and FEMA mitigation grant programs |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 12 acquisitions in this area were made in 2014. This is Ongoing as of 4/8/16. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Langwood Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 46 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

| Mitigation Action | |
|---|---|
| **Title** | **Wood Shadows Buyout Project** |
| **Category** | Property protection - flooding |
| **Objective(s)** | 1.1; 3.3; 4.2 |
| **Description** | Acquisition of 40 total parcels |
| **Department** | Harris County Flood Control District |
| **Timeframe** | As property owners volunteer for the voluntary project |
| **Cost** | Variable, dependent on owner participation |
| **Funding source** | |
| **Priority** | High |
| **Benefit** | An acquisition in this area would eliminate the repetitive loss properties that are a drain on the NFIP and restore the land to its natural function as a floodplain. |

**Status as of April 2016**

Mitigation action is ongoing. 22 acquisitions in Langwood area were made in 2014. This is Ongoing as of 4/8/16. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

**Status as of April 2016**

Mitigation action is ongoing. 24 acquisitions in Wood Shadows area were made in 2014. This is ongoing as of 4/8/16. See HCFCD https://www.hcfcd.org/our-programs/property-acquisition-program/

| Mitigation Action | |
|---|---|
| **Title** | **Improvements to the Disaster Assistance and Recovery Manual** |
| **Category** | Emergency Services - flooding; Post-disaster |
| **Objective(s)** | 1.3; 2.2; 5.2; 5.3 |
| **Description** | Project provides for the evaluation and revision of the Disaster Assistance and Recovery Manual (DARM) as needed based on feedback from deployment of the process described in the manual in a disaster event. |
| **Department** | Public Works and Engineering; Floodplain Management Office; Office of Emergency Management |
| **Timeframe** | Ongoing |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | Medium (The priority is ranked medium because the current DARM incorporates learning from previous events including Tropical Storm Allison and Hurricane Ike. The processes outlined in the manual have worked in the past. Optimization is desired, but not required.) |
| **Benefit** | This project will leverage feedback and lessons learned from deployment of the DARM to make improvements to the processes outlined in the manual. The result will be improved disaster response, assistance, and recovery. |

**Status as of April 2016**

Mitigation action is ongoing. The annual City of Houston Disaster Assistance and Recovery Training and a Review Session was held on July 2014. No changes were recommended at that time. No updates as of 4/8/16

| Mitigation Action | |
|---|---|
| **Title** | **Brays Bayou Flood Damage Reduction Project ("Project Brays")** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | Partnership project between the USACE and HCFCD; includes 21 miles of channel improvements, several stormwater detention basins, and environmental enhancements along Brays Bayou and some of its tributaries. |
| **Department** | Harris County Flood Control District |
| **Timeframe** | Ongoing, scheduled for completion in 2014 |
| **Cost** | $450 million |
| **Funding source** | HCFCD - 50%, Federal funding - 50% |
| **Priority** | High |
| **Benefit** | Significantly reduces the potential for flood damage along the channel including area occupied by the Texas Medical Center. |

**Status as of April 2016**

Mitigation is action ongoing. See below for construction activity update per Harris County Flood Control District.

**Construction Activities Update**
**Jul-14**
*(Schedule is updated quarterly)*

**Completed Construction**
*The following chart highlights construction that has been completed as of July 2014, as well as each project's total percent completion to date.*

| Project | Segments Complete | Total % Complete |
|---|---|---|
| Eldridge Road Basin | 8 (of 9) | 90% |
| Old Westheimer Basin and Upstream Channel Modifications | 3 (of 3) | 100% |
| Arthur Storey Park Basin | 12 (of 12) | 100% |
| Willow Waterhole Basin | 4 (of 8) | 60% |
| Channel Modifications | 7 (of 13) | 56% |
| Bridges | 9 (of 32) | 28% |

**Current Construction**
*The following construction projects are currently under construction.*

| Project | Segment | Start* | Finish* |
|---|---|---|---|
| Eldridge Road Basin | 9 (of 9) | 3rd Quarter 2012 | 3rd Quarter 2014 |
| Bridges (Wheeler/Lidstone Bridge) | 10 (of 32) | 2nd Quarter 2013 | 3rd Quarter 2014 |
| Willow Waterhole Basin | 5 (of 8) | 2nd Quarter 2014 | 4th Quarter 2015 |

**Scheduled Construction Next 6 Months**
*The following construction projects are anticipated to begin in the next 6 months.*

| Project | Segment | Start* | Finish* |
|---|---|---|---|
| Control Structures | DS 19 | 1st Quarter 2015 | 4th Quarter 2015 |
| Channel Modifications, Lidstone to Calhoun | 8 (of 13) | 4th Quarter 2014 | 4th Quarter 2015 |
| Galveston RR Bridge | 11 (of 32) | 1st Quarter 2015 | 1st Quarter 2016 |
| Channel Modifications, Bertner to Buffalo Speedway | 9 (of 13) | 1st Quarter 2015 | 1st Quarter 2016 |

*Note: construction schedule is anticipated and subject to change.

| Mitigation Action | |
|---|---|
| **Title** | **White Oak Bayou Federal Flood Damage Reduction Project** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | Partnership project between the USACE and HCFCD; includes channel improvements and detention storage along the upper portion of White Oak Bayou. Includes property acquisitions. |
| **Department** | Harris County Flood Control District |
| **Timeframe** | Ongoing, scheduled completion date not available at this time |
| **Cost** | $195 million |
| **Funding source** | HCFCD, FEMA, other Federal |
| **Priority** | High |
| **Benefit** | Will significantly reduce the potential for flood damage along the channel which extends from the suburban northwest to the central city. Areas along White Oak Bayou incurred extensive flood damage during TS Allison in 2001. |

**Status as of April 2016**

Mitigation action is ongoing. See below for construction activity update per Harris County Flood Control District. See https://www.hcfcd.org/projects-studies/white-oak-bayou-projects-studies/federal-flood-damage-reduction-project-white-oak-bayou/ for project timeline.

## ACTIVE MAINTENANCE PROJECTS

Cole Creek Erosion Repair Project – The Cole Creek Erosion Repair Project will repair and rebuild eroded side slopes of Cole Creek from its confluence with White Oak Bayou upstream to the Burlington Northern Santa Fe Railroad bridge east of Antoine Drive. Erosion has resulted in damage to the slopes and various storm sewer and outfall pipes in the project area. The maintenance project will include the removal and replacement of damaged outfall pipes and installation of buried riprap on the creek's slopes and toe line, which is the lowest point of a channel's banks. Riprap in Harris County is typically recycled concrete that is processed to fit together like natural rock. Riprap is usually buried to allow grass to grow over it and helps armor a channel's banks to prevent future erosion. Construction on the project began in early October 2012 and is expected to be complete in 2013. The project is estimated to cost $576,000. Project was completed on schedule in October 2013.

E127-00-00 Maintenance Project – The channel formally identified as HCFCD Unit E127-00-00 has experienced severe erosion that has created unstable banks and damaged outfall pipes. The E127-00-00 Maintenance Project will repair erosion and replace damaged outfall pipes along E127-00-00 and install a drop structure at the confluence of White Oak Bayou and E127-00-00. When water passes through a drop structure, it falls to a lower elevation. This structure helps slow the water's energy and velocity, thereby helping to prevent erosion. The overall goal of the project is to restore the channel's stability and improve its ability to convey storm water. The project will also replace damaged concrete slope paving along White Oak Bayou. Project construction is expected to begin in April 2013 and be complete in late 2013. Project was completed in late 2013.

| Mitigation Action | |
|---|---|
| **Title** | **Buffalo Bayou Detention Basin** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | Project addresses watershed storm water quantity and quality; includes construction of stormwater detention |
| **Department** | City of Houston Department of Public Works and Engineering |
| **Timeframe** | 2013-2014 (CFY2013-2017 CIP) |
| **Cost** | $6,847,000 |
| **Funding source** | City of Houston Stormwater Capital Projects/Rebuild Houston |
| **Priority** | High - On hold |
| **Benefit** | Project is necessary for mitigation of impacts resulting from combined stormwater drainage projects improvements in the vicinity of this project site. This project is under review based on public comment. Refer to Appendix B. |

**Status as of April 2016**

Mitigation action is ongoing. This project is currently on hold. The FY 2014 Capital Improvement Plan shows design funding in FY 2017.

| Mitigation Action | |
|---|---|
| **Title** | **Southpark and Southcrest Drainage and Paving** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | Project provides for the design and construction of storm drainage improvements, necessary concrete paving, curbs, sidewalks, driveways and underground utilities. |
| **Department** | City of Houston Department of Public Works and Engineering |
| **Timeframe** | 2013-2015 (CFY2013-2017 CIP) |
| **Cost** | $9,390,000 |
| **Funding source** | City of Houston Stormwater Capital Projects/Rebuild Houston |
| **Priority** | High |
| **Benefit** | Project will construct storm drainage improvements to address and reduce the risk of structural flooding. Improvements include modification of street conveyance and sheet flow, and provide detention as needed for mitigation. |

**Status as of April 2016**

Mitigation action is ongoing. Design is complete. Construction was substantially complete as of August 2014. As of 4/8/16 project was completed 2015 per the 2015-2019 CIP Summary.

| Mitigation Action | |
|---|---|
| **Title** | **Rampart Street Drainage and Paving** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | Project provides for the design and construction of storm drainage improvements in the area, necessary concrete paving, curbs, sidewalks, driveways and underground utilities. Project will serve the Westmoreland, Sharpstown, Breaburn, and Maplewood areas. |
| **Department** | City of Houston Department of Public Works and Engineering |
| **Timeframe** | 2012-2017 (CFY2013-2017 CIP) |
| **Cost** | $31,886,000 |
| **Funding source** | City of Houston Stormwater Capital Projects/Rebuild Houston |
| **Priority** | High |
| **Benefit** | Project will construct storm drainage improvements to address and reduce the risk of structural flooding. Improvements include modification of street conveyance and sheet flow, and provide detention as needed for mitigation. |

**Status as of April 2016**

Mitigation action is ongoing. Currently in design phase. Construction scheduled to begin August 2014. Construction is scheduled to be substantially complete by 4th quarter 2015. As of 4/8/16 project was completed 2015 per 2015-2019 CIP Summary.

| Mitigation Action | |
|---|---|
| **Title** | **Mitigation Program for Capital Improvement Projects** |
| **Category** | Structural - flooding |
| **Objective(s)** | 2.3; 3.4; 4.1; 5.1 |
| **Description** | This project provides for the right-of-way acquisition, design and construction of detention basins. This includes analyzing the feasibility of providing detention for mitigation of impacts due to City of Houston projects, existing infrastructure limited areas, and potential development. Preliminary engineering for regional detention projects for Halls, Little White Oak, Hunting, Sims, and White Oak bayous. |
| **Department** | City of Houston Department of Public Works and Engineering |
| **Timeframe** | 2012-2016 (CFY2013-2017 CIP) |
| **Cost** | $15,684,000 |
| **Funding source** | City of Houston Stormwater Capital Projects/Rebuild Houston |
| **Priority** | High |
| **Benefit** | The City constructs many projects that require determination and mitigation of impacts. Designing and contracting on a regional or sub-regional basis for multiple projects would reduce upfront and long-term maintenance costs at multiple sites. |

**Status as of April 2016**

Mitigation action is ongoing. This project is shown in the FY15 Capital Improvement Plan with funding from FY 2015 thru FY 2019. As of 4/8/16 funding was allocated each year. Ongoing.

| Mitigation Action | |
|---|---|
| **Title** | **Floodplain Information Outreach** |
| **Category** | Public information - flooding |
| **Objective(s)** | 2.1; 5.2; 5.3 |
| **Description** | Project provides for conveyance of floodplain information to the community by publishing floodplain information in the community section of the Yellow Pages phonebook. Flood insurance is promoted in the floodplain information and public information advertisements in the insurance section of the Yellow Pages phonebook. |
| **Department** | Public Works and Engineering; Floodplain Management Office |
| **Timeframe** | Ongoing |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | High |
| **Benefit** | Increased awareness contributes to compliance with floodplain regulations, purchase of flood insurance, and disaster preparedness. This activity is credited as part of the City's CRS submittal and contributes to the City's CRS rating which affords NFIP policy holders in the City of Houston discounted flood insurance premiums. |

| Mitigation Action | |
|---|---|
| **Title** | **Outreach to Floodplain Areas and Repetitive Loss Areas** |
| **Category** | Public information - flooding |
| **Objective(s)** | 2.1; 5.2; 5.3 |
| **Description** | Project provides for sending a letter with floodplain information to all special flood hazard area and repetitive loss area property owners. |
| **Department** | Public Works and Engineering; Floodplain Management Office |
| **Timeframe** | Ongoing |
| **Cost** | $5,000; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | High |
| **Benefit** | Increased awareness contributes to compliance with floodplain regulations, purchase of flood insurance, and disaster preparedness. This activity is credited as part of the City's CRS submittal and contributes to the City's CRS rating which affords NFIP policy holders in the City of Houston discounted flood insurance premiums. |

**Status as of April 2016**

Mitigation action is ongoing based on CRS Program Reverification. Annual outreach letter to be posed in Yellow Pages phone book each March

| Mitigation Action | |
|---|---|
| **Title** | **Outreach on Improvements to Storm Water Management Regulations** |
| **Category** | Public information - flooding |
| **Objective(s)** | 2.1; 5.2; 5.3 |
| **Description** | Project provides for the evaluation and revision of Chapter 9, Storm Water Design Requirements, and Chapter 13, Storm Water Quality Design Requirements of the City's Infrastructure Design Manual (IDM). All of the chapters of IDM are reviewed and revised on a rotating five year cycle to ensure that the manual's design criteria incorporate changes in technology, construction practices, related regulations and the goals of the community. |
| **Department** | Public Works and Engineering; Floodplain Management Office; Standards Review Section |
| **Timeframe** | 2013 |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | High |
| **Benefit** | Improved storm water management regulations will improve drainage in the City related to new private and public projects. Improved drainage will reduce the likelihood and frequency of street and structural flooding. Implementation of changes to storm water management regulations could result in improvement of the City's CRS score and an increased discount to NFIP policy holders in the City of Houston. |

**Status as of April 2016**

Mitigation action is ongoing. Draft regulations are currently under review and pending implementation. Draft Chapter 9 is available for review at http://edocs.publicworks.houstontx.gov/engineering-and-construction/standards-review-committee/2013-stormwater-revisions/chapter-9.html

| Mitigation Action | |
|---|---|
| **Title** | **Improvements to Map Information** |
| **Category** | Public information - flooding |
| **Objective(s)** | 2.1; 5.2; 5.3 |
| **Description** | Develop an upgraded GIS interface to provide improved web-based map information to the community. Incorporate preliminary maps, historic maps, and more current map changes into the GIS interface. |
| **Department** | Public Works and Engineering; Floodplain Management Office; Public Works and Engineering, Engineering and Construction Division |
| **Timeframe** | Ongoing |
| **Cost** | $0; staff time |
| **Funding source** | City of Houston Operating Budget |
| **Priority** | Low (The priority of this action is ranked low because the existing GIS interface and consultation with the Floodplain Management Office Staff provides the public with adequate map information service. This project will reduce the need for consultation staff.) |
| **Benefit** | Increased awareness contributes to compliance with floodplain regulations and purchase of flood insurance. This activity is credited as part of the City's CRS submittal and contributes to the City's CRS rating which affords NFIP policy holders in the City of Houston discounted flood insurance premiums. |

**Status as of April 2016**

Mitigation action is ongoing. Phase I of planned upgrades to the city GIS system were completed in August 2014. FMO is developing a project scope for additional phases of work..

| Mitigation Action | |
|---|---|
| **Title** | **Sheltering Project** |
| **Category** | Post-disaster; Other hazards - hurricane, tropical storm, tornado |
| **Objective(s)** | 1.3; 2.1; 5.2; 5.3 |
| **Description** | 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 required retrofit enhancements needed for each facility identified. Identify capacity of each facility to house refugees. |
| **Department** | Public Works and Engineering; Office of Emergency Management |
| **Timeframe** | Two to three years after grant funds are available |
| **Cost** | $100,000 |
| **Funding source** | HMGP funds, Office of Emergency Management Operating Budget |
| **Priority** | High |
| **Benefit** | 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 use as refuges of last resort or as host to evacuees from other areas. |

| Mitigation Action | |
|---|---|
| **Title** | **Data Collection Improvement** |
| **Category** | Other hazards - expansive soils |
| **Objective(s)** | 1.3; 5.2; 5.3 |
| **Description** | Improve the data collection capabilities of expansive soils incidents. This may include using the City's 3-1-1 help line 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 and the most vulnerable facilities could then be identified. |
| **Department** | Office of Emergency Management |
| **Timeframe** | Two to three years after grant funds are available |
| **Cost** | $100,000 |
| **Funding source** | HMGP funds, Office of Emergency Management Operating Budget |
| **Priority** | High |
| **Benefit** | Improve information and data that is needed and will be used to protect critical facilities and general population of city. |

**Status as of April 2016**

Mitigation action is ongoing. Projects awaiting funding.

## Section 9 – Adopt the plan

Following approval of the FMPC, the plan was adopted by the City Council. The resolution documenting the adoption is included in Appendix K.

## Section 10 – Implement, evaluate, and revise

(a)(b) Evaluation reporting

The City Floodplain Manager will be responsible for monitoring FMP implementation, reviewing progress, and recommending revisions to the plan in an annual report to be submitted to the FMPC. The Floodplain Manager directs the City Floodplain Management Office and is directly responsible to the City Engineer who, in turn, reports to the Deputy Director for Planning and Development Services. All three positions, as well as the Director of Public Works and Engineering, serve on the FMPC. The City Floodplain Management Office is responsible for reviewing applications and issuing permits for development within the regulatory floodplain located within the corporate city limits of Houston. The City Floodplain Management Office is also responsible for administering and enforcing all provisions of Chapter 19, City of Houston Code of Ordinances, and for managing the City's participation in the CRS.

The Floodplain Manager meets routinely with staff of the HCFCD regarding activities of mutual interest to the City of Houston and HCFCD which includes monitoring implementation and reviewing progress of CRS mitigation actions administered by HCFCD. The Floodplain Manager will monitor implementation and review progress on the FMP with all entities within the City of Houston government on a routine basis, but not less than annually. These functions may be carried out by telephone call, email, meetings, or site visits as may be appropriate.

The Floodplain Manager will evaluate their progress toward achieving the objectives of the FMP. The status of each mitigation activity will be established and compared to the qualitative and quantitative expectations for that activity expressed in this FMP. In addition, agendas and meeting minutes of all FMP planning functions will be assembled and compared with the expectations expressed in this document.

The Floodplain Manager will prepare the FMP progress report as part of the annual CRS recertification process. The 2014 Progress Report activities were incorporated into this FMP. It was reviewed by the Deputy Director for Planning and Development Services and presented to the FMPC for review and comment. The draft report was then revised to reflect the comments of the FMPC and submitted to the Mayor for approval along with the recertification documents. Following receipt of the Mayor's approval, the annual FMP report was released to members of the media and posted online at the City website (www.houstontx.gov), and a hard copy made available to the general public upon request from the City of Houston Floodplain Management Office.

## Appendices

| | |
|---|---|
| **Appendix A** | Ordinance for Rebuild Houston Oversight Committee |
| **Appendix B** | Public Participation Documentation |
| **Appendix C** | Map of Repetitive Loss Properties |
| **Appendix D** | Map of City of Houston Watersheds |
| **Appendix E** | Historical Hazard Data |
| **Appendix F** | Hazard Identification and Risk Estimation |
| **Appendix G** | Risk Assessment and Vulnerability Maps |

- 100-year Floodplain
- 500-year Floodplain
- Hurricane Wind, Category 1
- Hurricane Wind, Category 2
- Hurricane Wind, Category 3
- Hurricane Wind, Category 4
- Storm Surge, Category 1
- Storm Surge, Category 2
- Storm Surge, Category 3
- Storm Surge, Category 4
- Storm Surge, Category 5

| | |
|---|---|
| **Appendix H** | Open Space in the SFHA Map |
| **Appendix I** | SWEET Process Map |
| **Appendix J** | Request for Comment on 2016 Floodplain Management Plan |
| **Appendix K** | 2016 Floodplain Management Plan Adoption |