Flood Management Handbook

REGIONAL FLOOD MANAGEMENT COUNCIL

Houston-Galveston Area Council | July 2009

REGIONAL FLOOD MANAGEMENT COUNCIL

Flood Management Handbook

Houston-Galveston Area Council
3555 Timmons Lane • Suite 120
Houston, TX 77027

Preface

Statement of Purpose

The Houston-Galveston Area Council's (H-GAC) Board of Directors created the Regional Flood Management Council (RFMC) in 2005. The RFMC's purpose is to assist and advise elected officials in their decision-making responsibilities on issues related to all aspects of flood management in the Gulf Coast Planning Region.

The RFMC developed this handbook to provide an overview of best flood management practices including planning and mitigation techniques, regulatory tools, and funding resources available to local governments in the H-GAC region. It has been designed to help floodplain managers work more effectively with elected officials, developers, and landowners to reduce flood damage to life and property.

Acknowledgements

We thank everyone who provided support, feedback, and encouragement toward the creation of the handbook, particularly members of the RFMC and Best Management Practices Committee.

Regional Flood Management Council

Louis Bergman (Liberty County)
David Collins (Colorado County)
Cathy Dominguez (Brazos River Authority)
Scott Elmer (City of Missouri City)
G. Michael Fitzgerald (Galveston County)
Scott Hall (Lower Neches Valley Authority)
Kelly Hamby (Brazoria County)
Cruz Hernandez (City of Baytown)
Andrew Isbell (Walker County)
Phil Jones (Montgomery County)
Mark Jordan (Lower Colorado River Authority)
Spencer Karr (Trinity River Authority)
Blake Kellum (San Jacinto River Authority)
Lisa Krobot (Matagorda County)
Sidney Lewis (Chambers County)
Michael S. Marcotte (City of Houston)
Monica Martin (Wharton County)
Sarah Metzger (City of Pasadena)
Dale Rudick (City of Sugar Land)
Yancy Scott (Waller County)
Mike Talbott (Harris County Flood Control District)
Troy Toland (City of Conroe)
Mark Vogler (Fort Bend County Drainage District)

Best Management Practices Committee

Andrew Isbell (Walker County)
Burton Johnson (Burton Johnson Engineering, Inc.)
Dale Rudick (City of Sugar Land)
Shashi Kumar (City of Sugar Land)
Daya Dayananda (City of Pasadena)
Penny Goode (Brazoria County)
Scott Elmer (City of Missouri City)
Jing Chen (City of Missouri City)
John Grounds (Grounds Anderson, LLC)

The following people also provided invaluable information, illustrations, suggestions, and examples: Roy Sedwick and Heidi Carlin (Lower Colorado River Authority); Debbie Cahoon (Texas Water Development Board); Dale Hoff and Donetta Blanlott (FEMA Region VI); John Ivey (Halff Associates, Inc.); Jennifer Walker, P.E. (Dodson & Associates); John de Bessonet and Alisa Max (Harris County); Susan Smyer, Carol Ellinger, and Sheila Blake (City of Houston); Paul Bass, Gary Bezemek, Joan Blomquist, Jason Close, Robert Harrison, John Randolph, and Rondy Spardella (Harris County Flood Control District); and Jenniffier Hawes (Texas Department of Public Safety).

Finally, the efforts of Daniel Wong, former councilmember for the City of Sugar Land, must be acknowledged. His encouragement was essential to the formation of the RFMC and its decision to develop this handbook.

Table of Contents

INTRODUCTION

Flood Management, or actions taken to keep people and property safe from flooding, is critical in the flood-prone Houston-Galveston region. The typically flat topography, abundant rainfall, and common tropical weather, including hurricanes and severe storms such as Tropical Storm Allison in 2001, combine to increase the probability of flooding.

This handbook is designed to serve as a resource for flood managers. It illustrates techniques that have the broadest application across the region. Flood managers can use this handbook to help describe and explain flood management techniques to elected officials and other decision makers. To this end, each topic has been written as a stand-alone document, giving individuals the option of pulling out sections to present to others for explanatory purposes.

This handbook describes advantages and disadvantages of various activities and can be used toward flood management decisions. This handbook is not a compilation of rules and regulations that apply to flood management, nor is it a design manual that describes engineering requirements.

Within each chapter, topics are organized from the most broadly applicable in the region to the most specific. Most activities described in this handbook apply to three types of regional flooding:

- Riverine flooding associated with the area's many rivers, bayous and streams;
- Localized flooding, such as ponding and sheetflow, caused by flat terrain; and
- Coastal flooding, which is affected by tides and winds as well as rainfall.

Subject matter is divided into the following chapters:

Chapter 1: Planning

Chapter 2: Mitigation

Chapter 3: Regulation

Chapter 4: Funding

Appendices: List of acronyms, references, and a freeboard survey from the Texas Floodplain Management Association

Chapter 1

Planning

Planning is the first key step in successful floodplain management. It requires communities to consider future needs along with growth and development, to establish risks, and develop actions to mitigate those risks. It assists in identifying opportunities and funding needs and it provides a communication vehicle between a local government and its citizenry.

This chapter will briefly describe the methodology for assessing needs, describe data requirements and planning tools, consider different types of plans, and discuss the integration of floodplain management concepts into other community plans.

Assessment

The foundation of floodplain management planning is the assessment of the potential risks to the community. It is necessary to consider all possible types of flooding events, as well as the related impacts. The assessment process can be broken down into three steps.

Step One: Evaluate and prioritize flooding hazards

An evaluation of flood hazards involves a review of past flood events, the frequency of each event, and the probability of reoccurrence, both in and out of flood hazard areas. The Federal Emergency Management Agency (FEMA) documents and maps are a good place to get data; however, it is only a starting place as flooding can occur outside the mapped floodplain. A review of past flood events will give a good indication of where flooding will occur in the future. Prioritization of flooding hazards need to take into account risks and vulnerabilities in order to determine which hazards present the greatest threat to people, property, and essential services. The next section, Data Needs, will explore sources of data and planning tools in more detail.

Step Two: Identify resources and capabilities

After flooding hazards have been prioritized, a community must review plans, regulations, and policies to see if they adequately address all identified hazards. This review includes considering the strengths and weaknesses of the plans, regulations and policies.

Step Three: Develop and implement mitigation measures

To strengthen planning, a community will need to develop appropriate actions to address any identified weaknesses. The actions will need to be incorporated into plans, regulations, and policies. Chapter 2 will address mitigation measures in detail.

Data Needs

Local data, verified for accuracy, is needed to develop a plan for flood management. The types of data gathered should include accurate representations of the ground, post-flood evaluations, and floodplain reference marks.

Accurate Representations of the Ground

An accurate representation of the ground is important information when developing a plan regarding flood management. This information can be obtained through U.S. Geological Survey topographic maps, light detection and ranging (LiDAR) data, or site surveys. LiDAR data is topographic data collected using a plane equipped with a laser to measure the elevation below. LiDAR data should be compared to aerial photos or site surveys in order to accurately distinguish between structures, land features, and objects such as trees. Site surveys can be done with or without floodplain reference marks, described below.

The appropriate method of determining the area's topography should be chosen by each individual community and could involve a combination of all three topographic sources listed above. The Tropical Storm Allison Recovery Project (TSARP) used a combination of LiDAR data and on the ground site surveys to determine those areas at higher risk of flooding.

Post-Flood Evaluations

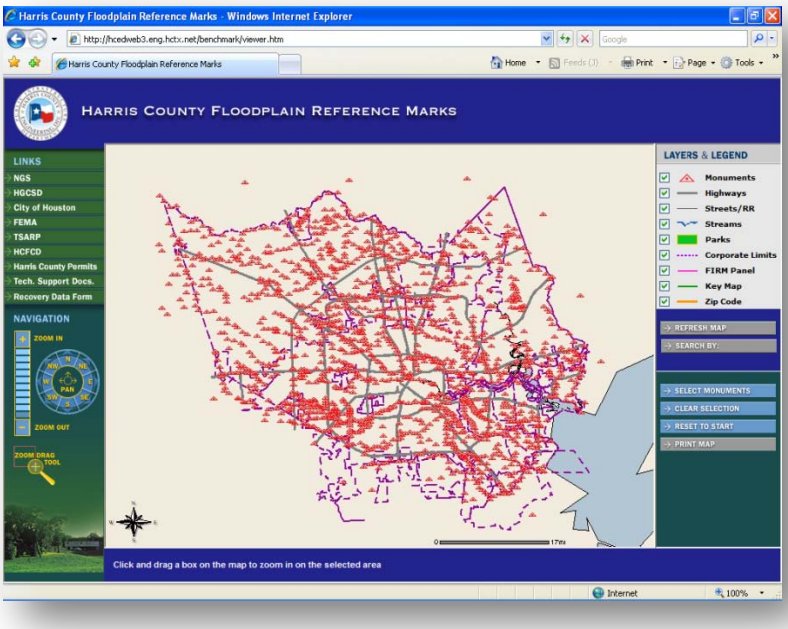
After each flood event an evaluation should be conducted to compare the realities of the event with what was expected. A flood flow frequency analysis includes an analysis of annual peak flows to estimate the flood event's exceedance probability, a comparison of a flood event's characteristics to previous flood characteristics (such as high water marks), and the identification of watershed changes (such as urban development and channel modifications). Examining these factors will provide a community with the information necessary for developing a plan for flood management, including specific mitigation measures to implement.

Floodplain Reference Marks

Floodplain reference marks, also known as benchmarks or elevation reference marks (ERMs), play a crucial role in the permitting of development and the administration of the National Flood Insurance Program (NFIP). The floodplain reference mark provides a known horizontal and vertical position that can serve as the reference point in determining the location of a structure within a special flood hazard area (SFHA) and if existing or proposed floors, mechanical equipment, and flood vents are above or below the base flood elevation (BFE).

Changes in reference points and subsidence must be taken into account when using floodplain reference marks, as they may change the relative or actual

Figure 1. Harris County's floodplain reference marks



location of a reference mark. Unless a community has developed a local floodplain reference mark system or verified the existence of marks, FEMA includes old marks on new maps. However, many of these marks are unstable, have been destroyed, or are inaccurate.

Communities should perform a visual inspection and keep an inventory of the published floodplain reference marks to determine if any have been destroyed, damaged, become unstable, or been affected by subsidence. The floodplain administrator should maintain a map depicting the status of each reference mark as good, unstable, or unrecovered and which are acceptable for use. This will save community officials and surveyors time in finding a suitable reference mark that is stable and close to the property where an elevation certificate or finished floor elevation is being set.

Data and Public Inputs

A number of tools are available to obtain accurate, reliable data used in developing plans, including Geographic Information Systems (GIS) and the community.

Geographic Information Systems

A GIS provides a unified means of compiling information about the social, economic, built, and natural environments. GIS maps can be updated when new information becomes available or situations change, and can help analyze and make decisions regarding geographically distributed problems. GIS can also be used to collect and process data, produce digital models of the floodplain, define floodplain boundaries, conduct hydrologic and hydraulic analyses, and prioritize flood control improvements.

GIS can be used to address flood losses through a number of applications. For example, Flood Insurance Rate Maps (FIRMs) are used to set rates for flood insurance. Insurance agents, property owners, and floodplain managers can look at a map to determine whether a property is within a mapped floodplain, floodway, or other hazard area. By showing the extent to which a community is at risk for flooding, FIRMs can help business and property owners make better financial decisions about protecting their property. Another application of GIS data is determining Base Flood Elevations. These are often required for construction and can be determined using data contained in a GIS.

Regulatory floodplains can be delineated utilizing GIS data. This data can be used to identify population and property value vulnerabilities, and devise plans to address these vulnerabilities. In addition, maintenance activities can be tracked and analyzed, including mapping the locations of facilities such as channels, bridges, dams, mechanical and electrical structures, and basins. Another application of maps generated using GIS data is to communicate public education messages by developing educational materials to explain key concepts.

The Community

Local stakeholders can provide valuable information about local flood hazards, including any history of flooding in the area. When the public is involved in the planning process plans will be designed to fit the needs of the community. Subsequently, there will likely be more support for the finished product.

There are a variety of exercises to facilitate community involvement. Below is a brief description of a few of these exercises.

Asset Mapping

Asset mapping is a process of identifying the resources and assets within a community. Once complete, this inventory provides a framework for meeting community needs.

Chapter 1: Planning

Visualization

Visualization exercises aid in developing a shared vision for a community's flood management plans. They often rely on tools ranging from freehand sketches to dimensional models.

Impact Analysis

An impact analysis is a brainstorming tool used to identify the unintentional results of actions taken in flood management planning. By identifying potential problems, it is often possible to avert them.

Scenario Analysis

A scenario analysis allows communities to identify potential outcomes of flood management activities given different environmental conditions. A simple example might be how a storm sewer system might function during 50%, 10%, and 1% storms.

Performance-Based Planning

Performance-based planning is the process of identifying criteria by which plan effectiveness can be measured. This tool focuses on desired outcomes instead of desired activities, accommodating a changing community.

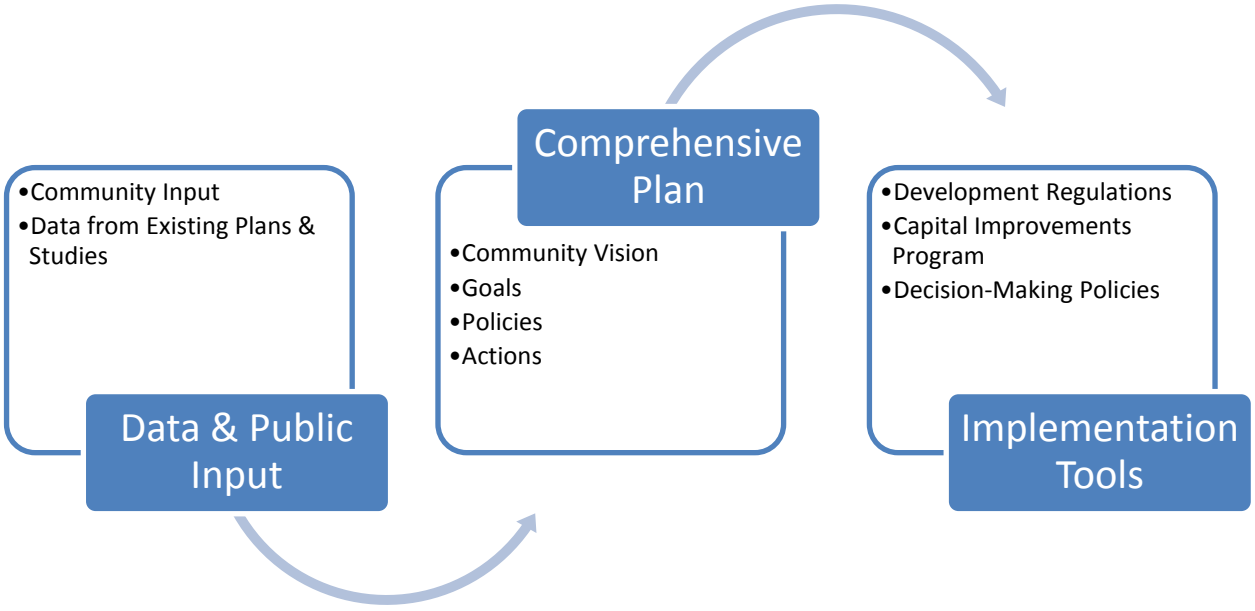
Planning

After data is collected, processed and analyzed, it is incorporated into a variety of community plans. This discussion will begin by examining comprehensive plans and their importance to flood management, followed by a review of three plan types specific to flood management: floodplain management plans, drainage plans, and flood mitigation plans. In addition, this section will review other plans that are closely related to flood management issues: hazard mitigation plans, capital improvement programs, thoroughfare plans, evacuation plans, and emergency management plans.

Comprehensive Plan

A comprehensive plan addresses many elements of flood management. This type of plan includes guidance on land use, transportation, zoning, subdivisions, capital improvements, parks, health, welfare, and safety. A comprehensive plan is beneficial because of the breadth and depth of the issues it can address. However, they typically involve the most cost, time, and effort to develop. Figure 2 illustrates the typical process of developing a comprehensive plan.

Figure 2. Development of a Comprehensive Plan



Comprehensive plans are typically funded through the general operating budget, approved by a planning commission, and adopted by ordinance of a city council. Counties and other communities may also develop comprehensive plans, although the authorities derived from such plans may be weaker than for a city. An alternative to a comprehensive plan is a visioning document, which includes less tangible recommendations.

Examples:

- The City of Manvel Comprehensive Plan recommends developing a master drainage plan to address flood control measures such as detention facilities, channelization, and bridge and culvert replacements. Through development of a master drainage plan the City would evaluate future

development and its potential risks. Other elements of the comprehensive plan address public facilities and locations of the floodplains and waterways.

- The City of League City Comprehensive Plan also recommends the development of a new master drainage plan, and incorporates existing water plans, such as the current master drainage plan, the wastewater master plan, and the water master plan.

Floodplain Management Plan

The Texas Water Code defines a floodplain management plan as a comprehensive plan for flood control within a watershed, based on analysis of alternative nonstructural and structural means of reducing flood hazards, including assessments of costs, benefits, and environmental effects and may include preliminary design of structural flood control projects. This type of plan might address detention requirements, freeboard requirements, release rate curves, impervious surface requirements, a no-rise policy, or a variety of other resources. It is important to have this plan in place if extensive development or future building is expected.

A floodplain management plan has multiple benefits and applications. Generally, floodplain management plans support the regulation of building and rebuilding within the FEMA-designated SFHA, otherwise known as the 1% (or 100 year) floodplain. It can provide a framework for action regarding the corrective and preventive measures in place to reduce flood-related impacts. It can also provide a high-level analysis of areas that are at high risk of experiencing flood damages.

If a community has not identified specific flooding problems and anticipates extensive development, a floodplain management plan might be the first flood-specific plan a community considers. If a community has identified areas with flooding problems and extensive development is not expected, it is advisable to develop a flood mitigation plan before addressing a floodplain management plan.

Oftentimes floodplain management is not contained in a single comprehensive document, but instead is incorporated into other rules, guidelines, or regulations, including:

- Floodplain Management Ordinance
- Financial Incentives to encourage appropriate development
- Community Master Planning
- Flood Hazard Zoning
- Open Space Preservation Ordinance
- Education and Outreach
- Emergency Management Program
- Mapping Program or GIS

Example:

- The City of Houston Floodplain Management Plan, approved in 2001, was developed to address requirements of the Community Rating System for cities designated as a repetitive loss community by FEMA. The City had elements of a floodplain management plan in various documents, and conducted a review of those documents, incorporating them into their plan. The plan included recommendations, such as measures related to land acquisition, stormwater quality, mapping, education, capital improvements, and outreach. This plan was subsequently subsumed by the City's hazard mitigation plan.

Drainage or Watershed Master Plan

Drainage master plans are broad-based plans that identify measures to prevent damage from future flood events, particularly damage from future development. In some ways, it is the stormwater equivalent of a major thoroughfare plan, addressing facilities or improvements necessary to accommodate new development. Drainage master plans do not address exact locations or design specifications for facilities; rather, general concepts. These plans serve as a guide for future activities and assist with future budgeting and funding.

Elements from a drainage master plan move through a detailed flood mitigation planning phase prior to implementation. Land developers often implement part or all of a drainage master plan as they complete developments. The inclusion of plan elements in a comprehensive land use plan, through setbacks or in the platting of subdivisions, is a common way to implement drainage master plans. A drainage criteria manual – or other engineering, building, or other development criteria manual – can incorporate elements of a drainage plan. A drainage plan will often identify improvements to the storm sewer system required to address disrepair or inadequate capacity due to increased development. One type of drainage plan, a stormwater drainage plan, often focuses on more frequent minor urban flooding.

A watershed master plan, while similar to a drainage master plan, usually addresses a broader scope and perspective than a drainage master plan. The watershed master plan will look at an entire watershed in a holistic manner, while a drainage master plan will be more detailed, addressing drainage and sheetflow in a specific manner.

A drainage master plan is essential to accommodate new development in a manner that does not increase flood risk, particularly if extensive development is expected to occur. Implementation of this type of plan will direct the actions of developers within a watershed.

Examples:

- The Harris County Flood Control District (HCFCD) developed "Blue Book" watershed master plans that are being revised to provide guidance when specific projects are designed in the future. These updated plans will answer questions such as, "What type of channel do we want--a wide, tree-lined, channel with an adjacent multi-use trail or a narrower, utilitarian channel? If improvements are made, how will the floodplains change as a result—and is that acceptable? How wide and tall does a bridge need to be built to accommodate future development?"

- The Brazoria County Master Drainage Plan, completed in 2002, anticipates future growth and provides tools and data for Brazoria County drainage districts to determine the effects of proposed developments or drainage improvements within the watersheds. The drainage plan also identified existing flooding problems.

- The City of Pearland began their planning process for their drainage master plan with a comprehensive collection of information about the existing drainage system. The drainage master plan addresses existing and potential future flooding problems suggesting improvements and modifications to remedy inadequacies in the existing system.

Flood Mitigation Plan

Flood mitigation plans identify one or more specific measures to address areas known to have existing flooding issues in order to reduce damages from future flood events. These plans can refer to specific projects, but in the context of this handbook, flood mitigation plans address areas known to have existing flooding issues at a community level.

Flood mitigation plans identify specific structural or non-structural measures to reduce damages from future flood events. These plans may also be used to communicate needs, request funding assistance, and to guide future development activities. Upon completion, flood mitigation plans are either implemented or nominated for consideration as part of a capital improvement program (CIP).

If existing flooding concerns are significant, the development of a flood mitigation plan might be undertaken before a drainage master plan or a floodplain management plan. A flood mitigation plan would not be appropriate in a situation where existing flood damage concerns have not been identified or where there are not sufficient funds to implement plans developed in a flood mitigation plan.

Examples:

- The City of Baytown Flood Mitigation Plan identifies existing flooding problems and proposes mitigation measures for those problems. The mitigation plan recommends nine action items, including public education regarding flood insurance, acquisition and relocation of repetitive loss properties, stormwater detention facilities, and channel improvements.

- The Brays Bayou Flood Damage Reduction Plan, also known as Project Brays, is a collaboration between the Harris County Flood Control District and the U.S. Army Corps of Engineers. The plan calls for over 21 miles of channel improvements along Brays Bayou, the construction of four detention basins on about 900 acres of land, and the modification or replacement of 32 bridges. The total cost of the project is about $450 million. The project is reducing the risk of flooding in the most populous watershed in Harris County.

Hazard Mitigation Plan

A hazard mitigation plan (HMP) is a specific type of plan required by several federal grant programs, including the Hazard Mitigation Grant Program and the Pre-Disaster Mitigation Program.

According to FEMA, a HMP is a plan that "establishes the broad community vision and guiding principles for reducing hazard risk, including the development of specific mitigation actions designed to eliminate or reduce

identified vulnerabilities" for the state or local government by or for which it was created. HMPs are not specific to flooding. They expand beyond the identification of structural alterations to decrease current risks. This type of plan often includes public education about existing and possible risks, as well as plans for future growth.

A total of 142 cities and counties in the H-GAC region have a HMP or participate in a multi-jurisdictional plan such as the Houston-Galveston Area Council Multi-Jurisdictional Hazard Mitigation Plan. The vast majority of these are Multi-Jurisdictional Hazard Mitigation Plans (MJHMPs), such as the Fort Bend County MJHMP, the Harris County MJHMP, and the Houston-Galveston Area Council MJHMP, which was adopted by eight counties and 70 municipalities. Other cities and counties throughout the region have developed and adopted their own HMPs or other collaborative efforts.

Example:

- The City of Baytown was included in the Harris County All Hazards Mitigation Plan, which identified and discussed a broad variety of hazards, identifying flooding as one of the most significant. This plan identified measures that the City of Baytown and its partners could take to mitigate flooding.

Capital Improvement Program

A CIP is a type of plan that identifies major improvements to a community's infrastructure, as well as a schedule for building and funding these improvements. A CIP typically encompasses a five-year timeframe and is updated annually. Often, the CIP will identify additional long-range projects to be considered beyond the five-year timeframe.

A CIP is essential to ensuring that public investment is done in such a way that it helps reduce or eliminate community exposure, risk, and vulnerability to flooding. It can guide future development away from flood hazard areas and prevent pubic improvements from being placed in areas where growth and development is not desired.

Flood management projects are incorporated into CIPs in the context of other community needs, such as the need for a wastewater treatment plant, a roadway, or a major park expansion. Elements of the types of plans described above, particularly the comprehensive, flood mitigation, and hazard mitigation plans, are often incorporated into a CIP. A CIP is essential to identifying, funding, and implementing large projects. The costs to develop and update a CIP may be prohibitive.

Example:

- The City of Pasadena's CIP includes a section on drainage improvements, including projects ranging from a regional detention basin to annual storm sewer replacements and localized drainage improvements.

Thoroughfare Plan

A thoroughfare plan identifies the means to gauge transportation demands and the options to meet those needs, while considering the social, economic, and environmental characteristics of the area. The development of transportation networks can significantly impact the amount, type, and location of future growth.

Oftentimes, a thoroughfare plan will take flooding issues into account. For example, thoroughfare improvements may avoid identified floodplains. Alternatively, a thoroughfare plan might consider populations that are at risk of flooding and what sorts of mobility those populations might require.

Thoroughfare plans might include a street classification system that can be used to influence flooding and drainage. A street classification system will define classes of streets, from major arterials down to residential roads. The profile or description for each street type may include elevation information and specifics regarding curb and gutter or roadside ditches. These specifications will influence drainage and flooding and may be driven by a floodplain management plan.

Example:

- The City of Manvel Transportation Corridor Plan identifies drainage facilities as potential "non-vehicular" transportation corridors, and thought is given to combining transportation and drainage within the same corridor as a means of improving both systems.

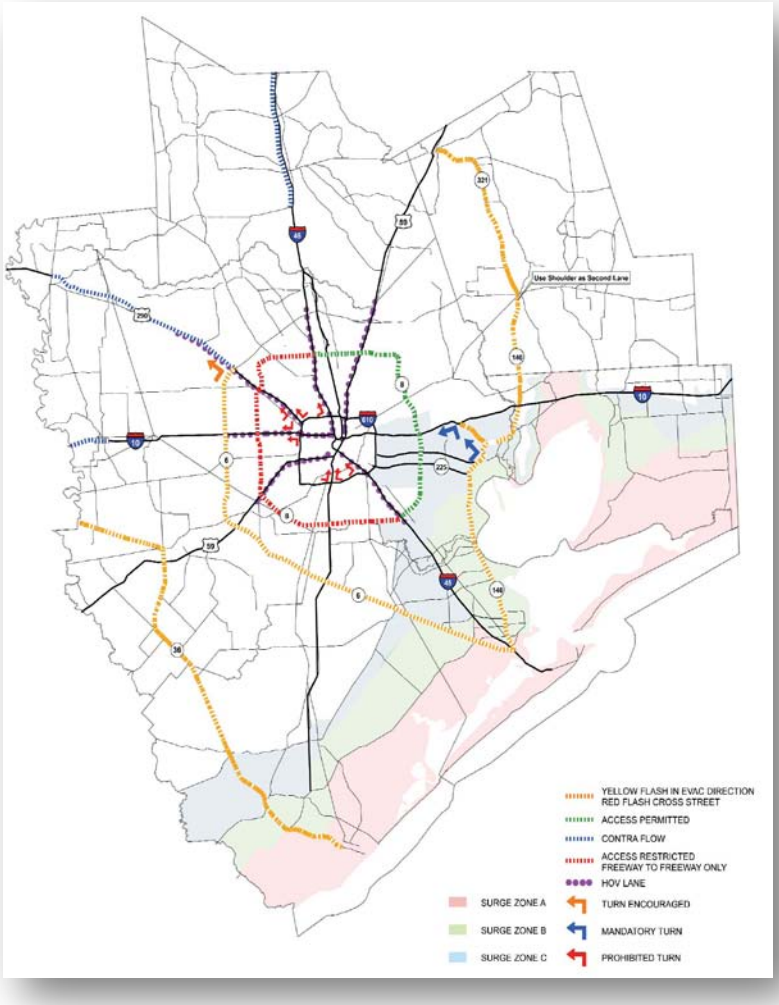
Evacuation Plan

Despite an extensive range of activities to mitigate flooding in the region, evacuations may be initiated to protect people in harm's way. While evacuation plans do not address the risk of property damage, they do address the risk of loss of life.

In 2006, H-GAC coordinated a multi-county evacuation task force to identify transportation issues within the metropolitan region. Working cooperatively with state and national evacuation planning organizations, the task force produced short-term recommendations to improve evacuation capabilities and long-term priorities.

The Unified Area Coordination Committee (UACC), consisting of representatives from the H-GAC region, makes decisions on staggering evacuations and enabling contraflow on the area's highways during an extreme event such as a hurricane. The committee is encouraged to participate in planning activities and other recommendations of the task force's recommendation report.

Figure 3. Map of evacuation routes developed by the Houston-Galveston Area Evacuation and Response Task Force.



Example:

- In response to the disastrous evacuation prior to Hurricane Rita's landfall in September 2005 the Brazoria, Chambers, Galveston and Harris Hurricane Evacuation Zip-Zones Coastal, A, B, C evacuation plan was created. The main purpose of the plan is to ensure an orderly evacuation in the event that a major storm heads for the H-GAC region. The four evacuation zones are divided along zip code boundaries. It was decided that evacuation schedules would be based on zip codes for ease of communication to the public since the majority of individuals know their zip code. The four zones correspond to storm surge risk areas. During an evacuation, those in the coastal zone are to evacuate first and then zone A, followed by zone B, and then zone C.

Emergency Management Plan

An emergency management plan includes shelter requirements, transportation issues for evacuation, an identified emergency operation center, incident command center operations, and duties of essential personnel. Continuity of operations plans, disaster recovery plans, emergency operations plans, and emergency response plans are all closely related to emergency management plans. Continuity of operations plans and disaster recovery plans focus on maintaining regular business operations as much as possible and returning to normal as quickly as possible. Emergency operations plans, emergency response plans, and emergency management plans focus more on preparing for and responding to the actual emergency.

An emergency management plan should address specific local hazards, including hurricanes, terrorist activities, infectious disease, and floods, among other emergencies. It should also describe how the community expects to employ available resources to protect its citizens during these emergencies that may threaten public health and safety or private and public property.

Emergency planning documents consist of the basic plan, supporting functional annexes, and, where appropriate, appendices. An emergency management plan requires the inclusion of 22 standardized annexes including such topics as communications and public information.

A reliable and interoperable communications system is essential to obtain the most complete information on emergency situations and to direct and control resources responding to those situations. State law requires every political subdivision (county and incorporated city) in Texas to prepare and keep current a local or inter-jurisdictional emergency management plan. Planning provides two principal benefits:

1. It allows jurisdictions to influence the course of events in an emergency by determining in advance the actions, policies, and processes that will be followed; and
2. It contributes to unity of effort by providing a common plan for activity in the event of an emergency.

Example:

- The City of Deer Park Emergency Management Plan is based on the four phases of emergency management, which include preparedness, response, recovery, and mitigation. The plan, developed by their Office of Emergency Management, guides the City before, during, and after both natural or man-made emergencies.

Chapter

2

Mitigation

This chapter focuses on mitigation measures a community can undertake to reduce the risk of flooding, the second key component of effective flood management. According to FEMA, mitigation is the effort to reduce loss of life and property by lessening the impact of disasters. Mitigation efforts enable individuals to recover more rapidly from floods and other disasters and lessen the financial impact. Effective mitigation is achieved through three main components – analyzing risk, reducing risk, and insuring for flood risk.

Mitigation measures have been organized from the broadest application to the most specific. Cost, appropriateness for the situation, ease of implementation, and effectiveness were considered. Circumstances may vary among communities so individual analyses must be conducted in each situation.

Mitigation measures well-suited to the Houston-Galveston region:

- Community Rating System
- Developing accessible flood-risk information (web-based FIRMs) and providing public education
- Flood forecasting
- Facility maintenance and repair
- Conveyance improvements to channels, storm sewers, and bridges
- Structure removal or elevation
- Land acquisition
- Detention basins
- Floodplain fill mitigation ponds and excavations
- Floodproofing
- Channel diversions
- Dams
- Levees
- Floodgates

Community Rating System (CRS)

CRS is a federal program that provides incentives to local governments to exceed the minimum requirements of NFIP. NFIP includes a minimum set of requirements necessary to allow members of a community to purchase federally-backed flood insurance.

The goals are:

- Reduce flood losses
- Facilitate accurate insurance rating
- Promote the awareness of flood insurance

The CRS program has ten levels, ranging from Class 1 to Class 10, which a community can achieve. Communities enter into the CRS at a Class 10 for which no savings are gained. As the community implements CRS activities they progress towards a Class 1 with flood insurance premium savings increasing by 5% for each rating grade achieved. Due to their limits of regulatory authority, counties cannot achieve a rating higher than Class 8. The cities of Friendswood and Kemah are rated highest in our region at a Class 5.

CRS activities fall into four categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness

Should your community participate in CRS?

- Property owners save money on flood insurance.
- Existing activities can earn CRS credit.
- Participation in CRS can lead to a reduction in loss of life and property damage.
- Counties don't have the authority to develop ordinances or building codes and are limited to achieving no higher than a Class 8.
- Small counties may be discouraged from joining CRS by the heavy paperwork required.

Authority and Funding

Every local government with a risk of flooding should consider participation in CRS and determine whether the benefits outweigh the costs in their situation. Administrative tasks would be funded through local funds, while implementation of each activity/mitigation measure would come from various sources including fees, taxes, bonds, and grants.

Many of the mitigation measures described in the remainder of this chapter can be used by a community toward CRS credit.

Local Examples:

Participation in CRS is limited in the region. Only 1 county (out of 13) and only 13 cities (out of over 100) participate, compared to nearly 100% participation in the NFIP. The Texas Water Development Board (TWDB) is actively working to increase participation in CRS.

- The City of Friendswood is a Class 5 community, one of the highest in the region. Almost a quarter of the city is within the mapped floodplain. Property owners in the mapped floodplain receive a 25% discount on their annual flood insurance premiums, saving approximately $602,000 each year.

- Harris County entered the CRS in 2004 and has achieved Class 8, the maximum rating that a county can achieve in Texas. For years, the County had been conducting many of the flood damage reduction measures listed in the CRS.

- The City of Missouri City, which has applied for CRS credit, but has not received it to date, has calculated the average amount that a property owner would save on their flood insurance. The average insurance premium in Missouri City is $870 to cover a building and $1,278 to cover a building and its contents. CRS participation would lower the average premium between $43 and $392 depending on the rating achieved by the City.

Public Education/Developing Accessible Flood-Risk Information (web-based FIRMs)

Public education regarding flood risks is an important part of preventing flood loss. Research has indicated that public education is most effective when initiated at the local level. The CRS in particular provides guidance regarding public education activities and groups them into six categories:

- elevation certificates
- map information
- outreach projects
- hazard disclosure
- flood protection information
- flood protection assistance

Should your community focus on public education and flood-risk information?

- An educated public is more likely to support flood regulations, plans, mitigation projects and funding.
- Direct mailing to floodplain residents can be as effective as more expensive radio and television advertising.
- Showing people how to read floodplain maps gives them a picture of the relative risk they may face in a flood event.

Public education activities can be an important tool for mitigating flood damage and loss. The more educated the public is on flood matters, the more support can be garnered for flood regulations, plans, mitigation projects, and funding.

One step toward having an educated public is ease of information access. Information, such as FIRMs, a community's flood regulations, and flood mitigation techniques, should be easily accessible electronically as well as in hard copy format.

FEMA's Digital Flood Insurance Rate Maps (DFIRMs) are making public education efforts significantly more successful. These maps support disaster response, planning, risk assessment, and some CRS activities. Additionally, FEMA is working on a Flood Map Modernization program, also referred to as Map Mod, for which one aim is to make digital maps accessible. In order to take advantage of these efforts a community could provide a link on their website or refer to these maps in a publication.

Authority and Funding

All communities have the authority to conduct public education activities and make flood-risk information accessible for their community. Local funds could be used to implement these activities and the directive for a community to do so would stem from the annual operating budget. Other funding opportunities could include grants or partnerships with other communities and organizations.

Local Examples:

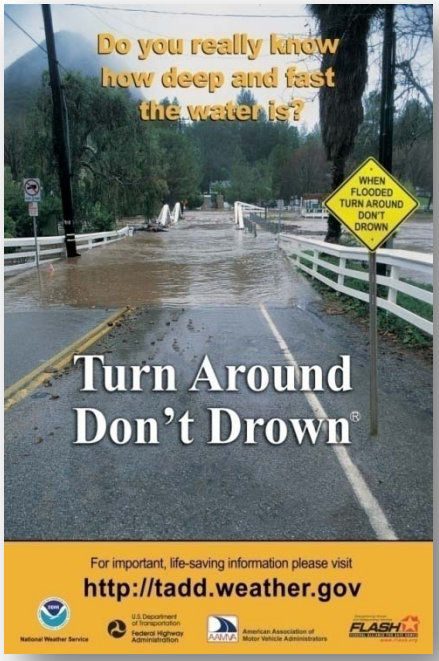
- The City of Sugar Land publishes a bi-monthly newsletter, *Sugar Land Today,* highlighting the key issues and events within the city. By including safety tips related to flooding, Sugar Land's

flood damage prevention activities, and sources for more information, the City is able to develop a more-informed populace and get credit for the CRS program. The publication is mailed to residents and businesses in Sugar Land and can be downloaded from the City's website.

Figure 4. Sugar Land's bi-monthly newsletter

- The "Turn Around, Don't Drown" campaign (TADD) produces public education materials in the form of posters, signs, stickers, and brochures to educate citizens on the dangers of flooded roadways. Materials for distribution can be obtained from the TADD Resources webpage of the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) website.

Figure 5. Turn Around Don't Drown poster



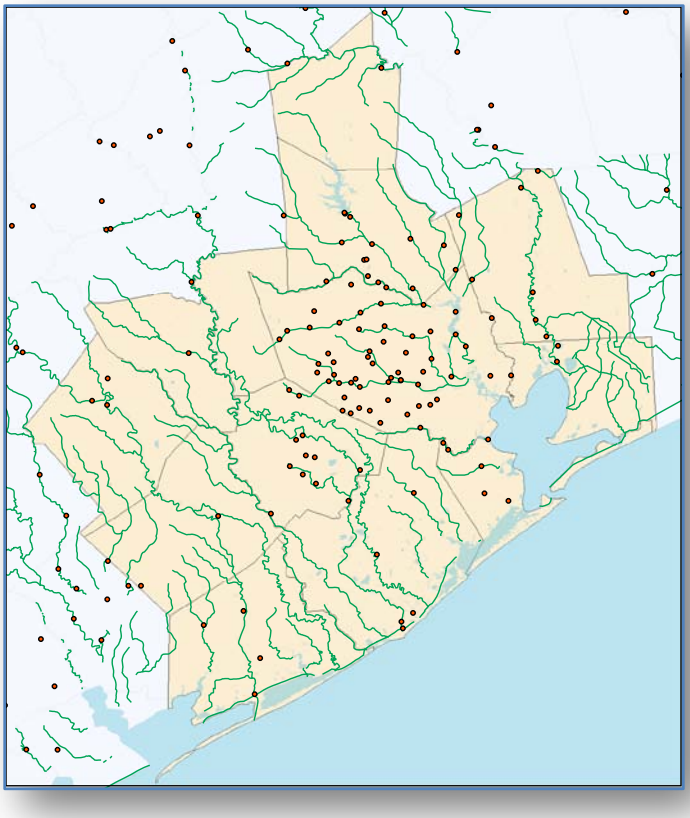
Flood Forecasting

Flood forecasting is the prediction of the height of the flood crest, the date and time a river is expected to overflow its banks, and the date and time a river is expected to recede to within its banks. Providing this information can allow governments and citizens to prepare for flooding. The U.S. Geological Survey (USGS) has stated that timely warnings and forecasts save lives and aid disaster preparedness. They have estimated that flood forecasting has reduced property damage, on average, by about 25% on an annual basis. There are three primary methods of flood forecasting that a community can use.

The first is regular review of river forecasts from the NWS. The NWS is responsible for preparing and disseminating river forecasts and has 13 river forecast centers across the country. The West Gulf River Forecast Center, located in Fort Worth, Texas, forecasts stream flow for the Houston-Galveston region. They use weather information, stream gage data from the USGS, and complex mathematical models to predict river flooding. Information is updated daily indicating the inches of rainfall in a one-hour, three-hour, or six-hour period that would result in flash flooding for each county.

The second method is the installation and monitoring of stream gauges. Stream gauges provide real-time stream-flow data and are indispensible tools to flood forecasting. They are often operated by multiple agencies simultaneously.

Figure 6. Map of gauging stations in the region



The third method is the reliance on the NOAA Weather Radio (NWR) program. Through their NWR program they make weather and hazard information, such as flood forecasts, available. Working with the Federal Communication Commission's (FCC) Emergency Alert System, NWR provides comprehensive weather and emergency information. In conjunction with federal, state, and local emergency managers and other public officials, NWR also broadcasts warning and post-event information for all types of hazards including natural (such as earthquakes or avalanches), environmental (such as chemical releases or oil spills), and public safety (such as AMBER alerts or 911 telephone outages).

Figure 7. Stream flow gauge along Clear Creek

A special receiver, scanner, or radio is required to listen to these broadcasts. Receivers typically cost between $20 and $200, depending on additional features. Many of them will respond to a special signal by switching on audio features automatically and emitting a tone, which is particularly useful when people are sleeping. These broadcasts can be heard in all parts of the region, although in some limited areas, reception may be unreliable.

Authority and Funding

All communities, especially those with a history of flooding, should participate in or stay informed of flood forecasts. For each community, flood forecasting activities are included in the annual operating budget. Taxes are the major source of funding.

Local Example:

- The City of Sugar Land has installed a number of flood monitoring devices throughout the city. These devices provide real-time data on rainfall and stream levels at critical locations throughout the city. Such information is helpful in preparing the City's operations staff for a possible flooding scenario or a potential emergency.

Should your community participate in flood forecasting?

- Flood forecasting helps governments and citizens prepare for flooding and can save lives.
- It is estimated that flood forecasting has reduced property damage, on average, by about 25% annually.
- Installing stream gages can be expensive and unnecessary if the area is well monitored by USGS and the NWS.

Facility Maintenance and Repair

Facility maintenance and repair can reduce flood damage. Both natural and man-made facilities require maintenance to function at an optimal level.

Maintenance activities can generally be grouped into one of two categories: vegetation management or structural maintenance and repairs.

Vegetation Management

Vegetation management includes:

- Mowing
- Pruning
- Application of herbicide
- Turf and wildflower establishment
- Selective clearing
- Tree planting
- Removal of accumulated dead vegetation

Figure 8. The slope is mowed to maintain function at an optimal level.

Vegetation management will vary depending on maintenance structure. For example, vegetation must be removed from locations where it can damage flood-control facilities, such as grass growing in the joints and weep holes of concrete-lined channels. In some instances, vegetation must be maintained to preserve engineering criteria for a facility. Some channel banks must have a certain level of "roughness" to function correctly. Or vegetation must be maintained to prevent the growth of undesirable plant species. Mowing grass-lined slopes on a regular basis can prevent the growth of Johnson grass, a non-native, invasive species with an insubstantial root system that contributes to erosion.

Should your community conduct facility maintenance?

- Maintenance keeps structures functioning at an optimum level.
- Regular maintenance and repair prevents the need for more costly repairs after a facility failure.

Structural Maintenance and Repairs

Structural maintenance and repairs can include:

- Erosion repair to address sinkholes, washouts, or slope failure
- Repair of broken or failing concrete lining

- Manhole or back-slope interceptor replacement
- Removal of accumulated silt
- Repair or replacement of rusted metal pipes or disjointed concrete pipes
- Regular maintenance and inspection of mechanical and electrical facilities such as flood gates, retaining walls, pumps, etc.

Authority and Funding

When these facilities fail, they must be repaired by the local community that owns them. Routine maintenance activities are paid for by taxes and are included as part of the annual operating budget.

Figure 9. Collapsed storm sewer outfall and subsequent repairs.

Local Examples:

- HCFCD has an annual multi-million dollar maintenance and repair budget, which has included a budget of $4.5 million for mowing contracts alone. In 2007, HCFCD completed a condition assessment to quantify the condition of its facilities, including channels and basins. This assessment identified $160 million in deferred maintenance costs, or projects that would likely need to be done to bring facility conditions up to recommended levels. The report also indicated that $16 million would be necessary each year to sustain the recommended condition level, once that level had been reached.
- The City of Sugar Land allocated $206,287 dollars for drainage maintenance in the 2009 annual budget. Activities included the maintenance of storm sewers, storm inlets, open ditches, and outfall structures. The City requires that these facilities be inspected quarterly as well as before and after a heavy rainfall event.

Conveyance Improvements to Channels, Storm Sewers, and Bridges

A conveyance improvement is a man-made change to the characteristics of a channel, storm sewer, or bridge.

Figure 10. Railroad bridge modifications reduce flow restrictions and as a result reduce the effect on future flood waters.

Conveyance improvements to a channel include straightening, curving, widening, deepening, or concrete-lining a channel. Conveyance improvements to storm sewers include switching to a curb and gutter system, or an open swale system, installing oversized pipes with restricted outlets to promote detention, and increasing the number of inlets. Changes to bridges include streamlined support columns and bridge footings, elevation, and widening.

For any project, improvements are based on whether the risk of flooding needs to be reduced upstream or downstream. They can be designed to carry stormwater out of an area quickly or to keep the flow slow so as to not overwhelm areas further down the line. Costs involved may include the moving of pipelines or underground utilities in addition to the project construction costs.

Should your community make improvements to conveyance?

- Improving conveyance could be more cost effective in highly developed areas than other mitigation measures, because buyouts may be too expensive and land too hard to come by for projects such as detention.
- Roads may need to be torn up in order to access storm sewers.
- Underground pipelines or utilities may need to be moved.

Authority and Funding

Entities responsible for making these improvements are those that own the facility or structure, which can include cities, counties, the Texas Department of Transportation (TxDOT), railroad companies, drainage districts, and others. Planned conveyance improvements are generally detailed in a CIP or standalone plan and can be funded through taxes, bonds, and grants.

Local Examples:

- Klein High School, located in the north-central part of Harris County, received a Hazard Mitigation Grant from FEMA in 2005 to make improvements to the storm sewer system. Flooding during rainstorms had become frequent at Klein High School due to campus expansions and continued development in the area requiring sandbags be used to block entry doors. Backflow prevention was installed on the existing system, 400 linear feet of pipe was laid to drain water from near the

gymnasium to an existing drainage ditch, and a 54-inch gravity pipe was installed. Since the completion of the $970,113 project, Klein High School has had no further problems with campus flooding.

- Project Brays is one of the largest projects ever managed by HCFCD, in cooperation with the Corps. This project incorporates more than 70 separate projects of stormwater detention, bridge modification, and channel improvement. A total of 21 miles of channel will be altered during this project; 18 miles will be widened and 3 miles will be deepened. As a result of this work, thousands of homes and commercial buildings in the watershed will effectively be removed from the 1% floodplain.

Figure 11. Artist's rendering of Project Brays

Structure Removal or Elevation

Structure removal or elevation reduces the risk of flood damage by modifying or eliminating at-risk structures, instead of modifying the flow of water.

Structure removal is often applied in the floodplain, generally on facilities with a history of flooding. A buyout is when a community purchases and subsequently removes a flood prone structure from the floodplain to reduce flood losses.

Structure elevation is applied in coastal areas, along rivers, and in other low-lying areas. Structures that may be elevated include homes, commercial buildings, roadways, and utilities. Determining the relative cost of an elevation project should include the actual costs as well as the cost effectiveness. Cost effectiveness takes into account the following attributes: frequency of flood, level of damage, project cost, project benefits, and criticality (impact or loss of function). The type of foundation largely determines the cost of elevating the structure due to the relative ease or difficulty involved. General unit costs for elevating a structure, according to FEMA's Selecting Appropriate Mitigation Measures for Floodprone Structures, range from $32/square foot for a wood frame on concrete or block foundation walls to $45/square foot for slab-on-grade.

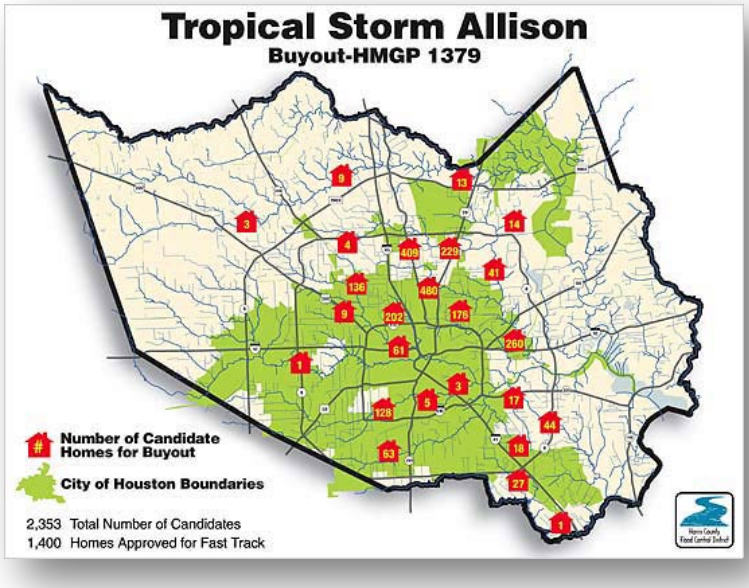
Authority and Funding

All entities have the authority to purchase property and subsequently remove structures, as well as elevate their own buildings and utilities. Only cities and counties have the authority to condemn property. These activities are generally included in the CIP or exist as a standalone plan and can be funded through taxes, bonds, or grants.

Local Example:

- Buyout Programs: When Tropical Storm Allison passed through the Houston-Galveston region in June 2001, it left behind millions of dollars in damage from flooding in downtown Houston and 73,000 flooded homes in Harris County alone. The City of Friendswood in Galveston County also suffered extensive flooding. The City received $19.7 million from FEMA through an accelerated buyout program following the storm. Under this program the City purchased and removed 200 homes that had flooded. Of these, 182 were substantially damaged and 122 had a history of flooding. Friendswood will maintain the property as open space.

Figure 12. Harris County's candidate homes for buyout as a result of Tropical Storm Allison



Is structure elevation or removal the appropriate mitigation technique?

- Structures removed are no longer at risk of flooding and resultant open space can help mitigate risk to neighboring structures.
- Removing structures takes fill out of the floodplain.
- Elevating a structure raises it above the BFE and if piers are used it also takes fill out of the floodplain.
- Structures left in the floodplain, but elevated, may result in stranded individuals in need of rescue during a flood event.
- Places with historical value can make removal undesirable.
- Elevating a facility may be expensive.

Land Acquisition

Land acquisition involves purchasing land in fee or purchasing land rights through an easement. Fee ownership is the underlying ownership of the property. Ownership of an easement grants specific rights to the owner of the easement which may limit the use of the property by the property owner or other easement holders. A typical drainage easement allows the easement holder to access property and to construct and maintain flood-damage reduction facilities or improvements, and prohibits the underlying fee owner, or property owner, from constructing features such as buildings, roadways, and fences that might interfere with the easement rights. Right-of-way (ROW) is a term that can apply to either fee ownership, easement ownership, or both.

There are three primary applications of land acquisition:

- **Channel ROW:** Channel ROW is land owned in fee or easement along a channel. Channel ROW is essential to having the right to enter a property for the purpose of maintaining it. If a grass- or tree-lined channel is to be mowed or pruned or if concrete is to be repaired on a concrete-lined channel, maintenance crews would have extremely limited rights of egress unless channel ROW is secured. Often, channel ROW is purchased in anticipation of future - even distant future - construction activities.

- **Floodplain Preservation:** One of the most cost-effective means of limiting flooding exacerbated by development activities is to purchase ROW for the purpose of floodplain preservation. Floodplain preservation can prevent development in locations at high risk of flooding. This preservation can prevent increases in impervious surfaces immediately adjacent to channels that might increase runoff and erosion. Finally, floodplain preservation can protect critical features of ecosystems such as wetlands and forested areas that play an important role in reducing flooding and maintaining water quality.

Should your community focus on land acquisition to reduce flood-risk?

- Land acquisition can be more cost-effective than large structural projects.
- It prevents structures from being built that would possibly be flooded later on.
- Property owners may resist if they feel they are not getting a fair price on their property.

- **Buyouts:** Some locations are prone to flooding. When these locations have already been developed, one of the best ways to prevent future flooding is to purchase the properties as a buyout, which is typically a voluntary activity. Because of limited money, buyouts target owner-occupied residential properties at extremely high risk of flooding as evidenced by a history of frequent and costly floods. Federally-funded buyout programs require well-defined benefit/cost calculations and a match from the local agency.

Authority and Funding

Land acquisition costs are fairly straightforward. In addition to the property itself, fees can include surveys, appraisals, and title insurance. Depending on the size of the property, the cost may be in the millions.

Properties can be acquired by any entity through voluntary purchase, but only cities and counties have the authority to condemn property, which can inflate the cost. A community's planned land acquisition activities are generally described in the CIP or in a standalone plan.

Funding can be locally generated through taxes or bonds. Additionally, limited federal funds are available through FEMA and other federal agencies. These grants usually require a match. If the property will accommodate multiple functions, the other functions may have funding sources that could help pay for the acquisition.

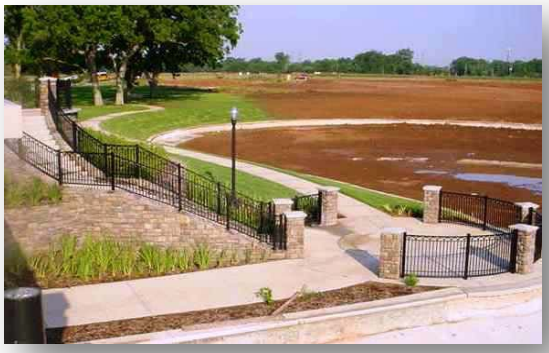
Local Example:

- HCFCD uses all three types of land acquisition throughout the county. One example where all three types of land acquisition were used in close proximity is at the confluence of Cypress and Little Cypress Creeks. In this area, houses historically prone to flooding were removed and the homeowners relocated to an area at lower risk of flooding. Channel ROW is used to maintain the wooded slopes of Cypress Creek. Additional ROW was acquired in conjunction with Harris County as the site for future parkland and detention. Property containing forested wetlands was acquired, and these wetlands will be preserved for their flood-reduction properties at the same time development is prevented at this critical junction of Cypress and Little Cypress Creeks.

Detention Basins

A detention basin is a facility where water can be temporarily stored during and after a heavy rain event. Its purpose is to reduce the risk of flooding for a large portion of a watershed by extending the time that is available to manage floodwaters. Basins can often be designed to meet water quality, aesthetic, or recreation objectives, in addition to flood management objectives. This discussion of detention basins focuses on regional facilities, as opposed to development-specific basins.

Figure 13. Detention basins within the City of Missouri City



Authority and Funding

Regional detention basins are one of the structural mitigation measures most frequently used by communities in this region to reduce the risk of flooding. All entities have the authority to use detention basins for mitigation as long as they have the necessary funds and land. They are often part of a CIP funded by bond funds, but can also be funded through taxes or grants and exist as a standalone plan. They may be part of a larger watershed plan that is funded in part by federal matching funds through the Corps. Costs include permitting, design, land acquisition, construction, and maintenance. Costs can often be minimized by building in undeveloped areas.

Local Example:

- Greens Bayou Federal Flood Damage Reduction Project is a partnership of the Corps and HCFCD, and includes the construction of 11 detention basins.

Figure 14. Detention basin control structure in the Greens Bayou watershed

Is a detention basin the appropriate mitigation measure to use?

- Basins can often be designed to meet water quality, aesthetic, or recreation objectives, in addition to flood management objectives.
- Detention basins are harder to implement in a watershed that is already highly developed.

Floodplain Fill Mitigation/ Excavation of the Floodplain

Floodplain fill mitigation ponds and excavation are created in response to a decrease in available storage in the floodplain. They are designed to hold stormwater, thus to decrease the likelihood of flooding.

Floodplain fill mitigation and excavation can come in the form of a pond as well as low lying areas that could be landscaped. If a pond is used for fill mitigation, the water always held by the pond cannot be counted as potential flood storage. Only the area between the water surface and the natural ground level is counted for mitigation. One design criteria that must be considered when creating a fill mitigation area is that it must be connected to the drainage system, allowing floodwaters to come and go, decreasing the possibility of flooding.

Floodplain fill mitigation ponds and excavation differ from detention basins in their application. When storage in the floodplain is reduced it can increase the BFE. Structures that did not previously flood during a storm event may subsequently be subject to flooding. In response, fill must be excavated and flood water storage created. In contrast, detention basins are necessary when imperviousness has increased on a property, which subsequently increases the amount of runoff from the property.

Authority and Funding

All entities have the authority to implement this mitigation measure as long as they have land and money available for development. Floodplain fill mitigation ponds and excavations are generally included in a CIP or a standalone plan and can be funded through taxes, bonds, or grants.

Local Examples:

- In 2004 TxDOT and the City of Sugar Land developed a mutually beneficial plan. During the second phase of expanding State Highway 59, TxDOT needed fill material to use for construction purposes. As a result of inputting fill in the floodplain, TxDOT needed to excavate fill for purposes of fill mitigation. Meanwhile, the City of Sugar Land was designing the first phase of the Brazos River Park just east of Highway 59. This phase included the construction of several ponds that would be used for fishing and canoeing. The cost of excavation for the ponds was expected to be in the millions. The resulting agreement was that TxDOT would excavate the ponds at no cost to the City and the excavated fill would then be used in the construction of the highway. The ponds would fulfill TxDOT's need to mitigate fill in the floodplain and in exchange TxDOT would construct an exit ramp so that visitors could more easily access the Brazos River Park as well as a deceleration lane so that entering into the park would be safer.

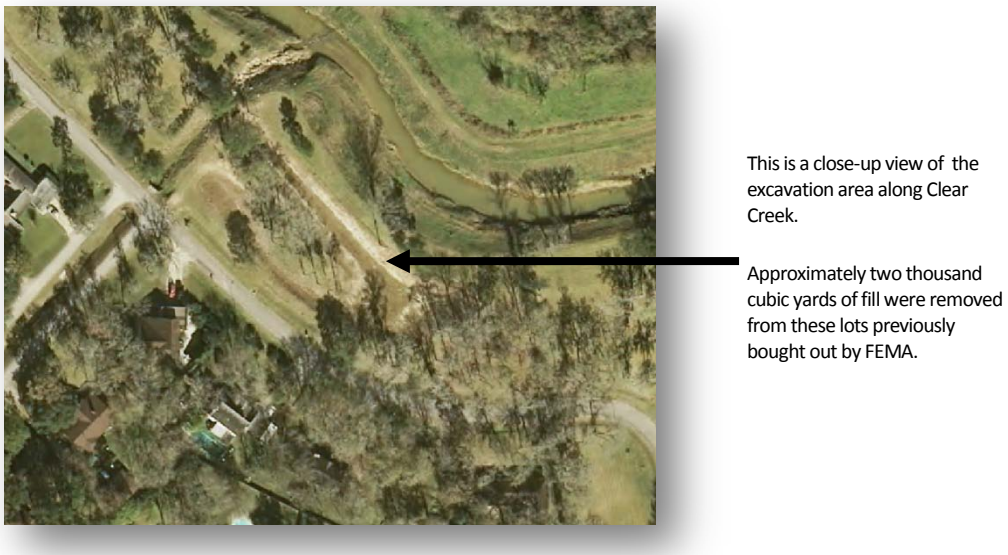
Is floodplain fill mitigation and excavation the right technique for your community?

- Many communities have regulations in place that require fill removal to counterbalance projects that add fill.
- Appropriate land may be difficult to locate and obtain.

Figure 15. Overview of Pearland's Yost Road project

- The City of Pearland/Harris County Area Access and Corridor Study identified the need to raise and widen Yost Road in Pearland, in addition to connecting it with Scarsdale Boulevard. In order to counterbalance the additional fill added to the floodplain in raising the road above the 100-year floodplain elevation, approximately 2,000 cubic yards of fill were excavated from nearby FEMA buyout lots on Sleepy Hollow Drive. Aerial photos of the project area can be seen in Figures 15 and 16.

Figure 16. Close-up of area excavated



Floodproofing

Floodproofing is the elimination or reduction of the risk of flooding to a commercial or public structure. Residences may not be mitigated through floodproofing. Floodproofing can include the following measures: anchoring a building to resist collapse and movement; installation of watertight closures; reinforcement of walls; usage of sealants to reduce seepage through walls; installation of pumps to control interior water levels; installation of check valves to prevent the entrance of floodwater or sewage flows through utilities; and the location of electrical, mechanical, utility, and other equipment and contents above the likely flood level.

Floodproofing is an appropriate mitigation measure for critical facilities that cannot be relocated or where relocation is cost prohibitive. Floodproofing is not an option when the structure is located in an area prone to rapidly rising, high-velocity floodwaters where warning times are short. Warning time must be sufficient to engage floodproofing components and then evacuate the danger zone.

The cost of floodproofing varies greatly and depends on the type and size of structure to be floodproofed, local flood characteristics, and the necessary elevation to which the structure must be floodproofed. In general, it is less expensive to floodproof a new structure than an existing structure, and larger structures have a lower cost per unit area for floodproofing than smaller structures.

Should that structure be floodproofed?

- Structures with historical value can be protected without having to relocate them.
- In general, it is more expensive to floodproof an existing structure.
- If possible, public structures should be built where the flood risk is lower.

Authority and Funding

All entities have the authority to floodproof their structures or utilities. The directive to floodproof a facility would be included in the CIP, a standalone plan, or a Hazard Mitigation Plan. Funding for floodproofing comes through taxes, bonds, or grants.

Local Example:

- The Texas Medical Center was devastated by Tropical Storm Allison in June 2001. The Texas Medical Center consists of 42 medical institutions, including 19 hospitals, most of which are connected by an underground tunnel system. Floodproofing controls that were in place at the time were completely overwhelmed by the massive amount of rain. Since then, 20 submarine doors, able to withstand up to 12 feet of water, have been installed throughout the Medical Center tunnel system. The total cost of the project was in excess of $5 million.

Channel Diversions

Channel diversions reroute an existing channel and divert excess stormwater flow, thereby, reducing flood risk. Channel diversions are also known as bypass channels.

A diversion might be implemented under the following circumstances:

- to remove the main floodway from a densely populated area to a less populated area
- to provide additional capacity when the channel right-of-way is restricted
- to divert floodwaters around a sensitive environment

Figure 17. A bypass channel as it could be applied to any existing channel

Channel diversions can be expensive. Construction costs usually include excavation, control devices at the beginning and end of the bypass channel, and land acquisition.

Authority and Funding

Any community can construct a bypass as long as they own the land and complete all necessary permits. Channel diversions are generally part of a CIP or exist as a standalone plan. Funding can include taxes, bonds, and grants.

Local Examples:

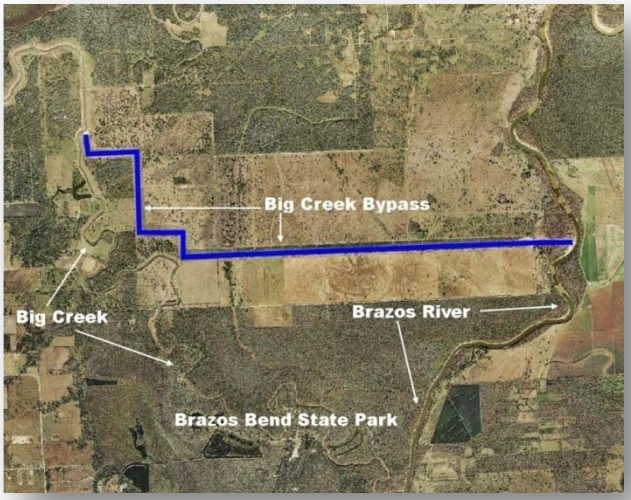
- To address persistent flooding along White Oak Bayou, HCFCD has a project to reduce current flood levels and to allow additional development in the watershed without having a negative impact on flood levels. The current project includes additional channel modifications, the excavation of several detention basins, and the creation of a diversion channel around Jersey Village.

Is a channel diversion the best mitigation technique for your community?

- Channel diversions can be used to protect natural resources and other amenities that cannot be relocated.
- Diversions are expensive and require large amounts of contiguous, linear land.

- Big Creek Bypass diverts floodwaters from Big Creek, one of the most flood prone creeks in Fort Bend County, to the Brazos River upstream of Brazos Bend State Park. When Big Creek is full, the 6.6 mile bypass channel diverts 65-75% of water around the park and directly into the Brazos River.

Figure 18. 2008 aerial photo of the Big Creek Bypass



Dams

A dam is a structure which separates one part of a water body from another. Its primary purpose is to retain water. It blocks a waterway's natural flow path, resulting in inundation and detention. This discussion is limited to dams that are intended to mitigate flooding.

Dams store runoff from a rain event and then slowly release the water. This reduces flooding for areas downstream because it distributes the water to the main waterway over a greater period of time. A dam can be installed upstream of an area that floods regularly as long as there are no populations upstream that will be adversely affected.

Figure 18. Dam, in Missouri City, designed to maintain the water level upstream and mitigate flooding downstream

Photo courtesy of the City of Missouri City

The cost of a dam includes the cost of initial construction, maintenance, and acquisition of land rights for land that will be periodically inundated upstream of a dam. The cost of dam maintenance varies greatly depending on the type of dam involved. Maintenance costs of a dam often include removal of sediment. In September 2008, when Hurricane Ike hit the Houston area many local dams were damaged. Costs to repair damage sustained by the Lake Conroe Dam are estimated at approximately $1 million, which would cover spot repairs on approximately 1,500 feet of the 12,000 foot dam.

Authority and Funding

Any entity can construct a dam as long as they own the land, have the necessary funds, and obtain all of the appropriate permits. Dams are generally included in a CIP or exist as a standalone project plan. Funding sources include taxes, bonds, and grants.

Should your community construct a dam to mitigate flood-risk?

- An amenity lake may be created through the installation of a dam.
- Aging dams can pose a risk of catastrophic failure and this risk may be unknown to those downstream.

Local Example:

- Dams can pose a risk for property and individuals downstream if they are not designed, operated, or maintained properly. Should a dam fail – even a small one – the results could be catastrophic for those downstream. Below is a table which lists, by county, the number of buildings and individuals at risk of dam failure in the H-GAC region.

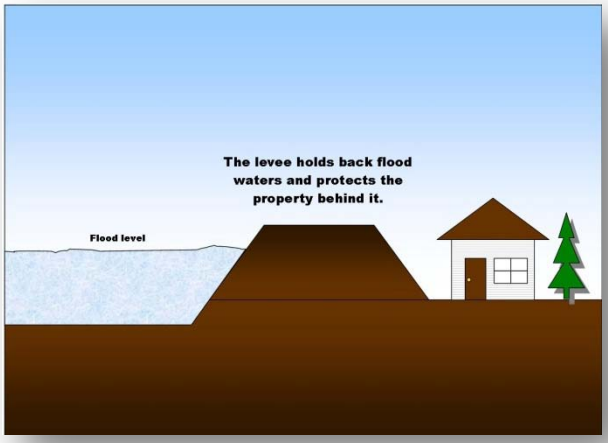
Table 1. Buildings and people at risk of dam failure

Jurisdiction (County)	Potential Residential Buildings at Risk	Potential Commercial Buildings at Risk	Potential People at Risk
Austin	1	1	1
Brazoria	36	1	93
Chambers	50	1	102
Colorado	1	0	1
Fort Bend	310	1	249
Galveston	2	0	5
Harris	7,940	71	9,534
Liberty	21	1	52
Matagorda	1	1	1
Montgomery	3,750	8	5,006
Walker	54	1	100
Waller	1	1	3
Wharton	1	0	1
TOTAL	12,166	88	15,147

Levees

A levee is a barrier built to keep a river, bayou, or other waterway away from people or sensitive habitats. For example, as floodwaters in a river rise, they are not able to impact a community because the levee holds back the water. However, this does not remove the area behind the levee from the floodplain – it is still the floodplain.

Figure 20. Diagram of a basic levee



Three things must be taken into account when considering the installation of a levee. First, it is important not to remove too much floodplain storage. Excess removal could restrict flood waters and slow drainage upstream. Second, levees are designed to protect an area from a certain flood level and storm intensity. If these levels are exceeded, a levee may be overtopped or may fail completely. Third, in order for a levee to continue functioning properly and provide security for those behind it, a levee should be regularly inspected and maintained.

Authority and Funding

Any entity can construct a levee as long as they own the land, have the necessary funds, and get all of the appropriate permits. Levees are generally included in a CIP or exist as a standalone plan. Funding sources include taxes, bonds, and grants.

Local Examples:

- The Cities of Texas City and La Marque have a levee system that protects the cities from storm surge. Work on the levee began after Hurricane Carla flooded Texas City with ten feet of water in 1961. Completed in 1987, the 17 miles of earthen levees were designed to withstand the force of at least a Category 3 hurricane. During Hurricane Ike in 2008, the levee system sustained approximately $2 million in damages and suffered extensive erosion, but its integrity was not compromised and neither Texas City nor the portions of La Marque within its protective boundaries flooded.

Figure 21. Levee reconstruction work

- In the City of Sugar Land, most of the major master-planned communities are located within one of five Levee Improvement Districts. The levees are designed to protect residents from floodwaters of the Brazos River and Oyster Creek. In Levee Improvement District No. 17, levees protect more than 2,000 acres of a master-planned community.

Figure 22. Levee and stormwater pump station in the City of Sugar Land

Photo courtesy of the City of Sugar Land

Should a levee be used by your community?

- Levees can provide great flood protection if properly maintained and if the flood level for which it was designed is not exceeded.
- There is a risk of catastrophic levee failure.
- Levees can provide a false sense of security.
- Levees remove floodplain storage.

Floodgates

Floodgates are used to control the flow of water and can be a part of flood prevention. Floodgates are often incorporated into reservoir, river, stream, levee, or storm surge systems. Water flow can be either partially restricted or completely stopped, depending on the water level and desired effect.

Some floodgates are left in the open position while others are left closed. Those generally left open will be locked into place when flood waters or storm surge threatens to enter a water system. Those usually left closed will be opened when waters are building behind the floodgate so as to reduce the risk of flood damage to those upstream.

Initial costs can be split into costs for possible property purchase, design costs, and construction costs. Maintenance costs can include annual maintenance as well as more intensive rehabilitation of the floodgates.

Should a floodgate be installed in your community?

- Floodgates can allow for normal flow of a waterway, but then completely stop flow when necessary.
- Floodgates are expensive and if operated manually there is the potential for operator error.

Authority and Funding

Any entity can construct floodgates as long as they own the land, have the necessary funds, and get all of the appropriate permits. Floodgates are generally included in a CIP or exist as a standalone plan. Funding sources can include taxes, bonds, and grants.

Local Examples:

- The Clear Creek floodgates are designed to remain closed the majority of the time to maintain the proper hydrologic characteristics in Clear Lake by preventing the addition of excess water from Galveston Bay. In times of flooding, or potential flooding, the floodgates are opened to release water.

Figure 23. Clear Creek second outlet channel floodgates

- The AMIL Gates, operated by the City of Sugar Land, help maintain a constant water surface elevation in Oyster Creek and the lakes that tie into it. During flooding conditions the gates divert flow from Oyster Creek into the Brazos River through a series of bypass channels. The gates are self-actuating and operate automatically in response to water pressure, without electricity. The gates have annual maintenance costs of approximately $12,000 while a rehabilitation project, scheduled for fiscal year 2009, is expected to cost $375,000.

Figure 23. AMIL Gates in the City of Sugar Land divert flood waters and protect the city

Photo courtesy of the City of Sugar Land

Chapter

3

Regulation

The third key component to effective flood management is the regulatory system. Without the ability to regulate development, flood management planning would be ineffective. Before discussing specific regulations available to communities we must first understand the regulatory authority granted to the various communities as well as the regulatory tools available for implementation.

Different types of communities have different available methods to regulate flood-related development activities. These differences can be classified according to the type of community: home rule city, general law city, county, or special purpose district. A **home rule city** is one that is allowed to draft its own laws, and needs only to look at state laws to determine what it may not do. **General law cities**, **counties**, and **special purpose districts** have less authority, being limited to only those activities and authorities specifically granted by the state.

Implementing Regulations

Cities and counties regulate using different mechanisms. Cities pass ordinances, while counties pass county court orders. The regulatory tools listed below are implemented through either an ordinance or a county court order as appropriate. Table 2 shows the regulation available to each type of community.

- **Zoning:** a land use tool that designates allowable uses of land based on mapped zones which separate one set of land uses from another.
- **Building code:** regulations developed by a local government regarding the safety standards that must be met when constructing buildings and other structures.
- **Infrastructure design standards:** criteria that must be adhered to in designing public works structures, including those having to do with drainage and flood management.
- **Subdivision regulations:** a land use tool that dictates requirements regarding land division.
- **Developer agreements:** a contract between a developer and a local government which establishes the regulations for a property's development.
- **Impact fees:** a payment that some local governments implement, giving individuals the option to pay into a fund in lieu of mitigating an effect. The collected funds are then used on larger, community-wide projects.

- **Floodplain management regulations:** regulations that specify the type, location, and elevation of allowable floodplain and floodway structures.
- **Development code:** regulations developed by a local government which dictate how development will occur.

Table 2. Regulatory implementation tools available to communities

Communities / Regulations	Home rule city	General law city	County	Special purpose districts
Zoning	✓	✓		
Building code	✓			
Infrastructure design manual	✓			✓
Subdivision regulations	✓	✓	✓	
Developer agreement	✓	✓	✓	✓
Impact fees	✓	✓	✓	✓
Floodplain Management Regulations	✓	✓	✓	
Development Code	✓	✓		

A variety of best management practices, listed in the box to the right, can be used to provide flood protection through regulatory actions. The first two are requirements for participating in the NFIP. It is good practice when managing flooding to first *do no harm*. In keeping with this objective the regulations of this chapter have been organized from prevention to management of flood risk.

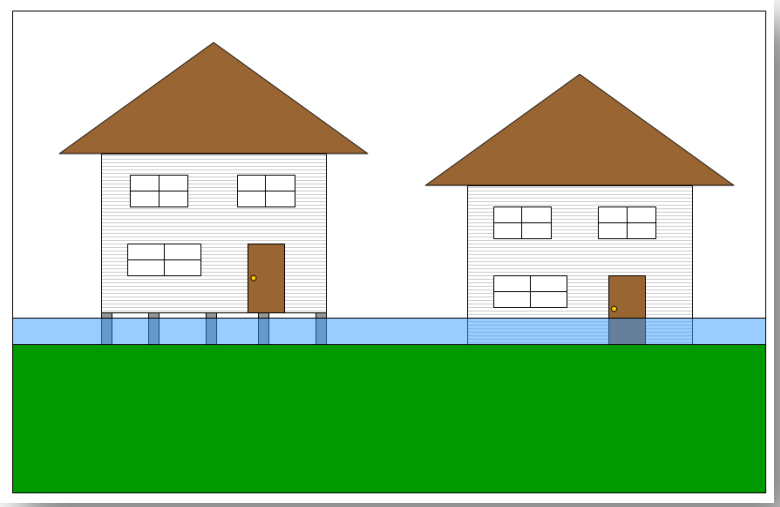
Regulatory practices well-suited to the Houston-Galveston region

- Require new development to be elevated above the base flood elevation and natural ground
- Require no net fill in the floodplain
- Adopt no adverse impact regulations
- Prohibit new development in areas at high risk for flooding
- Require ultimate development considerations when designing new construction and development
- Accommodate and encourage low impact development and small scale approaches to flood management
- Require detention for new development and multiple storm frequencies
- Update the design frequency of storms used to develop new construction and development

Structural Elevation

Many communities require that new construction and substantial modifications to existing facilities adhere to freeboard requirements. Freeboard is the elevation of a structure above the BFE. FIRMs identify BFEs in many communities. Other communities must determine BFEs on a site-by-site basis. Most communities require that facilities be elevated at least as high as the BFE except in unusual circumstances. Communities can further reduce the potential for flood damage by requiring additional freeboard or elevation above the natural ground.

Figure 25. Structures elevated above the BFE have a reduced risk of damage from floods.



According to the NFIP, there is a 26% chance that a non-elevated home in the floodplain will incur damage during a 30-year mortgage period. (For reference, there is only a 9% chance that a major fire will occur in the same period.)

Two notable projects underway might help incorporate freeboard into regulations. First, FEMA has proposed a modification to the International Residential Code (IRC) to include one foot of freeboard. Second, the Texas Floodplain Management Association (TFMA) is collecting information for a freeboard survey so that communities can easily see what standards other communities use for freeboard. This survey is included in the Appendix.

Should your community require additional freeboard?

- The NFIP requirement for structure elevation above the BFE and/or the natural ground can substantially reduce the risk of flood damage and significantly reduce insurance on those structures.
- In areas outside the mapped floodplain that experience severe flooding, it may make sense to require elevation of structures.

Local Examples:

- TFMA has surveyed 159 communities across Texas, including 44 in the Houston-Galveston region, regarding freeboard requirements. In 2008, at both the state and regional level, 77% of those surveyed require freeboard of one to two feet for new construction. Many of these communities also require freeboard above the natural ground, the crown of the road, or the curb.

- Brazoria County has specifications regarding elevation of structures in all areas of special flood hazards. They require that residential structures be elevated two feet above the BFE. Non-residential construction must be either elevated or "designed so that below the base flood level

the structure is watertight … and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy."

- The City of Pasadena's ordinances require that the lowest floor be elevated to "a minimum of one (1) foot above the centerline of the street at the midpoint of the lot, or one (1) foot above the BFE using City of Pasadena bench marks … whichever is higher." In some areas, two feet is required instead of one.

No Net Fill

No Net Fill is a design criteria that requires all fill placed in a floodplain be balanced with at least an equal amount of soil material removal. No Net Fill also denotes "no net loss" of floodplain storage. A natural function of a floodplain is to store excess floodwater. A loss of storage area results in an increase in flow downstream and, ultimately, higher flood elevations downstream.

Construction materials, structures, and substrate for elevating new construction above the floodplain can all add fill to the floodplain. A No Net Fill regulation requires the excavation and removal of fill from the floodplain to balance the volume of fill added to the floodplain.

Figure 26. Fill is removed from the floodplain to compensate for fill added

Local Examples:

- The City of Missouri City does not allow encroachments, new construction, substantial improvements, or fill, in the regulatory floodplain, unless it has been shown that flood levels will not increase as a result of the encroachment.

- Brazoria County regulates the placement of fill outside the floodplain in addition to requiring a permit for fill within the floodplain. Particulars of the building regulations include:

  - Fill must be evenly dispersed and spread
  - The source of the fill must be identified
  - If the natural flow of water is altered, the property owner must mitigate for the altered flow by installing ditches, swales, detention, or other means
  - If more than 250 cubic yards per acre will be placed on a property, a permit is required from the Floodplain Administrator and a hydraulic analysis certified by a professional engineer is required.

Should a No Net Fill regulation be established in your community?

- Without a No Net Fill regulation in effect the BFE may be raised and existing structures previously above the BFE may now be at greater risk of flooding.
- Any fill removed must be disposed of outside of the floodplain and it may be difficult to find an acceptable disposal site.
- Unmonitored fill removal can result in low spots that will fill with water during rain events.

No Adverse Impact (NAI)

NAI is a set of principles to direct floodplain management developed by the Association of State Floodplain Managers (ASFPM). In essence, NAI floodplain management takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners. The adverse effects or impacts can be measured in terms of increased flood peaks, increased flood stages, higher flood velocities, increased erosion and sedimentation, or other impacts the community considers appropriate. In order to comply with this policy many of the regulatory techniques discussed in this chapter could be utilized.

The ASFPM states, "In general, if your community permits development that results in an adverse impact, your community may be liable, even if you meet the minimum federal standards." Current NFIP standards, considered the minimum for floodplain management, protect new construction, but may allow the following adverse impacts:

- Diversion of floodwaters onto other properties
- Reduction of channel and overbank conveyance areas
- Filling of essential valley storage
- Changing of floodwater velocities with little or no regard to their impact on others in the floodplain and watershed

A policy of NAI would help to address these adverse impacts.

Is a policy of NAI right for your community?

- NAI has the potential to reduce the costs associated with flooding.
- NAI regulations may protect communities from liability.
- An NAI policy may not prevent very small, un-measurable impacts from occurring.

Local Examples:

- The City of Sugar Land amended its development code by ordinance to incorporate a policy of NAI in 2007. New language referencing the policy was inserted into the chapter regarding flood damage prevention regulations. The addition charged the City's floodplain administrator with the duty and responsibility of enforcing the policy. "This policy," the addition reads, "requires that the action of one property owner does not adversely impact the rights of other property owners, as measured by increased flood peaks, flood stage, flood velocity, and erosion and sedimentation."

- Harris County does not explicitly incorporate NAI into its regulations. It does, however, incorporate the philosophy of NAI throughout its regulations. For example, the requirements regarding the placement of fill are consistent with NAI principles. When fill is being placed on a property a "Permittee's Acknowledgement of Disclaimer Regarding Placement of Fill on Private Property" must be obtained and completed. This document states that the fill should be placed on the property in a way that will not flood or damage a nearby property and references Section 11.086 of the Texas Water Code.

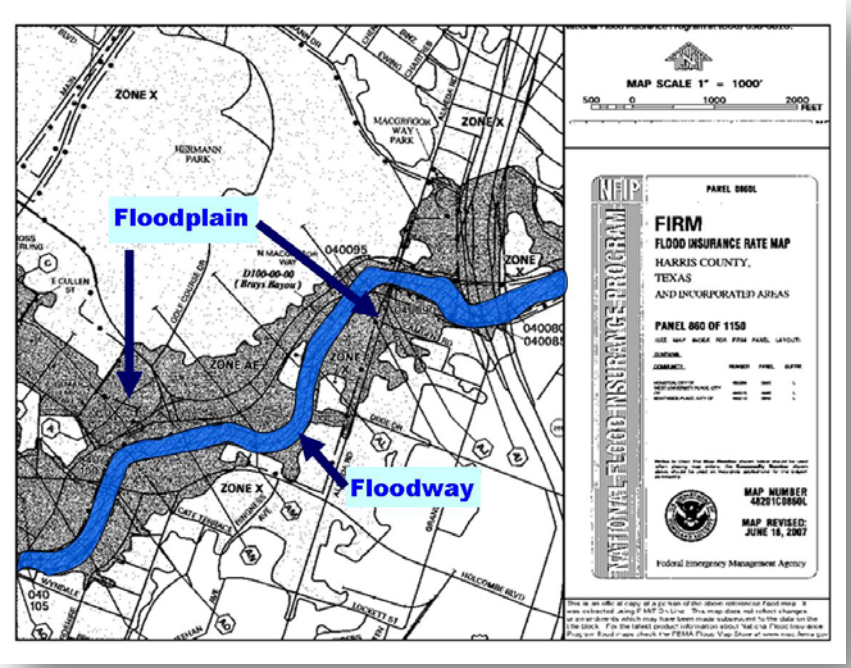
Development in High-Risk Flood Areas

Common sense dictates that development should avoid high-risk flood areas. While the floodway is frequently among the areas at high risk of flooding, high-risk areas are not limited to the mapped floodway.

In some parts of the country, it is reasonable to consider restrictions or prohibitions for the entire floodplain. However, in this relatively flat region, to prohibit development in the expansive floodplain might be too restrictive. Protection of the floodway is a good first step.

NFIP regulations strictly limit development within a floodway. FEMA recommends the floodway be reserved and kept free of obstructions to allow floodwaters to move downstream. Placing fill or buildings in a floodway may block the flow of water and increase flood heights.

Figure 27. A typical illustration of a floodway and floodplain



Local Examples:

- The City of Houston recently proposed a regulation that would have prohibited any new development in the floodway. However, citizen opposition, citing the devaluation of their property, caused an adjustment of the effort. The ordinance, section 19-43 of the City's code of ordinances, was subsequently modified and now contains strict performance standards for any new development or substantial improvements to existing buildings within the floodway. This regulation should significantly reduce new development and building that is at high risk of flood damage.

- The City of Pasadena has enacted a regulation prohibiting development in a portion of the 1% (100-year) flood hazard zone. Section 9-188(8) of the City's code of ordinances prohibits all new development in the 1% flood hazard zone in the Armand Bayou Watershed south of the tidal influenced flow.

Should your community prohibit development in high-risk flood areas?

- While NFIP regulations may allow some development within the floodway, there are several reasons to prohibit new development within the floodway, even with appropriate "no rise" certification including:
  - Reduced flood damages
  - Improved water quality
  - Increased opportunities for recreation
  - Preservation of wildlife and natural habitats
  - Enhanced erosion control
  - Increased property values
  - Sustained economic prosperity

- Some will view these high flood risk areas as valuable waterfront property resulting in strong opposition.

Ultimate Development

The concept of ultimate development assumes that all possible development within a watershed has already occurred and that no additional adverse flooding effects are likely. Few watersheds within the H-GAC region are fully developed and developments within the watersheds are rarely designed with ultimate development of the watershed in mind. Master planned developments in the region typically have infrastructure designed to handle stormwater runoff within the development but may not accommodate runoff resulting from ultimate development upstream. New development can influence the frequency and nature of flooding within a watershed, whether by alteration of the floodplain or modification of hydraulic and hydrologic behavior of waterways.

Some would argue that a policy of NAI cancels the need to consider ultimate development in stormwater infrastructure design. In other words, if no development will have an adverse impact, then that development will have no effect on future conditions. However, NAI may not account for some un-measureable, incremental changes to floodplains which, when multiplied many times, may slightly raise the BFEs. Furthermore, one community's NAI policies do not necessarily extend to other upstream communities within the same watershed. How one community in a watershed develops can have an effect on other communities in that watershed.

Note: The terms "fully developed watershed conditions," "ultimate conditions," and "built out" are synonymous.

Figure 28. From 2000 to 2008 the intersection of FM 2920 and Kuykendahl saw a dramatic increase in development. Consideration of ultimate development would have been appropriate and beneficial in a situation like this.

Local Example:

- The City of Huntsville maintains that planning for future development at the time of original construction is the intelligent thing to do economically and in regard to flood management. Its development code requires that ultimate development be considered, and that developers, when designing a drainage facility, must plan for runoff quantities for a fully-developed watershed. In particular, developers are to use a runoff coefficient of at least 0.75 for all upstream property that is undeveloped. To accommodate for future development developers of drainage facilities must assume that, when developed, upstream property will retain 25% of the rainfall that reaches its surface while 75% will runoff.

Should your community enact ultimate development regulations?

- Forecasters estimate that the population of the region will increase by over 3 million by 2035. Presumably, the change in land use accompanying this growth will influence the nature of floodplains and flood prone areas adding more structures at risk of flood damage.
- By considering future conditions when regulating development now, it may be possible to mitigate damage to existing and yet-to-be-built structures within the region.

Low Impact Development (LID)

LID is a comprehensive land planning and engineering design approach to managing stormwater with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds. Its basic principle emulates nature: manage stormwater at the source using uniformly distributed, decentralized, micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source.

Instead of treating stormwater in large, costly facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. These landscape features, known as Integrated Management Practices (IMPs), are the building blocks of LID. Almost all components of the urban environment have the potential to serve as an IMP. This includes not only open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment or revitalization projects.

Figure 29. This cistern catches rainwater from the rooftop of the City of Houston Northeast Water Production Plant and is then used to water the landscaping on site.

Figure 30. This bio-swale is located in the parking lot of the Gene Green Park off Beltway 8 in northeast Harris County.

Local Examples:

- The City of Houston Department of Public Works and Engineering Design Manual describes seven LID techniques permitted within city limits, including bioretention, infiltration trenches, porous pavement, vegetative swales, green roof, hard roof, and rain barrels. Of these, hard roofs, green roofs, and porous pavement are thought to have an impact on detention rates.

- Harris County has developed regulations allowing the implementation of LID techniques.

Are LID regulations appropriate for your community?

- Proponents say that LID is an ecologically functional and economically sustainable approach to stormwater management, especially compared to conventional infrastructure and regulatory approaches. By managing runoff close to its source through site design, LID can enhance the local environment, protect public health, and improve community livability – all while saving developers and local governments money. Furthermore, in some situations, LID addresses water quality requirements imposed by the Clean Water Act and other programs.

Detention

A detention basin is an area where excess stormwater is stored or held temporarily and then slowly drained when water levels in the receiving channel recede. Detention increases the *time* that is available to manage floodwaters, but not the *amount* of floodwaters that must be managed.

In this region, excavated facilities account for most stormwater storage. Stormwater enters a detention basin through a storm sewer pipe, by sheet flow from the surrounding development, or by overflow from a rising channel. Basins generally include a control structure to slow water (re)entering a channel.

Detention basins usually address specific building sites or developments. Some communities require that development over a certain size include detention as part of the site plan. Regional basins receive and store water for a large area, addressing flood damage potential for a large part of a watershed.

Figure 31. This detention basin, off of Kingsley Drive in Pearland, is also a soccer field for the community.

Local Examples:

- Harris County requires detention be incorporated into all projects over one acre and commercial development projects that have a property depth of at least 150 feet and discharge into a Harris County roadside ditch. In some watersheds, Harris County allows builders to pay an impact fee that is used to develop flood damage reduction projects within the watershed.

- The City of Sugar Land Design Standards requires the use of on-site detention for all new developments unless regional detention facilities are built to mitigate the developmental impacts. The City adopted a drainage ordinance in the Sugar Creek area where a regional detention facility has been constructed. According to this ordinance (No. 1129) the developer has the option of paying a drainage impact fee in lieu of on-site detention.

Figure 32. This detention basin, located at the intersection of US 59 and Alt 90 in Sugar Land, was paid for in part by fees collected from developers in lieu of on-site detention construction at developments.

Are detention regulations appropriate for your community?

- Detention basins can hold tremendous amounts of water, increase property values when the basins are thoughtfully designed, incorporate sports fields or other multi-functional amenities, and substantially decrease the cost of storm sewer pipes.
- Detention basins require acreage and regular maintenance such as trash and debris removal.
- If not properly maintained, a basin may become a mosquito breeding ground or the outlet could become obstructed.

Design Frequency of Storms

The design frequencies of storms are standard rainfall amounts and storm durations that engineers use when analyzing and designing new construction. Regulations often specify that projects must be designed to a specific storm frequency. There is growing concern that the design frequencies typically used may be inappropriate, and that regulations should specify larger, less frequent storms. Moreover, the rainfall amounts and storm durations used to determine various design frequencies may inadequately correlate to the actual frequencies of such storms, leading to more flooding than expected.

Facilities designed to accommodate a specific storm frequency might include culverts, bridges, channels, storm drains, detention basins, and any structure that must be elevated above the BFE. Streets are also a part of the drainage system and are designed to hold stormwater for a specific storm frequency. Communities in this region often characterize a storm event that drops one inch of rain in an hour as a 50% (or 2-year) storm. The NWS, the USGS, and others have analyzed historic rainfall data to develop these guidelines and determine the size and intensity of various probabilities of storm events.

Figure 33. A storm event has surpassed the design frequency for which the street was designed

For example, a residential street in a master-planned community that is designed for a 50% (or 2-year) storm will probably fill with water, on average, about once every two years. If the standard design frequency for residential streets in that community were instead set at the 20% (or 5-year) storm, the probability that the street would flood in any given year would decrease substantially.

Note: By referring to storms by their probability (e.g., a 4% storm) instead of by their frequency (e.g., a 25-year storm), individuals may better understand the concept of how a 100-year storm can occur twice in ten years.

Table 3. Storm probabilities and their equivalent storm frequencies

Storm probability	100%	50%	10%	4%	1%	0.2%
Storm frequency	1-year	2-year	10-year	25-year	100-year	500-year

Table 4. Minimum design criteria for storm sewers in selected communities

Regulatory Agency	Design Frequency	Min. Pipe Diameter	Min. Velocity	Max. Velocity	Tailwater
Montgomery County	20% storm	24''	3 fps*	10 fps	25 yr
City of Sugar Land	50% storm	24''	3 fps		25 yr
City of Houston	50% storm		3 fps	12 fps	100 yr
Harris County	50% storm	24''	3 fps	8 fps	100 yr
Fort Bend County	50% storm		3 fps	10 fps	25 yr
Texas Department of Transportation	50%-2% storm		2 fps	12 fps	
Brazoria County	20% storm	24''	3 fps	10 fps	25 yr

*fps = feet per second

Local Examples:

Table 4 summarizes some of the variations in design frequency considerations for storm sewers in various communities:

- Harris County set the design frequency of storms for newly developed storm sewer systems at a 50% (2-year) storm. However, to address more extreme events, Harris County requires a demonstration of an overflow path, also referred to as sheet flow, for floodwaters. During extreme rain events floodwater is often unable to enter the overloaded storm sewer system. A typical accommodation is to grade the subdivision so that water will sheet flow through the subdivision and into a nearby channel, instead of pooling within the subdivision and around (and in) buildings.

- The City of Houston has designed drainage so that street ponding of short duration contributes to the overall drainage capability of the system. Stormwater design requirements in the city's Design Manual state that maximum ponding elevation shall be no higher than the ground elevation at the right of way line during a 1% storm. Additionally, ponding at high points of the street can be no deeper than 6 inches above the curb and at low points no deeper than 18 inches.

Should your community update the design frequency of storms for which facilities are designed?

- Updating the design frequency of storms to accommodate larger, less frequent storms reduces the risk of flooding and can be cost effective for new development.
- Upgrading existing storm sewer systems to comply with the requirements for a larger design storm could be costly as well as disruptive to the community.

Tools Available for Implementing Flood Management Regulations

Table 5 depicts the various regulatory tools that can be used to implement each regulation.

Table 5. Tools available for implementing various flood management regulations

Regulations / Tools	Elevation	No Net Fill	NAI	Prohibit development in high risk areas	Ultimate development	LID	Detention	Design Frequency of Storms
Zoning				✓				
Building code	✓							
Infrastructure design manual						✓	✓	✓
Subdivision regulations							✓	
Developer agreements		✓	✓			✓	✓	
Impact fees		✓	✓				✓	
Floodplain Management Regulations	✓	✓	✓	✓	✓	✓		✓
Development Code	✓	✓	✓	✓	✓			✓

Chapter

4

Funding

The fourth, and final, key component of effective flood management is funding. Most funding sources originate from local, state, or federal governments, although there are other sources.

Local funding sources are typically generated from local tax revenue or through a bond program. State funding is typically administered by TWDB or similar agencies. Primary sources of federal funding include FEMA and the Corps of Engineers. Funding programs are listed below and described more fully in the chapter. Table 7, located at the end of the chapter, provides a quick reference of eligible activities for the various fund sources.

Local Funding

- Taxes
- Bond Programs
- Utility Fees
- Impact Fees

State Funding

- TWDB's Flood Protection Planning Program
- Office of Rural Community Affairs
- Texas Parks and Wildlife Department
- Texas Department of Transportation

Federal Funding

- FEMA
    - Flood Mitigation Assistance Program

  - Hazard Mitigation Grant Program
  - Pre-disaster Mitigation Grant Program
  - Repetitive Flood Claim Program
  - Severe Repetitive Loss Program
  - Public Assistance Grant Program
- U.S. Army Corps of Engineers
  - Section 205 program: Small flood control projects
  - Section 208 program: Snagging and clearing
  - Section 22 program: Planning assistance to states
  - Section 206 program: Floodplain management services program
  - Section 211(f) program: Local agency reimbursements
- National Resources Conservation Service

Other Sources

- Private Foundations
- Corporations
- Land Trusts

Local Funding

Local funding is generally under the control of the community wishing to make improvements. The biggest challenges are finding an appropriate mechanism and overcoming political opposition.

Taxes

Many local government agencies have the authority to levy taxes for the purpose of flood damage reduction.

For example, in 2007 the City of Sugar Land established a separate drainage fund to account for the portion of property taxes dedicated toward drainage activities. At the time, Sugar Land's ad valorem property tax rate was $0.30 per $100 assessed valuation. Of every 30¢ collected, 2¢ were dedicated toward drainage.

HCFCD, like some drainage districts, is funded in part by an ad valorem tax assessed on property owners, the proceeds of which are directed toward flood control initiatives. Drainage districts often collaborate with other government agencies to fund and implement flood management activities. Table 6 shows examples of various drainage district tax rates.

Table 6. Drainage district tax rates

Entity	Tax rate per $100 assessed valuation (2007)
Harris County Flood Control District	$0.032410
Galveston County Consolidated Drainage District	$0.142500
Fort Bend County Drainage District	$0.018000
Willow Fork Drainage District	$0.200000
Angleton Drainage District	$0.170850
Danbury Drainage District	$0.353723
Velasco Drainage District	$0.082075
Montgomery County Drainage District No. 6	$0.266100
Brookshire-Katy Drainage District	$0.093900

Bond Programs

The proceeds from the issuance and sale of bonds are frequently used to fund large-scale projects included in a CIP. Repayment of the bond financing is usually through tax revenue. The benefit of bond funds is that they can provide a large amount of money at one time when those funds are not readily available in the general budget. One main drawback is that borrowed money, such as the proceeds from the issuance of bonds, requires payment of interest. For this reason, some agencies prefer a pay-as-you-go system, eliminating

interest payments. However, if bonds are sold at a low interest rate it may be the most cost-effective funding method.

As an example, Harris County and HCFCD use bond funds to pay for flood control projects. Typically, the authorization for the issuance of bonds is tied to the funding for the CIP. HCFCD plans to spend $325.2 million of available funds for ongoing and planned projects for the five-year period from fiscal year 2009 to fiscal year 2013. While a portion of this spending will be paid for using funds derived from the sale of bonds and the investment income thereon, HCFCD's partnership with the Federal Government through the Corps and FEMA forms the foundation of the HCFCD's CIP for the next 15 years or more.

Utility Fees

A community's stormwater or drainage infrastructure is a separate system from other utilities such as public utilities (water, trash, and sanitary sewer) or private utilities (electricity, natural gas, telephone, and cable television). The Municipal Drainage Utilities Act in the Local Government Code (Chapter 402, Subchapter C) establishes authority for any municipality to create, operate, and fund existing or future drainage utility systems. As part of this authority, the municipality may impose a drainage charge to each property that is benefitted by the drainage system. Charges are based on the size, land use, amount of impervious cover, and/or benefit to the property. While a drainage charge may be collected along with other utility fees, the proceeds from the drainage charge must be separated from other utility fees and must be used specifically for drainage-related projects or activities. Among other expenses related to drainage systems, the revenues may be used for capital improvement projects, planning studies, system maintenance, stormwater quality monitoring, public education, and payment of bond obligations.

For example, in 2001 the City of Dickinson established a drainage fee to help fund drainage projects. The fee schedule in 2008 is as follows:

Single Family Residential..... $4.00 monthly
Non-Residential < 1/4 acre ..... $7.00 monthly
Non-Residential 1/4 - 1/2 acre..... $13.00 monthly
Non-Residential > 1/2 acre ..... $25.00 monthly
Multi-family Residential (Per Unit) ..... $3.00 monthly

Similarly, the City of Sealy established a drainage utility fee in 2005 as a means of protecting the public health and safety in the city from loss of life and property caused by surface water overflows, stagnation, and pollution. The rates are as follows:

Single Family Residential..... $4.00 monthly
Non-Residential - per ERU* ..... $7.00 monthly
Multi-family Residential (Per Unit) ..... $2.00 monthly

* One (1) ERU (Equivalent Residential Unit) is equal to 5,000 square feet of impervious cover. For all non-residential purposes, the number of ERUs is determined by dividing the total impervious area of the property by 5,000. The drainage utility fee for such properties is the base fee per month multiplied by the number of ERUs.

Impact Fees

Chapter 395 of the Local Government Code allows local governments to levy impact fees against new development. The revenue from the impact fee must be used to pay for capital improvements built in support

of the new development. Specifically, the revenue can be used to pay for surveying, engineering, land acquisition, or development or updating of a capital improvement plan related to the new development by a contractor.

As an example, the City of Missouri City established an impact fee for the Northeast Oyster Creek Subwatershed Area in 1992. As part of the process, the City developed land use assumptions and a CIP, which were used to establish the fee. The land use assumptions and CIP are periodically updated. Updates are largely pursuant to new development, and the subwatershed area has been expanded to incorporate them. The fee is assessed against new development at the time of final platting.

State Funding

In addition to administering some federal grant programs (notably FEMA programs such as the Hazard Mitigation Program) the state provides limited funding for flood damage reduction projects. The following are examples of state funds that may be available.

TWDB's Flood Protection Planning Program (FPP)

Local governments that participate in the NFIP may apply to the TWDB to receive FPP funds. Projects eligible are those that contribute toward the evaluation of possible solutions to flood problems. This can include cost/benefit analysis of structural and non-structural solutions and assessment of public opinions and needs. In most instances, grants cover no more than half of total costs. However, if a community has a lower than average income and high unemployment, the grant can cover up to 75% of the costs.

From 1992 to 1994, Galveston County received three FPP grants totaling $375,000. The grant funds were used to determine baseline hydraulic and environmental data for Dickinson Bayou and its tributaries, to prepare a drainage criteria manual, and to develop a method of cooperation between local groups to implement flood control measures. Finally, flood reduction measures were analyzed and selected, and an implementation plan was produced.

Office of Rural Community Affairs (ORCA)

ORCA provides grant funds to cities with a population less than 50,000 population and counties with less than 200,000 non-metropolitan residents under the Community Development Fund (CD). Grant funds can be used for sewer and water system improvements, street and drainage improvements, and housing activities. The funds can also be used for planning activities, although these activities are rarely funded in our region.

Texas Parks and Wildlife Department (TPWD)

TPWD has grants available for the acquisition, development, or renovation of parklands. In conjunction with other funding sources, these grants can be used to fund multi-functional facilities that include flood mitigation measures.

Texas Department of Transportation

TxDOT has a program titled Participation-Waived Project/Equivalent-Match Project (PWP/EMP) which permits a local government to forgo payment of their 10% of a Federal Highway Bridge Replacement and Rehabilitation Program bridge project if they agree to use an equal amount for improvements to another deficient structure. Eligible projects include low water crossings and main-lane cross-drainage structures, and could be used to fund a flood mitigation project such as elevation of a bridge, as long as they are classified as deficient.

Federal Funding

Federal funds for flood damage reduction activities primarily come from FEMA or the Corps, although limited funding may come from other agencies. Additional federal sources may be available to help fund projects, particularly when the projects are multi-objective in nature. For example, the Corps can help provide funding for recreation, ecosystem, or water supply projects in conjunction with flood damage reduction projects.

Federal Emergency Management Agency

FEMA has several programs to fund flood damage reduction programs. Some of these funds are given to the state to administer at a local level.

- *Flood Mitigation Assistance Program (FMA):* In 1994 the FMA was developed as a part of the National Flood Insurance Reform Act (NFIRA). Its primary purpose is to reduce or eliminate claims filed under the NFIP. In the State of Texas, the FMA is administered by TWDB. Funds provided by the grant to a community will be no more than 75% of the total eligible costs of the plan development or project. There are two types of FMA grants available to communities:

  - Planning Grants – awarded to those developing or updating flood mitigation plans.
  - Project Grants – awarded only to those with an approved flood mitigation plan. These are given to aid communities in implementing flood loss reduction measures, such as those described in the mitigation chapter, on NFIP insured structures. FEMA prefers that these funds be funneled toward repetitive loss properties.

- *Hazard Mitigation Grant Program (HMGP):* Authorized by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the HMGP provides funds to state and local governments following a disaster in order to implement long-term hazard mitigation measures. The ultimate goal is to reduce the loss of life and property.

  In Texas, the HMGP is administered through the Governor's Division of Emergency Management (GDEM). Generally, the application process must be begun within 30 days of the disaster declaration. FEMA will fund up to 75% of the total eligible costs of the mitigation measures.

  Between 1978 and 1995 Liberty County residents submitted over $5 million in National Flood Insurance claims. In 1994 and 2006, Liberty County was awarded HMGP funds totaling $4.3 million for the acquisition and demolition of 192 properties. These properties, once structures have been demolished, will remain open space.

- *Pre-Disaster Mitigation Grant Program (PDM):* The PDM program is administered by the GDEM and funds mitigation planning and projects for state and local governments before a disaster occurs. The purpose of the PDM program is to reduce risk to life and property, and to reduce dependence on post-disaster funding. FEMA will provide up to 75% of the total eligible costs of the project. If a community has been officially designated as "small impoverished," up to 90% of project costs will be funded by FEMA.

- *Repetitive Flood Claim Program (RFC):* Authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 and administered by the GDEM, the RFC provides funds to states and local governments to reduce the risk of flood damage to properties that have received insurance claims under the NFIP. Mitigation measures for which these funds can be applied include property acquisition, elevation of structures, dry floodproofing of non-residential structures, and local flood control projects costing no more than $1 million. If a community cannot supply the required 25% of a project's costs, and are therefore unable to be funded under the FMA, FEMA may supply up to 100% of the money.

- *Severe Repetitive Loss Program (SRL):* Authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, the SRL grant program aims at reducing or eliminating the long-term flood damage risk to severe repetitive loss structures. A severe repetitive loss structure is one that has received at least four NFIP insurance claims of at least $5,000 each or at least two claims with the total of the two being more than the value of the structure. This program is administered by the TWDB.

- *Public Assistance Grant Program (PA):* These funds are available to communities for quick response and recovery from disaster. Funds can be used for debris management, emergency protective measures, and work on damaged public facilities. If funded, FEMA will provide at least 75% of the eligible costs. The program is administered by the GDEM.

US Army Corps of Engineers

The Corps is responsible for investigating, developing, and maintaining the nation's water and related environmental resources. One of the Corps' interests is providing support to state and local governments for the planning and construction of flood damage reduction projects.

As of September 2008, the Corps' Galveston District , which includes the entire H-GAC region, partnered with local governments on the following flood control projects: Clear Creek Project (Fort Bend, Harris, and Galveston Counties), the Lower Colorado River Basin Study (Colorado, Wharton, and Matagorda Counties), the Greens Bayou project (Harris County), and the Sims Bayou Flood Control Project (Harris County). This assistance was provided in response to authorizations from the United States Congress, usually in Water Resources Development Act (WRDA) legislation. Large projects must be individually authorized. Smaller projects can be addressed through the Corps' Continuing Authorities Program. This program allows for support of projects without the burden of seeking specific congressional authorization. The first two funding sources listed below are a part of this program.

- *Small Flood Control Projects:* (Authorized by Section 205 of the Flood Control Act of 1948.) Work under this Continuing Authorities Program provides for local protection from flooding by the construction or improvement of flood control works such as levees, channels, and dams. Non-structural alternatives are also considered and may include measures such as installation of flood warning systems, raising and/or floodproofing of structures, and relocation of flood prone facilities. The local government must provide a 35%, non-federal match.

- *Snagging and Clearing for Flood Control:* (Authorized by Section 208 of the Flood Control Act of 1954.) Work under this Continuing Authorities Program provides for local protection from flooding by channel clearing and excavation, with limited embankment construction using material from the clearing operation only. The local government must provide a 35%, non-federal match.

Figure 34. Corps project at Sims Bayou

- *Planning Assistance to States:* (Authorized by Section 22 of the WRDA 1974.) This authority allows for the Corps to assist the states in the preparation of comprehensive plans for the development, utilization, and conservation of water and related land resources.

- *Floodplain Management Services Program:* (Authorized by Section 206 of the Flood Control Act of 1960.) The Corps is authorized to provide technical assistance, planning guidance, and general information related to the management, development, and use of the nation's floodplains. When requested, the Corps will provide new and existing hydrologic, hydraulic, and

regulatory information to federal, state, local, and private entities. The Corps can conduct hydrologic, hydraulic, and flood frequency studies and analyses to assist in predicting flood elevations.

- *211(f) Projects:* Various WRDA have given certain local agencies the opportunity to undertake the planning, design, and construction of federal flood control projects. The first such authorization was in 1996 in Section 211(f) of WRDA. In this way these projects are referred to as 211(f) projects. These projects are generally large in scale, last several years or more, and are typically measured in hundreds of millions of dollars in cost. New project authorizations are extremely rare. Specific projects that have been authorized by WRDAs of various years in the Houston-Galveston area include Brays, White Oak, and Hunting Bayous.

National Resources Conservation Service (NRCS)

NRCS administers several programs as part of The Watershed Protection and Flood Prevention Act (PL 83-566) as amended on August 4, 1954. This act authorized NRCS to cooperate with states and local agencies to carry out works of improvement for soil conservation; other purposes including flood prevention, conservation, development, utilization, and disposal of water; and conservation and proper utilization of land. The Trinity River project, part of which is contained in this region, was authorized to reduce flood and sediment damage to farmland.

Other Funding Sources

A variety of other funding sources are available, although they may be difficult to find and hard to obtain. Perhaps the most common of these sources are private foundations, corporations, and private land trusts.

Private Foundations

Private foundations, for the purpose of this discussion, are non-profit corporations organized for the purpose of providing grants. Most of these foundations have specific guidelines and philanthropic goals, and requests for funding must be clearly matched to the goals of the foundation. Rarely do these foundations specifically mention flood damage reduction goals, but their goals often include community development or conservation goals, which may be related to flood damage reduction activities.

The Houston Endowment has provided funding to the Houston Parks Board for the acquisition of land along bayou corridors. While the primary goal of the grant might be environmentally grounded, the acquisition of land along bayou corridors also helps preserve the floodplain and keep development out of some areas at high risk of flooding.

Corporations

Some corporations include philanthropic contributions as part of their budget, often tying their donations to business goals and corporate citizenship initiatives. Like private foundations, corporate goals rarely relate directly to flood damage, although some funding can be indirectly related to flood damage prevention. For example, in 2008, Reliant Energy announced that it would contribute to efforts of the National Fish and Wildlife Foundation to acquire land in the Columbia Bottomland forest in Brazoria County. While the primary reason for the purchase is to preserve and improve forests for the purpose of sequestering carbon to offset carbon emissions produced by Reliant, one of the additional benefits of the acquisition is to improve flood control.

Land Trusts

Land trusts are a form of non-profit organization whose goals are primarily directed toward the conservation of open space. While the land acquisition goals may not be directly tied to flood damage reduction, the preserved land often provides flood damage reduction benefits. For example, the Trust for Public Land in 1997 purchased a key tract of land in the Cypress Creek watershed which was then transferred to the Katy Prairie Conservancy (KPC). Since then, KPC has worked with a variety of funders and partners to acquire additional land rights that protect important parts of the Cypress Creek floodplain.

Table 7. Eligible activities for various funding sources

Fund Source \ Eligible Activities	Planning/Planning studies	Large mitigation projects > $1 million	Small mitigation projects < $1 million	Maintenance/Repair	Land acquisition	Debris Management	Multi-functional facilities	Public education	Conservation	Technical Assistance
Taxes		✓	✓	✓						
Bond Programs		✓								
Utility Fees	✓	✓	✓	✓				✓		
Impact Fees	✓				✓					✓
TWDB's Flood Protection Planning Program	✓									
ORCA's Community Development Fund	✓		✓							
Texas Parks and Wildlife Department					✓		✓			
Texas Department of Transportation			✓							
FEMA: Flood Mitigation Assistance Program	✓	✓	✓							
FEMA: Hazard Mitigation Grant Program		✓	✓		✓					
FEMA: Pre-disaster Mitigation Grant Program	✓	✓	✓							
FEMA: Repetitive Flood Claim Program			✓		✓					
FEMA: Severe Repetitive Loss Program			✓		✓					
FEMA: Public Assistance Grant Program				✓		✓				
Corps: Small Flood Control Projects			✓							
Corps: Snagging and Clearing for Flood Control				✓						
Corps: Planning Assistance to States	✓									
Corps: Floodplain Management Services Program	✓									✓
Corps: 211F Projects	✓	✓								
National Resources Conservation Services									✓	
Private Foundations									✓	
Corporations									✓	
Land Trusts									✓	

Appendices

The following appendices are included in this section:

- Acronyms
- List of References
- Freeboard Survey

Acronyms

ASFPM: Association of State Floodplain Managers
BFE: Base Flood Elevation
CD: Community Development Fund
CFM: Certified Floodplain Manager
CIP: Capital Improvement Program
CO: Certificate of Occupancy
Corps: U.S. Army Corps of Engineers
CRS: Community Rating System
DFIRM: Digital Flood Insurance Rate Map
ERM: Elevation Reference Mark
ERU: Equivalent Residential Unit
FCC: Federal Communication Commission
FEMA: Federal Emergency Management Agency
FIRM: Flood Insurance Rate Map
FMA: Flood Mitigation Assistance Program
FPP: TWDB's Flood Protection Planning Program
GDEM: Governor's Division of Emergency Management
GIS: Geographic Information Systems
HCFCD: Harris County Flood Control District
H-GAC: Houston-Galveston Area Council
HMGP: Hazard Mitigation Grant Program
HMP: Hazard Mitigation Plan
IMP: Integrated Management Practices
IRC: International Residential Code
KPC: Katy Prairie Conservancy
LID: Low Impact Development
LiDAR: Light Detection and Ranging
MJHMP: Multi-Jurisdictional Hazard Mitigation Plan
NAI: No Adverse Impact
NFIP: National Flood Insurance Program
NFIRA: National Flood Insurance Reform Act
NOAA: National Oceanic and Atmospheric Administration
NRCS: National Resources Conservation Service
NWR: NOAA Weather Radio
NWS: National Weather Service
ORCA: Office of Rural Community Affairs
PA: Public Assistance Grant Program
PDM: Pre-disaster Mitigation Grant Program
P.E.: Professional Engineer
PWP/EMP: Participation-Waived Project/Equivalent-Match Project
RFC: Repetitive Flood Claim Program
RFMC: Regional Flood Management Council
ROW: Right-of-way
SFHA: Special Flood Hazard Area
SRL: Severe Repetitive Loss Program
TADD: Turn Around, Don't Drown
TCRFC: Texas Colorado River Floodplain Coalition
TFMA: Texas Floodplain Management Association
TPWD: Texas Parks and Wildlife Department
TSARP: Tropical Storm Allison Recovery Project
TWDB: Texas Water Development Board
TxDOT: Texas Department of Transportation
USGS: U.S. Geological Survey
UACC: Unified Area Coordination Committee
WRDA: Water Resources Development Act

List of References

The following list represents references and links for each of the four chapters and the appendices.

Introduction

- http://www.fema.gov/news/disasters_state.fema?id=48
- http://www.hcfcd.org/hcfloodhistory.html

Chapter 1: Planning

Data Needs

- http://www.dodson-hydro.com/gis/index.htm
- http://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
- http://tsarp.org
- http://fema.gov/library/viewRecord.do?id=2206
- http://hcedweb3.eng.hctx.net/benchmark/viewer.htm

Data and Public Input

- http://www.ci.arlington.tx.us/news/2003/archive_1103_01.html
- http://www.twdb.state.tx.us/rwpg/rpgm_rpts/92483600.pdf
- http://www.colorado.edu/hazards/publications/informer/infrmr1/infrmr1a.htm#step2
- http://outreach.msu.edu/bpbriefs/issues/brief4.pdf
- http://jpl.sagepub.com/cgi/content/abstract/17/2/189
- http://www.connectsi.us/visions/documents/VEGlossary010807Rv5.doc
- http://www.sustainable.org/Placemaking_v1.pdf

Comprehensive Plan

- http://www.cityofmanvel.com/files/archives/comp-plan/Final/ComprehensivePlan.pdf
- http://tx-leaguecity.civicplus.com/common/modules/documentcenter2/documentview.aspx?DID=132

Floodplain Management Plan

- http://www.lcra.org/library/media/public/docs/com_rural_planning_handbook.pdf

- http://www.h-gac.com/community/community/hazard/hazard_mitigation_plan.aspx

Drainage or Watershed Master Plans

- http://www.cohcdp.swmp.org/cdp/cohFramset.htm
- http://www.cityofpearland.com
- http://www.twdb.state.tx.us/rwpg/rpgm_rpts/99483318.pdf
- http://www.twdb.state.tx.us/rwpg/rpgm_rpts/99483318.pdf
- http://www.twdb.state.tx.us/rwpg/rpgm_rpts/2000001012.pdf
- http://www.twdb.state.tx.us/RWPG/rpgm_rpts/IndividualReportPages/2001483356.asp

Flood Mitigation Plan

- http://www.hcfcd.org/P_braysbayou.html
- http://www.twdb.state.tx.us/RWPG/rpgm_rpts/2003483506_Baytown.pdf
- http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0604830570WhartonFloodMitigation.pdf

Hazard Mitigation Plan

- http://www.fema.gov/plan/mitplanning/index.shtm
- http://www.fema.gov/library/viewRecord.do?id=3571
- http://www.h-gac.com/community/community/hazard/plan/default.aspx
- http://www.hcfcd.org/P_braysbayou.html

Capital Improvement Program

- http://www.ci.pasadena.tx.us/CIP_BUDGET.htm

Thoroughfare Plan

- http://www.cityofmanvel.com/files/archives/comp-plan/Final/ComprehensivePlan.pdf

Evacuation Plan

- http://www.gcoem.org/content/view/1383145/

Emergency Management Plan

- http://www.ci.deer-park.tx.us/department/?fDD=16-0

- http://www.fema.gov/plan/gaheop.shtm
- http://communication.howstuffworks.com/how-disaster-recovery-plans-work.htm
- http://www.fema.gov/government/coop/index.shtm
- http://www.txdps.state.tx.us/dem/pages/downloadableforms.htm#mitigation

Chapter 2: Mitigation

Introduction

- http://www.fema.gov/government/mitigation.shtm

Community Rating System

- http://www.fema.gov/business/nfip/crs.shtm
- http://training.fema.gov/EMIWeb/CRS/index.htm
- http://www.fema.gov/business/nfip/crs.shtm
- http://www.cifriendswood.tx.us/agendas/cc071217%20Regular/CDD%2012-17-07/City%20Manager%20Report/CRS%20report.pdf

Developing accessible flood-risk information and providing public education

- http://www.tsarp.org/effectivefirms.html
- http://www.hcfcd.org
- http://www.weather.gov/nwr/
- http://www.fema.gov/mitigationbp/brief.do?mitssId=944
- http://www.fema.gov/plan/prevent/fhm/mm_main.shtm
- http://tadd.weather.gov/tadd-resources.shtml

Flood Forecasting

- http://www.weather.gov/nwr/
- http://www.weather.gov/ahps/rfc/rfc.php

Facility maintenance and repair

- http://www.sugarlandtx.gov/finance/budget/fy09/documents/2009_budget/Public-Works.pdf

Conveyance improvements to channels, storm sewers, and bridges

- http://www.fema.gov/mitigationbp/brief.do?mitssId=5107
- http://www.projectbrays.org/about.html
- http://www.hcfcd.org/P_braysbayou.html

Structure removal or elevation

- http://www.hcfcd.org/faq_buyout.html
- http://www.hcfcd.org/ME_tsabuyout.html
- http://www.fema.gov/news/newsrelease.fema?id=6305
- http://www.tsarp.org/tsa_over/index.html

Detention basins

- http://www.epa.gov/owmitnet/mtb/wetdtnpn.pdf
- http://www.cityofchicago.org/city/webportal/portalContentItemAction.do?contenTypeName=COC_EDITORIAL&contentOID=536910986&topChannelName=HomePage
- http://www.hcfcd.org/P_greensbayou.html

Floodplain fill mitigation ponds and excavations

- http://documents.publicworks.houstontx.gov/documents/flood_plain/faqs/faq_mitigation.pdf
- http://www.sugarlandtx.gov/sugarland/publications/documents/Feb05_Mar05.pdf
- http://www.cityofpearland.com/vertical/Sites/%7BCA80BAF8-A883-4878-AB6D-7FC8DAE7D62E%7D/uploads/%7B29816D24-ABAB-4B7C-A4E1-4DABD374248B%7D.PDF

Floodproofing

- http://www.fema.gov/pdf/fima/job6.pdf
- http://irc.nrc-cnrc.gc.ca/pubs/cbd/cbd198_e.html
- http://www.fema.gov/mitigationbp/brief.do?mitssId=5106

Channel diversions

- http://www.co.fort-bend.tx.us/upload/images/commissioner_precinct_1/PCT1_Newsletter0606.pdf

- http://www.ljaengineering.com/projects.html?id=83
- http://www.herald-coaster.com/articles/2006/07/12/news/news01.txt

Dams

- http://www.sjra.net/pdf-docs/ike-archives.html
- http://www.h-gac.com/community/community/hazard/documents/section_4_3_vulnerability_assessment.pdf
- http://www.okcc.state.ok.us/Publications/How_A_Small_Flood_Control_Dam_Works.pdf
- http://www.stucky.ch/en/contenu/pdf/the_role_of_dams_in_the_XXI_century.pdf

Levees

- http://www.ibhs.org/publications/downloads/20070605_135844_24539.pdf
- http://www.leveeboard.org/about_the_levee/about_the_levee.html
- http://www.txcn.com/sharedcontent/dws/txcn/houston/stories/khou080908_tnt_texas_city_levees.57a7e5a9.html
- http://www.chron.com/disp/story.mpl/front/4064472.html
- http://www.galvnews.com/story.lasso?ewcd=04b68095d6f870c1

Floodgates

- http://www.sugarlandtx.gov/finance/budget/fy09/documents/proposed/cip/Drainage.pdf
- http://www.sugarlandtx.gov/city_hall/city_secretary/agendas/FY2006/060606cc/4b/4b.htm
- http://www.hcfcd.org/P_clearcreek2.html

Chapter 3: Regulation

Introduction

- http://www.stlouisco.com/plan/Subdivision/1005-020.pdf
- http://www.beginningwithhabitat.org/toolbox/land_subdivision.html
- http://www.capecodcommission.org/bylaws/develagree.html
- http://www.tml.org/pdftexts/HRHChapter1.pdf
- http://www.joesarver.us/AN%20OVERVIEW%20OF%20IMPACT%20FEES%20IN%20TEXAS.pdf

- http://www.state.nj.us/drbc/Flood_Website/floodplainmgmnt.htm
- http://www.brazoria-county.com/engineer/New%20Subdivision%20Regs/SUBDIVISION%20REGULATIONS1-Final%2010-24-06.pdf

Structural Elevation

- http://www.municode.com/resources/gateway.asp?pid=10137&sid=43
- Brazoria County. *The County of Brazoria Revised Building Regulations*. Adopted 24 May 2005. Amended 24 October 2006.
- http://www.floods.org/Newsletters/News_Views/NV_Aug08.pdf
- http://www.floodsmart.gov/floodsmart/pages/flood_facts.jsp

No Net Fill

- http://www.municode.com/resources/gateway.asp?sid=43&pid=11263
- Brazoria County. *The County of Brazoria Revised Building Regulations*. Adopted 24 May 2005. Amended 24 October 2006.

NAI

- http://www.floods.org/NoAdverseImpact/whitepaper.asp
- http://www.floods.org/NoAdverseImpact/NAI_Legal_Issues.pdf

Development in High-Risk Flood Areas

- http://www.fema.gov/faq/faqDetails.do?action=Init&faqId=1095
- http://www.municode.com/resources/gateway.asp?pid=10137&sid=43

Ultimate Development

- http://ci.huntsville.tx.us/business/development_code/

LID

- http://documents.publicworks.houstontx.gov/documents/design_manuals/2008_coh_infrastructure.pdf
- http://www.houstoncec.org/documents/Minutes/JTSWQ010808_2.pdf
- http://www.lid-stormwater.net/background.htm#why_LID

- http://www.lid-stormwater.net/background.htm
- http://www.lowimpactdevelopment.org
- https://www.gis.sc.gov/marine/NERR/present/LID/Vandiver_StormwaterWorkshop.pdf

Detention

- http://www.hcfcd.org/detention.html
- http://www.municode.com/resources/gateway.asp?sid=43 pid=13286
- http://www.eng.hctx.net/permits/pdf/subdivision_regs.pdf
- http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/chapter5_basins.PDF
- http://eerc.ra.utk.edu/divisions/wrrc/BMP/bmp.htm

Design Frequency of Storms

- Harris County. *Floodwise: Urban Stormwater Management Study*. November 2006.
- http://www.co.fort-bend.tx.us/getSitePage.asp?sitePage=7531
- Hoff, Dale. Higher Standards Reference Guide for Local Floodplain Management Regulations. FEMA Region VI, accessed April 2008.

Chapter 4: Funding

Local Funding

- http://tlo2.tlc.state.tx.us/statutes/lg.toc.htm

State Funding

- http://www.twdb.state.tx.us/rwpg/rpgm_rpts/94483026.pdf
- http://www.twdb.state.tx.us/assistance/financial/financial_main.asp#flood
- http://www.orca.state.tx.us/index.php/Community+Development/Grant+Fact+Sheets/Community+Development+%28CD%29+Fund
- http://www.tpwd.state.tx.us/business/grants/
- http://www.txdot.gov/business/governments/pwp_emp.htm

Federal Funding

- http://www.swg.usace.army.mil/items/wra/waterresourcespaphlet.pdf

- http://www.txdps.state.tx.us/dem/pages/index.htm
- http://www.fema.gov/government/grant/hma/index.shtm
- http://www.fema.gov/government/grant/pa/index.shtm
- http://www.hcfcd.org/wrda.html
- http://www.nrcs.usda.gov/programs/watershed/

Other Funding Sources

- https://www.reliant.com/PublicLinkAction.do?i_chronicle_id=090175228018f6a4&language_code=en_US&i_full_format=pdf
- http://www.houstonendowment.org/
- http://www.tpl.org/tier3_cd.cfm?content_item_id=1446&folder_id=966

Appendices

- http://www.tfma.org

Freeboard Survey

The Texas Floodplain Management Association (TFMA) has been collecting information since 2004 regarding standards in communities throughout Texas. H-GAC's Regional Flood Management Council encourages all communities in the region to participate in this survey. Completed surveys can be sent to tfma@verizon.net or to H-GAC's Community and Environmental Planning Department at P.O. Box 22777, Houston, TX 77227-2777. A blank survey can also be found on the TFMA website: www.tfma.org. Results of the survey are posted on the website as well.

Community Name: _____

Your contact information: _____

_____

_____

Do any of the following apply to your community?

1. Zone AE/VE - New construction must be elevated ___ feet above the BFE as shown on the FIRM (existing conditions).

2. Zone AE/VE - New construction must be elevated ___ feet above the BFE determined by a study based on fully developed watershed (future conditions).

3. Zone A (un-numbered) - Developer must conduct a study to define the BFE.

   Yes____ No ____ (Not a requirement).

4. Zone A (un-numbered) - Developer must conduct a study to define the floodway boundary.

   Yes____ No ____ (Not a requirement).

5. Zone A (un-numbered) - Developer must conduct a study to define the floodway boundary based on fully developed watershed (future conditions).

   Yes____ No ____ (Not a requirement).

6. Floodway - no development allowed within the floodway.

   Yes____ No ____ (Not a requirement).

7. No fill is allowed in the floodway or floodplain without mitigation (No Adverse Impact).

   Yes____ No ____ (Not a requirement).

8. Detention requirements.

   Yes____ detention is required No___ Not a requirement.

9. Zone X (Shaded) - New construction must be elevated ___ feet above natural grade or the crown of the nearest street.

10. Zone X (Unshaded) - New construction must be elevated ___ feet above natural grade or the crown of the nearest street.

11. Elevation Certificate Requirements - Note: some communities require multiple submittals.

    Required prior to forming/pouring lowest floor? Yes___ No___

    Required when structure is completed? Yes___ No___

    Required prior to issuing a certificate of occupancy (CO)? Yes___ No___

12. Is your community enrolled in CRS? Yes___ No ___ Current CRS Rating___

13. Is your community interested in enrolling in CRS? Yes___ No___

14. Is your community floodplain manager a CFM? Yes___ No ___

15. What other floodplain management requirements has your community established?

    _____

    _____

    _____

    _____

Thank you for participating in the TFMA Annual Freeboard Survey. Survey results will be posted on the TFMA website www.tfma.org

Mike Howard, CFM State NFIP Coordinator	Roy Sedwick, CFM TFMA Executive Director	Heidi Carlin, CFM LCRA and TCRFC	John Ivey, P.E., CFM TFMA Certification Committee