

## **CHAPTER 5. RECOMMENDATION OF FLOOD MANAGEMENT EVALUATIONS AND FLOOD MANAGEMENT STRATEGIES AND ASSOCIATED FLOOD MITIGATION PROJECTS**

The goal of Task 5 is for the San Jacinto Regional Flood Planning Group (RFPG) to recommend flood mitigation projects (FMPs), flood management strategies (FMSs), and flood management evaluations (FMEs) for inclusion in the regional flood plan. While Chapter 4 details the process to identify the areas with the greatest flood risk evaluation needs, greatest flood mitigation needs, as well as potentially feasible FMPs, FMSs, and FMEs, Chapter 5 outlines the actions that were recommended. The actions recommended by the San Jacinto RFPG are not necessarily anticipated to be performed during the same regional flood planning cycle through which they are identified.

### **Chapter 5.A. RFPG Evaluation and Recommendation**

The San Jacinto RFPG considered recommendations on flood mitigation actions beginning at the San Jacinto RFPG meeting on April 14, 2022 where major considerations and screening criteria, detailed in subsequent sections, were presented to the San Jacinto RFPG. At the following San Jacinto RFPG meeting held on May 12, 2022, the San Jacinto RFPG was provided with an interactive GIS dashboard to facilitate review of identified FMPs, FMSs, and FMEs. Comments were received and addressed on identified actions following the May San Jacinto RFPG meeting. Ahead of the San Jacinto RFPG meeting held on June 9, 2022, both an updated list and one-page summary reports of each identified action were provided for review.

At the meeting on June 9, 2022 the San Jacinto RFPG unanimously approved the list of actions for recommendation in the regional flood plan pending any direct disapproval from regional sponsors following the vote. It was clarified by the San Jacinto RFPG at this meeting that the vote to recommend these actions does not remove the need for these actions to meet other applicable regulation or criteria. Since the June meeting, 4 FMEs and 2 FMPS have been redefined as not recommend by the San Jacinto RFPG. The FMPs now considered not recommended were due to those projects yielding no direct flood risk reduction or not containing a BCR. The FMEs no longer recommended were due to being out of the San Jacinto region bounds, being included in other regions, having already proceeded with an evaluation, or being a duplicate within the list. The complete table of recommended actions can be found for FMEs, FMPs, and FMSs in Appendix 5-6, Appendix 5-7, and Appendix 5-8, respectively. Recommendation by the San Jacinto RFPG also does not serve as a specific endorsement of the actions, but rather recommendation that the actions be eligible for future funding through the TWDB.

### **Chapter 5.B. Sponsor Outreach**

The lists of identified FMEs, FMSs, and FMPs documented in Chapter 4 were largely collected using publicly available reports such as Hazard Mitigation Plans, Master Drainage Plans, and Flood Protection Plans. The compiled list of all identified FMEs, FMPs, and FMSs can be found in Appendix 4-4, 4-6, and 4-5, respectively. Specific evaluations, strategies, and projects identified in these reports were included to be able to collect a broad sample of potentially feasible actions that represented the needs identified by

entities across the region. An initial effort to reach out directly to potential sponsors was targeted at those sponsors with the most identified FMEs, FMSs, and FMPS. Several outreach efforts were successful in that sponsors were able to confirm interest in identified actions, clarify details, provide supporting data, or identify which actions may have already been funded and should not be considered for recommendation.

Due to the amount of analysis necessary to populate required details for actions in the plan, a cut-off date of April 14, 2022 was communicated to entities and community officials through monthly emails sent to the San Jacinto RFPG email distribution list. The email distribution list developed included contacts for entities and community officials from across the region and utilized applicable contacts collected through the ongoing General Land Office's Combined River Basin Flood Study (Central Region). Members of the public were also able to register for this distribution list through the San Jacinto RFPG website.

Given that this is the first regional flood planning cycle and that many entities within the region are unfamiliar with the implications of this planning effort – that flood mitigation actions must be recommended in the regional flood plan to be eligible for future state funding assistance through the TWDB - the San Jacinto RFPG decided that an affirmative willingness to sponsor a given action would not be a prerequisite for inclusion in the plan. This approach was adopted because:

1. It provides a comprehensive representation of flood mitigation and study needs in the region.
2. It increases the funding opportunities available to entities in the region.
3. It does not obligate entities identified as sponsors to take action and it does not require any financial commitment on behalf of the sponsor.

Following recommendation of the list of FMEs, FMSs, and FMPS at the San Jacinto RFPG meeting held on June 9, 2022, all sponsors received a table of actions recommended in the plan along with one-page summary reports including details of each action recommended in the plan for their review. They were also provided a survey meant to collect information on sponsor funding and potential funding sources for actions listed in the plan. The results of this survey are documented in Chapter 9.

## **Chapter 5.C. Flood Management Evaluations (FMEs)**

### **5.C.1. Summary of Approach to Recommending FMEs**

The San Jacinto RFPG evaluated the identified potential FMEs and recommended all FMEs that met TWDB requirements and addressed the significant need for better understanding of flood risk and implementation of specific flood risk mitigation solutions within the San Jacinto region. Recommended FMEs were required to demonstrate alignment with at least one regional floodplain management and flood mitigation goal developed in Task 3, and each recommended FME should identify and investigate at least one solution to mitigate the 1% ACE (annual chance exceedance) with the intent of FMEs involving H&H modeling to evaluate multiple storm events. Given the relatively high number of identified FMEs in the region, not all FMEs may be completed during the same planning cycle as they are recommended. Based on these TWDB requirements, the San Jacinto RFPG identified and recommended four types of FMEs: Watershed Planning, Engineering Project Planning, Flood Preparedness, and Other.

The majority of recommended FMEs were based on input from sponsors relating to future studies or evaluations needed to progress conceptual flood mitigation solutions as well as the development of more accurate flood risk information to inform future project identification and prioritization. Other FMEs were identified based on the findings of Task 4A, which involved a high-level assessment of the San Jacinto region based on multiple risk factors with the goal of identifying areas with the greatest gaps in flood risk information and areas of greatest known flood risk and mitigation needs. The HUC-12s determined to have high flood risk are distributed throughout the San Jacinto region, especially in the middle and southern portions of the region. This includes large portions of the City of Houston, as well as the Cities of Pearland, League City, Texas City, and Galveston. Harris, Brazoria, and Galveston Counties are among the areas determined to have the highest flood risk. Watershed studies that included flood mapping updates were proposed for areas of high knowledge gap scores (Map 14) while Master Drainage Plans were proposed for areas of high known flood risk (Map 15).

The primary reason for not recommending an FME was based on sponsor input. An FME was not recommended if a sponsor indicated that the proposed study is currently in progress, has been competed, or was no longer a priority. In some cases, multiple FMEs were combined into a single FME for recommendation due to the proximity of the study areas.

Specific project recommendations identified from these FMEs cannot be defined at this time, but the goal of completing these FMEs is to identify feasible FMPs that meet TWDB requirements. The FMEs will involve additional planning, H&H modeling, and analysis to assess flood risk reduction effectiveness, identify potential impacts, and tabulate benefits for the 1% ACE at a minimum.

### 5.C.2. Description and Summary of FMEs

A total of 378 potential FMEs were identified and evaluated by the San Jacinto RFPG. Of these identified FMEs, 374 were recommended, representing a combined total of approximately \$198 million of flood management evaluation needs across the region. The number and types of projects recommended by the San Jacinto RFPG are summarized in **Table 5-1**.

TABLE 5-1: SUMMARY OF RECOMMENDED FMES

FME Type	FME Description	Number of Identified FMEs	Number of Recommended FMEs	Total Cost of Recommended FMEs
Watershed Planning	Flood mapping updates; Master Drainage Plans	113	113	\$75,260,000
Project Planning	Updated H&H modeling; Additional engineering analysis	262	258	\$121,760,000
Preparedness	Studies on flood preparedness	1	1	\$250,000
Other	Bayou protection or flood risk management studies	2	2	\$60,000
Total		378	374	\$197,330,000

Recommended FMEs are illustrated in Map 19 (Appendix 5-1). The full list of FMEs and supporting technical data is provided in Table 15 (Appendix 5-6). A one-page report summary for each recommended FME is included in Appendix 5-5C. The recommended FMEs encompass study area across 10 counties, providing complete coverage of the entire region. Overall, the completion of these FMEs represent significant progress in the identification of future FMPs that will lead to drainage infrastructure improvements and flood risk reduction throughout the San Jacinto region.

## Chapter 5.D. Flood Mitigation Projects (FMPs)

### 5.D.1. Summary and Approach in Recommending FMPs

For consideration as an FMP, a project must be defined in a sufficient level of detail to meet the technical requirements of the flood planning project *Scope of Work* and the associated *Technical Guidelines for Regional Flood Planning (Exhibit C)* developed by the TWDB. In summary, the San Jacinto

RFPG must be able to demonstrate that each recommended FMP meets the following TWDB requirements:

1. Supports at least one regional floodplain management and flood mitigation goal.
2. The primary purpose is mitigation (response and recovery projects are not eligible for inclusion in the Regional Flood Plan).
3. The FMP is a discrete project (not an entire capital program or drainage master plan).
4. Implementation of the FMP results in:
  - a. Quantifiable flood risk reduction benefits
  - b. No negative impacts to adjacent or downstream properties (a No Negative Impact determination is required)
  - c. No negative impacts to an entity's water supply
  - d. No overallocation of a water source based on the water availability allocations in the most recently adopted State Water Plan.

In addition, the TWDB recommends that, at a minimum, FMPs should mitigate flood events associated with the 1% ACE. However, the San Jacinto RFPG can document the reasons that an FMP that doesn't mitigate to the 1% ACE still recommend the FMP.

The quantifiable risk reduction benefits are discussed in the individual FMP descriptions within this chapter. The risk reduction benefits are also summarized in the FMP one-pagers located in Appendix 5-5A. The no negative impact determination requirement is discussed in Chapter 4 section 4.B.3.d. In regards to how the recommended FMPs affect water supply, an elaborated explanation can be found in Chapter 6 Section 6.A.6.d.

Updated construction cost estimates and estimates of project benefits must also be available to define a benefit-cost ratio (BCR) for each recommended FMP. The TWDB recommends that proposed projects have a BCR greater than one, but the San Jacinto RFPG may recommend FMPs with a BCR lower than one with proper justification.

The San Jacinto RFPG also considered non-structural FMPs primarily focused on improving regulations and permit requirements. These FMPs involved updating or improving regulations and permit requirements which can significantly reduce flood risk, in the long term. Regulation improvements average a BCR range between 4.0 - 11.0, depending on the type of regulatory adoptions made (National Institute of Building Services, 2019). The most conservative BCR from the study, specific to riverine flooding, was a 5.0 for constructing new buildings with adopted 2015 International Wildland-Urban Interface Codes. In the San Jacinto region, non-structural FMPs that did not have a previously calculated BCR from reports or studies have been assigned a BCR of 5.0.

All potentially feasible FMPs that had the necessary data and detailed hydrologic and hydraulic modeling results available to populate these technical requirements were considered for recommendation by the San Jacinto RFPG. Pertinent details about the FMP evaluation are provided in the following section.

### 5.D.2. Description of Recommended FMPS

A total of 36 potential FMPS were identified and evaluated by the San Jacinto RFPG. Of these, 34 FMPS were recommended for inclusion in the Regional Flood Plan. The two FMPS that were excluded due to yielding no direct flood risk reduction benefits and having no BCR. The FMPS recommended consist of both structural and non-structural projects. The FMPS recommended represent a combined cost of \$29.1 billion worth of flood management project needs across the region.

**Table 5-2** summarizes the types of FMPS, the number of FMPS for each type, and the total cost of the recommended FMPS. The full list of recommended FMPS and supporting data is included in Table 16 in Appendix 5-7. A one-page report summary of each recommended FMP is included in Appendix 5-5.

TABLE 5-2: SUMMARY OF RECOMMENDED FMPS

Structural	FMP Type	Number of Identified FMPS	Number of Recommended FMPS	Total Cost of Recommended FMPS
Yes	Comprehensive; Master Drainage Plan projects	14	13	\$27,890,681,000
No	Preparedness; Improve regulations and permit requirements	22	21	\$1,985,000
Total		36	34	\$27,892,666,000

### 5.D.3. Summary of Recommended Non-structural FMPS

Non-structural FMPS include property or easement acquisition, elevation of individual structures, Flood Early Warning Systems, and other similar projects. When identifying and recommending FMPS, emphasis was placed on mitigation and preparedness. **Figure 5-1** shows the distribution of recommended non-structural flood mitigation projects. By quantity, most recommended non-structural Flood Mitigation Projects are categorized as preparedness. Reference material for the non-structural FMPS can be found in Appendix 5-4A.

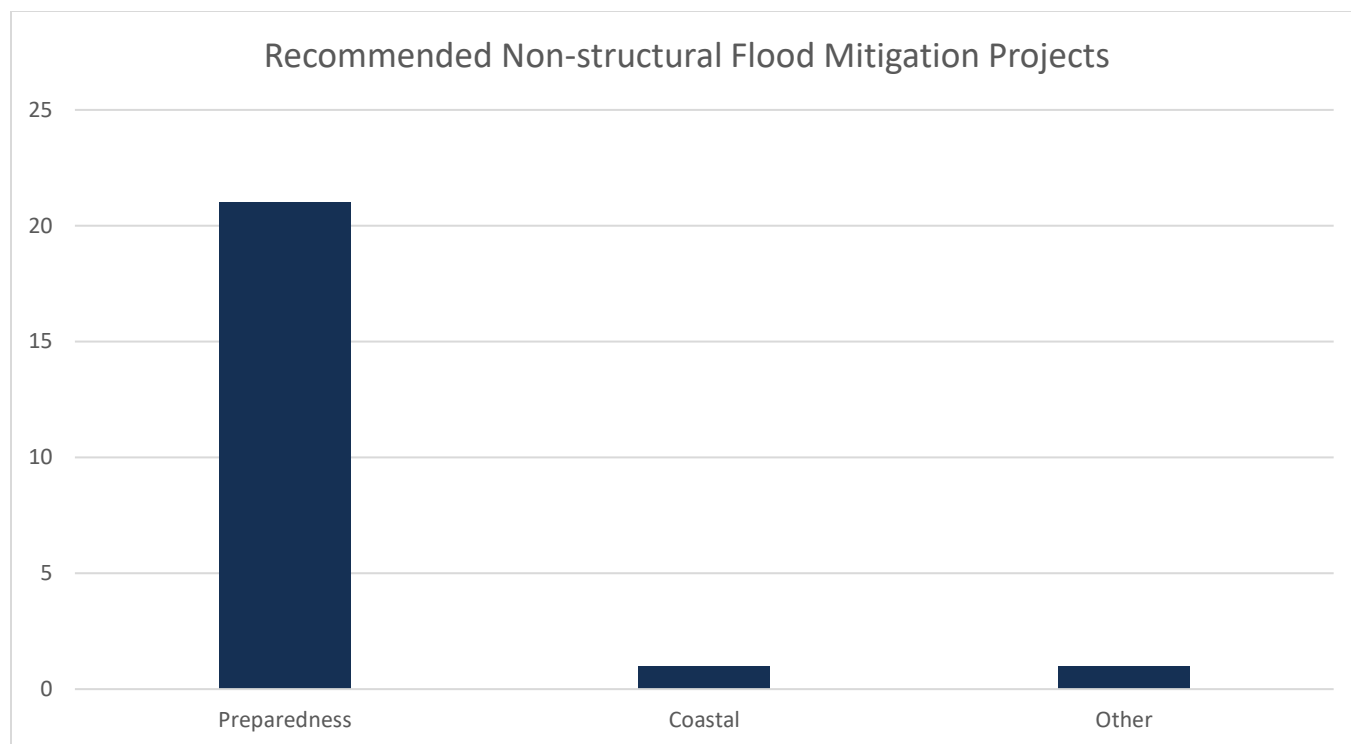


FIGURE 5-1: DISTRIBUTION OF RECOMMENDED NON-STRUCTURAL FLOOD MITIGATION PROJECT BY TYPE

#### 5.D.4. Recommended Structural FMPs

A total of 13 structural FMPs were recommended by the San Jacinto RFPG. The following sections detail each project's various components, H&H modeling, cost, benefit, and any other pertinent information.

##### 5.D.4.a. Lower Clear Creek & Dickinson Bayou Flood Mitigation Plan (063000026)

This project was developed as part of a comprehensive flood mitigation plan for the Lower Clear Creek and Dickinson Bayou Watersheds with a focus on the riverine impacts along the main channel of each waterway. The flood mitigation plan focused on mitigating the risk of extreme events similar to Hurricane Harvey, Tropical Storm Allison, and other large tropical storms, as well as flood damages from smaller more frequent storms. The targeted reduction in flood depths was set as multiple feet of reduction at Interstate 45 (I-45) during a 1% ACE storm.

League City led the engagement of numerous stakeholders along Dickinson Bayou to fund Phases 1 through 3 of the study that recommended this project. League City also entered into an agreement to receive Planning Assistance to States (PAS) funding from the United States Army Corps of Engineers (USACE) under the authority provided by Section 22 of the Water Resources Development Act of 1974 (PL 93-251), as amended. USACE Galveston District provided in-kind services and was engaged in all aspects of the project including technical reviews and a downstream boundary condition analysis accounting for storm surge and future sea level rise. Key planning partners and study contributors included:

1. League City
2. USACE
3. Harris County Flood Control District (HCFCD)
4. Galveston County
5. City of Friendswood
6. Galveston County Consolidated Drainage District

This project is supported by state-of-the-art hydrologic and hydraulic models leveraging current NOAA Atlas 14 rainfall, 2018 LiDAR data, and a 1D/2D unsteady-state modeling approach. Existing and future conditions flood risks were evaluated based on the 24-hour duration 50%, 20%, 10%, 2%, 1%, and 0.2% ACE Atlas 14 storm events. To confirm efficacy during long-duration storm events such as tropical storms and hurricanes that produce high volumes of runoff, Hurricane Harvey rainfall was also modeled through the combination alternatives. The recommended project was selected from a total of 10 flood mitigation projects that were evaluated along Dickinson Bayou.

The recommended project is outlined as “Alternative 3: Detention + Conveyance + I-45 Tunnel” in the supporting report. Six individual components make up this overall recommendation, as shown in **Figure 5-2** below:

1. Friendswood Detention Basin
2. Timber Creek Golf Course Detention Basin
3. Channel Benching Above OHWM – FM 1959 to Bay Area Blvd.
4. 40-Foot Diameter Tunnel Diversion from I-45 to Galveston Bay
5. SH 3 and UPRR Capacity Improvements
6. FM 270 Auxiliary Opening



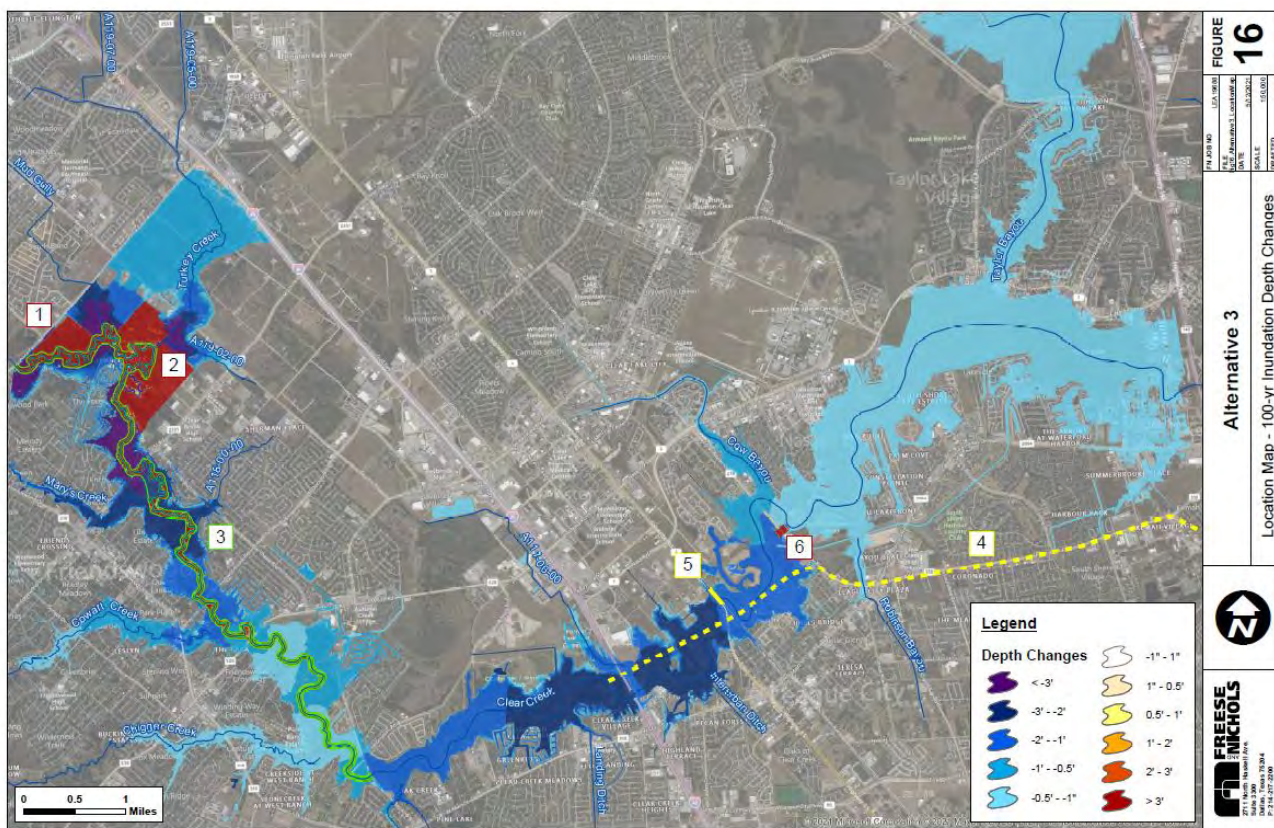


FIGURE 5-2: ALTERNATIVE 3 LOCATION & INUNDATION DEPTH CHANGE MAP

The 40-foot I-45 to Galveston Bay tunnel was retained based on an efficiency analysis of various tunnel configurations. This alternative provides significant benefits, with water surface elevation reductions of over seven feet in the 1% ACE storm event immediately downstream of FM 1959. This project also provides notable water surface elevation reductions in the vicinity of I-45, with reductions exceeding two feet in the 1% ACE storm event. Clear Creek through Clear Lake benefits from water being diverted by the tunnel out of Clear Creek and bypassing the Lake down to Galveston Bay. The engineering report estimates the capital cost required for this FMP is \$1,150 million, yielding a benefit cost ration (BCR) of 0.06.

The estimated flood risk reduction benefits following the implementation of Lower Clear Creek FMP include the removal of an estimated 26 miles of roadway and 911 structures from the 1% ACE floodplain, 835 of which are residential structures. This correlates to an estimated 3,653 individuals removed from the 1% ACE flood risk. Additionally, 1,358 structures would have reduced risk within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

#### 5.D.4.b. CDBG-MIT

These project applications were developed and submitted to compete for funding from the Community Development Block Grant Mitigation - Hurricane Harvey (CDBG-MIT) that Congress appropriated in

February of 2018. To be considered, the projects must be for mitigation activities for qualifying disasters which included Hurricane Harvey. The applications were submitted by HCFCD in partnership with Harris County Engineering in 2020 and subsequently was not selected for funding, however the criteria and data required for consideration by the CDBG-MIT grant makes these projects well suited for consideration as recommended FMPs to the Regional Flood Plan (RFP).

There are 20 structural projects paired with detention alternatives to insure no negative impact as result of these flood mitigation solutions, which were grouped into 5 recommended FMPs that aim to provide flood risk reduction benefits. These projects are also a part of a locally adopted plan, the HCFCD 2018 bond program for Flood Risk Reduction, where Harris County voters approved \$2.5 billion in bonds to finance flood damage reduction projects. This bond program had included an expectation of and will require partnership funding to complete and further leverage the flood risk reduction goals of the program.

A benefit-cost analysis (BCA) was developed based on benefit quantification methods and assumptions used in FEMA tools such as the FEMA BCA Toolkit version 6.0 and HAZUS. These tools were not used directly, but the methods and assumptions in the FEMA Toolkit and HAZUS were applied using a combination of geospatial and tabular analysis tools to utilize spatially variable modeled water surface elevation data more efficiently and to incorporate detailed information at an individual structure level. The result concluded with a benefit cost ratio (BCR) for each project which is reported below. Also reported are the unique methodologies used to determine flood risk reduction benefits determined by the San Jacinto RFP team. For a summary of each FMP, refer to the one pager attached in Appendix 5-5.

### ***Brays Bayou CDBG-MIT Application Projects (063000027)***

The Brays Bayou Mitigation Project is a joint effort between HCFCD and the City of Houston. The project is composed of various drainage and flood control improvements including improved channel conveyance and stormwater detention basins. Collectively, the components of this project are referred to as improvements to Bintliff Ditch (HCFCD Channel D133-00-00) and the Sharpstown Area. The project is generally located west of IH-610 between Brays Bayou to the South, Harwin to the north, and east of Fondren Road. The area is a mix of single family residential, institutional, commercial and multi-family parcels. The existing drainage system in the area is primarily curb and gutter with some open ditch streets. Bintliff Ditch drains from north to south and outfalls to Brays Bayou. There is significant ponding throughout the study area and flood losses closer to Brays Bayou and along Bintliff Ditch. The goal of the project was aimed at mitigating the risk of riverine flooding in the southwestern area of Harris County as shown in **Figure 5-3**.

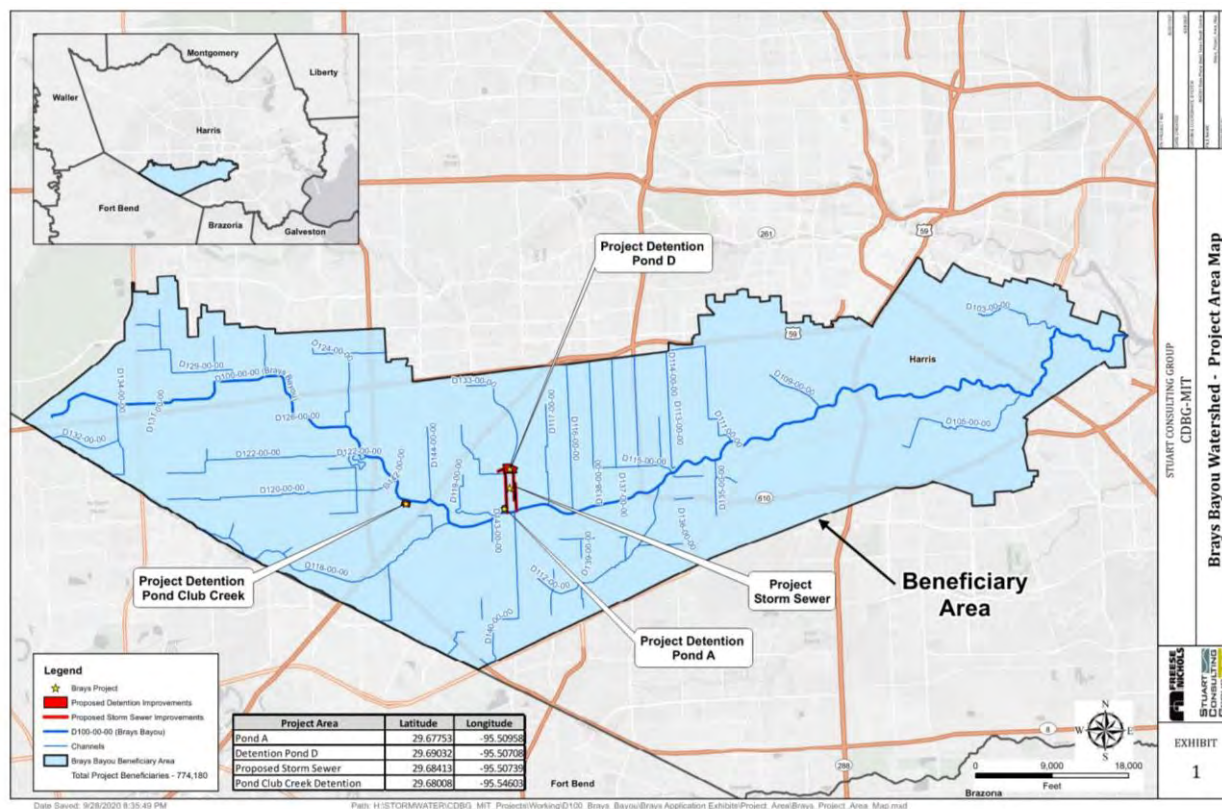


FIGURE 5-3: BRAYS BAYOU WATERSHED CDBG-MIT APPLICATION PROJECT AREA

The project reduces flood risk by improving storm sewer conveyance and adding detention storage at a total estimated cost of \$107 million. Based on various forms of hydraulic analysis, the project reduces ponding in approximately 10 miles of streets and removes many structures from possible flood damages throughout the project extents. In addition to the direct flood reduction benefits, Lift Station #31, which was significantly damaged during Hurricane Harvey, sees a reduction in flood risk.

As mentioned above were the tools and approach used to create a BCR, which concluded a 0.13 for this project. Although the BCR is not greater than 1.0 the project demonstrates that 57.5% of the beneficiaries of Brays Bayou Watershed mitigation project are low-to moderate-income persons. More details on the methodology used in the BCA can be provided in Appendix 5-4C.

The hydraulic and hydrologic modeling completed to support this project utilizes Atlas 14 rainfall and Storm Water Management Model (SWMM). Hydraulic results were provided in raster format for both the 1% and 0.2% ACE for both pre-project and post-project conditions. The analysis of benefit and flood risk reduction provided and performed for this FMP were based on the above-mentioned raster results under a process developed by the San Jacinto RFG.

The application states that the project reduces the extreme event water surface elevation throughout the drainage area and mitigates for increases in conveyance (impacts) with multiple detention basins. Using these statements along with HCFCD and the City of Houston's no adverse impact operating policies, an assumption was made that the project would cause no negative impacts.



It is important to note that this project will complement the ongoing, USACE supported Project Brays with overall water surface elevation reductions along the tributary channel. Project Brays is a joint effort program led by HCFCDD and the USACE along with several local stakeholders. The program consists of over 75 projects throughout 31 miles of Brays Bayou to reduce flood risk, increase greenspace, and provide amenities for the community.

Based on the analysis completed by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of Brays Bayou Watershed Mitigation CDBG-MIT FMP includes the removal of an estimated five miles of roadway and 160 structures from the 1% ACE floodplain, 118 of which are residential structures. This correlates to an estimated 2,890 individuals removed from the 1% ACE flood risk. Additionally, 78 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5. .

### ***Sims Bayou CDBG-MIT Application Projects (063000037)***

A suite of structural mitigation measures makes up the Sims Bayou Watershed Mitigation CDBG-MIT application, all of which work to reduce localized and regional flooding for subdivisions and businesses during hurricanes, tropical storms, and intense rainfall events within Sims Bayou. These types of significant rainfall events cause the local drainage and flood control systems to be overwhelmed, resulting in riverine and urban flooding. The Sims Bayou Watershed Mitigation Project entails three (3) individual activities totaling an estimated \$106 million in construction shown in **Figure 5-4**:

1. South Post Oak Stormwater Detention Basin (SWDB) and Channel Conveyance Improvements (C147)
2. South Shaver SWDB (C506-01-E0003)
3. Salt Water Ditch SWDB and Channel Conveyance Improvements (C118)

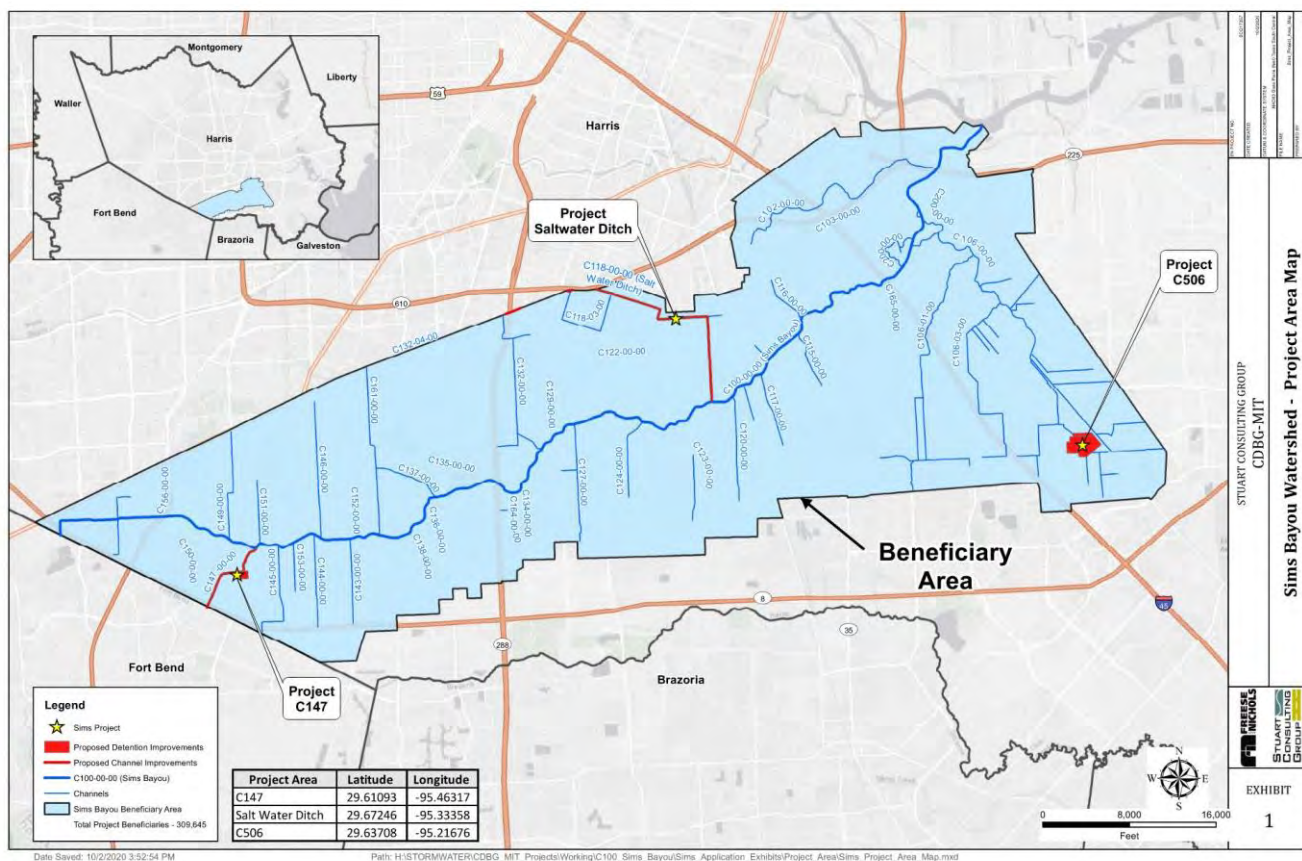


FIGURE 5-4: SIMS BAYOU WATERSHED CDBG-MIT APPLICATION PROJECT AREA

The South Post Oak SWDB and Channel Conveyance Improvements consists of widening 7,000 feet of channel C147-00-00 from Sims Bayou to the C147-02-00 diversion channel. There are several bridge structures along this reach that will be replaced as a part of the project. The project also seeks to a mitigate impacts from channel conveyance improvements by increasing the volume of the C457-01 detention basin. Since completion of this application, the project has advanced through Preliminary Engineering yielding 30% engineering plans. Additionally, some excavation has already been performed on the detention pond as part of an agreement with agreement with a nearby land owner.

The South Shaver Detention Basin (C506) is aimed at maximizing the detention volume within the property owned by HCFCD to construct a 96-acre detention basin. The finished project will remove approximately 45 acres of land and 355 structures from the 1% ACE floodplain. Control structures at the discharge of the basin will limit the flow leaving the basin to help attenuate peak flows within the surrounding flood control channels.

The objective of the Saltwater Ditch improvements along C118 is to maximize the stormwater conveyance capacity by converting the existing drainage ditch into multiple barrels of Steel Reinforced Polyethylene (SRPE) storm sewer. The finished project will achieve a 10-year level of service, a significant improvement over the existing 2-year level performance. To mitigate the increased runoff volume generated by the by the project, a detention pond will also be constructed. The Saltwater Ditch project provide benefits in the 10-year storm event to approximately 1,000 structures.

As mentioned above were the tools and approach used to create a BCR, which concluded a 1.8 for this project. More details on the methodology used in the BCA can be provided in Appendix 5-4D.

All three projects were modeled utilizing locally required methodologies and the latest versions of HEC-RAS at the time of starting modeling activities. Atlas 14 rainfall was not utilized and rather rainfall was used (TP-40) that current FEMA mapping is based on. The sponsor policy at the time was to focus on the 0.2% ACE rainfall event as a reasonable stand in for Atlas 14 1% ACE rainfall until such time that new FEMA maps based on Atlas 14 are made best available. No negative impact from this project was assumed up and including the 0.2% ACE event since the project sponsor HCFCD enforces a strict no adverse impact policy. Ultimately, the hydraulic and hydrologic modeling results were provided to the Technical Team by the stakeholder as one single resultant raster for both the pre-project and post-project 1% and 0.2% ACE conditions. The analysis of benefit and flood risk reduction provided and performed for this FMP were based on the above-mentioned raster results under a process developed by the San Jacinto RFPG.

The analysis conducted by the San Jacinto RFPG found that the estimated flood risk reduction benefits following the implementation of Sims Bayou Watershed Mitigation CDBG-MIT FMP includes the removal of an estimated 17 miles of roadway and 2,283 structures from the 1% ACE floodplain, 2127 of which are residential structures. This correlates to an estimated 9,352 individuals removed from the 1% ACE flood risk. Additionally, 1,328 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***Halls Bayou CDGB MIT Application 1 Projects (063000040)***

The projects in this application are designed to provide watershed-wide flood threat reduction measures in Halls Bayou as shown in **Figure 5-5**. The Halls Bayou watershed is a historically underserved area of north Harris County, TX. Projects in this application are sponsored by HCFCD and include improvements in both conveyance and detention on both the mainstem and tributaries of Halls Bayou. Listed below are the five projects submitted as part of the CDBG-MIT grant application in the Halls Bayou watershed, totaling an estimated \$99.65 million in construction:

1. **C-28:** Channel conveyance improvements on Tributaries P118-25-00 and P118-25-01
2. **C-30:** Channel conveyance improvements on Tributary P118-27-00
3. **C-23:** Channel conveyance improvements on Tributary P118-08-00
4. **C-41 Hardy West:** Stormwater detention improvements in the vicinity of Hardy West
5. **C-41 Mainstem:** Main stem channel conveyance improvements upstream of Keith Weiss Park and downstream of Hooper Road; stormwater detention improvements in the vicinity of P118-21-Phase II

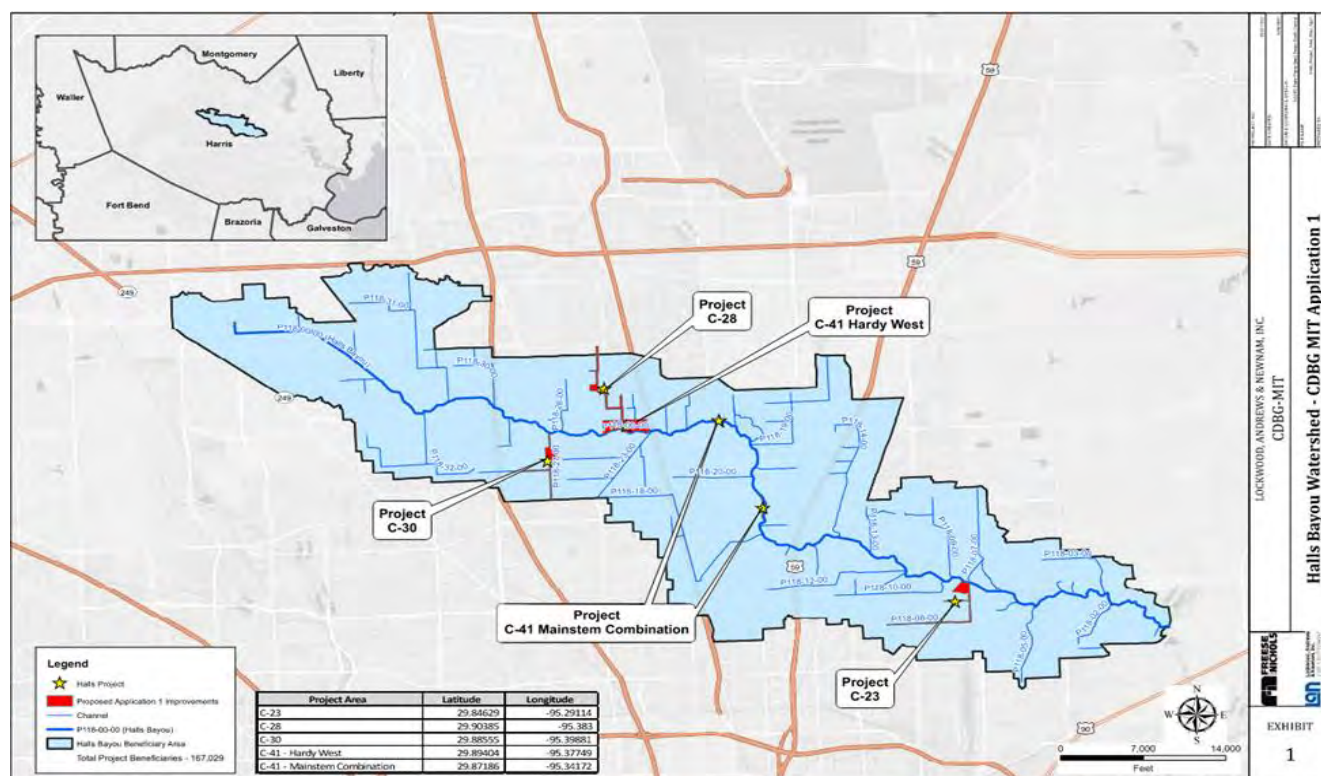


FIGURE 5-5: HALLS BAYOU CDBG-MIT APPLICATION PROJECT AREA

All projects were modeled utilizing locally required methodologies and the latest versions of HEC-RAS at the time of starting modeling activities. Atlas 14 rainfall was not utilized and rather rainfall was used (TP-40) that current FEMA mapping is based on. The sponsor policy at the time was to focus on the 0.2% ACE rainfall event as a reasonable stand in for Atlas 14 1% ACE rainfall until such time that new FEMA maps based on Atlas 14 are made best available. No negative impact from this project was assumed up to and including the 0.2% ACE event since the project sponsor HCFCF enforces a strict no adverse impact policy. Ultimately, the hydraulic and hydrologic modeling results were provided to the Technical Team by the stakeholder as individual resultant rasters for both the pre-project and post-project 1% and 0.2% ACE conditions. These were then combined in ArcGIS to create a single data source for further analysis. The assessment of benefit and flood risk reduction performed for this FMP were based on the combined raster results under a process developed by the San Jacinto RFPG.

As mentioned above were the tools and approach used to create a BCR, which concluded a 1.46 for this project. It is important to note that the Halls Bayou Watershed CDBG-MIT Application 1 Covered Project will provide many community benefits for which an economic value could not be quantified as part of this analysis. More details on the methodology used in the BCA can be provided in Appendix 5-4E

While the activities are expected to show greatest benefits at the neighborhood level, engineering analysis has been performed at the watershed level. Therefore, the evaluation consisted of a combination of project study reports and HEC-RAS model results to determine flood risk. The estimated flood risk reduction benefits following the implementation of CDBG-MIT grant Halls Bayou Watershed FMP includes the removal of an estimated 17 miles of roadway and 3,023 structures from the 1% ACE floodplain, 2,652 of which are residential structures. This correlates to an estimated 9,386 individuals



removed from the 1% ACE flood risk. Additionally, 3,259 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***White Oak Bayou CDBG MIT Application Projects (063000046)***

This CDBG-MIT grant application is located in the White Oak Bayou Watershed and is made up of five (5) individual structural flood risk reduction measures that consist of regional channel and detention projects including Kolbe Road, Barwood, E132-00-00, Tower Oaks, & Little White Oak Bayous. This flood and drainage activity improves drainage at neighborhood and regional levels by making improvements to subdivisions within the White Oak Bayou watershed and to the E132-00-00 and Little White Oak Bayou channels as shown in **Figure 5-6**. The proposed improvements are sponsored by HCFCD and supported by Harris County Engineering total an estimated \$120 million in construction costs include:

1. Kolbe Road Drainage Improvements: include the addition of storm sewers under the existing roadside ditches throughout the project site. The storm sewer redirects a portion of drainage area from Cypress North Houston to now drain to HCFCD channel E133-01-00. The change in flows requires detention to mitigate any adverse impact, so right-of-way (ROW) acquisition is included in the project requirements.
2. Barwood: Approximately 1,300 linear feet (LF) of 48-inch new RCP installed along N Eldridge Road, connecting to the intersecting existing lines. A 25.0 acre-foot detention pond to the north of Advance Drive, connecting to the existing system with approximately 220 LF of 48-inch RCP, would be created to offset negative impacts of the increase storm sewer capacity. Approximately 2,500 LF of 48-inch RCP; 1,600 LF of 54-inch RCP; and 860 LF of 72-inch RCP would be added to replace 4,960 LF of existing RCP storm sewer.
3. E132-00-00: Includes enclosing a portion of the upstream channel, modifying the width of the remaining channel, and acquiring right-of-way (ROW) for additional detention storage volume or channel widening.
4. Tower Oaks Meadows: Proposed improvements involve building storm sewers ranging in size from 24' circular RCP to dual 9'X4' reinforced concrete box culverts. Converting roadways to curb and gutter streets where storm sewer improvements are proposed as well as re-grading existing roadside ditches.
5. Little White Oak: Involves channel widening 8,700 feet of Little White Oak Bayou (HCFCD Unit No. E101-00-00) from Tidwell Road (upstream) to Crosstimbers Street (downstream) along with two detention basins and additional in-line storage.



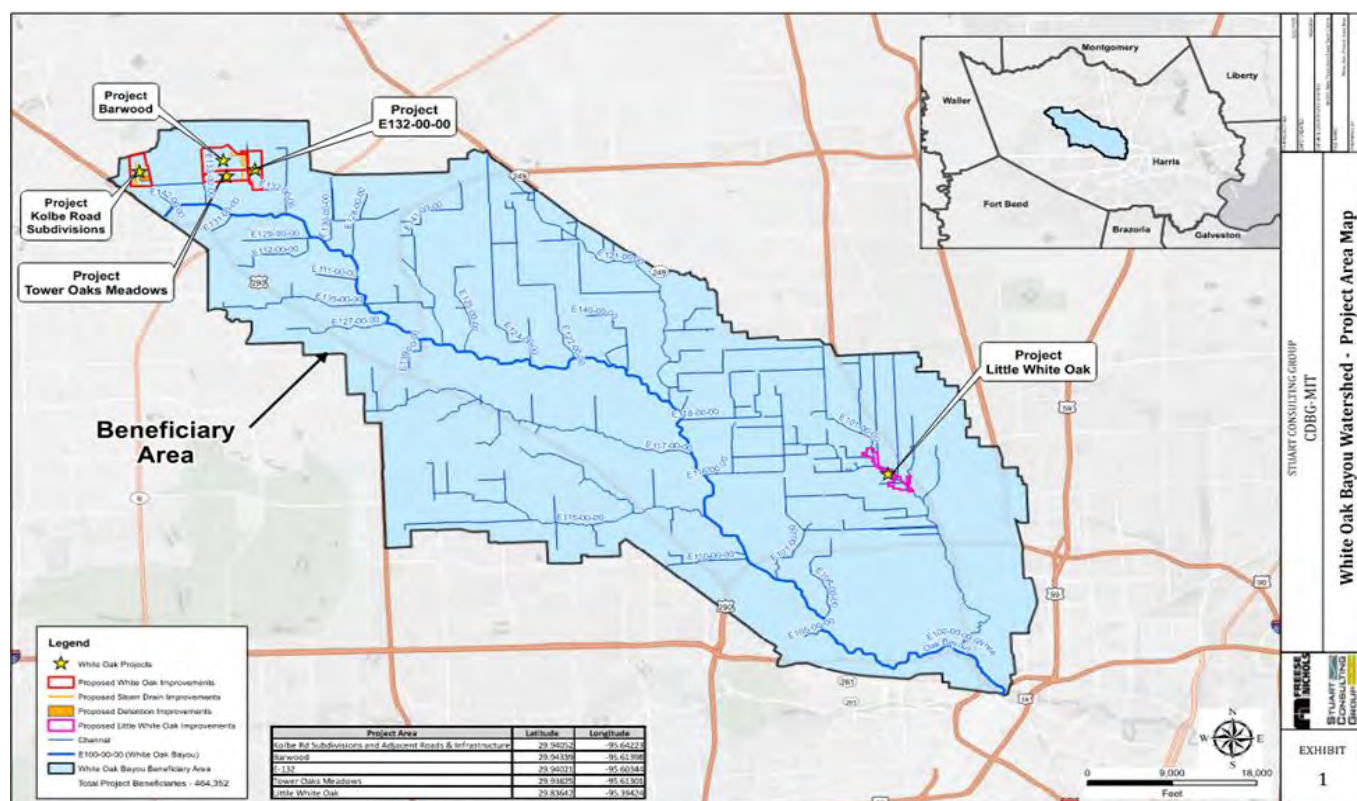


FIGURE 5-6: WHITE OAK BAYOU WATERSHED CDBG-MIT APPLICATION PROJECT AREA

All projects were modeled utilizing locally required methodologies and criteria established by the project sponsor including a strict requirement of no adverse impact. Of the five different projects included, the San Jacinto RFGP only received a HEC RAS model for the Little White Oak project. All other projects utilized the XPSWMM program and a summary of their results was received in spreadsheet format. These projects utilized 2008 and 2018 LiDAR as a basis for modeling and mitigates impacts up to 0.2% ACE TP-40 event and/or 0.1% ACE Atlas 14 event. While the TP-40 rainfall is not considered the best available for the region, a TP-40 0.2% ACE event is a reasonably close to the 1% ACE Atlas 14 event to serve as a stand-in. The four projects submitted with spreadsheet results were combined with the results pulled from resultant rasters of the Little White Oak Project. The data available in the spreadsheet format was limited and included results only related to pre and post project structure counts. Therefore, to remain consistent across all included project, the benefit analysis on the FMP was unable to include certain analysis items such as those related to area and population calculations.

As mentioned above were the tools and approach used to create a BCR, which concluded a 0.80 for this project. It is important to note that the White Oak Bayou Watershed Mitigation Project will provide many community benefits for which an economic value could not be quantified as part of this analysis. More details on the methodology used in the BCA can be provided in Appendix 5-4F.

The estimated flood risk reduction benefits following the implementation of White Oak Bayou Watershed Mitigation Project CDGB-MIT application removes an estimated seven miles of roadway and 670 structures from the 1% ACE floodplain, 605 of which are residential structures. This correlates to an estimated 3,899 individuals removed from the 1% ACE flood risk. Additionally, 549 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk

following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***Greens CDBG-MIT Application Projects***

Projects submitted as part of the CDBG MIT grant in Greens Bayou include Projects: Fountainview Section 1&2, Castlewood Section 3&4, North Forest, Mid-Reach Greens, Parkland Estates, and Humble Road Place as shown in **Figure 5-7**. This action plan will address riverine flooding to subdivisions and businesses throughout the Greens Bayou Watershed in Harris County experience flooding conditions during hurricanes, tropical storms and even intense rainfall events that overwhelm drainage systems. The project sites identified throughout this application are part of an organized county-wide effort to analyze infrastructure shortfalls, build community resilience, and mitigate future hazards through flood risk reduction projects and strict floodplain management practices. In total the structural measures included in this FMP have an estimated construction cost of \$120 million. Listed below are details of each project sponsored by HCFCF in conjunction with Harris County Engineering:

1. **Fountainview Section 1&2:** Replaces the existing storm sewer systems with new systems capable of conveying the 2-year, or 50% ACE, rainfall event without modifying the current storm sewer alignment or pavement grades. The evaluation and construction of extreme event overflow structures at each cul-de-sac is included in the project scope. To create no adverse impact downstream, a 10-acre-foot detention basin is proposed along the northern boundary of the project.

Survey data and storm sewer flowline information were provided for this study area for the existing storm sewer system and was utilized when modeling the existing system in a local modeling package called HouStorm. Elevation measurements were pulled from 2008 lidar and hydrology based on the FEMA effective HEC-HMS model which used TP-40 rainfall based totals.

2. **Castlewood Section 3&4:** Convert all roadside ditches and culverts to a curb and gutter roadway with underground storm sewer. Additional work to relocate utilities and provide sidewalks is included in the project as well. The new storm sewer will convey the 2-year, or 50% ACE, storm while the curb and gutter pavement will provide additional storage and conveyance for events up to a 100-year, or 1% ACE, rainfall event. Two major outfalls will be located on the eastern side of Woodgate and Connorvale. The Woodgate outfall will also have an extreme event swale. Other extreme event flow paths and approximately 40 acre-feet of detention.

Hydrographs were developed for each drainage area within HEC-HMS by calibrating the peak flow of the hydrograph to the peak flow obtained from the Rational method for each respective drainage area. Precipitation data was based on the frequency duration values obtained from NOAA Atlas 14 for the Castlewood area. Detailed hydraulic modeling was completed utilizing a 1D/2D XP-SWMM model.

3. **North Forest:** Consists of splitting the existing storm sewer into two systems and constructing a detention basin to receive and store the flows from the subdivision. Extreme event overflow locations are included in the project scope as well. The existing outfall configuration will remain and continue to discharge into the P145-03-03 channel. The 110-acre-foot detention basin receives flow from the eastern part of the subdivision via proposed 60-inch RCP storm along North Forest Boulevard. The basin is spread over 12.32 acres with an average depth of eight feet.

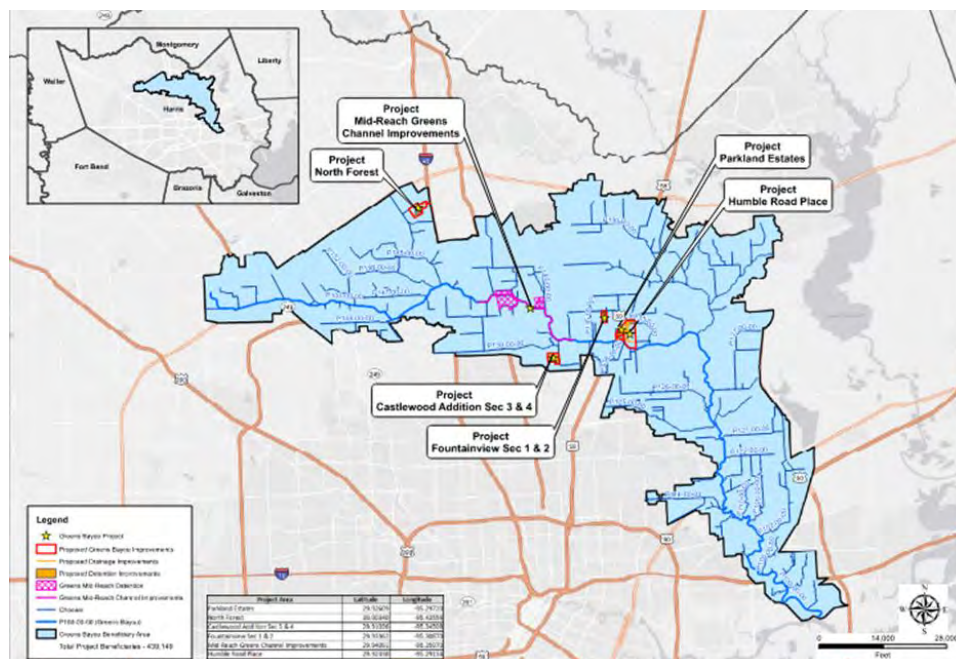
The drainage analysis for the subdivision and the flow from the surrounding off-site areas was performed using a general approach with a Storm Water Management Model (XP-Storm 2018.2) program. The system capacity was analyzed using the 24-hour, 0.2% ACE rainfall depth of 18.9 inches for the Greens Bayou watershed, as specified by local policy.

4. **Mid-Reach Greens:** Improvements to approximately 5.5 miles of Greens Bayou (HCFC Unit P100-00-00) from Imperial Valley Drive to JFK Boulevard and includes two stormwater detention basins adjacent to the Bayou located just east of Hardy Toll Road.

A hydrologic analysis was performed to develop peak flow data to be utilized in the HEC-RAS modeling effort. The following storm events were analyzed as part of this study: 50%, 10%, 2%, 1% ACE. The Atlas 14 rainfall data was utilized as part of this study. The unsteady capabilities of HEC-RAS (v. 5.0.7) were utilized for the hydraulic analysis as part of this study. As per local sponsor policy, this project delivers flood risk reduction with no adverse impact to adjacent properties.

5. **Humble Road Place and Parkland Estates Subdivisions Drainage Improvements:** The construction of a bypass channel under the existing railroad. The bypass channel will reduce the upstream water surface elevations during extreme events by providing additional flow capacity in the P133-00-00 channel. A mitigation basin in proposed downstream to account for any adverse impacts.

A 1D/2D HEC-RAS model (unknown version) was developed to support the development of this project. Per direction of local policy, the current effective 0.2% ACE rainfall totals (TP-40) were utilized as a stand-in for the 1% ACE (Atlas 14) until such time as current policy and maps are updated to reflect the new standard.





Technical Team only received a HEC RAS model for the Greens Mid-Reach project. Other projects utilized the XPSWMM, HouStorm, or other methods as mentioned above. A summary of their results was received by the technical team in spreadsheet format and used for FMP benefit analysis. These projects utilized 2008 and 2018 LiDAR as a basis for modeling and mitigates impacts up to 0.2% ACE TP-40 event and/or 0.1% ACE Atlas 14 event. While the TP-40 rainfall is not considered the best available for the region, a TP-40 0.2% ACE event is a reasonably close to the 1% ACE Atlas 14 event to serve as a stand-in. The four projects submitted with spreadsheet results were combined with the results pulled from resultant rasters of the Greens Mid-Reach project. The data available in the spreadsheet format was limited and included results only related to pre and post project structure counts. Therefore, to remain consistent across all included project, the benefit analysis on the FMP was unable to include certain analysis items such as those related to area and population calculations.

As mentioned above were the tools and approach used to create a BCR, which concluded a 2.13 for this project. The BCR was determined as the ratio of the present value of Total Expect Benefits to Total Project Cost. It is important to note that the Greens Bayou Watershed Covered Project will provide many community benefits for which an economic value could not be quantified as part of this analysis. More details on the methodology used in the BCA can be provided in Appendix 5-4I.

The estimated flood risk reduction benefits following the implementation of CDBG MIT grant Greens Watershed FMP includes the removal of an estimated 1,816 structures from the 1% ACE floodplain, 1,550 of which are residential structures. This correlates to an estimated 21,508 individuals removed from the 1% ACE flood risk. Additionally, 2,076 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

#### **5.D.4.c. San Jacinto Master Drainage Plan**

The following projects were developed as part of the San Jacinto River Regional Watershed Master Drainage Plan (SJMDP). In the wake of Hurricane Harvey, HCFCD, San Jacinto River Authority (SJRA), Montgomery County (MOCO), and the City of Houston recognized the need for flooding mitigation strategies along the San Jacinto River. The SJMDP evaluated the existing conditions in the basin and developed a comprehensive flood mitigation plan. From the SJMDP, sixteen structural flood mitigation alternatives were recommended for future development. These 16 structural alternatives have been grouped into the following 6 FMPs.

Several agencies or communities were identified as potential partners that could provide assistance in the implementation of the project. The following sponsor/funding agencies have been identified for all of the following projects: SJRA, Texas Water Development Board (TWDB), Texas General Land Office (GLO), and the USACE.

This project is supported by hydrologic and hydraulic models leveraging NOAA Atlas 14 rainfall and a 1D unsteady flow. The models utilized Digital Elevation Models (DEM) developed from regional 2018 LiDAR to cover the limits of the San Jacinto River watershed. Major watersheds within the San Jacinto River basin were modeled individually and then combined into one comprehensive model. Maximum depth rasters were extracted from the model for the 1% and 0.2% ACE events. In the SJMDP, each individual alternative was modeled to determine the benefits on the watershed as a whole. However, the evaluation of the specific impact of each alternative was not conducted. The SJMDP project team,

instead, assessed benefits throughout the entire watershed. This approach was taken due to an alternative having the potential to benefit structures downstream of the primary benefit area. Assessing benefit throughout the entire watershed also was deemed appropriate due to the channelization alternatives requiring a separate upstream detention project. Each FMP that stems from the SJMDP that involves channelization, has also been paired with detention alternatives or has been recommended to be completed subsequent to an upstream detention alternative. For further details on the modeling approach used by the SJMDP project team, please refer to the report in Appendix 5-4G.

The benefit cost ratio was determined for each individual alternative considered in the SJMDP. The benefit cost ratio was also provided in an estimated range and calculated using spreadsheet calculations that follow the same principles as FEMA's BCA toolkit. Since most SJMDP FMPs involve multiple alternatives, the benefit-cost ratio was determined by the San Jacinto RFPG through a weighted average using the highest cost from the range provided with the corresponding Benefit-Cost Ratio for all alternatives recommended in each SJMDP FMP. FMPs in the SJMDP were grouped based on guidance provided in the report, which can be referenced in Appendix 5-4G.

Each SJMDP FMPs that involve channelization, has been paired with detention alternatives or has been recommended to be completed subsequent to an upstream detention alternative. These FMPs have been paired with detention alternatives in order to mitigate impacts.

#### ***SJMDP Caney Creek - Channelization with Detention (063000058)***

This project includes three structural mitigation alternatives along Caney Creek and has combined two detention projects to mitigate the channelization project. These projects are highlighted in **Figure 5-8**, which include:

1. Detention at FM 1097
2. Detention at SH105
3. Channelization at I-69



FIGURE 5-8: SJMDP CANEY CREEK PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: MOCO, HCFCD, and the Texas Department of Transportation (TxDOT). Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

The project aims to reduce flooding along Caney Creek by implementing two dry dam detention facilities to impound stream flow during flood events along with channelization near the confluence of East Fork of San Jacinto River. The channelization increases conveyance and requiring a separate upstream detention project. The channelization must be constructed with detention at FM 1097 or detention at SH105 to capture runoff from Caney Creek. The dry dam detention facility at FM 1097 includes a 1.2-mile-long earthen impoundment that would provide 13,900 acre-feet of storage capacity, while the dry dam at SH 105 includes a 0.8-mile-long earthen impoundment with 28,090 acre-feet of storage. The channelization at I-69 includes 700-foot-wide benching for a 7.8-mile-long stretch from 0.5 mile downstream of I-69 to the confluence of East Fork of San Jacinto River.

Based on the analysis done by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of SJMDP Caney Creek - Channelization at IH-69 & Detention at FM1097 + SH105 FMP includes the removal of an estimated 42 miles of roadway and 2,422 structures from the 1% ACE floodplain, 1,827 of which are residential structures. This correlates to an estimated 4049 individuals removed from the 1% ACE flood risk. Additionally, 336 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these

improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***SJMDP East Fork San Jacinto River – Detention (063000059)***

This project includes a structural mitigation alternative along the East Fork of the San Jacinto River, through the construction of Winters Bayou Dry Dam Detention Basin, highlighted in **Figure 5-9**.



FIGURE 5-9: SJMDP EAST FORK WINTERS BAYOU PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: San Jacinto County, TxDOT, U.S. Department of Agriculture (USDA), Burlington Northern Santa Fe (BNSF) Railroad, Union Pacific Railroad (UPRR), and HCFCD. Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

This detention project aims to reduce flooding along the East Fork of the San Jacinto River by implementing a dry dam facility that impounds stream flow during flood events. Out of several potential detention locations this site was chosen based on the ability to reduce flows, limited existing development, and the large impact Winters Bayou has on the water surface and flow of the East Fork. The dry dam detention facility includes a 1.60-mile-long earthen impoundment that captures runoff from Winter's Bayou. The flow control structure consists of a 48-ft tall concrete dam with 5 – 10'x10'



RCBC directly connected into a secondary (300') tiered dual spillway. The amount of material required to construct such a system would entail close to 1.3 million cubic meters of materials to create 2,479 acres at the 1% ACE level to create approximately 45,055 acre-ft of storage capacity spanning an area of 2,479 acres.

Based on the analysis done by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of SJMDP project, Winters Bayou Detention, includes the removal of an estimated 17 miles of roadway and 651 structures from the 1% ACE floodplain, 506 of which are residential structures. This correlates to an estimated 1,412 individuals removed from the 1% ACE flood risk. Additionally, 297 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***SJMDP Lake Creek – Detention (063000060)***

This project includes three structural mitigation alternatives along Lake Creek and has combined two detention projects to mitigate the channelization project. These projects are highlighted in **Figure 5-10**, which include:

1. Caney Creek Detention
2. Little Caney Creek Detention
3. Garrett's Creek detention



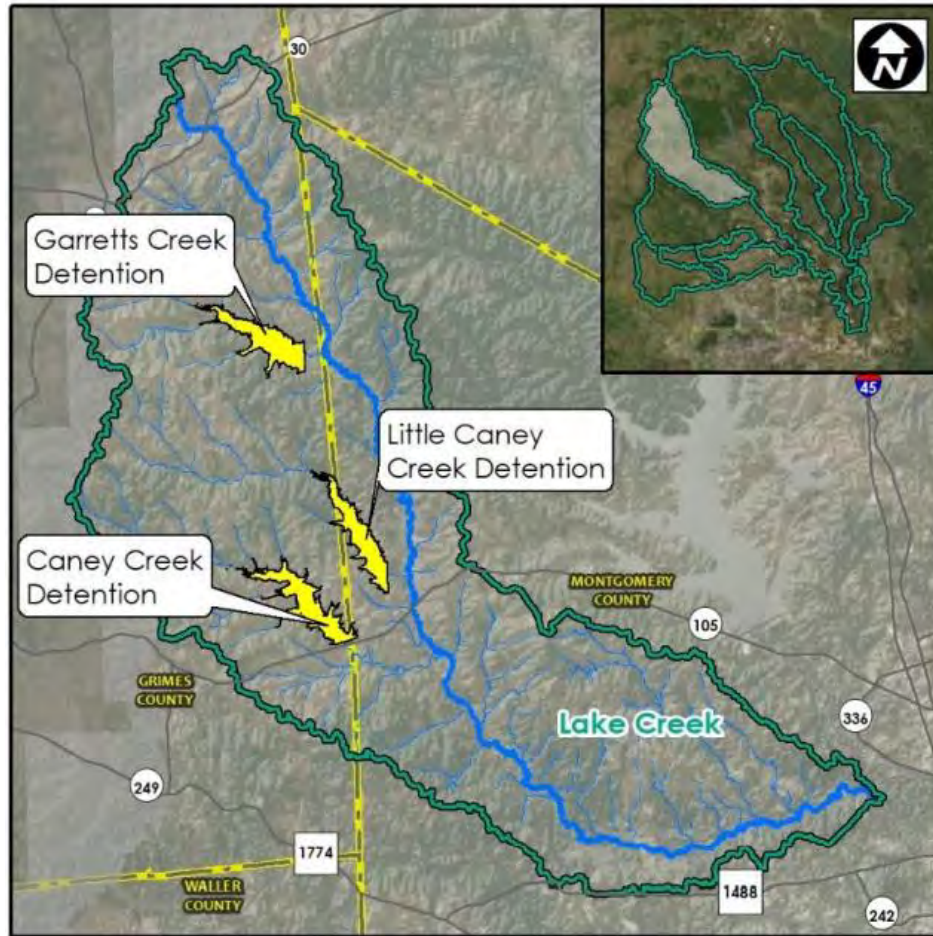


FIGURE 5-10: SJMDP LAKE CREEK PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: Grimes County, MOCO, HCFCF, and TxDOT. Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

The project aims to reduce flooding along Lake Creek by implementing three dry dam detention facilities to impound stream flow during flood events. The Caney Creek Detention consists of a dry dam detention facility approximately 0.3 miles upstream of SH 105 on Caney Creek. This dry dam detention facilities includes a 0.76-mile-long earthen impoundment that would provide 19,750 acre-feet of storage capacity with a maximum dam height of 52 ft. Little Caney Creek Detention, which is located approximately 1.1 miles upstream of Lake Creek on Little Caney Creek, West FM 1486 consists of a dry dam detention facility. The facility includes a 0.83-mile-long earthen impoundment that would provide 17,500 acre-feet of storage with a maximum dam height of 51 ft. Garrett's Creek Detention also consists of a dry dam detention facility, which is located 0.7 miles upstream of Lake Creek on Garretts Creek. The facility includes a 1.2-mile-long earthen impoundment that would provide 16,850 acre-feet of storage with a maximum dam height of 43 ft. All detentions contain a primary outfall consisting of 3-5'x5' RCB and secondary spillway approximately 200 ft in length, however Garrett's Creek secondary spillway has approximately 100 ft in length.

Based on the analysis done by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of SJMDP Lake Creek – Detention on Garretts Creek, Little Caney Creek, & Caney Creek includes the removal of an estimated 5 miles of roadway and 355 structures from the 1% ACE floodplain, 265 of which are residential structures. This correlates to an estimated 383 individuals removed from the 1% ACE flood risk. Additionally, 41 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***SJMDP Peach Creek - Channelization with Detention (063000061)***

This project includes three structural mitigation alternatives along Peach Creek and has combined two detention projects to mitigate the channelization project. These projects are highlighted in **Figure 5-11**, which include:

1. Detention at Walker
2. Detention at SH 105
3. Channelization at I-69

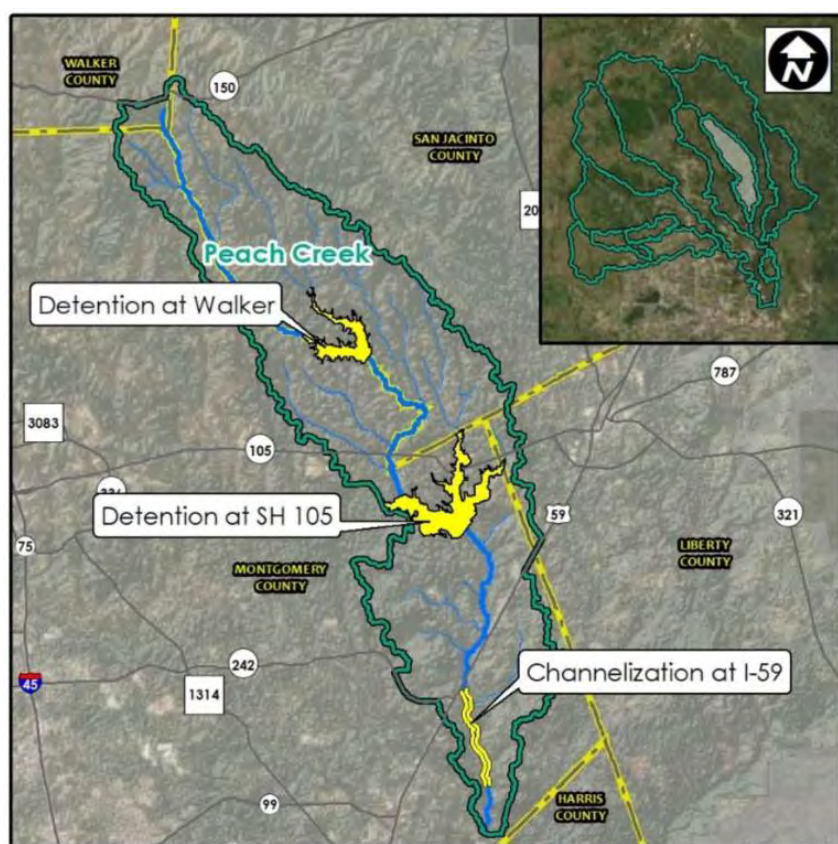


FIGURE 5-11: SJMDP PEACH CREEK PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: San Jacinto County, MOCO, and TxDOT. Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

The goal of these projects is to reduce flooding in the Peach Creek watershed by combining the benefits of two dams with channelization of the main stem of Peach Creek. The Walker detention project is roughly a \$200 million-dollar dry dam project that is modeled to reduce Atlas 14 water surface elevations (WSEL) from 1% ACE to 10% ACE. The Walker detention facility occupies close to 1,200 acres of land at the 1% ACE water level and would hold close to 36,000 acre-feet of water volume. Similarly, to the Walker Creek detention facility, further downstream on Peach Creek, the SH 105 detention is a ~\$400-million-dollar dry dam project that shows an Atlas 14 WSEL reduction of 1% ACE to 4% ACE, occupying 3,000 acres of area and 36,000 acre-feet of volume at 1% ACE level. And the furthest downstream, the channelization of peach creek at I-69 increases the conveyance capacity of this section of channel. This project contains 4.3 miles of channelization with 800-feet of benching, ultimately reducing the immediate downstream WSEL from a 1% ACE to 4% ACE at an approximate cost of \$160 million. The three projects show an average WSEL reduction of approximately 1.2” in the 1% ACE event in the section of channel from I-69 to the confluence of the East Fork.

Based on the analysis done by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of recommended projects from the SJMDP along Peach Creek - including the detention projects at Walker and SH 105 as well as the channelization at I-69, showed the removal of an estimated 24 miles of roadway and 1,146 structures from the 1% ACE floodplain, 842 of which are residential structures. This correlates to an estimated 1855 individuals removed from the 1% ACE flood risk. Additionally, 98 structures would have reduced area within the 100-year floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

#### ***SJMDP Spring Creek - Channelization with detention (063000062)***

This project includes four structural mitigation alternatives along Spring Creek and has combined two detention projects to mitigate the channelization projects. This project must also be completed with detention on Birch Creek and Walnut Creek in order to mitigate impacts. These projects are highlighted in **Figure 5-12**, which include:

1. Walnut Creek Detention
2. Birch Creek Detention
3. Woodlands Channel (200-ft)
4. I-45 Channelization



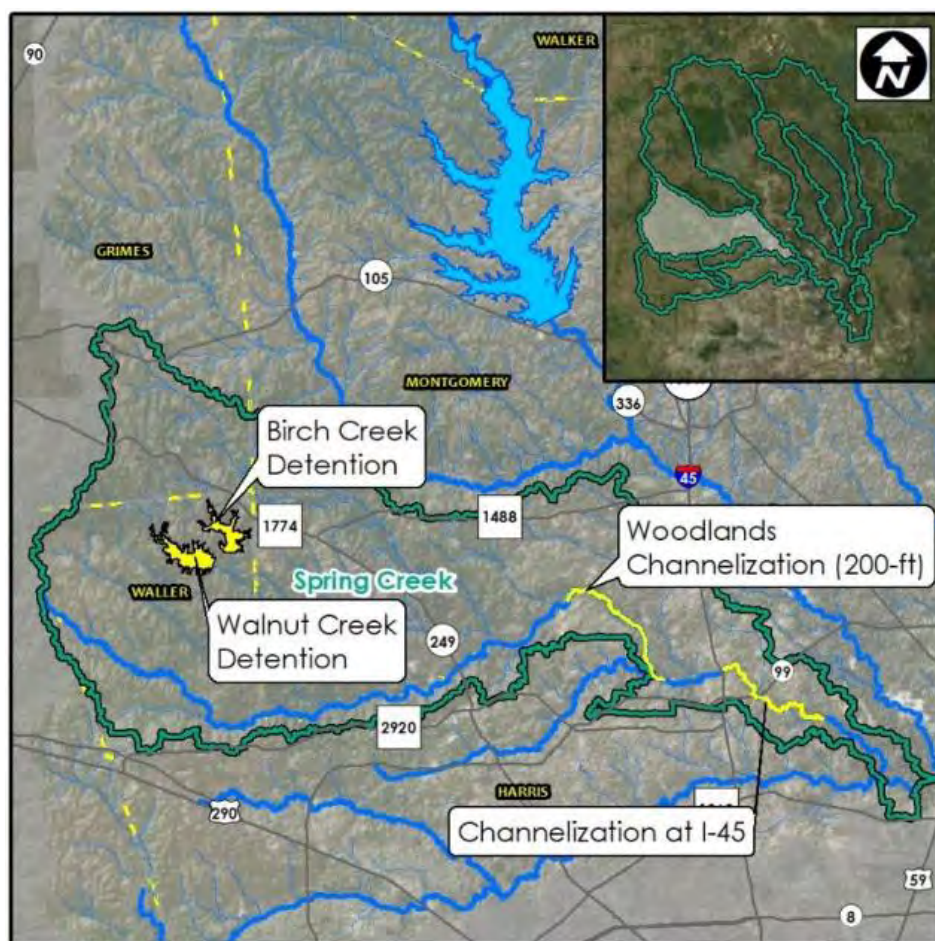


FIGURE 5-12: SJMDP SPRING CREEK PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: Waller County, Harris County, City of Tomball, The Woodlands Township, Municipal Utility District 386 (MUD 386), Woodlands Water Agency (WWA), Federal Emergency Management Agency (FEMA), MOCO, HCFCD, and TxDOT. Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

The project aims to reduce flooding along Lake Creek by implementing two dry dam detention facilities to impound stream flow during flood events and a total of 15.7 miles of channelization at I-45 and through the Woodlands. The channelization increases conveyance requiring a separate upstream detention project first. The Walnut Creek Detention consists of a dry dam detention facility approximately 12 miles upstream of Spring Creek on Walnut Creek. This dry dam detention facilities includes a 1.2-mile-long earthen impoundment that would provide 12,159 acre-feet of storage capacity with a maximum dam height of 46 ft. Walnut Creek also contains contain a primary outfall consisting of 2-4'x4' RCBC and secondary spillway approximately 200 ft in length. Birch Creek Detention, which is located approximately 12 miles upstream of Spring Creek on Birch Creek, also consists of a dry dam detention facility. The facility includes a 0.7-mile-long earthen impoundment that would provide 7,731 acre-feet of storage, a maximum dam height of 41 ft, and a primary outfall consisting of 2-4'x3' RCBC and secondary spillway approximately 200 ft in length. The proposed Woodlands Channelization (200-ft)



improvement is located upstream of Kuykendahl Road and downstream of Willow Creek confluence on Spring Creek. This improvement consists of 8.8 miles of channelization with 200-foot-wide benching and 7,200 acre-feet of required mitigation storage. The I-45 channelization is located from I-45 to approximately 4 miles downstream of Riley Fuzzel Road on Spring Creek. This improvement consists of 6.9 miles of channelization with 300-foot-wide benching and requires 8,000 acre-feet of mitigation storage.

Based on the analysis done by the San Jacinto RFPG, the estimated flood risk reduction benefits following the implementation of SJMDP Woodlands (200-ft) and I-45 Channelization with detention at Birch Creek and Walnut Creek includes the removal of an estimated 69 miles of roadway and 5,479 structures from the 1% ACE floodplain, 4,732 of which are residential structures. This correlates to an estimated 18,240 individuals removed from the 1% ACE flood risk. Additionally, 680 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

### ***SJMDP West Fork San Jacinto River - Benching and Channelization (063000064)***

This project includes two structural mitigation alternatives along the West Fork San Jacinto River. This project is expected to be conducted after or in conjunction with the detention projects on Lake Creek or Spring creek to mitigate impacts from the channelization. These projects are highlighted in **Figure 5-13**, which include:

1. HW 242 Channelization
2. Kingwood Benching

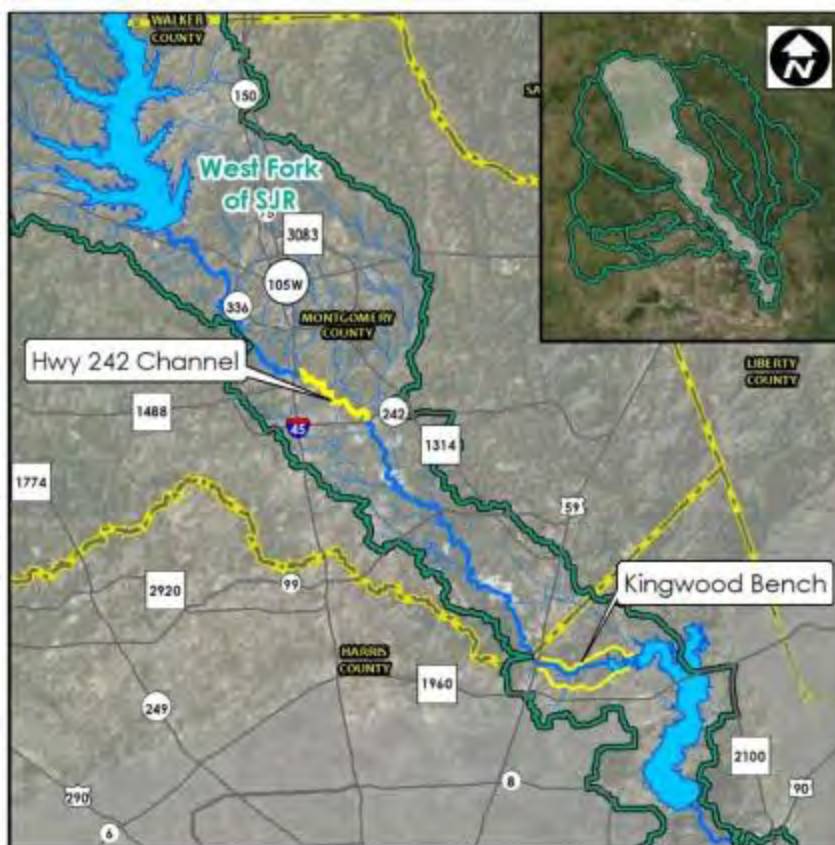


FIGURE 5-13: SJMDP WEST FORK PROJECT AREA

In addition to the sponsors mentioned in the SJMDP summary above, the following are other identified potential sponsors/funding agencies: Harris County, MOCO, HCFC, and the City of Houston. Upon the completion of this project, an agency will also need to be determined to own and maintain the detention basins.

The project aims to reduce flooding along West Fork of San Jacinto River through 5.7 miles of channelization and 5 miles of channel benching. This project must also be conducted after or in conjunction with detention on Lake Creek or Spring Creek to mitigate potential adverse impacts. The goal of the Highway 242 channelization is to reduce flooding by widening a 5.7-mile-long stretch of increase conveyance capacity of West Fork to lower the water surface elevation, which would also require 12,400 acre-feet of mitigation storage. Improvements are planned to widen the West Fork to 750-feet with a 2-foot bench above the stream bed. As for the Kingwood bench portion of the project to also increase conveyance capacity of West Fork involves widening a 5-mile-long stretch with 3,500-feet wide of benching. This project would require 923 acre-feet of mitigation storage.

Based on the analysis done by the San Jacinto RFP, the estimated flood risk reduction benefits following the implementation of SJMDP West Fork San Jacinto River - Kingwood Benching & HW 242 Channelization includes the removal of an estimated 28 miles of roadway and 1,638 structures from the 1% ACE floodplain, 1,460 of which are residential structures. This correlates to an estimated 7,636 individuals removed from the 100-year flood risk. Additionally, 1,209 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these

improvements For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

#### **5.D.4.d. Galveston Bay Surge Protection Coastal Storm Risk Management (063000127)**

Identified in the Coastal Texas Protection and Restoration Feasibility Study, or Texas Coastal Study (2021), the Galveston Bay Surge Protection Coastal Storm Risk Management project includes various features along Galveston Island and Bolivar Peninsula, across the Bolivar Roads, and in the bay itself. The project is highlighted below in **Figure 5-14**. The goals of this study between The USACE and the GLO were to promote a resilient and sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the Nation's economy. The objectives of the project are:

1. Reduce risk to human life from storm surge impacts along the Texas coast;
2. Reduce economic damage from coastal storm surge to business, residents, and infrastructure along the Texas coast;
3. Enhance energy security and reduce economic impacts of petrochemical supply-chain related interruption due to storm surge impacts;
4. Reduce risks to critical facilities (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact;
5. Manage regional sediment, including beneficial use of dredged material from navigation and other operations so it contributes to storm surge reduction where feasible;
6. Increase the resilience of existing hurricane risk reduction systems from sea level rise and storm surge impacts; and
7. Enhance and restore coastal landforms that contribute to storm surge attenuation where feasible.





Figure ES-6: Galveston Bay Storm Surge Barrier System

FIGURE 5-14: GALVESTON BAY SURGE PROTECTION PROJECT AREA

The Galveston Bay Storm Surge Barrier System can be split into two zones: Gulf Defenses and Bay Defenses. The Gulf Defenses include:

1. **The Bolivar Roads Gate System:** across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island;
2. **West Galveston and Bolivar Peninsula Beach and Dune System:** 43 miles of beach and dune segments on Bolivar Peninsula and West Galveston Island that work with the Bolivar Roads Gate System to form a continuous line of defense against Gulf of Mexico surge, preventing or reducing storm surge volumes that would enter the Bay system; and
3. **Galveston Seawall Improvements:** improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge.

The Bay Defenses include:

4. **Galveston Ring Barrier System (GRBS):** An 18-mile GRBS that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston;



5. **Clear Lake Gate System and Pump Station:** A surge gate at Clear Lake that would reduce surge volumes that push into neighborhoods in the Clear Lake area;
6. **Dickinson Bay Gate System and Pump Station:** A surge gate at Dickinson Bay that would reduce surge volumes that push into neighborhoods in the low-lying areas along Dickinson Bayou; and
7. **Nonstructural Improvements:** Complementary non-structural measures to further reduce Bay-surge risks along the western perimeter of Galveston Bay

The modeling and analysis, performed by Mott MacDonald, consisted of the Clear Creek, Dickinson Bayou, and Galveston Watersheds. The Clear Creek Watershed had previously developed, calibrated, and well-documented hydrologic and hydraulic models, in HEC-HMS and HEC-RAS, respectively, and an effort was made to alter those models as little as possible due to their documented accuracy. The Dickinson Bayou Watershed HEC-HMS model was developed from available data and generating and calibrating 24 sub-watersheds. The Dickinson Bayou Watershed HEC-RAS model was developed using the 1979 HEC-2 model and represents 1979 topography, not current data. It is highly recommended for the next level of analysis to conduct a topographic data collection campaign. The Galveston Watershed was modeled using the EPA SWMM for hydrology and hydraulics.

The estimated flood risk reduction benefits following the implementation of Galveston Bay Surge Protection Coastal Storm Risk Management FMP includes the removal of an estimated 1,056 miles of roadway, 2,086 critical facilities, and 75,744 structures from the 1% ACE floodplain, 61,751 of which are residential structures. This correlates to an estimated 346,773 individuals removed from the 1% ACE flood risk. Additionally, 4,094 structures would have reduced area within the 1% ACE floodplain but would not be fully removed from flood risk following these improvements. For a summary and additional information on this project refer to the one pager attached in the Appendix 5-5.

## Chapter 5.E. Flood Management Strategies (FMSs)

### 5.E.1. Summary and Approach in Recommending FMSs

The San Jacinto region identified several FMSs to recommend for inclusion in the RFP. An FMS is a proposed plan to reduce flood risk or mitigate flood hazards to life or property. These strategies are broader in application than the level of detailed analysis necessary for an FME or FMP. For consideration as an FMS, strategies should adhere to requirements included in the project Scope of Work and the associated *Technical Guidelines* developed by the TWDB. The San Jacinto RFPG shall recommend FMSs that meet the following TWDB requirements:

1. Support at least one regional floodplain management and flood mitigation goal.
2. Provide mitigation for flood events and measurable reductions in flood impacts in support of the RFPG's specific flood mitigation and/or floodplain management goals.
3. Should not negatively affect a neighboring area or an entity's water supply.
4. If the FMS contributes to water supply, the FMS may not result in an overallocation of a water source based on the water availability allocations in the most recently adopted State Water Plan.

TWDB recommends that, at a minimum, the FMSs should mitigate flood events associated with the 1% ACE flood event where feasible. Where mitigation for 1% ACE is not feasible, FMSs to mitigate more frequent events can be included as recommended FMSs.

In addition, each potentially feasible FMS should demonstrate no negative impact to neighboring areas due to its implementation. Each of the recommended FMSs for the region are anticipated to have no adverse impacts from flooding or to the water supply based on the available data for each FMS.

Some of the recommended FMSs were combined into a single FMS for recommendation due to similarity with other FMSs. These FMSs included mitigation of repetitive flood losses and retrofitting of public buildings and critical infrastructure that were determined to be a better fit at a county-wide scale.

### **5.E.2. Description and Summary of Recommended FMSs**

A total of 64 FMSs were collected through stakeholder outreach and publicly available documentation such as Hazard Mitigation Plans. Of these, all FMSs were recommended for inclusion in the regional flood plan. Generally, these FMSs are city-wide and county-wide strategies. The FMSs represent a combined cost of \$1.1 billion and support several of the regional floodplain management and flood mitigation goals described in Chapter 3.

**Table 5-3** summarizes the types of FMSs, the number of FMSs for each type, and the total cost of the recommended FMSs. The full list of FMSs and supporting data is included in Table 17 in Appendix 5-8. A one-page report summary of each recommended FMS is included in Appendix 5-5B.

TABLE 5-3: SUMMARY OF RECOMMENDED FMSS

FMS Type	FMS Description	# of Potential FMSs Identified	# of FMSs Recommended	Total Cost of Recommended FMSs
Education and Outreach	Programs or initiatives that aim to educate the public on the hazards and risks of flooding.	15	15	\$5,370,000
Flood Measurement and Warning	Installation of or improvements to rain or stream gauges to monitor water levels and have real-time feedback during flood events.	6	6	\$1,585,000
Infrastructure Projects	Critical maintenance and improvements to existing drainage systems throughout a community.	8	8	\$16,030,000
Property Acquisition and Structural Elevation	Buyouts or elevation of structures with high flood risk or historical flooding impact as well as land preservation and restoration programs.	16	16	\$1,103,975,000
Regulatory and Guidance	Updates or creation of new ordinances, development codes, design standards, or other floodplain management regulations to minimize future flood risk or reduce current flood risk.	10	10	\$5,705,000
Other	Other flood management strategies that do not fit into the one of the above categories	9	9	\$2,245,000
<b>Total</b>		<b>64</b>	<b>64</b>	<b>\$1,134,910,000</b>