halff

REGION 8
2023 LOWER BRAZOS AMENDED REGIONAL FLOOD PLAN

Region 8 Lower Brazos Amended Regional Flood Plan

July 2023

Prepared for:
Texas Water Development Board

Prepared by:
Region 8 Regional Flood Planning Group

With assistance from:
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LOWER BRAZOS
REGIONAL FLOOD
PLANNING GROUP
REGION 8

November 27, 2023

TO:

Mr. Jeff Walker, Executive Administrator
Texas Water Development Board
Stephen F. Austin Building
1700 N. Congress Avenue, 6th Floor
Austin, Texas 78701

RE: Region 8 Lower Brazos Amended Regional Flood Plan Comments

Dear Mr. Walker:

On behalf of the Lower Brazos Regional Flood Planning Group (RFPG), I am pleased to submit the Amended Regional Flood Plan for the Lower Brazos Regional Flood Planning Region (Region 8).

The Amended Regional Flood Plan for Region 8 (dated July 2023) was adopted and approved for submittal by the RFPG at its meeting on June 22, 2023. Upon receiving comments from the Texas Water Development Board (TWDB) on November 6, 2023, the following items were corrected and/or updated accordingly:

Report Chapters

- Executive Summary
- Chapter 2
- Chapter 3
- Chapter 4
- Chapter 5
- Chapter 10

TWDB Exhibit C Tables

- Table 1 – Summary of Flood Infrastructure
- Table 2 – Summary of Proposed and Ongoing Flood Mitigation Projects
- Table 3 – Existing Conditions Flood Risk Summary Table
- Table 5 – Future Conditions Flood Risk Summary Table
- Table 6 – Existing Floodplain Management Practices
- Table 13 – Potentially Feasible Flood Mitigation Projects
- Table 15 – Recommended Flood Management Evaluations
- Table 16 – Recommended Flood Mitigation Projects
- Table 17 – Recommended Flood Management Strategies
- Table 19 – FMS, FMP, and FME, Funding Survey
- Tables 24-40 – Additional Project Details
- Model Submission Spreadsheet

Geodatabase Feature Classes

- ExFldExpAll
- ExFldExpPol
- ExFldExpPt

- ExFldInfraPol
- ExFpMP
- FME
- FMP
- FMP_Details
- FMS
- FutFldExpAll
- FutFldExpPol
- FutFldExpPt
- Goals
- ModelCoverage

A comprehensive list of the comments provided by TWDB, and comment responses, detailing the changes made to each item can be found in Appendix 10.10.

If you or your staff have any questions about the various electronic files that collectively constitute the Amended Regional Flood Plan, please contact me at shinojosa@halff.com or by phone at 936-777-6372. We look forward to your feedback on the Amended Regional Flood Plan.

Sincerely,

Sam Hinojosa, PE, CFM

Halff Associates, Inc – Region 8 Technical Consultants Team

c: Jake Madewell, TWDB Regional Flood Planner
Pamela Hannemann, BRA, Region 8 Lower Brazos RFPG Sponsor

REGION 8 – LOWER BRAZOS
REGIONAL FLOOD PLANNING GROUP

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June 22, 2023

Mr. Jeff Walker
Executive Administrator
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

Re: Region 8 Amended Lower Brazos Regional Flood Plan Adoption

Dear Mr. Walker,

The Region 8 Lower Brazos Regional Flood Planning Group (LBRFPG) met on June 22, 2023 and confirmed the amended Regional Flood Plan is complete. The LBRFPG adopted the amended Lower Brazos Regional Flood Plan and directed the technical consultant, Halff, to submit the Plan to the Texas Water Development Board by July 14, 2023.

Sincerely,

Alysha Girard
Chair, Region 8 – Lower Brazos Regional Flood Planning Group

Enclosures
cc. Mr. Jake Madewell – Regional Flood Planner, Flood Planning

Acknowledgements

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Lower Brazos Table of Contents

10.7 – Responses to the TWDB Comments on Regional Flood Plan 10-17

10.8 – Plan Adoption 10-17

10.9 – Conformance with Title 31 TAC §362.3 Guidance Principles 10-18

List of Tables

List of Figures

List of Appendices

Appendix 6 – Impact and Contribution of the Regional Flood Plan

Appendix 7 – Flood Response Information and Activities

Appendix 8 – Administrative, Regulatory, and Legislative Recommendations

Appendix 9 – Flood Infrastructure Financing Analysis

Appendix 10 – Adoption of Plan and Public Participation

Acronyms and Abbreviations

1D	One-Dimensional Model
2D	Two-Dimensional Model
ACE	Annual Chance Exceedance or Annual Chance Storm Event
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BFE	Base Flood Elevation
BLE	Base Level Engineering
BRA	Brazos River Authority
BRIC	Building Resilient Infrastructure and Communities
CDBG	Community Development Block Grant
CDBG-MIT	Community Development Block Grant - Mitigation
CDBG-DR	Community Development Block Grant – Disaster Recovery
CDC	Centers for Disease Control and Prevention
CIP	Capital Improvement Project
COG	Council of Governments
CRS	Community Rating System
CTP	Cooperating Partners Program
CWSRF	Clean Water State Revolving Fund
DD	Drainage District
DEM	Digital Elevation Models
DMP	Drainage Master Plan
EAP	Emergency Action Plan
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
EWP	Emergency Watershed Protection
FAFDS	First American Flood Data Services
FEMA	Federal Emergency Management Agency
FIF	Flood Infrastructure Fund

FIRM	Flood Insurance Rate Map
FIUP	Flood Intended Use Plan
FMA	Flood Mitigation Assistance
FME	Flood Management Evaluations
FMP	Flood Mitigation Projects
FMS	Flood Management Strategies
FPA	Floodplain Administrator
FPP	Flood Protection Plan
FRMP	Flood Risk Management Program
GIS	Geographic Information Systems
GLO	General Land Office
H&H	Hydrology and Hydraulics
HIFLD	Homeland Infrastructure Foundation Level Data
HMAP	Hazard Mitigation Action Plan
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HUC	Hydraulic Unit Code
HUD	Housing and Urban Development
LID	Levee Improvement District
LIDAR	Light Detection and Ranging
LOS	Level of Service
MUD	Municipal Utility District
NFHL	National Flood Hazard Layer
NCEI	National Center for Environmental Information
NFIP	National Flood Insurance Program
NHC	National Hurricane Center
NLD	National Levee Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service

NSFHA	Non-Special Flood Hazard Areas
NWS	National Weather Service
O&M	Operations and Maintenance
PDM	Pre-Disaster Mitigation
PWERT	Public Works Emergency Response Team
RFC	River Forecast Center
RFPG	Regional Flood Planning Group
SFHA	Special Flood Hazard Areas
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation
SVI	Social Vulnerability Index
SWCD	Soil and Water Conservation Districts
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TDEM	Texas Department of Emergency Management
TFMA	Texas Floodplain Management Association
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCID	Water Control Improvement District
WRDA	Water Resources Development Act
WSEL	Water Surface Elevation
WUG	Water User Group

Definitions

0.2 Percent Annual Chance Floodplain. The 0.2 percent annual chance floodplain is defined as the area that will be inundated by a flood event having a 0.2 percent chance of being equaled or exceeded in any given year. The 0.2 percent annual chance floodplain is also referred to as the 500-year flood.

1 Percent Annual Chance Floodplain. The 1 percent annual chance floodplain is defined as the area that will be inundated by a flood event having a 1 percent chance of being equaled or exceeded in any given year. The 1 percent annual chance floodplain is also referred to as the base flood or 100-year flood.

Critical Facilities. Critical facilities are defined by the Texas Water Development Board (TWDB) as hospitals, schools (K through 12), schools for children with special needs, fire stations, police stations, emergency shelters, water and wastewater treatment plants, power generating facilities, power transmitting facilities, emergency operations centers (EOCs), assisted living facilities, and nursing homes.

Low Water Crossing. Low water crossings are roadway creek crossings that are subject to frequent inundation during storm events or subject to inundation during a 50 percent annual chance storm event.

Lower Brazos Regional Flood Plan: Executive Summary

ES.1 – Overview of Regional Flood Planning Region

In 2019, the 86th Texas Legislature passed Senate Bill 8, authorizing and establishing the regional and state flood planning process. It assigned the oversight and production of this process and its resulting documentation to the Texas Water Development Board (TWDB). Fifteen Regional Flood Planning Groups (RFPGs) were created to represent the major river basins in Texas. This report outlines the findings of the Amended Region 8 Lower Brazos Regional Flood Plan for the first cycle of regional and state flood planning.

The Lower Brazos Regional Flood Planning Group (RFPG) is comprised of 12 voting members and 10 non-voting members who helped guide the production and development of this plan; these members were selected by a nomination process, including liaisons with adjacent planning regions and a coastal liaison. To ensure a diversity of perspectives were included, members represent a wide variety of entities and interest groups potentially affected by flooding, including:

- Agriculture
- Counties
- Electric Generation Utilities
- Environmental Interests
- Flood Districts
- Industry
- Municipalities
- Public
- River Authorities
- Small Businesses
- Water Districts
- Water Utilities

The Lower Brazos Planning Region encompasses all or part of 43 counties and 193 municipalities and covers over 23,000 square miles and approximately 20,000 stream miles. The area spans from the southern tip of Archer County to Freeport in Brazoria County, bordering the Gulf of Mexico and is home to over 3 million residents and constitutes 10 percent of the population of Texas. Of the 193 local communities, there are at least 40 communities with a population greater than 30,000; and 18 communities with a population greater than 50,000. The coverage of the Lower Brazos Planning Region can be seen in *Figure ES.1.*

Much of the population and associated infrastructure in the Lower Brazos Planning Region is located in the central and southern portions of the basin. Cities in proximity to metropolitan areas, such as Austin and Houston, have greater populations. Additionally, the Bryan/College Station and Waco areas have significant portions of their population located in the Lower Brazos Planning Region. As expected, much of the existing flood infrastructure is located near these areas with high population density, as well as in communities located closer to the coastline. Rural parts of the basin have significant portions of the region's agricultural land and associated economic activity.

Figure ES.1: Lower Brazos Planning Region

ES.2 – Public Participation

Public outreach and participation played a crucial role in developing the first planning cycle of the State Flood Plan. Feedback obtained from entities and members of the public provided critical insight that aided in identifying and confirming flood risk and project needs in the region. The Lower Brazos Planning Region utilized various methods to reach the public and inform them about the development of the first flood plan for the region.

Early on, a regional website (lowerbrazosflood.org) and email address were developed by the planning group's Sponsor, the Brazos River Authority (BRA), to inform and communicate with the public on the

progress of the Lower Brazos Regional Flood Plan. Updates were also provided by the planning group's Sponsor through social media and monthly email blasts to individuals throughout the region, including those signed up to receive project information about the flood plan. The RFPG posted meeting notices and materials in accordance with the Texas Open Meetings Act, and meeting notices were posted on the Lower Brazos RFPG website. A public outreach survey and interactive webmap were developed and posted to the RFPG website to solicit input and provide an opportunity for interest groups to submit relevant data for incorporation into the plan.

Additionally, the Lower Brazos RFPG held monthly public meetings both in-person and virtually at the BRA's Central Office in Waco to discuss project tasks. The public was provided the opportunity to speak at the beginning of each meeting. Five public roadshow meetings were also held in person at various cities across the region (Waco, Granbury, Georgetown, College Station, and Rosenberg) to inform interested groups about the planning process and also collect information essential to the planning process.

ES.3 – Existing and Future Flood Exposure

A flood exposure analysis was performed to guide the Lower Brazos Regional Flood Plan by establishing a consistent measure of flood hazard within the basin. The analysis considered vulnerability, land use, estimated precipitation data, and constructed drainage-related infrastructure.

Datasets of hydrologic and hydraulic modeling and flood risk mapping from various sources were collected and compiled together to create a comprehensive, continuous set of the best available existing flood risk data for the Lower Brazos Planning Region. The compiled mapping included both the 1 percent and 0.2 percent annual chance event (ACE) storms. The sources of the flood risk datasets included the United States Army Corps of Engineers (USACE), United States Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and the TWDB. These different datasets were prioritized based on the quality and coverage extents to determine which information to use when the datasets were overlapping. The main flood risk data sources for the Lower Brazos Planning Region, in priority order, are listed below:

- Local Community Submitted Data
- National Flood Hazard Layer (NFHL) Pending (Detailed and Approximate Studies)
- NFHL Effective (Detailed Study Only)
- Base Level Engineering
- Cursory Fathom Data provided by the TWDB
- NFHL Effective (Approximate Study Only)
- Flood-Prone Areas Related to Reservoirs and Levees

A flood hazard "quilt" dataset was developed from the different flood risk datasets to inform the Lower Brazos Regional Flood Planning efforts in identifying vulnerable areas and infrastructure. The flood hazard quilt is not intended to be used for regulatory purposes, such as local floodplain management and development regulation, or by FEMA or the National Flood Insurance Program (NFIP) since the data sources have varying levels of quality and detail. Also, most data sets did not account for Atlas 14 rainfall

rates, the latest rainfall data published by the National Oceanic and Atmospheric Administration (NOAA). **Additional studies are needed to develop comprehensive, consistent, and up-to-date existing flood risk data across the region.**

Flood risk and vulnerability analyses were performed using the flood hazard quilt with consideration to infrastructure, area, and population of the basin collected previously. Each dataset was overlayed with the extents of the 1 percent and 0.2 percent ACE flood hazard quilts to determine risk. **Approximately 22 percent of the region (5,000 square miles) is located in the extents of the 1 percent and 0.2 percent ACE flood hazard quilts.** *Table ES.1* summarizes the existing flood risk in the Lower Brazos Planning Region. As shown, Waller, Somervell, Robertson, Limestone, Grimes, Falls, Eastland, and Brazoria counties all have high vulnerability to flooding.

Using the existing condition flood hazard data as a baseline, the Lower Brazos RFPG conducted a future condition flood risk analysis, representing a "no action" scenario in 30 years. "No action" assumes continued population growth, regulations, land use, and development trends. Additionally, natural processes such as sea level rise, subsidence, and geomorphic changes were considered as these factors may contribute to changing flood hazards in the future. The future condition flood risk analysis consisted of creating both flood hazard and flood exposure data.

To estimate the 30-year, "no action" future flood hazard data throughout the Lower Brazos Flood Planning Region, the existing 0.2 percent ACE flood hazard extents were used as a proxy for the future 1 percent ACE flood hazard extents in a manner consistent with the guidance provided by the TWDB. To illustrate the future 0.2 percent ACE flood hazard extents, the RFPG utilized the future 1 percent ACE flood hazard extents with an additional buffer consistent with the difference between the existing 1 percent and 0.2 percent ACE water surface elevation or inundation area, depending on available data. The only exception to this methodology was the main stem of the Brazos River; associated flood hazard areas were left unchanged after careful consideration by the RFPG. **The extent of the flood hazard areas is estimated to increase by 10 percent in the Lower Brazos Planning Region in the next 30 years if no action is taken. As with existing conditions, additional studies are needed to develop comprehensive, consistent, and up-to-date future flood risk data across the region.**

The future condition flood exposure and vulnerability analyses were conducted using the flood hazard data described above and the same approach that was implemented to determine the flood exposure and vulnerability for existing conditions. These analyses show potential structures, critical facilities, roadways, agricultural areas, and people are at risk of being impacted by flooding in the future. *Table ES.1* summarizes the increase in flood risk in the Lower Brazos Planning Region with consideration of future conditions. The increase in flood risk will greatly impact growing populations in the region. Infrastructure exposure was also shown to increase in the future conditions flood risk analyses.

Table ES.1: Summary of Increased Exposure in 0.2 percent ACE Flood Hazard Area

Feature	Existing Conditions	Future Conditions	Percent Increase with No Action
Population	261,925	421,657	61%
Total Structures	107,719	168,534	56%
Residential Structures	79,169	134,024	69%
Non-Residential Structures	28,550	34,510	21%
Critical Facilities	325	533	64%
Roadway Crossing	7,799	7,819	0.3%
Roadway Segments (miles)	4,432	5,639	27%
Agricultural Area (sq. mi)	945	1,030	9%

ES.4 – Overarching Goals for the Region

The results of the flood risk analysis indicated the need to develop regional standards and goals to help manage existing flood risk and prevent the creation of new flood risk in the future.

Existing floodplain management practices within the Lower Brazos Planning Region were evaluated to determine where there is potential for enhancement. Based on this evaluation, two distinct categories of recommended standards were developed, including standards for region-wide application and standards recommended by zone. The four zones were established for the region: Coastal, Upper Coastal, Brazos Valley, and Middle Brazos. The two distinct categories of recommended standards allow for a broad application, as well as a tailored formulation for capturing variability in flood risk, natural hydrography, topography, climatological effects, and demographics throughout the river basin.

It is important to note that the RFPG does not have the authority to enact or enforce floodplain management, land use, or other infrastructure design standards. Any standards considered, recommended, and accepted by the Lower Brazos RFPG are intended to encourage implementation by local entities in the region with flood-related authority. The RFPG determined that standards produced as part of the flood planning effort should be classified as recommendations for general consideration by entities and communities within the region. For context, adopted standards are minimum standards that must be implemented by entities to qualify for the inclusion of any flood management mitigation actions in the regional flood plan on their behalf. Although standards for adoption are not proposed for this initial flood plan, it is conceivable that future updates to the regional flood plans may incorporate standards for adoption. *Table ES.2* summarizes the recommended standards for the Lower Brazos Flood Planning Region.

Table ES.2: Summary of Recommended Standards

Recommended Standard	Region-wide	Zone 1 "Coastal"	Zone 2 "Upper Coastal"	Zone 3 "Brazos Valley"	Zone 4 "Middle Brazos"
National Flood Insurance Program (NFIP) Participation	X				
Compensatory Storage Requirement in 1% (100-year) Annual Chance Event	X				
No Adverse Impacts for the 1% (100-year) Annual Chance Event	X				
Improved Flood Response	X				
Improved Flood Risk Awareness/ Education	X				
Use of Best Available Rainfall Data		X	X	X	
No Adverse Impacts for the 1% ACE and 10% ACE		X	X	X	
Form a Voluntary Buyout Program		X			
Long-term Operation and Maintenance Planning of Drainage Infrastructure		X			
Drainage Corridor Preservation			X	X	
Compensatory Storage Requirement in 0.2% ACE				X	X
Requirements for Culvert and Bridge Crossings				X	X
Roadway Requirements within the Floodplain				X	X
Culvert and Bridge Hydrologic and Hydraulic Analysis Requirement				X	X

In addition to the proposal of standards, the Lower Brazos RFPG developed goals to track the region's progress in achieving better flood risk awareness and prevention. As summarized in *Table ES.3*, ten goals were developed with both short- and long-term targets. The achievement of these goals would benefit five categories determined to be critical for the Lower Brazos Planning Region: floodplain management, mitigation projects, flood studies and analysis, flood readiness and warning, and education and outreach. By establishing these goals, the RFPG can track the region's progress and help guide the

development of critical components in future flood planning cycles. **The individual Lower Brazos Flood Planning Region goals support the overarching goal of protecting against the loss of life and property by reducing the increase in future flood risk.**

Table ES.3: Lower Brazos Regional Flood Planning Goals

Goals
1. Increase the number of counties and communities enrolled in the NFIP.
2. Increase the number of counties and communities that have adopted higher than NFIP standards, including directing development away from the floodplain.
3. Increase the number of entities that have adopted the best available data and science for their designs and plans.
4. Improve safety at low water crossings by adding warning systems/signage or improving low water crossings in high-risk areas.
5. Reduce the number of structures at risk of flooding during the 1 percent annual chance flood event by both structural (flood infrastructure) and non-structural (elevation, acquisition, relocation, etc.) means.
6. Reduce the number of critical facilities at risk of flooding during a 1 percent annual chance of flooding to above the 0.2 percent annual chance flood event by both structural (flood infrastructure) and non-structural (elevation, buyouts, relocation, etc.) means.
7. Increase the accuracy of flood hazard data in the region by performing detailed studies using the best available terrain, land use, and precipitation data to reduce gaps in floodplain mapping.
8. Increase the number of communities with warning and emergency response programs that can detect flooding threats and provide timely warning of impending flood danger.
9. Increase the number of flood gauges (rainfall, stream, reservoir, etc.) in the region.
10. Increase public outreach and education activities to improve awareness of flood hazards and the benefits of flood planning in the region.

ES.5 – Identification, Evaluation, and Recommendation of Flood Management and Mitigation Actions

To address the identified flood risks, the Lower Brazos Planning Region developed a list of potential flood mitigation actions that could lead to a better understanding of flood risk or mitigate the current flood risk in the basin. Those actions included flood management evaluations (FMEs), flood mitigation projects (FMPs), and flood management strategies (FMSs). FMPs are proposed structural or non-structural projects that, when implemented, will reduce flood risk. FMSs are intended to be "big picture" mitigation efforts, capturing flood risk reduction actions that do not align with FMEs or FMPs. An FME is

a proposed study of a specific, flood-prone area that is needed to assess flood risk and/or determine whether there are potentially feasible FMSs or FMPs that could mitigate the flood risk.

Previously compiled data, such as assessments of historic flooding, existing infrastructure, flood hazard, flood exposure and vulnerability, and existing policies, were utilized to identify flood mitigation actions. Areas of greatest known flood risk and areas with the greatest gaps in flood risk information were determined to help guide the recommendation and inclusion of the most pertinent flood mitigation actions. To locate these areas, the RFPG considered the specific criteria listed below:

- Buildings in flood-prone areas
- Low water crossings
- Agricultural land in flood-prone areas
- Critical facilities in flood-prone areas
- Community NFIP participation
- Flood risk knowledge gaps
- Emergency need
- Updated Hazard Mitigation Action Plans (HMAPs)
- Historic flooding events
- Social Vulnerability Index (SVI)

These factors were quantified across the region using HUC-12s, which are the smallest available watershed units provided by the TWDB. The RFPG chose to utilize hydrologic areas for this task to support the overarching plan goal of proposing regional solutions that are not confined to jurisdictional boundaries. Scoring related to overall flood risk and flood risk knowledge gaps directed the delineation of FMEs in the form of drainage master plans and regional watershed studies.

Over 680 potential FMEs, FMPs, and FMSs were identified through the public outreach survey, roadshow workshops, research of publicly available documents, and flood exposure analysis. However, the list of potential flood mitigation actions was not exhaustive for the Lower Brazos Planning region. The RFPG developed several metrics to screen potential FMEs, FMPs, and FMSs and create a finalized list for recommendation. The primary screening criteria that kept many potential FMEs, FMPs, and FMSs from recommendation was the need for explicit sponsorship approval from local entities. The RFPG decided that without the verbal or written affirmation of an entity's desire to implement a specific action, there was confirmation that the FMEs, FMPs, or FMSs needed to be completed or that the identified entity would be willing to drive it forward. Therefore, recommendations were not made for FMEs, FMPs, or FMSs that did not have confirmation from the proposed sponsor.

Each identified flood mitigation action was evaluated, regardless of recommendation. General information was gathered from the source documentation of each FME, FMS, and FMP, including:

- General description and location, including impacted HUCs and counties;
- Sponsor(s) who will manage the implementation of the action; along with other entities that may have oversight;
- Estimated costs determined through source documentation or historical data;
- Potential funding sources;

- Associated RFPG approved flood management and mitigation goals;
- Determination of whether the action meets an emergency need; and,
- Identify associated hydraulic and hydrologic models or maps that would support the action.

Benefit areas were delineated for the FMEs, FMSs, and FMPs, and these bounds were used to generate flood risk and flood risk reduction metrics. For FMEs, the delineations were compared to the flood risk exposure analysis previously described to determine the at-risk infrastructure and population within the evaluation area. A more detailed analysis was performed for FMPs. Hydrologic and hydraulic models were collected for each FMP and used to perform a flood risk analysis using the existing conditions modeling results and a flood risk reduction analysis using modeling results representing the implementation of the proposed project. FMSs are high-level mitigation actions, so flood risk and flood risk reduction were not calculated.

After an extensive screening and evaluation process, the RFPG recommended 49 FMPs, 10 FMSs, and 97 FMEs for inclusion in the Lower Brazos Regional Flood Plan. The summaries are shown in *Table ES.4*, *Table ES.5*, and *Table ES.6.*

Recommended FMPs are largely the results of Master Drainage Plans and FIF studies completed by entities within the region. The projects are largely composed of channel and crossing improvements that would reduce risk to structures and provide better mobility during storm events. The recommended FMSs primarily target flood preparedness through many avenues, including increasing regulations, creating flood warning systems, erosion control, floodproofing of key infrastructure, and property acquisition. Recommended FMEs can be separated into two key categories; the majority are evaluations that will explore the feasibility of potential FMPs and FMSs, while others are proposed studies and evaluations to close gaps in flood risk knowledge. **The estimated budget (2020 dollars) for the recommended FMEs, FMSs, and FMPs, is $4.7 billion.** The estimated cost for non-recommended FMEs, FMSs, and FMPs is $237 million. Although FMEs, FMSs, and FMPs without sponsors were ultimately not recommended by the RFPG, these flood mitigation actions have potential merit in flood risk reduction and may be considered in future flood planning cycles.

Table ES.4: Summary of Recommended FMPs

FMP Types	Number of Identified FMPs	Number of Recommended FMPs	Cost of Recommended FMPs
Low Water Crossings or Bridge Improvements	17	10	$28,272,000
Regional Channel Improvements	26	25	$3,603,269,000
Regional Detention	1	1	$8,699,000
Storm Drainage Improvements	4	4	$9,419,000
Comprehensive Drainage Improvements	8	8	$643,007,000
Property Acquisition	1	1	$600,000
Total	**57**	**49**	**$4,293,266,000**

Table ES.5: Summary of Recommended FMSs

FMS Types	Number of Identified FMSs	Number of Recommended FMSs	Cost of Recommended FMSs
Education and Outreach	1	0	N/A[1]
Flood Measurement and Warning	15	2	$1,000,000
Infrastructure Projects	27	2	$360,500,000
Property Acquisition and Structural Elevation	17	2	$2,400,000
Regulatory and Guidance	28	1	$500,000
Other	51	3	$2,000,000
Total	**139**	**10**	**$366,400,000**

[1]Not enough information was available to determine an accurate cost estimate to implement.

Table ES.6: Summary of Recommended FMEs

FME Type	Number of Identified FMEs	Number of Recommended FMEs	Cost of Recommended FMEs
Regional Watershed Studies	60	15	$5,343,000
Studies on Flood Preparedness	29	2	$1,000,000
Drainage Master Plans	125	5	$1,774,000
Feasibility Assessments	32	13	$4,850,000
Preliminary Engineering	132	42	$13,058,000
H&H Analysis	45	20	$3,554,000
Total	**423**	**97**	**$29,579,000**

ES.6 – Impacts of the Recommended Flood Management and Mitigation Actions

To determine the impacts of the recommendations made in the Lower Brazos Regional Flood Plan, an analysis was performed to summarize the benefits that would be provided if all recommended FMEs, FMSs, and FMPs were implemented. The analysis included metrics similar to those used in the flood risk analysis, in addition to potential socioeconomic, recreational, environmental, agricultural, geomorphic, navigation, and water quality benefits. During this cycle, the avoidance of future flood risk resulting from later implementation of actions not recommended by the RFPG and policy changes were also analyzed.

In the near term, implementation of all recommended FMEs in the Lower Brazos Regional Flood Plan would result in a decrease in the percentage of the region with inadequate mapping from 33 percent to 28 percent. Implementing all recommended FMPs in the Lower Brazos Regional Flood Plan would result in a reduction in the population, structures, roads, and agricultural areas exposed to the 1 percent

ACE storm. Other benefits of plan implementation listed below are more qualitative. These include, but are not limited to:

- Protection of natural riverine features and creating of open spaces and pedestrian trails for recreational use.
- Reduction of water pollution associated with flooded structures.
- Protection of agricultural resources.
- Mitigation of water and wastewater services disruption.
- Protection of valuable infrastructure through stabilization of geomorphic processes.

Additional flood risk that might arise in a "no action" future scenario can be avoided through a consistent effort to fulfill the floodplain management goals and standards set forth by the RFPG. This effort would involve the recommendation of "Regulatory and Guidance" FMSs identified in this planning cycle, which are particularly relevant to mitigating future flood risk in a region where the construction of over 480,000 new residential structures is anticipated to accommodate population growth over the next 30 years. **Furthermore, if all regional watershed study FMEs identified in this planning cycle (recommended and non-recommended) were to be implemented, no areas of the Lower Brazos Flood Planning Region would lack sufficient modeling or mapping data.** Implementing the actions mentioned above would facilitate the regulation of development, the establishment of higher standards, and the use of the best available data, all interdependent strategies for avoiding potential increases in flood exposure over time. Implementing Drainage Master Plan FMEs identified in this plan would help identify potential projects that could be included as FMPs in future planning cycles. The implementation of these identified projects would ultimately mitigate future flood risk.

Impacts to water supply were also evaluated. In 1997, the TWDB established 16 regional water planning areas (RWPA) and appointed members representing key public interests to the regional water planning groups (RWPG). Region 8 primarily covers water planning regions G and H. **None of the recommended FMEs, FMSs, and FMPs would negatively impact or substantially contribute to the water supply.**

ES.7 – Flood Infrastructure Financing Analysis

The Lower Brazos RFPG recommended 156 flood mitigation actions to address flood risk across the planning region. Combined, these flood mitigation actions are anticipated to cost $4.7 billion to implement. The RFPG developed a comprehensive assessment of funding opportunities to help the legislature with future funding and grant needs to address flood risk in the region and, ultimately, the state.

As opposed to other types of infrastructure, flood projects do not typically generate revenue, and many communities do not have steady revenue streams to fund flood projects. Consequently, communities often must seek state or federal funding assistance for regional flood mitigation. **From the initial public outreach survey, the most referenced difficulty with obtaining funding from state or federal programs was that many entities in the Lower Brazos Flood Planning Region do not meet the requirements of programs they wish to apply for due to having lower social vulnerability than other applicants.**

A more targeted survey was provided to the sponsors of recommended actions to determine how much funding they could provide locally. **Overall, an estimated $4.7 billion of funding is needed to implement the recommended FMEs, FMSs, and FMPs in the Lower Brazos Regional Flood Plan beyond what is anticipated to be funded by local sponsors.** This figure represents 90 percent of the total cost of the flood mitigation actions identified in this plan. The state and federal agencies listed below administer grant and loan programs that could be used as potential funding sources for recommended actions:

- Federal Emergency Management Agency (FEMA)
- Department of Housing and Urban Development (HUD)
- Texas Water Development Board (TWDB)
- Texas State Soil and Water Conservation Board (TSSWCB)

The findings presented in this inaugural cycle of flood planning result from extensive data collection and analysis efforts. However, future cycles of Regional Flood Planning will continue to develop more detailed and accurate datasets representing the infrastructure, population, land use, and flood risk of the region. Furthermore, as recognition and understanding of the planning efforts increase, public engagement will help identify additional needed FMEs, FMSs, FMPs, and associated funding, throughout the Lower Brazos basin.

ES.8 – Plan Adoption and Recommendations

The Lower Brazos Regional Flood Plan provided a comprehensive overview of the flood mitigation needs across the region. The needs range from flood reduction projects to flood management strategies to additional flood risk studies. Future flood planning cycles will foster more participation by entities in the region and identify additional flood mitigation actions.

In addition to localized actions, administrative, legislative, and regulatory recommendations were made for state-wide and region-wide policies and programs that could address flood risk on a higher level. These recommendations provide guidance on funding allocation, safety and maintenance programs, distribution of regulatory authority, and improvements to the regional and state flood planning process, among others. **By implementing some or all of these recommendations, the RFPG believes the State of Texas could begin to comprehensively address flood risk and allocate resources efficiently.** The Lower Brazos Regional Flood Plan adequately provides for the preservation of life and property and, when implemented, would not cause negative impacts on neighboring areas.

The RFPG approved the submittal of the Amended Region 8 Lower Brazos Regional Flood Plan to the TWDB on June 22, 2023. In accordance with Title 31 Texas Administrative Code (TAC) §361.20, the Lower Brazos Regional Flood Plan conforms with the guiding principles established in Title 31 TAC §362.3.

Chapter 1: Lower Brazos Planning Area Description

1.1 – Introduction: The Regional Flood Plan in Context

1.1.1 Origins of the 2023 State Flood Planning Process

In Texas, the billion-dollar flood disaster is becoming a regular occurrence. Between 2015 and 2017, flooding alone caused nearly $5 billion in damages to Texas communities. In conjunction with the impact of Hurricane Harvey, the total cost in 2017 approached $200 billion in financial losses (National Oceanic and Atmospheric Administration, 2021) and nearly 100 deaths. As Texas grappled with how to manage flood risk better and reduce loss of life and property from future disasters, the Texas Water Development Board (TWDB) prepared the first-ever statewide flood assessment, which described Texas' flood risks, provided an overview of roles and responsibilities, and included an estimate of potential flood mitigation costs and a summary of interest groups views on the future of flood planning.

This plan was prepared because:

- flood risks, impacts, and mitigation costs had never been assessed at a statewide level
- flood risks pose a serious threat to lives and livelihoods
- much of Texas is unmapped or uses out-of-date maps (Peter M. Lake, 2019)

The TWDB presented its findings to the 86th Texas legislative session in 2019. Later that year, the legislature adopted changes to the Texas Water Code §16.061 establishing a regional and state flood planning process led by the TWDB. The legislation provided funding to improve the floodplain mapping efforts and develop regional plans to mitigate the impact of future flooding. Regional flood plans for Texas' 15 major river basins must be submitted to the TWDB by January 10, 2023. An updated version of the regional flood plans will be due every five years thereafter. (TWDB Flood Planning Frequently Asked Questions, 2021)

1.1.2 Overview of the Planning Process

The Lower Brazos Planning Region (also known as Region 8) is one of 15 Texas river basins preparing a regional flood plan. Given the state's diverse geography, culture, and population, the planning effort is being carried out at a regional level in each of the state's major river basins. When complete, the TWDB will compile these regional plans into a single statewide flood plan and present it to the legislature in 2024. Regional flood plans must be based on the best available science, data, models, and flood risk mapping. The legislature allocated funding to be distributed by the TWDB to procure technical assistance to develop the flood plans.

1.1.2.a Who's Preparing the Plan?

The TWDB has appointed Regional Flood Planning Groups (RFPG) for each region and has provided them with funding to hire a technical consultant to prepare their plans. The TWDB administered the regional planning process members through a contract with the planning group's sponsor, who the RFPG selected. The Lower Brazos Flood Planning Group chose the Brazos River Authority (BRA) to serve as its

sponsor. The sponsor's role is to support meetings and communications and manage the technical consultant contract. The Technical Consultant Team, led by Halff, was selected to prepare this plan.

The RFPG's responsibilities include directing the work of the technical consultant, soliciting, and considering public input, identifying specific flood risks, and identifying and recommending flood management evaluations, strategies, and projects to reduce risk in their regions. To ensure a diversity of perspectives are included, members represent a wide variety of interest groups potentially affected by flooding, including:

- agriculture
- counties
- electric generation utilities
- environmental interests
- flood districts
- industry
- municipalities
- public
- river authorities
- small businesses
- water districts
- water utilities

Even though each basin has a different leadership team, the TWDB provided detailed specifications to guide the preparation of the flood plans. When complete, the regional plans will outline a path to reducing existing risk to life and property and improve floodplain management data and practices. They will also identify potential Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs), which may be appropriate for future study and funding.

1.1.2.b Data Sources

To ensure that flood plans are based upon consistent and reliable information in every basin, the TWDB compiled geographic information system (GIS) data resources in the TWDB Flood Planning Data Hub. GIS layers are provided for:

- critical infrastructure
- flood infrastructure
- flood risk
- hydrology
- jurisdiction boundaries
- parks
- population
- property
- terrain
- transportation

A dedicated GIS team organized and analyzed this data for the Lower Brazos Planning Region, identified additional data sources needed to meet the TWDB's objectives, and used the data to prepare the illustrative maps included in this report.

To supplement the data provided by the TWDB, the Technical Consultant Team also developed a Lower Brazos RFPG – Interest Groups Survey to gather data from public officials with flood-related responsibilities. At least two recipients from each community received this detailed survey to increase response rates. The total number of recipients in any given community varied with the size of the community – larger communities had four to five recipients, while smaller communities had two to three. Respondents provided contact information and flood-related responsibilities, verified flood information that had already been collected, responded to questions to support the development of the Regional Flood Plan, and verified and provided geospatial data through data uploads and web maps. An interactive web map allowed survey respondents to draw in both problem areas and proposed projects that were not included in other information about the Lower Brazos Planning Region.

1.1.2.c Previous Studies

Relevant studies previously performed in the Lower Brazos Planning Region were collected to be used for reference material. Two studies were performed that looked at the impacts of the Brazos River in the southern portion of the basin. The *Lower Brazos Flood Protection Planning Study*, completed in 2019, and the *Hydrologic and Hydraulic Analysis of the Brazos River*, completed in 2021, provide overviews of the current conditions along the Brazos River in Fort Bend and Brazoria counties. Additionally, the Draft *Fort Bend Drainage Master Plans* provide detailed analysis of flooding conditions throughout the county. The *Lower Brazos Flood Protection Planning Study* was conducted by the BRA using Flood Protection Planning Grant funds from the TWDB. The *Hydrologic and Hydraulic Analysis of the Brazos River* and the Draft *Fort Bend Drainage Master Plans* were both conducted by the Fort Bend County Drainage District using local funds.

Several studies were also provided by sponsors to support projects submitted to the RFPG for inclusion in the Regional Flood Plan, including master drainage plans and FIF studies.

Additional studies were performed by the RFPG during the Amendment process, as discussed in Chapter 4: Assessment and Identification of Flood Mitigation Needs. These studies assisted in developing projects for areas within the region that were identified as having high flood risk and outdated flood risk data.

1.1.2.d Public Outreach

Over 550 interest group contacts representing entities with flood-related responsibilities received the survey in July via email, which included flood planning basics and the survey link.

Figure 1.1 illustrates all categories of interest groups included in the data collection effort. *Table 1.1* describes the various methods used to contact interest groups and the number of interest groups reached by each effort.

Figure 1.1: Outreach Efforts and Contacts Made

To ensure everyone had the opportunity to participate, the Technical Consultant Team in coordination with the BRA, followed up over email a week later. Calls went out to recipients who had not yet responded, and the identified interest groups provided some secondary contacts. The second round of calls was made to over 100 recipients who had not responded to the survey and worked for entities with a population greater than 20,000. This outreach effort resulted in a response rate of approximately 14 percent. Survey results are included throughout Chapter 1 and the chapters to follow. More information regarding public outreach is included in Task 10 of this plan.

Table 1.1: Outreach Efforts to the Lower Brazos Planning Region Interest Groups

Method of Outreach	Number of Interest Group Contacts Reached
Email 1	553
Email 2	553
Call 1	569
Call 2	106

(Halff Associates, Outreach Effort Data)

1.1.2.e Funding Sources

To fund projects identified by these plans, the legislature created a new flood financial assistance fund and charged the TWDB with administering the fund. The Texas Infrastructure Resiliency Fund, as approved by Texas voters in November 2019, is being used to finance the preparation of these plans and will also be used to finance the recommended flood-related studies and projects. Communities that identify future projects aimed at flood mitigation will be eligible for financial assistance through grants

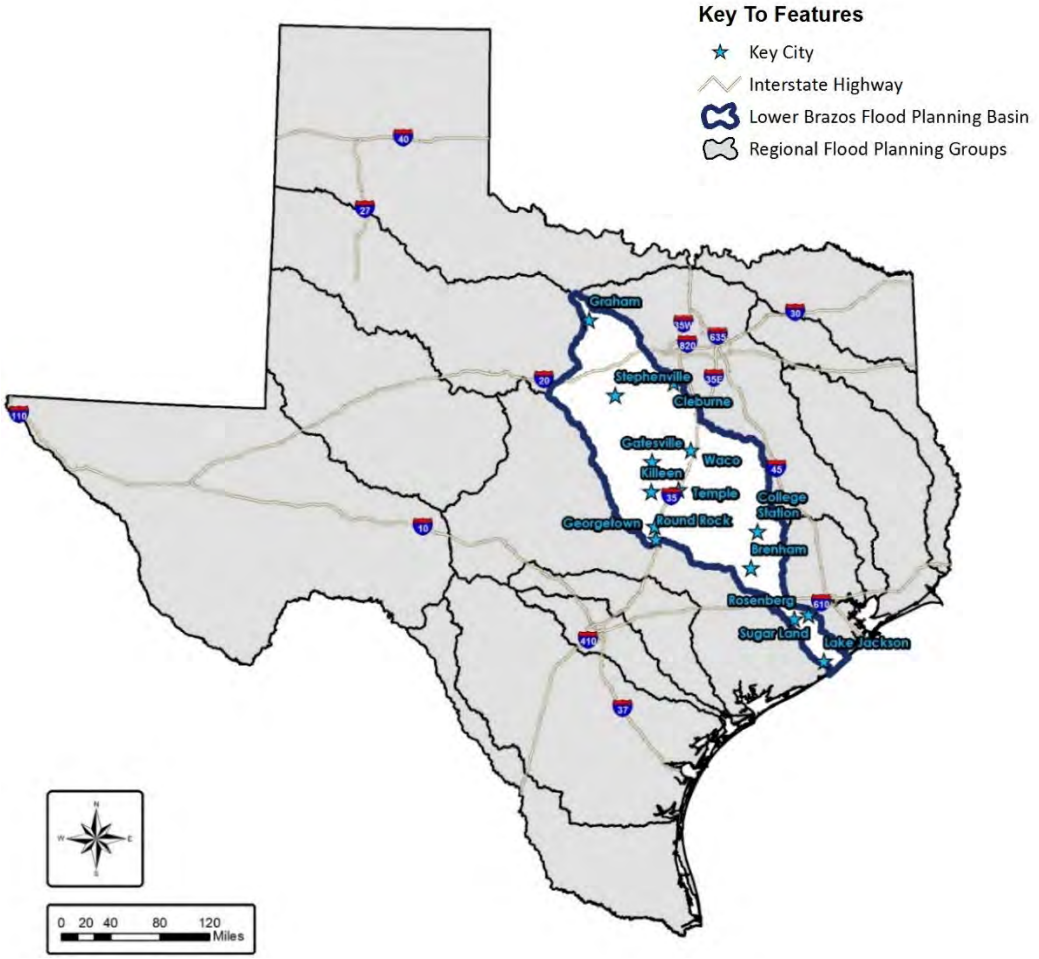
and loans from the TWDB. Additional discussion of funding sources available for flood mitigation activities, including federal and state funding, is discussed in Task 4B of this plan.

1.2 – Characterizing the Lower Brazos Planning Region

1.2.1 Social and Economic Character

The Lower Brazos Planning Region covers an area of over 23,000 square miles, 43 counties, and 193 municipalities. The Lower Brazos Planning Region boundary is determined by the hydrologic characteristics of the Lower Brazos River basin and intersects with several political jurisdictions, including counties, cities, and special districts (refer to *Figure 1.2*). To better understand the current and future character and conditions of the Lower Brazos Planning Region, this section will provide a brief, general description of communities, population, the various types of development, economic activities, and industrial sectors at the greatest risk of flood impacts.

Figure 1.2: Lower Brazos Planning Region



1.2.1.a. Municipal Population and Future Growth

Current Population

According to population estimates by the TWDB, the current population of the Lower Brazos Planning Region is 3,035,000 and constitutes 10 percent of the population of Texas. Of the 193 local communities, there are at least 40 communities with a population greater than 30,000; and 18 communities with a population greater than 50,000, according to the Water User Group Data from the TWDB. The cities with a population between 115,000 and 150,000 include Killeen (Bell County) in the Central Lower Brazos River Basin, Waco (McLennan County) also in the central area of the basin, Sugar Land (Fort Bend County) in the southern area of the basin, and Georgetown and Round Rock (Williamson County) on the western boundary of the basin. College Station in Brazos County in the southern area of the Lower Brazos River basin has a population of just over 100,000. *Table 1.2* details the cities in the Lower Brazos Planning Region with a population of over 80,000.

Table 1.2: Communities in the Lower Brazos Planning Region with Population Greater than 80,000

Community	County	Population 2020
Killeen	Bell	144,243
Waco	McLennan	132,512
Sugar Land*	Fort Bend	132,098
Round Rock*	Williamson	123,598
Georgetown	Williamson	118,763
College Station	Brazos	100,854
Bryan	Brazos	84,196
Temple	Bell	81,736
Cedar Park*	Williamson	81,716

*Community is not fully contained in the Lower Brazos Region. The population for the portion of the community within the region may be smaller than listed.
(Texas Water Development Board)

Figure 1.3 illustrates the total population by census tracts in the Lower Brazos Planning Region utilizing 2021 ESRI population estimates, which are the most current population estimates for 2021. *Figure 1.4* describes the 2020 population estimate by Water User Groups for communities in the Lower Brazos Planning Region.

Figure 1.3: Lower Brazos Planning Region Population by Census Tract

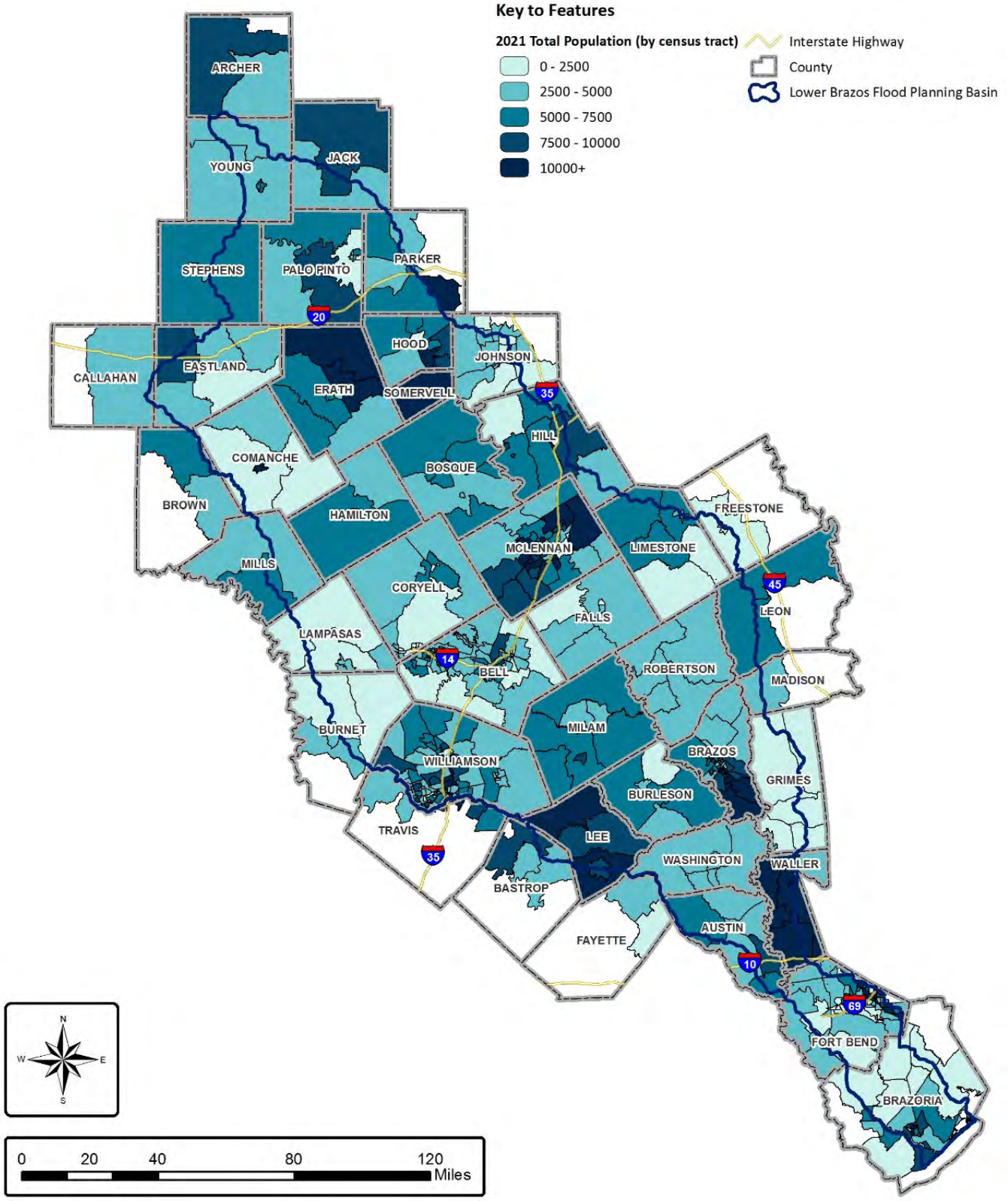
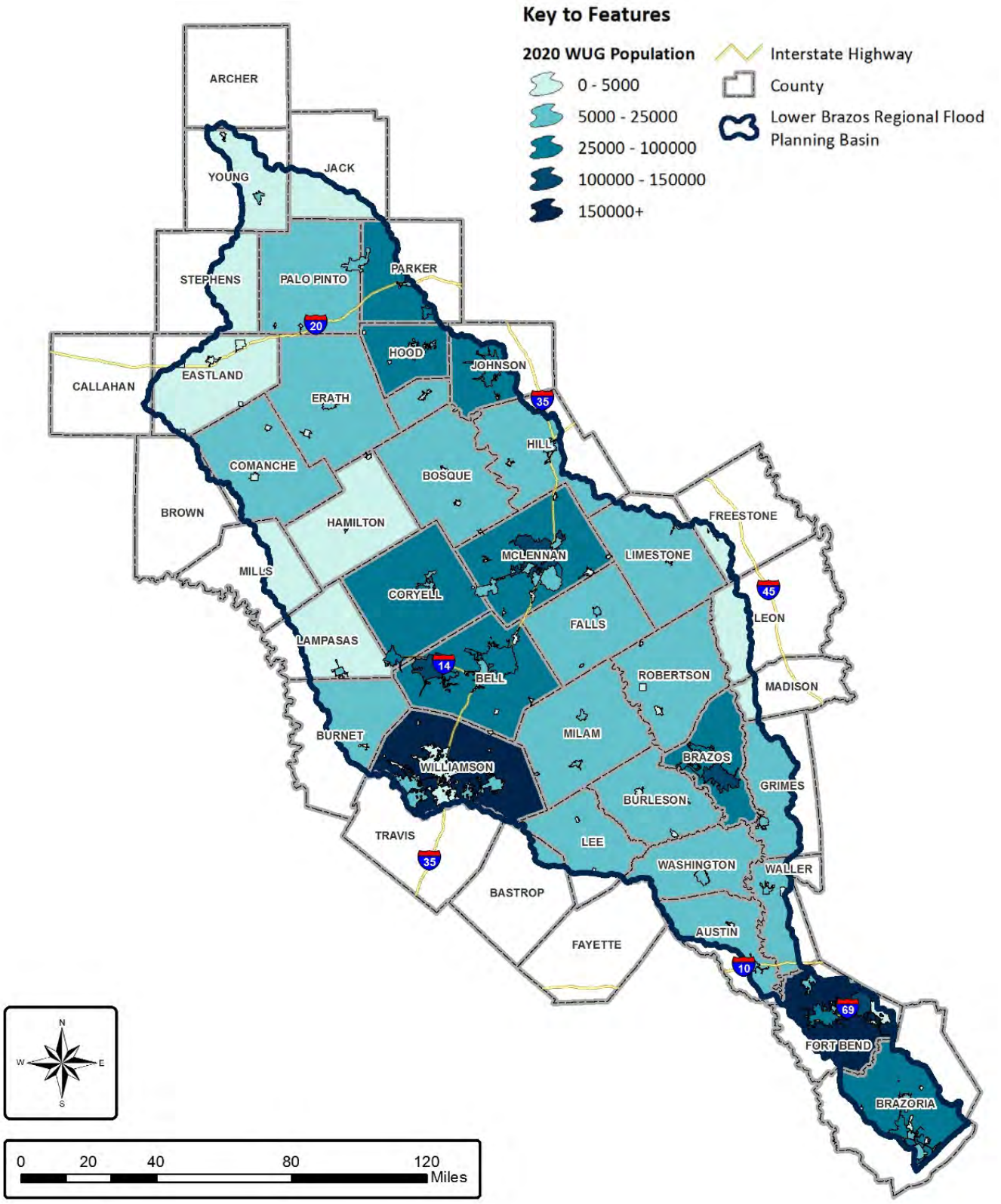


Figure 1.4: Lower Brazos Planning Region Population by Communities



Projected Growth within the Lower Brazos Planning Region

Based on population projections for Water User Groups (WUGs) by the TWDB, the areas within the Lower Brazos Planning Region are expected to experience high population growth primarily in the metropolitan areas of Killeen-Temple-Fort Hood in the west-central area of the Lower Brazos basin; Waco in the east-central area of the basin; Sugar Land-Houston in the south of the basin; and the Round Rock-Austin Metropolitan Area at the western edge of the basin. By 2050, the total population in Killeen, Round Rock, and Georgetown will exceed 220,000 people each, while the cities of Waco, Sugar Land, and College Station will have a population of greater than 150,000 people each. *Table 1.3* details the population of the cities with the largest population in the Lower Brazos Planning Region in 2050.

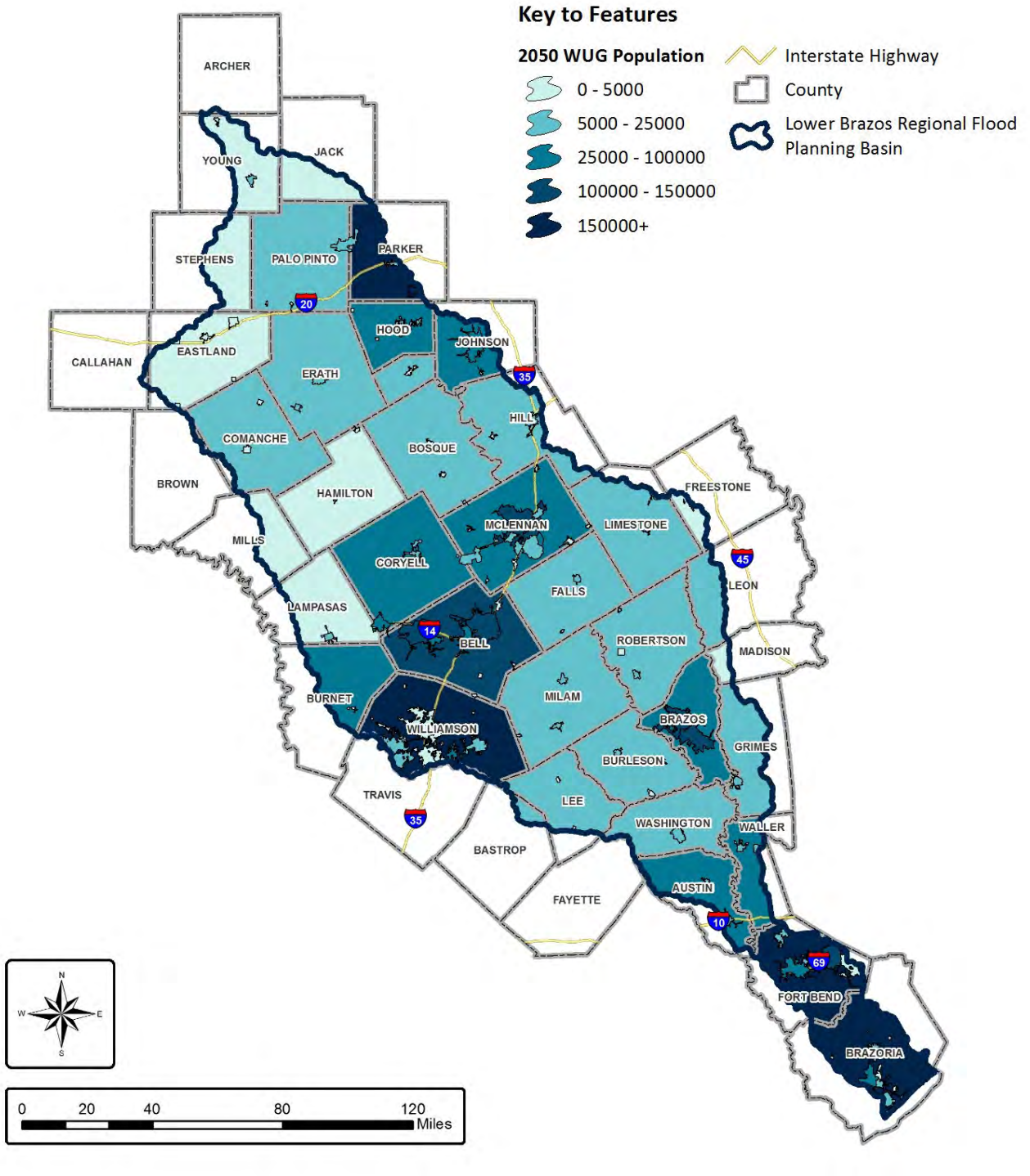
Table 1.3: Communities in the Lower Brazos Planning Region with Projected Population in 2050 Greater than 100,000

Community	County	Population 2020	Population 2050	Percent Increase
Georgetown	Williamson	122,109	249,196	104%
Round Rock	Williamson	123,650	238,864	93%
Killeen	Bell	144,243	221,696	54%
College Station	Brazos	100,854	195,852	94%
Waco	McLennan	132,511	160,966	21%
Sugar Land	Fort Bend	124,493	147,048	18%
Bryan	Brazos	84,196	140,827	67%
Temple	Bell	81,736	125,626	54%
Leander	Williamson	53,860	143,840	153%

(Texas Water Development Board)

As described in *Table 1.3*, by 2050, Bryan in the Bryan-College Station Metropolitan Area and Sugar Land in the Sugar Land-Houston-The Woodlands Metropolitan Area will have populations exceeding 140,000. The population for Temple and Leander will also increase to over 110,000 as these cities capture the growth in the Austin Metropolitan Area. *Figure 1.5* illustrates the expected increase in population for communities in the Lower Brazos Planning Region based on Water User Group Data from the TWDB.

Figure 1.5: Lower Brazos Planning Region Future Population



The cities with the highest population growth rate between 2020 and 2050 will be communities adjacent to or near the metropolitan areas with the largest and most dense pockets of population. These include unincorporated areas of Coryell County (near Killeen), Fort Bend County (near Sugar Land), Brazoria

County (near Lake Jackson), and the cities of Hutto, Leander, and Georgetown in the Austin-Round Rock-San Marcos Metropolitan Area.

Table 1.4 details the 10 fastest-growing cities and unincorporated areas within counties in the Lower Brazos Planning Region.

Table 1.4: Top Ten Fastest Growing Communities 2020-2050

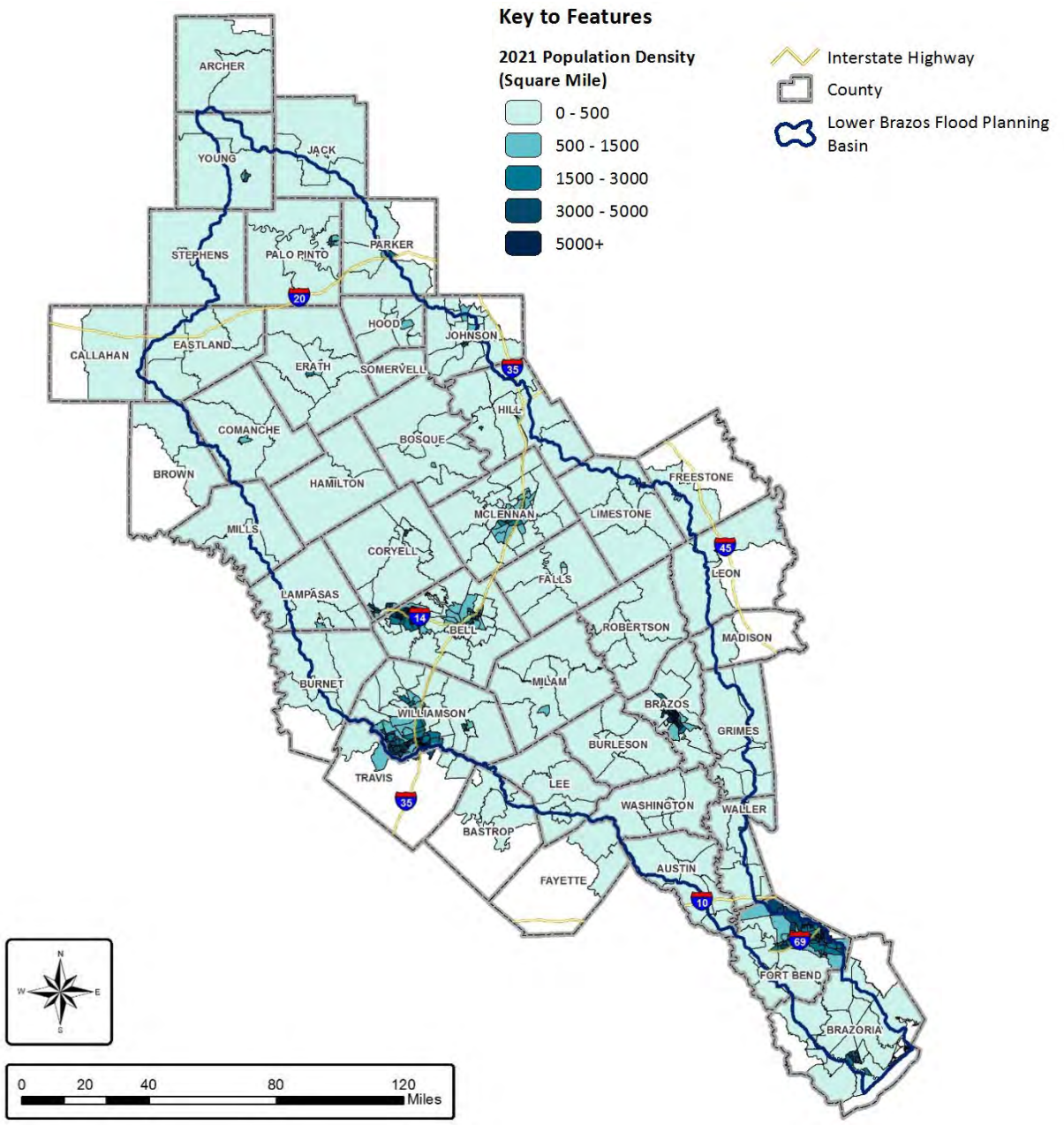
Community	Population 2020	Population 2050	Rate of Population Growth
Unincorporated Area in Coryell County, Coryell County	2,474	9,942	302%
Hutto, Williamson County	17,326	56,194	224%
Leander, Travis, and Williamson Counties	59,821	151,328	153%
Unincorporated Area in Fort Bend County	107,087	264,898	147%
Unincorporated Area in Williamson County	39,226	93,158	137%
Sienna, Fort Bend County	21,743	47,894	120%
Prairie View, Waller County	3,400	7,406	118%
Unincorporated Area in Brazoria County	100,247	207,557	107%
Georgetown, Williamson County	118,763	244,043	105%
Copperas Cove, Lampasas, and Coryell Counties	36,253	52,061	104%

(Texas Water Development Board)

As illustrated in *Figure 1.6*, the communities in the Lower Brazos Planning Region with the highest population density are Sugar Land and Lake Jackson in Austin-Oyster and Lower Brazos Hydraulic Unit Code (HUC)-8; College Station and Bryan in the Navasota HUC-8; Round Rock in San Gabriel HUC-8; Killeen and Temple in Leon and Cowhouse HUC-8; and Waco in Middle Brazos-Lake Whitney HUC-8.

A HUC is a United States Geological Survey watershed delineation or boundary based on surface hydrologic features. Each hydrologic unit is assigned a 2 to 12-digit number that uniquely identifies the unit within a classification system consisting of 21 regions (2-digit), 222 subregions (4-digit), 370 basins (6-digit), 2,270 subbasins (8-digit), approximately 20,000 watersheds (10-digit), and approximately 100,000 subwatersheds (12-digit). A HUC-8 represents the subbasin level analogous to medium-sized river basins. There are 14 HUC-8s in the Lower Brazos Planning Region.

Figure 1.6: Population Density by Census Tract

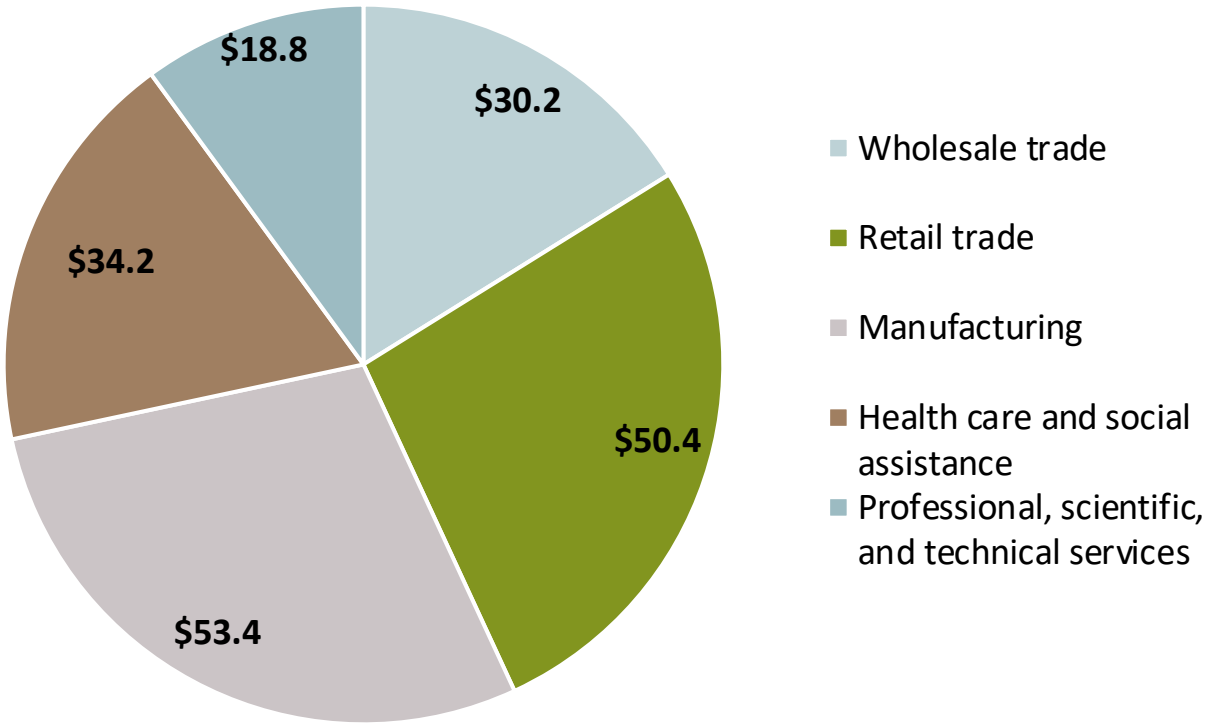


1.2.1.b. Economic Activity

The Lower Brazos Planning Region is home to key industries, such as wholesale and retail trade, manufacturing, and health care and social assistance, which contribute to the gross domestic product of the Lower Brazos Planning Region and support the local and state economies. Based on the 2017 Economic Survey, the total value of sales or revenue generated by firms and businesses in the Lower Brazos Planning Region amounts to over $215.9 billion, constituting approximately 4.5 percent of the total revenue generated by all firms and businesses in Texas. As shown in *Figure 1.7*, the industry sector

generating the most revenue for the Lower Brazos Planning Region is manufacturing at $53.4 billion, followed closely by retail trade at $50.4 billion and health care and social assistance at $34.2 billion.

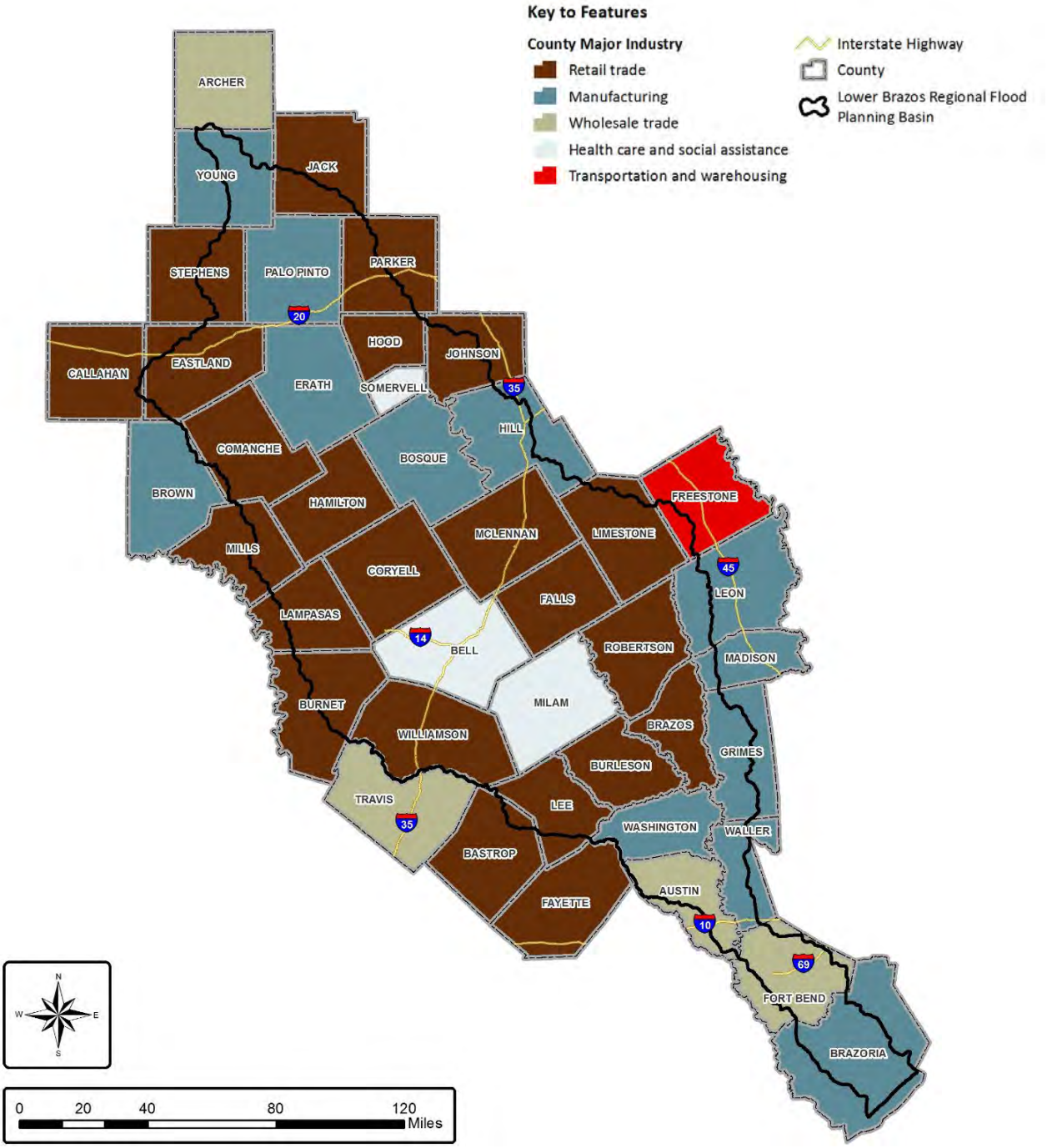
Figure 1.7: Major Industries in the Lower Brazos Planning Region



(United States Census Bureau)

The health care and social assistance sector employs the largest number of people in the Lower Brazos Planning Region, at approximately 304,170 employees, followed by the retail trade sector, at approximately 153,120 employees. The industry sector with the third-largest number of employees is accommodation and food services, with approximately 113,130 employees. *Figure 1.8* illustrates the dominant industry in each county in the Lower Brazos Planning Region.

Figure 1.8: Major Industry by County



Commercial Activity

Within the Lower Brazos Planning Region, Fort Bend County generates the most commercial activity and largest revenue at $45.9 billion and has the highest number of firms or businesses (15,663). Its dominant industry sector is wholesale trade. Williamson County has the second-largest number of total firms and third-largest revenue, generating over $29 billion, of which almost $10 billion is in the retail trade

industry. Brazoria County, south of the Lower Brazos Planning Region and bordering Fort Bend County, generates the second-largest revenue, at $37 billion, of which $24 billion is generated in the manufacturing industry sector.

Table 1.5 lists the five counties generating the most sales and revenue in the Lower Brazos Planning Region. These counties also have the largest number of firms and businesses, and their dominant industry sectors employ between 90,000 and 215,100 employees.

Table 1.5: Top Five Counties by Total Revenue, Firms, and Employees

County	Total Revenue (in Billion)	Total Number of Firms and Businesses	Total Number of Employees	Dominant Industry Sector
Fort Bend*	$45.9	15,663	213,164	Wholesale Trade
Brazoria*	$37.1	5,304	91,045	Manufacturing
Williamson	$29.7	9,751	172,007	Retail Trade
Bell	$22.2	4,670	122,842	Health Care and Social Assistance
Madison*	$19.3	4,157	84,856	Manufacturing
Total	$154.2	39,545	683,914	

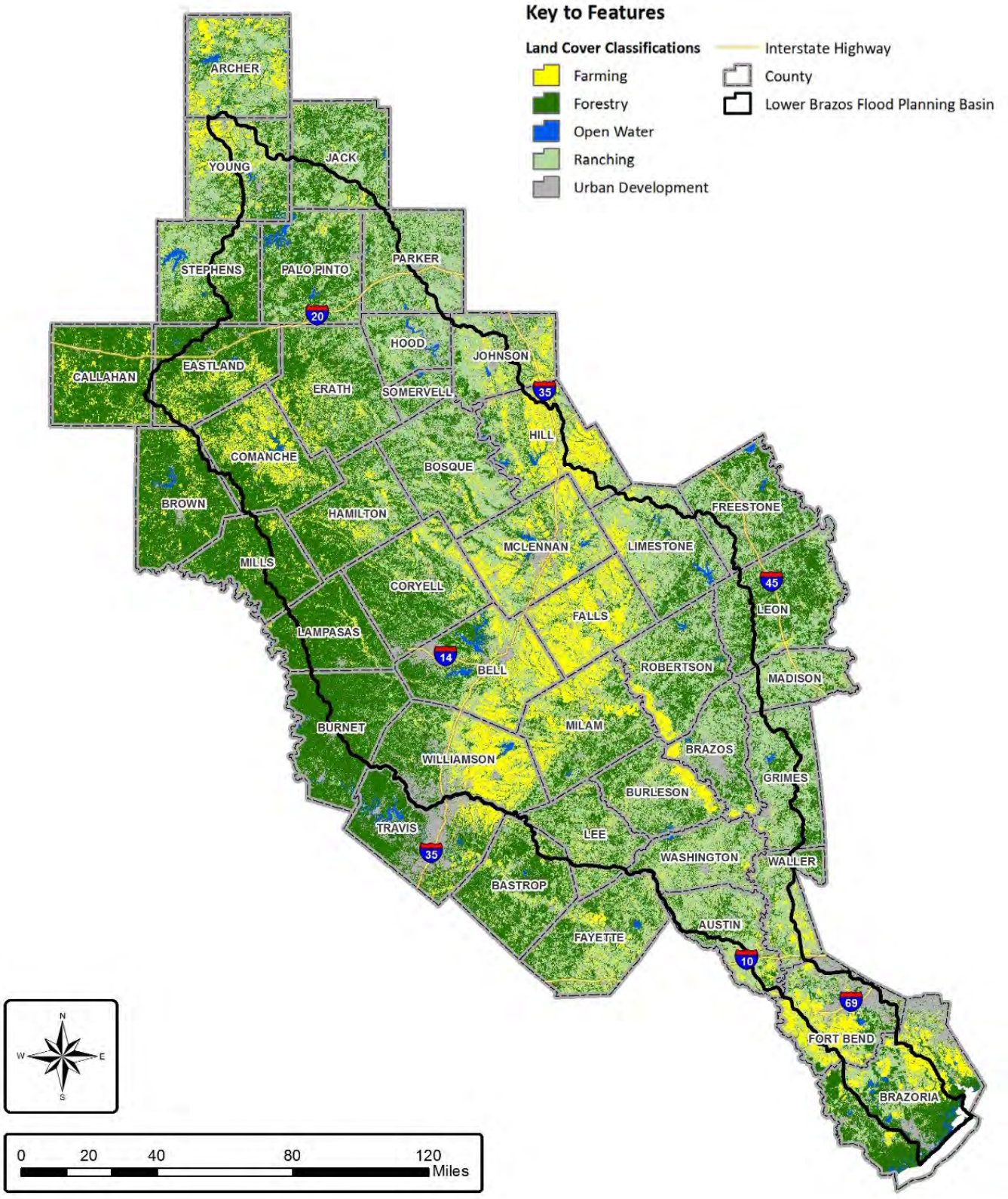
*Counties are not fully contained within the Lower Brazos Planning Region
(United States Census Bureau)

Agricultural Activity

According to the United States Department of Agriculture (USDA) Landcover data, over 20 million acres in the Lower Brazos Planning Region are rural, contributing to the economy of the state and the region through farming, ranching, and forestry. Approximately 8.8 million acres of the Lower Brazos Planning Region are utilized for ranching, providing critical support to Texas's cattle production, which remains the state's top agricultural commodity in market value (Texas Department of Agriculture, 2021).

Similarly, 9.7 million acres of rural lands in the Lower Brazos Planning Region are comprised of forestry, the sixth top agricultural commodity in the state. Of the 2.3 million acres of farmland in the Lower Brazos Planning Region, significant areas of the rural land are producing wheat, sorghum, corn, and oats, which are in the top 10 most important agricultural commodities in terms of market value in Texas. *Figure 1.9* illustrates the variety of agricultural uses in the basin (Texas Department of Agriculture, 2021).

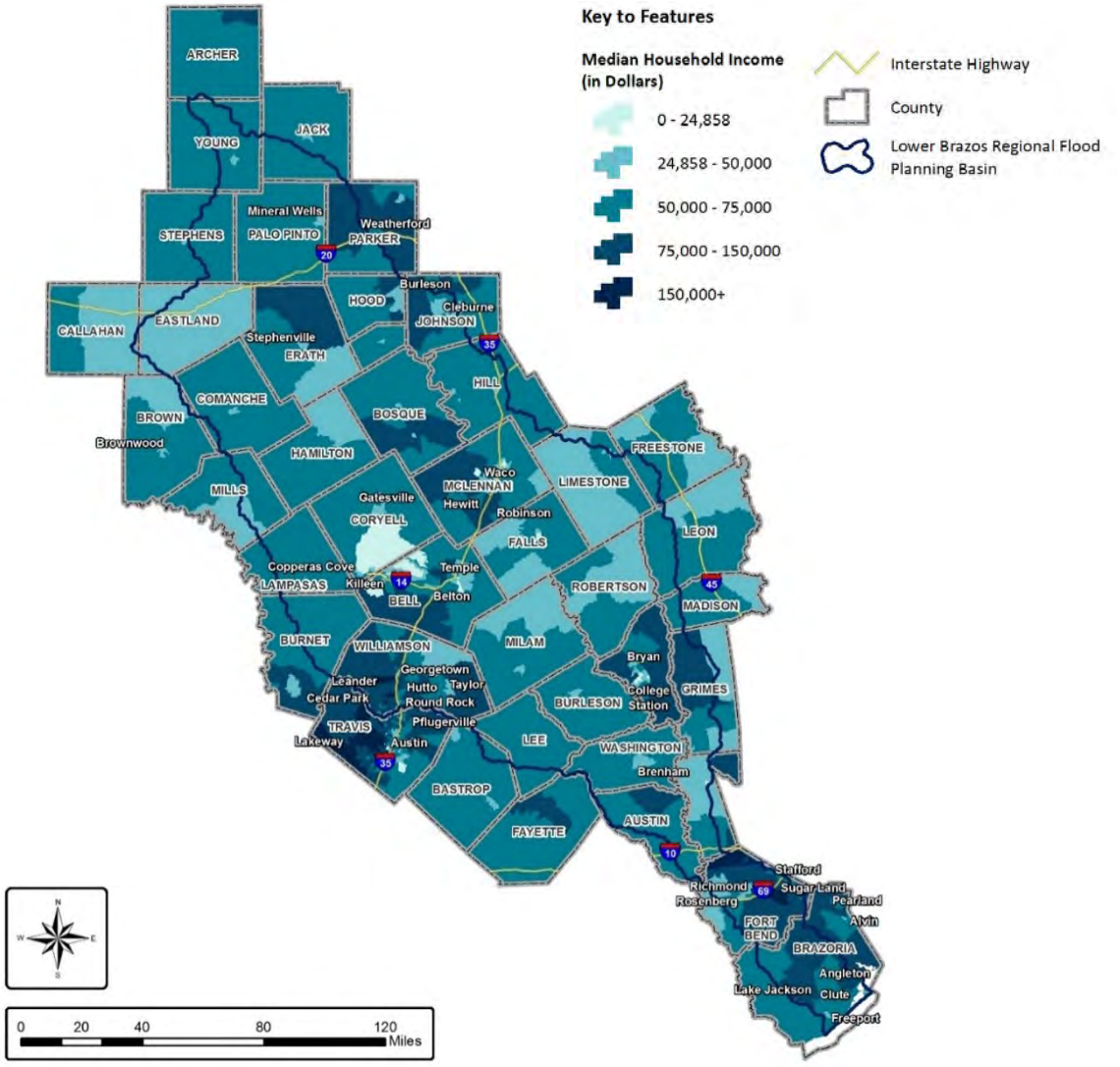
Figure 1.9: Land Cover



Economic Status of Population

According to the 2019 five-year American Community Survey, the median household income for Texas is $61,874. Over half of all census tracts in the Lower Brazos Planning Region, approximately 53 percent, have a median household income below the median household income for Texas. As illustrated in *Figure 1.10*, the census tracts with the lowest median household income (less than $30,000) are primarily in the urban centers of Killeen, Waco, and College Station. The census tracts with median household income greater than $30,000 but less than the state's median household income are primarily in the central area of the basin, namely Limestone, Falls, Robertson, Milam, Coryell, and Lampasas counties. In the northern area of the basin, census tracts in Bosque, Eastland, and Palo Pinto counties also have a median household income below the median value for Texas. Census tracts with a median household income higher than $92,000 are in the suburban areas of Austin and Round Rock in Williamson County, Waco in McLennan County, College Station in Brazos County, Sugar Land in Fort Bend County, and Bellville in Austin County.

Figure 1.10: Median Household Income by Census Tract

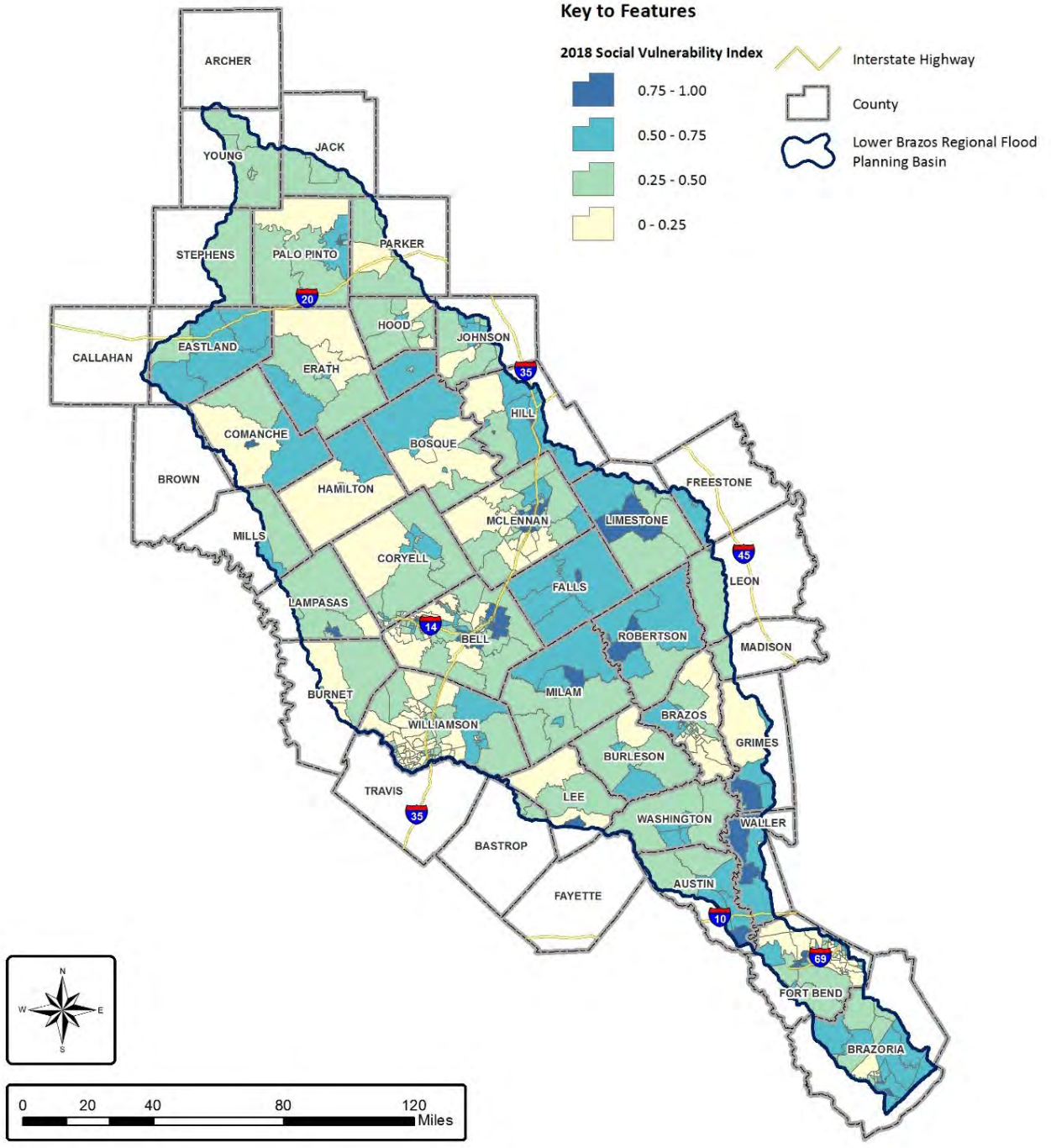


Social Vulnerability in the Lower Brazos Planning Region

Social vulnerability refers to the potential negative effects on communities caused by external stresses on human health, according to the Centers for Disease Control and Prevention (CDC). Stresses include natural or human-caused disasters, such as floods or disease outbreaks. According to the CDC, identifying communities with high social vulnerability in the Lower Brazos Planning Region is critical for flood planning and mitigation since communities with high social vulnerability are at a greater risk of incurring loss of life and property during a flood event. Factors contributing to a community's social vulnerability include the number of residents in poverty, lack of access to transportation, and living in crowded housing. These conditions reduce residents' capacity to withstand and recover from disasters like hurricanes. Federal agencies like the Federal Emergency Management Agency (FEMA) and the United States Department of Housing and Urban Development (HUD) utilize the Social Vulnerability Index (SVI) to assist communities during and after human-made and natural disasters.

The SVI indicates the relative social vulnerability of every census tract in the United States and ranks each tract based on percentile values between zero and one, with higher values indicating greater vulnerability. The index considers 14 factors: poverty, unemployment, income, education, age, disability, single-parent households, race/minority status, limited English-speaking ability, housing type, crowding, and vehicle ownership. The TWDB has provided SVI values for census tracts in the Lower Brazos Planning Region. The census tracts with the highest SVI value (census tracts that are in the top quartile of social vulnerability) are primarily in and around the mid-sized communities of Waco and Temple in the central area of the basin and the small-sized communities of Cameron and Calvert in Milam and Robertson counties (refer to *Figure 1.11).* Other census tracts with high social vulnerability include the less-populated communities of Hempstead in Waller County and Groesbeck in Limestone County. These communities are at a greater risk of incurring loss of life, property, and livelihood due to high social vulnerability attributed to a higher poverty rate, diminished mobility or access to transportation, and unsafe housing conditions.

Figure 1.11: Social Vulnerability by Census Tract



1.2.2 Flood-Prone Areas and Flood Risks to Life and Property

1.2.2.a. Identification of Flood-Prone Areas

By juxtaposing the floodplain quilt, or 1 percent annual chance exceedance (ACE) storm, with the current and expected population in 2050, this flood plan has identified the communities with a high growth rate most at risk of flooding in the future. Specifically, seven communities in the Lower Brazos

Planning Region have over one-fourth of their land area in the floodplain quilt and will have a population growth rate of 10 percent or more by 2050. These communities include Richwood, Lake Jackson, Clute, and Danbury in Brazoria County. The floodplain quilt was also intersected with critical facilities, agricultural lands, roadways, and low water crossings. The location and quantity of this infrastructure were provided through the TWDB and refined by the Halff Associates Team. *Table 1.6* shows the number of these metrics at flood risk for the 1 and 0.2 percent ACE storms. Approximately 20 percent of the Lower Brazos Planning Region is in the 1 percent ACE storm, as shown in *Figure 1.12*

Figure 1.12: Floodplain Quilt by 2050 Population

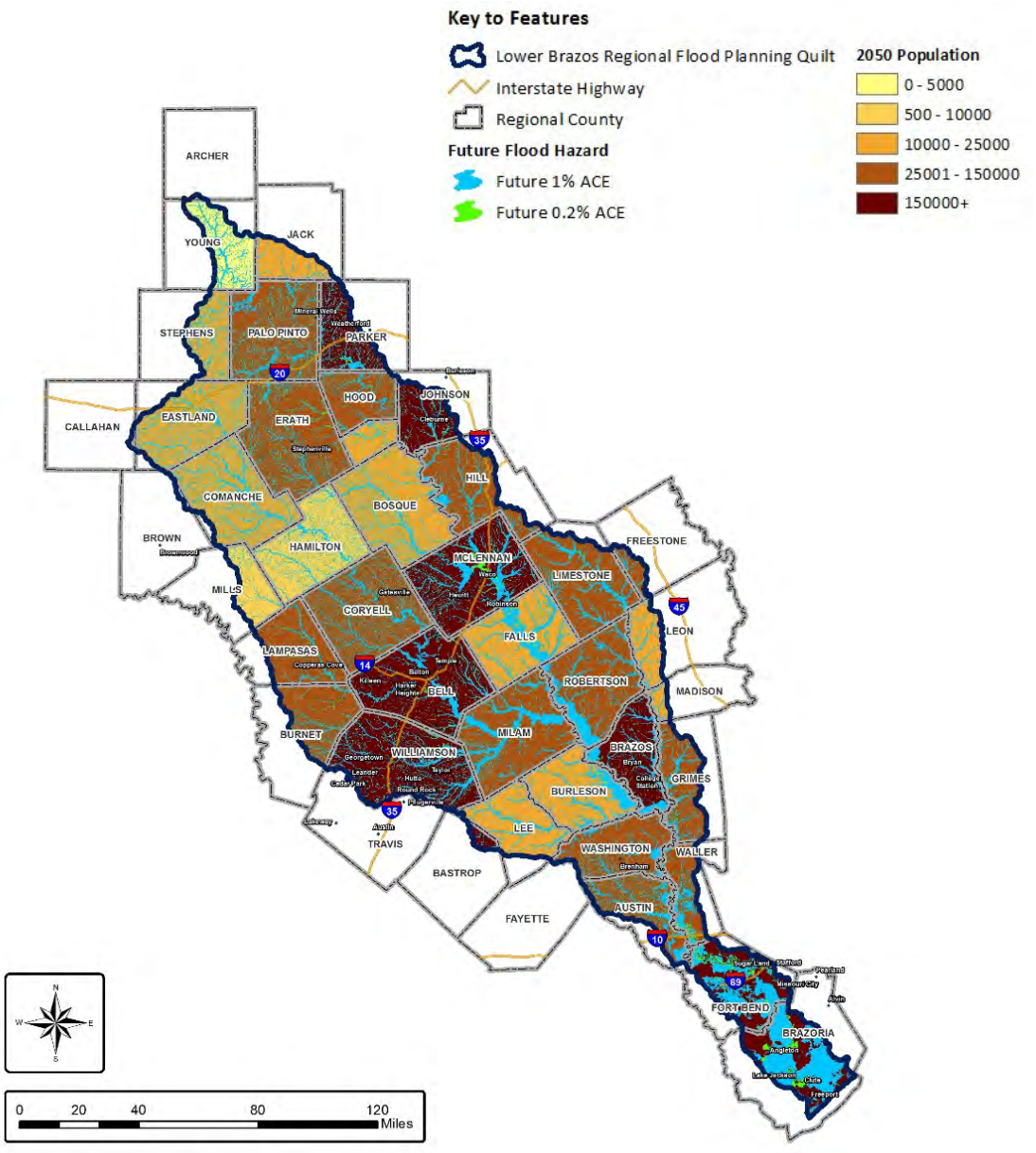


Table 1.6: Flood-Prone Infrastructure

Potential Flood Risk Event	Number of At-Risk Structures	Number of At-Risk Critical Facilities	Number of At-Risk Roadway Crossings*	Impacted Agricultural Areas (sq mi)
Existing 1 percent ACE	63,060	200	5,170	840
Existing 0.2 percent ACE	107,720	380	5,390	940

*Includes low water crossings only.

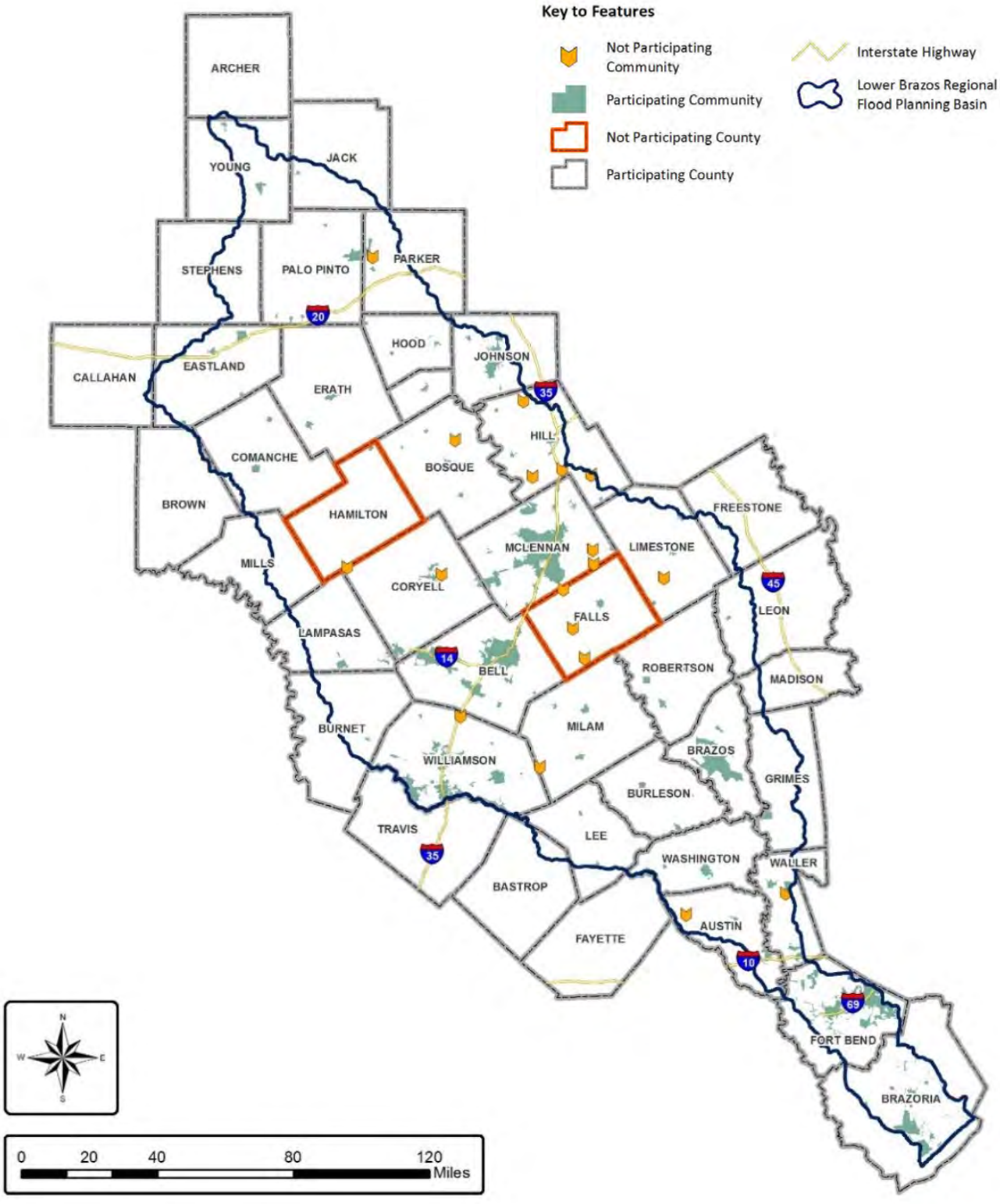
(Texas Water Development Board and Federal Emergency Management Agency)

1.2.2.b. Rates of National Flood Insurance Program (NFIP) Participation and Related Flood Planning Activity

Eighteen communities and two counties within the Lower Brazos Planning Region do not participate in the NFIP administered by FEMA. As shown in *Figure 1.13*, these cities and towns are primarily located in the central area of the Lower Brazos River Basin in McLennan, Hill, Falls, Limestone, Coryell, Parker, Waller, and Williamson counties. Hamilton and Falls counties in the west-central and central areas of the Lower Brazos River basin do not participate in the NFIP (refer to *Figure 1.13*). These counties and communities have portions of their land area intersecting the 1 percent ACE floodplain, where residents are at risk of incurring life and property loss during a flood event. Flood planning efforts in the Lower Brazos Planning Region should consider the increased vulnerability of communities within the 1 percent ACE floodplain that do not participate in the NFIP, which helps residents recover from the impact of flood damage to their real estate and personal property.

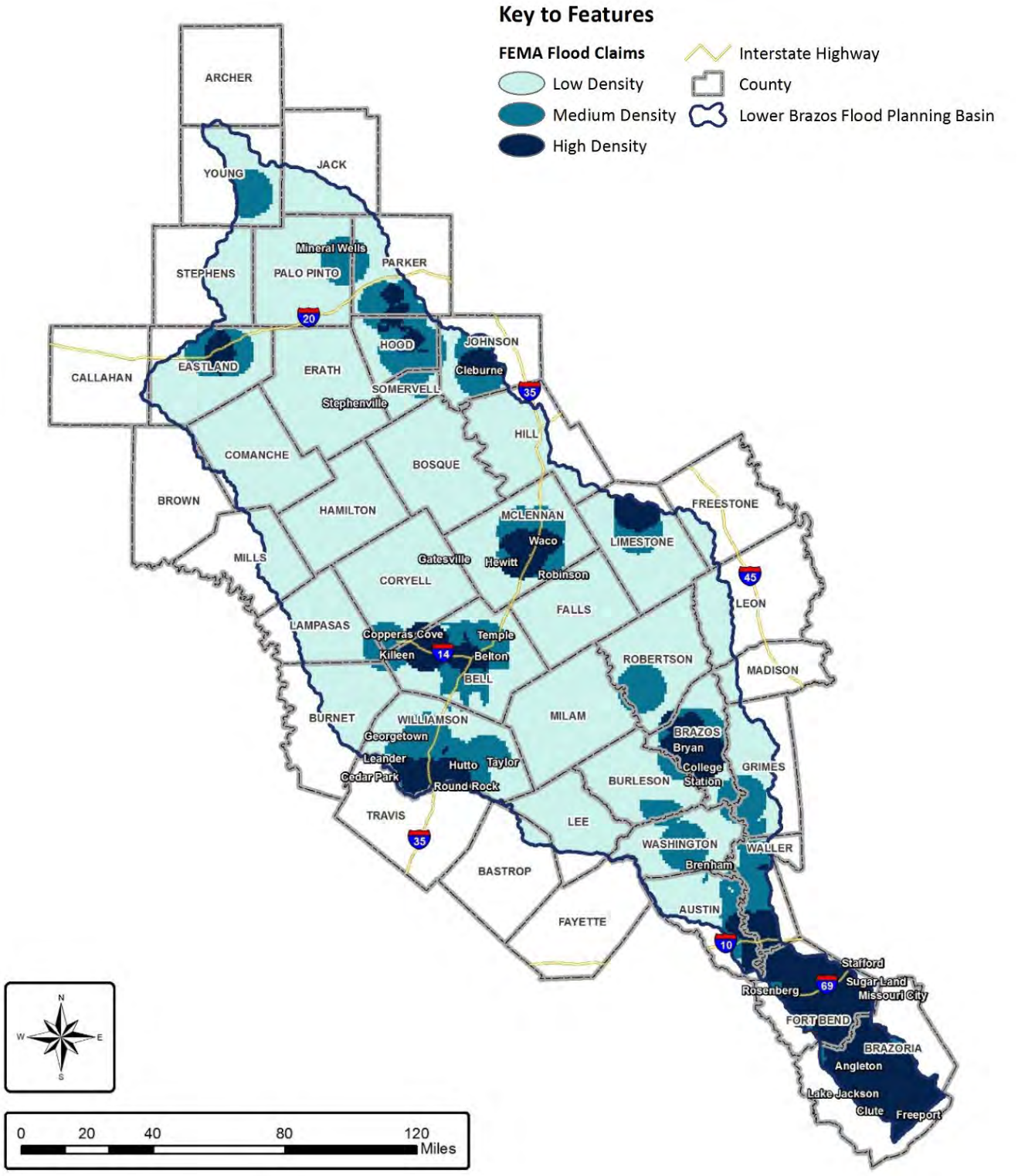
Figure 1.14 illustrates the distribution of flood claims filed with FEMA in the Lower Brazos Planning Area boundary indicating areas where both natural and built flood infrastructure is deficient in protecting homes from flooding. The highest density of FEMA flood claims is in Brazoria and Fort Bend counties in the southern area of the basin, which has high existing and future population growth. The metropolitan areas of Killeen, Waco, Round Rock, and College Station also have a high density of flood claims. In the northern area of the basin, Cleburne and the suburbs of Weatherford have a high density of flood claims.

Figure 1.13: NFIP Participation



(Federal Emergency Management Agency)

Figure 1.14: FEMA Flood Claim Density



(Federal Emergency Management Agency)

1.2.2.c. Agricultural and Natural Resources Most Impacted by Flooding

The Lower Brazos basin is comprised of five main land uses, which include farming, forestry, ranching, urban areas, and open water. *Table 1.7* provides the acreage for each land use in the basin. The following section discusses the detrimental impact of flood events on the agricultural and natural resources of the Lower Brazos Planning Region.

Table 1.7: Lower Brazos Planning Region Land Use Summary

Land Use	Total Area in Lower Brazos Basin (acres)	Total Area in Lower Brazos Basin within the 1 percent ACE Floodplain (acres)	% of Area at 1 percent ACE Flood Risk
Farming	2,325,760	535,424	23%
Forestry	9,732,480	933,057	10%
Ranching	8,783,360	683,035	8%
Urban Development	1,699,840	135,680	8%
Total	22,541,440	2,184,981	10%

(Texas Water Development Board and United States Department of Agriculture)

Farming

Flooding or excess precipitation can wash nutrients downstream or result in complete or partial loss of crops. The severity of impact flooding has on farming depends on many factors, including what is planted, what time of year the flood event occurs, and the wind speed of the storm. Additionally, a crop's growth stage influences the susceptibility to damage or loss due to excess water. Different crops have different resiliency to excess precipitation and prolonged standing water. Permanent crops, such as fruit trees tend to be more resilient to excess precipitation and standing water than row crops, such as cotton. Heavy rain before planting could delay planting or prevent planting entirely. Damage can also occur after a crop has been harvested. Crops, such as hay or cotton, that have been harvested but not bailed or processed can be degraded by heavy rainfall in the Lower Brazos Planning Region. According to the United States Department of Agriculture Risk Management Agency, the Lower Brazos Planning Region experienced over $140 Million in crop losses due to flooding, hurricanes, and tropical storms from 1989-2020.

Forestry

Forestry impacts due to flooding are also multifaceted. Flash flooding can bring swift-moving debris that could physically wound a tree creating the conditions for contaminated flood water to introduce diseases to the tree. Sustained flooded conditions can deplete the oxygen supply and cause root damage to trees. Floods that occur during the growing season can kill trees much faster than similar conditions during the dormant season, according to the Texas A&M Forest Service, an agency chartered by the Texas Legislature to manage the interests of forests in Texas. Furthermore, as described in research conducted by the University of Arkansas Agriculture Research and Extension, flooding can positively impact forests by clearing weaker trees, spreading seeds, and stimulating the growth of surviving trees.

Ranching

Information from Texas A&M AgriLife Extension illustrates how ranching activities in the Lower Brazos Planning Region are also impacted by flooding. Livestock can be swept away, drowned, or injured by flash floods. Livestock exposed to contaminated flood waters can experience health issues such as pneumonia or foot rot. Livestock could also be exposed to disease-carrying mosquitoes during flood events. Flood events can cause delays in building back livestock herds. Damages to feed crops can also reduce ranching capabilities.

Natural Resources

The Lower Brazos Planning Region contains many natural resources that flood events can negatively impact. As with livestock, wildlife can be injured or killed by flash floods. Severe flood conditions can degrade stream health and impact ecosystems in the region. Flooding can cause an imbalance in the ecosystem of the Brazos River Estuary. Oil and gas extraction can also be interrupted by flood conditions.

The agricultural land use in the Lower Brazos basin that has the largest acreage within the 1 percent ACE floodplain is forestry, with over 930,000 acres in the 1 percent ACE floodplain. In other words, 10 percent of the entire land area used for forestry is in the 1 percent ACE floodplain. The total acreage of land used for ranching in the Lower Brazos basin in the 1 percent ACE floodplain is over 683,000 acres, which is 8 percent of the entire land area used for ranching in the basin. While the total acreage of land used for farming in the 1 percent ACE floodplain, approximately 433,200 acres, is less than the forestry or ranching land acreage in the 1 percent ACE floodplain, the percentage of the total farming land in the 1 percent ACE floodplain is the highest, at 19 percent, compared to other agricultural uses.

The HUC-8s with the most significant amount of agricultural land area in the 1 percent ACE floodplain are Lower Brazos – Little Brazos and Middle Brazos – Lake Whitney in the northeastern area of the Lower Brazos Planning Region, as detailed in *Table 1.8*.

Table 1.8: Land Use Acreage Within the 1 percent ACE Floodplain by HUC-8

HUC-8	Farming	Forestry	Ranching	Total	HUC Total Acreage
Austin Oyster	33,552	108,738	36,500	178,790	446,059
Bosque	4,308	9,680	9,545	23,533	269,796
Cowhouse	2,045	15,478	6,950	24,473	465,569
Lampasas	6,293	41,903	13,772	61,968	967,883
Leon	16,825	52,134	22,995	91,954	1,933,332
Little	55,422	34,092	37,372	126,887	642,122
Lower Brazos	38,561	136,259	130,776	305,597	1,051,241
Lower Brazos - Little Brazos	182,840	101,918	131,001	415,759	1,726,263
Middle Brazos - Lake Whitney	39,848	74,575	69,915	184,339	1,598,530
Middle Brazos Palo Pinto	7,954	95,477	59,037	162,468	2,017,175
Navasota	11,466	122,840	76,874	211,181	1,437,563
North Bosque	8,454	31,576	24,562	64,592	795,789
San Gabriel	18,383	34,170	20,870	73,423	874,721
Yegua	7,257	74,217	42,866	124,339	845,755
Total	433,209	933,057	683,035	2,049,302	15,071,798

(Texas Water Development Board and United States Department of Agriculture)

1.2.3 Key Historical Flood Events

1.2.3.a. Historic Events Before Current Level of Regulation

In December 1913, a notable record flood occurred across the Lower Brazos River Watershed (Ellsworth, 1923). After a very wet autumn which led to high stages, the watershed received about 3 inches of rainfall on average over 10 days, and many levees were damaged. As a result, the confluence of the Brazos River and major tributary Little River at Valley Junction reached a record stage of 55.0 feet on Dec 4, 1913. Four days later, a record stage of 61.2 feet was recorded at the Richmond gage in Fort Bend

County, according to the United States Geological Society and firsthand accounts, which notes that the floodplains of the Colorado and Brazos rivers merged with each other. At least 174 people were killed due to flooding along the Brazos River (Sawyer, 2021).

September 1921 brought heavy rainfall and flooding to central Texas (Ellsworth, 1923). The United States Weather Bureau recorded 16 inches of rainfall in Williamson County on September 9, 1921. As a result, the Little River near Cameron crested at a record gage height of 49.50 feet, and the gage height for the Brazos River at Jones Bridge, near Bryan, Texas, rose to 47.90 feet between September 8-12. The Little River Basin, particularly in Williamson and Milam counties, suffered 159 fatalities, the most significant loss of life across the Lower Brazos Planning Region. Collectively, $4,000,000 in damages and 224 fatalities were recorded in the Lower Brazos watershed, as reported by the United States Geological Society.

The floods of April to June 1957 followed a period of severe drought in Texas (State of Texas Board of Water Engineers). Palo Pinto County recorded 19 inches of rainfall in May 1957, resulting in the downstream gage at the Brazos River near Glen Rose, Texas, reaching 33.89 feet, the fifth-highest record. Little River near Cameron reached a gage height of 39.56 feet with a stream flow of 116,000 cfs, the third-highest record. The long-duration event generated extensive runoff; 9.3 million acre-feet of total volume passed the Richmond gage. United States Army Corps of Engineers estimated statewide flood damages totaling $100,000,000.

These major flood events, amongst others, led to the construction of multiple flood control reservoirs to regulate the flow of the Brazos River. While major flooding in recent years has resulted in significant loss of life and property, gages with long periods of record throughout the watershed show that flooding was more severe in the region before regulation.

1.2.3.b. Historic Tropical Flooding Events

Tropical Storm Frances

Tropical Storm Frances made landfall on September 13, 1998, between Corpus Christi and Victoria. While Harris County was among the hardest hit in the Coastal Region, Brazoria County averaged 10 inches of rainfall in 24 hours. According to the National Hurricane Center, West Columbia received more than 16 inches of rainfall in 24 hours. A major disaster declaration was issued for Brazoria County due to inland flooding. One direct fatality connected to flood conditions was reported in Brazoria County, as reported by National Oceanic and Atmospheric Association's (NOAA) Storm Event Database.

Hurricane Ike

Hurricane Ike made landfall on September 13, 2008, near Galveston as a Category 2 hurricane, bringing strong wind and rain to Texas and Louisiana. The National Hurricane Center (NHC) reported wind gusts of 80 mph in Rosharon and 83 mph in Danbury, making Hurricane Ike one of the most destructive weather events on record for the Lower Brazos Planning Region. While Hurricane Ike did not bring record-setting rainfall to the basin, the storm's wind field stretched 400 miles wide and produced severe storm surges ranging from 5 to 10 feet along the coast of Brazoria County, as reported by NHC's Tropical

Cyclone Report for Hurricane Ike. As a result, Ike is the second most severe flooding event in the region's history by a number of flood claims.

Tropical Storm Hermine

Tropical Storm Hermine made landfall on September 5, 2010, in northeast Mexico before turning towards central Texas. The storm developed into a band of intense rainfall along I-35. The NHC reported 16 inches of total rainfall for Lake Georgetown between September 7th to 9th, 2010, of which 15 inches fell in 24 hours. As a result, Little River, near the City of Little River, reached a gage height of 40.58 feet, the second-highest on record. As reported by NOAA's Storm Event Database, flash flooding in Bell, Johnson, and Williamson counties resulted in three direct fatalities.

Hurricane Harvey

Hurricane Harvey made landfall near Rockport, Texas, on August 25, 2017, as a Category 4 hurricane. Brazos River recorded the highest gage height since regulation of flows began, with 55.19 feet and 52.65 feet at Richmond and Rosharon, respectively. Rainfall within the Brazos River watershed between August 25 and September 1 ranged from 13 to 39 inches, the highest of which is comparable to the average annual precipitation for the watershed, according to NOAA. This extreme rainfall resulted in Harvey being the most damaging storm in the Lower Brazos Planning Region since the NFIP launched in 1968. As reported by NOAA's Storm Event Database, flash floods in Fort Bend County resulted in three direct fatalities.

1.2.3.c. Historic Flooding of Non-Tropical Origin

Winter 1991-1992

Winter 1991-1992 brought heavy rainfall and flash flooding to most of the Lower Brazos Planning Region (Halff Associates, 2019). According to the United States Geological Survey, the heaviest rain fell in Coryell County, which received an average depth of 7 inches in 12 hours. Little River reached a stage of 38.95 feet at Cameron, which remains the highest stage after the 1957 flood at this location. The Brazos River floodplain reached five miles width near Bryan and merged with Oyster Creek downstream of Rosenberg.

Spring 2007

Spring 2007 brought heavy rainfall to the Lower Brazos Planning Region after 18 months of drought (Halff Associates, 2019). The Brazos River watershed upstream of Whitney Reservoir received 13 inches of rainfall in May 2007, raising the Brazos River near Aquilla to a stage of 23.28 feet. The Brazos River reached 46.45 feet with 85,900 cfs streamflow near Bryan, the highest stage recorded since the gage began collecting data in 1994. Flash floods in the Leon and Little River watersheds resulted in at least eight direct flood fatalities, as reported by the NOAA Storm Event Database.

Memorial Day 2015

At the end of an above-normal month of rainfall in central Texas, an intense storm produced flash flooding in the Lower Brazos Planning Region on May 23, 2015 (Halff Associates, 2019). The Brazos River near Hempstead reached a stage of 49.97 feet on July 18, its third-highest stage since flood control reservoirs were implemented in the upper watershed. On May 25, 2015, as the system approached

Harris County, it merged with a smaller cell in Fort Bend County, resulting in widespread flooding along the lower reach of the Brazos River. Maximum rainfall was recorded at 12 inches over two days near Richmond. Brazos River near Rosharon reached a stage of 51.46 feet on June 5, the sixth-highest recorded stage. Flash floods in the Leon River watershed and Fort Bend County resulted in at least five direct flood fatalities, as reported by the NOAA Storm Event Database.

Spring 2016

Widespread heavy rain during Spring 2016 led to elevated stages along the Brazos River and wet antecedent conditions for a higher intensity storm that produced 17 inches of rainfall in 24 hours on May 26 in Brenham. This translated to river stages of 54.89 feet at Hempstead and 54.74 feet at Richmond. These gages recorded stages not seen since the flood of 1913, but the stage at the Richmond gage would be surpassed the following year during Hurricane Harvey in 2017. Flash flooding resulted in at least 15 deaths in the Brazos River watershed. Among the fatalities of the Spring 2016 floods were nine soldiers from Fort Hood, as reported by the NOAA Storm Event Database.

FEMA Flood Claims

The FEMA flood claim data began with the establishment of the NFIP in 1968. Total NFIP flood claims connected to each major historical flood event are summarized in *Table 1.9* for significant historical flood events within the Lower Brazos watershed.

Table 1.9: FEMA Flood Claims for Significant Historical Flood Events within the Lower Brazos watershed

Flood Event	Year	Number of Flood Claims	Flood Claims Paid
Hurricane Harvey	2017	44,323	$311,463,534
Spring 2016	2016	8,816	$47,200,156
Hurricane Ike	2008	12,750	$22,477,298
Tropical Storm Hermine	2010	3,363	$20,035,360
Memorial Day 2015	2015	3,815	$8,270,617
Tropical Storm Frances	1998	7,621	$6,061,991
May-June 2007	2007	2,362	$5,502,155
September 1979	1979	602	$3,060,896
Winter 91-92	1992	208	$2,622,179

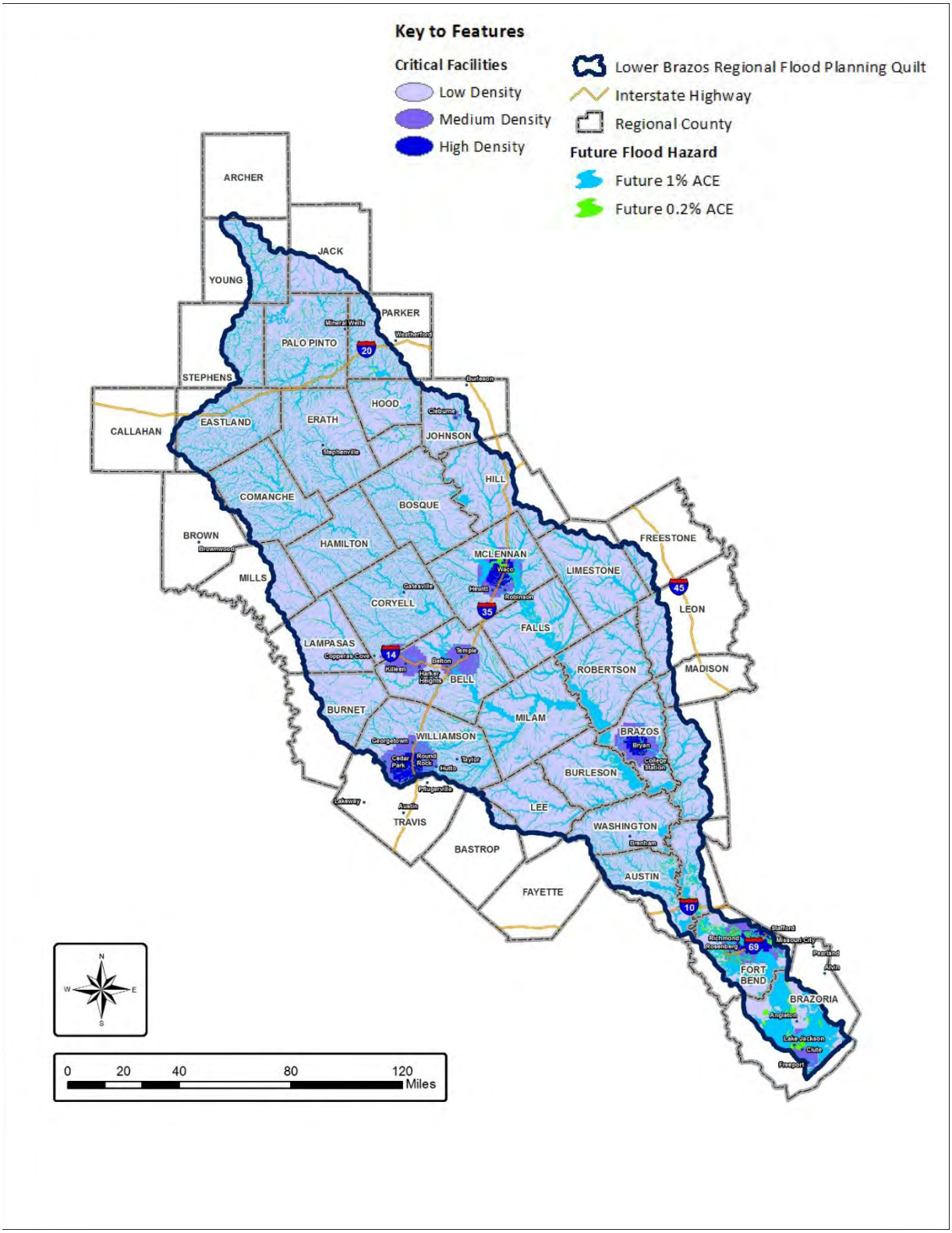
(Federal Emergency Management Agency)

1.2.3.d. Location of Critical Facilities

Critical facilities are community assets, such as hospitals, fire stations, police stations, storage of critical records, energy-producing facilities, water and wastewater treatment plants, and similar facilities that require special consideration in floodplain management and disaster planning. Critical facilities must always continue to function and provide services during a flood. In the Lower Brazos Planning Region, critical facilities are located in the communities along the Interstate 35 corridor, such as Waco, Killeen, and Round Rock in the central portion of the Lower Brazos Planning Region, as well as the heavily

populated areas in Fort Bend and Brazoria Counties in the south of the Lower Brazos Planning Region. *Figure 1.15* illustrates the density of critical facilities in the Lower Brazos Planning Region.

Figure 1.15: Density Map of Critical Facilities



1.2.4 Political Entities with Flood-Related Authority

The Technical Consultant Team, led by Halff Associates, has identified all political subdivisions with flood-related authority as interest groups for the survey distribution in the Lower Brazos Planning Region. These entities include cities, counties, river authorities, soil and water conservation districts, water control and improvement districts, flood control and improvement districts, municipal utility districts, and levee improvement districts, among others.

Table 1.10 details the number of entities with various levels of flood-related regulatory authority in the Lower Brazos basin. Flood-related authority includes a range of actionable powers, from enforcing ordinances to the ability to raise money to execute flood mitigation projects. The publication and enforcement of flood ordinances and regulations are primarily left to the cities, counties, and drainage districts.

Table 1.10: Political Entities with Flood-Related Authority

Entity	Number
Cities	193
Counties	43
Municipal Utility District	256
Municipal Water District	3
Water Control and Improvement District	23
Management District	13
Development District	3
Drainage District	8
Levee Improvement District	16
Special Utility District	8
Improvement District	7
Fresh Water Supply District	7
Council of Government	8
Water Authority	11
Total	599

(Texas Water Development Board)

Fort Bend and Brazoria counties at the southern tip of the Lower Brazos basin are among the largest number of water and flood-related entities functioning within the Lower Brazos Planning Region, including drainage districts, fresh water supply districts, and municipal utility districts. In addition to these entities, Fort Bend County has 13 levee improvement districts. Entities in Fort Bend County, such as Fulshear and Sienna, also operate several additional utility districts. The area comprising Williamson County at the western boundary of the basin and nearby communities such as Leander and Round Rock has the next highest number of political entities with several municipal utility districts, water control and improvement districts, and water, sewer, irrigation, and drainage districts. Counties north of the Lower

Brazos basin have relatively fewer flood-related political entities responsible for flood planning, management, and mitigation.

1.2.4.a. Summary of Existing Flood Planning Documents

The summary of the existing flood planning documents section provides insight into the regulatory and policy environment governing floodplain management in the various jurisdictions of the Lower Brazos Planning Region. It summarizes the most common types of regulation, structural controls, and planning activities.

Floodplain Ordinances

The regulatory framework guiding floodplain management in the Lower Brazos Planning Region is comprised primarily of local floodplain ordinances. Overall, there are 255 floodplain management and flood prevention ordinances in the Lower Brazos basin. Cumulatively, these ordinances:

- restrict and prohibit land uses that are dangerous
- control alteration of floodplains, channels, and natural protective barriers
- describe permitting and variance procedures for land use regulation in relation to flood prevention
- define the duties of the floodplain administrator
- specify subdivision and construction standards
- prescribe penalties for non-compliance to standards
- define overall rules and regulations for flood control and flood hazard reduction

Some communities, like Killeen and Austin counties, have included drainage design manuals and detailed construction standards within their ordinances for flood hazard reduction. Overall, Brazoria County, at the southern tip of the basin, has the highest number of local flood reduction and floodplain management ordinances, at over 24 ordinances. Counties in the center of the Lower Brazos Planning Region, including McLennan, Bell, Williamson, and Hill counties, have over 13 local flood management ordinances each.

Current Local Regulations and Development Codes

Some counties and cities have included flood control measures in the local subdivision regulations for stormwater management using recurrence intervals such as the 50 percent, 10 percent, 4 percent, and 1 percent ACE storms. Similarly, McLennan County, in the central area of the Lower Brazos basin, has included detailed drainage and flood control requirements within the county's subdivision regulations. Williamson County, close to the western boundary of the Lower Brazos basin, has specified stormwater management controls and infrastructure for subdivision development. The Fort Bend County Drainage District in the south of the basin has conducted detailed hydrology and hydraulics analysis to determine the base flood elevation profile for the watersheds in the county. The City of Fulshear in Fort Bend County in the south of the basin has developed a Downtown Drainage Planning Study that provides recommendations for improving drainage in Fulshear Downtown.

Local and Regional Flood Plans

Several counties and municipalities in the Lower Brazos Planning Region have developed hazard mitigation plans. One example is the North Central Texas Council of Governments 2021 Hood County Hazard Mitigation Action Plan. Municipal Utility Districts and Levee Improvement Districts in the basin's southern area have also developed emergency action plans for flood mitigation. The Fort Bend County Drainage District has conducted detailed hydrology and hydraulics analysis to determine the base flood elevations for the watersheds in the county, including the Brazos River. The City of Sugar Land in Fort Bend County has overseen the development of several drainage improvement analyses for various locations in the city. Sienna, just southeast of Sugar Land, has created the Sienna South Levee System Master Drainage Plan and a 2021 emergency action plan.

1.3 – Assessment of Existing Flood Infrastructure

The assessment of existing flood infrastructure provides an overview of existing flood infrastructure and natural areas that contribute to lowering the flood risk of communities in the Lower Brazos Planning Region. This assessment of existing flood infrastructure, both natural and man-made, is based on data provided by the TWDB. This data includes both structural and natural flood protection features and is summarized in this section. Additional information on major public flood infrastructure self-reported by entities who took the Lower Brazos Basin Community Survey is also included. Existing flood infrastructure is provided in *Table 1* in *Appendix 1.1*. *Map 1* in *Appendix 0* shows an overview of the location of the flood infrastructure.

1.3.1 Natural Features

An inventory of the natural features that perform essential flood-related functions in the Lower Brazos Planning Region is integral to the flood planning process. This inventory includes wetlands, lakes, reservoirs, parks, and preserves. As detailed in *Table 1.11*, there are over 249,000 acres of wetland in the Lower Brazos basin. Over 60 percent of the wetlands in the basin are freshwater forested/shrub wetlands, of which the largest wetland acreage is in the Navasota HUC-8 watershed on the central-eastern boundary of the Lower Brazos Planning Region. The Lower Brazos HUC-8 watershed, which includes mid-sized cities like Sugar Land, Fulshear, and Rosenberg, has 38,214 acres, or 25 percent of the total freshwater forested/shrub wetlands in the basin.

Table 1.11: Types of Wetland by HUC-8

HUC-8 Watershed	Estuarine and Marine Wetland (acres)	Freshwater Emergent Wetland (acres)	Freshwater Forested / Shrub Wetland (acres)	Total Wetland (acres)	Total Wetland (percent)
Austin-Oyster	25,463	23,854	16,285	65,602	26%
Bosque	-	405	928	1,333	1%
Cowhouse	-	260	1,750	2,010	1%
Lampasas	-	623	1,559	2,182	1%
Leon	-	2,813	5,582	8,395	3%
Little	-	936	3,311	4,247	2%
Lower Brazos	1,973	17,064	38,214	57,251	23%
Lower Brazos-Little Brazos	-	5,578	15,345	20,923	8%
Middle Brazos-Lake Whitney	-	1,888	9,096	10,984	4%
Middle Brazos-Palo Pinto	-	2,477	4,673	7,150	3%
Navasota	-	8,344	40,606	48,950	20%
North Bosque	-	574	1,987	2,561	1%
San Gabriel	-	1,361	5,683	7,044	3%
Yegua	-	2,260	8,426	10,686	4%
Total	27,436	68,437	153,445	249,318	100%

(United States Fish and Wildlife Service)

Overall, the Austin-Oyster HUC-8 watershed at the southern tip of the basin comprises over one-fourth of the total wetland in the Lower Brazos Planning Region, performing critical flood-related functions. Approximately 15 percent of the entire Austin-Oyster HUC-8 watershed land area is covered with wetlands. While Lower Brazos and Navasota HUC-8 watersheds contain over 20 percent each of the total wetland acreage of the Lower Brazos basin, only 5 and 3 percent of their land area, respectively, is comprised of wetland. HUC-8 watersheds in central and northern areas of the basin stretching from Graham and Stephenville in the north to Killeen and Bryan in the south comprise of less than 5 percent of the total wetland acreage of the basin, and less than 1 percent of their land area has wetland coverage. These HUC-8 watersheds, therefore, lack the relative protection and flood mitigation functions performed by natural features, such as wetlands.

Lakes, reservoirs, parks, and preserves are critical natural infrastructure performing mitigating functions during flood events. *Table 1.12* details the acreage of each of these natural features and the total land area in the HUC-8 watersheds covered by these natural features. Austin-Oyster HUC-8 watersheds in the southern tip of the basin and San Gabriel at the southwestern boundary of the Lower Brazos Planning

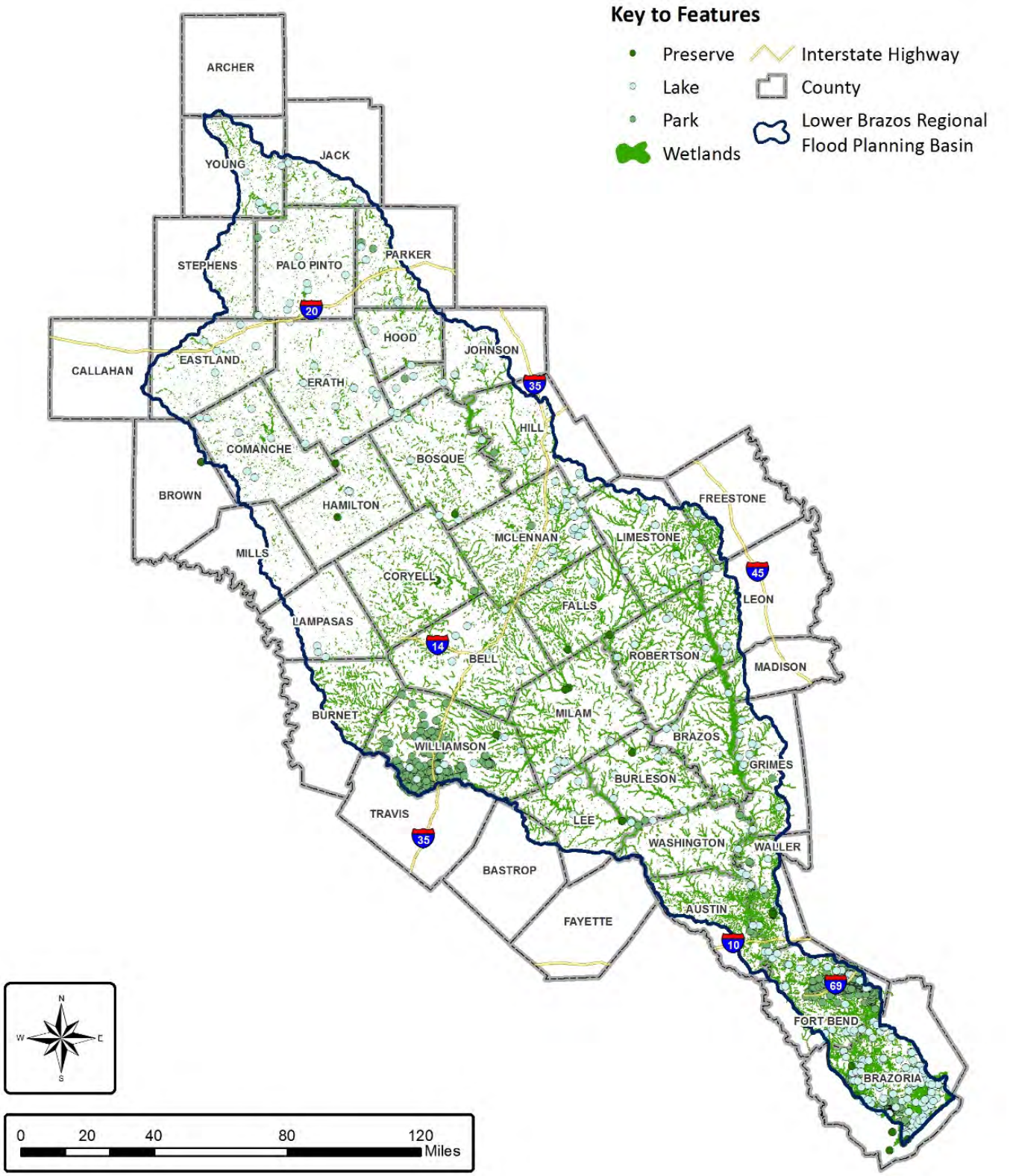
Region have approximately 17 percent of the land area covered with lakes, reservoirs, parks, and preserves. Other HUC-8 watersheds in the Lower Brazos Planning Region that have 12 to 13 percent of the land area covered with lakes, reservoirs, parks, and preserves are Middle Brazos – Palo Pinto and Middle Brazos – Lake Whitney HUC-8 watersheds in the north and northeastern portion of the Lower Brazos Planning Region as well as the Lower Brazos HUC-8 watersheds in the south of the Lower Brazos Planning Region. HUC-8 watersheds in the central and central northern basin area have 2 percent or less of their land area comprising of food mitigating natural features. *Figure 1.16* illustrates the location of parks, lakes, preserves, and wetlands in the Lower Brazos Planning Region.

Table 1.12: Lakes, Reservoirs, Parks, and Preserves by HUC-8

HUC-8 Watershed	Lakes (acres)	Reservoirs (acres)	Parks (acres)	Preserves (acres)	Total Lakes, Reservoirs, Parks, Preserves (acres)	Percent of Total HUC-8 Land Area
Austin-Oyster	8,448	3,389	39,169	267	51,273	17%
Bosque	94	6,218	107	145	6,564	2%
Cowhouse		3,305		152	3,457	1%
Lampasas	142	6,356	946	-	7,444	2%
Leon	2,751	13,861	381	580	17,573	6%
Little	184	-	-	918	1,102	0%
Lower Brazos	8,309	5,170	13,464	8,754	35,697	12%
Lower Brazos-Little Brazos	2,098	-	294	2,124	4,516	1%
Middle Brazos-Lake Whitney	8,735	26,598	2,883	-	38,216	12%
Middle Brazos-Palo Pinto	30,623	-	9,016	-	39,639	13%
Navasota	19,950	-	1,469	-	21,419	7%
North Bosque	756	2,338	529	34	3,657	1%
San Gabriel	374	5,540	32,332	13,530	51,776	17%
Yegua	1,895	11,571	9,237	3,148	25,851	8%
Total	84,359	84,346	109,827	29,652	308,184	100%

(United States Fish and Wildlife Service, United States Army Corp of Engineers, Texas Parks and Wildlife Department)

Figure 1.16: Natural Features in Lower Brazos Planning Region



1.3.2 Constructed Flood Infrastructure/Structural Protections

The existing major infrastructure features in the Lower Brazos Planning Region include publicly-owned dams, levees, and weirs. In total, there are 485 public dams in the basin, of which 19 percent are in the Middle Brazos – Lake Whitney HUC-8 in the northeastern basin area. Leon HUC-8 watershed has 71 dams or 15 percent of all dams in the basin. Other HUC-8 watersheds with close to 10 percent of the dams in the basin are the Cowhouse HUC-8 watershed in the central area and San Gabriel in the southwestern Lower Brazos basin. The San Gabriel HUC-8 also has 36 of the 41 weirs in the basin.

The HUC-8 watersheds with the fewest dams are Bosque, Yegua, Lower Brazos, and Austin-Oyster. However, the Lower Brazos and Austin-Oyster watersheds have a relatively large number of levees, accounting for 66 percent of the total levees in the Lower Brazos Planning Region.

Table 1.13 details the dams, levees, and weirs in the Lower Brazos Planning Region. *Figure 1.17* illustrates the location of dams and levees in the Lower Brazos Planning Region.

Table 1.13: Dams, Reservoirs, Levees, and Weirs by HUC- 8

HUC-8 Watershed	Publicly-owned Dam	Levee	Weir	Total
Austin-Oyster	7	23	-	30
Bosque	3	-	-	3
Cowhouse	46	-	-	46
Lampasas	15	1	-	16
Leon	71	4	-	75
Little	43	1	-	44
Lower Brazos	9	27	1	37
Lower Brazos-Little Brazos	46	7	-	53
Middle Brazos-Lake Whitney	90	4	-	94
Middle Brazos-Palo Pinto	24	1	4	29
Navasota	31	1	-	32
North Bosque	45	1	-	46
San Gabriel	50	-	36	86
Yegua	5	-	-	5
Total	485	59*	41	585

*11 Levees extend through both the Austin-Oyster and Lower Brazos HUC-8 watersheds.
(United States Army Corps of Engineers)

The two HUC-8 watersheds that abut the Gulf Coast have coastal barriers and revetments that provide structural protection against coastal flooding, as summarized in *Table 1.14.*

Table 1.14: Coastal Infrastructure in Austin-Oyster and Lower Brazos HUC-8

HUC-8 Watershed	Coastal Barrier	Sea Wall	Coastal Revetment
Austin-Oyster	29	8	9
Lower Brazos	4	-	-
Total	32*	8	9

*One coastal barrier extends through both the Austin-Oyster and Lower Brazos HUC-8 watersheds.
(United States Fish and Wildlife Service and General Land Office)

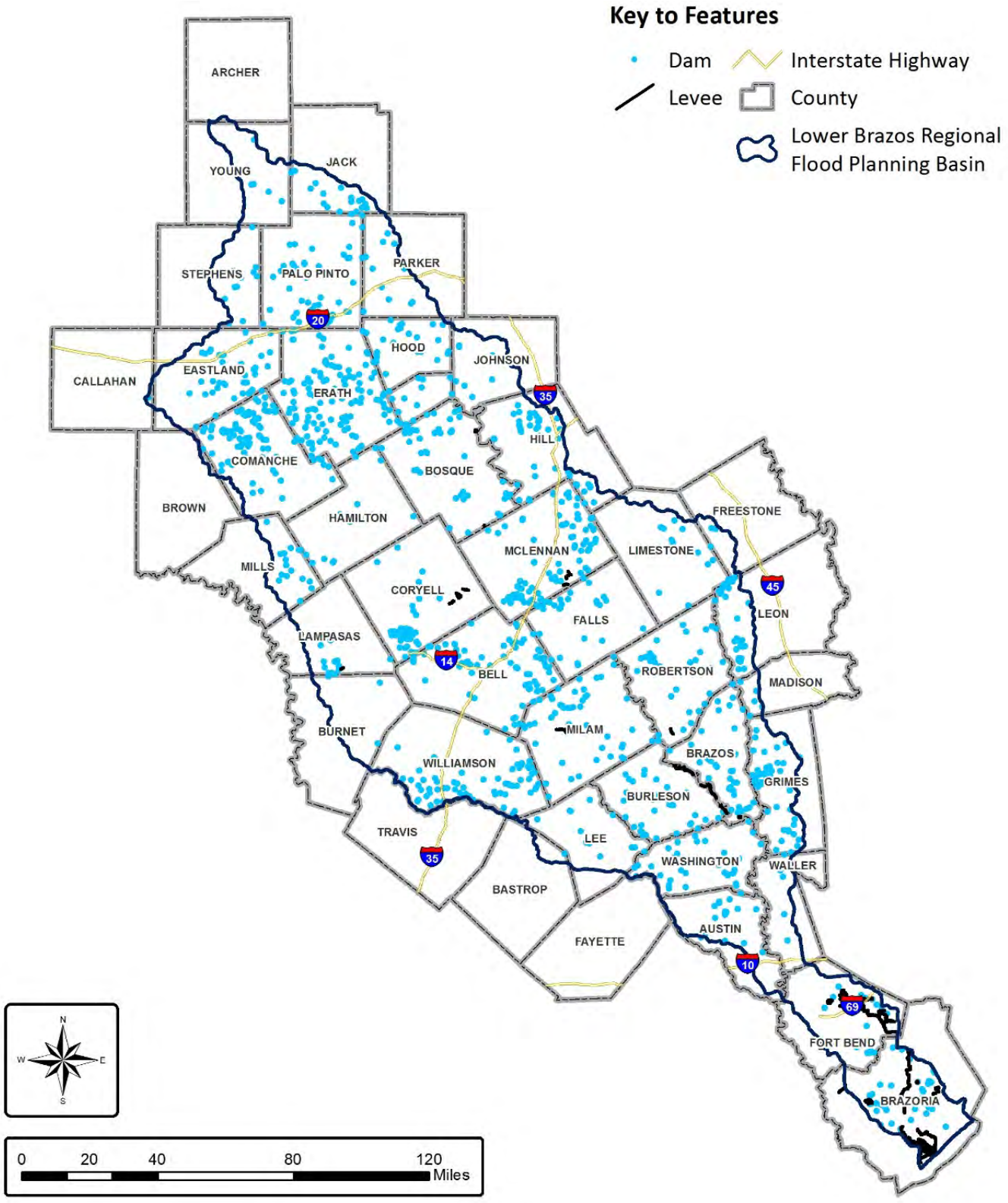
Other information that assists flood protection planning in the Lower Brazos Planning Region includes high and low water marks. There are 1,513 high water marks and 1,168 low water marks in the Lower Brazos Planning Region. As detailed in *Table 1.15*, the San Gabriel HUC-8 watershed in the southwestern area and the Austin-Oyster HUC-8 watershed in the southern area have the highest percentage of high and low water marks in the Lower Brazos Planning Region, at 21 percent and 14 percent, respectively. Leon HUC-8 watershed in the central area of the Lower Brazos Planning Region has 313 high and low water marks comprising 12 percent of all flood water marks in the Lower Brazos Planning Region. The HUC-8 watersheds in the northern and central areas of the basin, such as Bosque, Cowhouse, and Lampasas, as well as Yegua in the southwest, have the fewest number of high and low water marks.

Table 1.15: High/Low Water Marks by HUC-8

HUC-8 Watershed	High Water Mark	Low Water Mark	Total	Percent
Austin-Oyster	368	1	369	14%
Bosque	6	19	25	1%
Cowhouse	6	8	14	1%
Lampasas	68	103	171	6%
Leon	75	238	313	12%
Little	166	60	226	8%
Lower Brazos	90	39	129	5%
Lower Brazos-Little Brazos	125	99	224	8%
Middle Brazos-Lake Whitney	112	107	219	8%
Middle Brazos-Palo Pinto	52	69	121	5%
Navasota	39	106	145	5%
North Bosque	28	51	79	3%
San Gabriel	353	205	558	21%
Yegua	25	63	88	3%
Total	1,513	1,168	2,681	100%

(Texas Water Development Board)

Figure 1.17: Constructed Flood Infrastructure in the Lower Brazos Planning Region



1.3.3 Non-Functional or Deficient Flood Mitigation Features

This section summarizes the Lower Brazos Planning Region's non-functional or deficient flood mitigation infrastructure. This information is based on self-reported data from communities that have responded to the Lower Brazos Basin Interest Group Survey and have self-assessed the condition of their infrastructure as Functional, Non-Functional, or Deficient. This self-reported data has been augmented by information obtained from Levee Safety Assessments by the Levee Improvement Commission in the Texas Commission on Environmental Quality and the Soil and Water Conservation Society's (SWCS) Levee Program and Small Watershed Programs to indicate areas where the existing infrastructure is failing to do its job of protecting the population or is at risk of failure.

The following tables provide information on the level of service (LOS) and functional classification of the dams and levees in the Lower Brazos Planning Region. The LOS is dependent on the assumption that regular maintenance has been performed.

Table 1.16 describes the functional classification of levees by HUC-8. Eleven levees extend into both the Austin-Oyster and Lower Brazos HUC-8s and are shown in both categories. *Table 1.17* provides the total number of levees in each classification.

Table 1.16: Functional Classification of Levees by HUC-8

HUC-8 Watershed	Levees 100-Year LOS	Levees Not Assessed	Levees In Progress	Levees Functional
Austin-Oyster	11	20	1	3
Bosque	-	-	-	-
Cowhouse	-	-	-	-
Lampasas	-	1	-	-
Leon	-	4	-	-
Little	-	1	-	-
Lower Brazos	21	22	1	5
Lower Brazos-Little Brazos	-	7	-	-
Middle Brazos-Lake Whitney	-	4	-	-
Middle Brazos-Palo Pinto	-	1	-	-
Navasota	-	1	-	-
North Bosque	-	1	-	-
San Gabriel	-	-	-	-
Yegua	-	-	-	-

(United States Army Corps of Engineers)

Table 1.17: Functional Classification of Levees in the Lower Brazos Planning Region

Functional Classification	Number of Levees
Total Count	59
With 100-Year LOS	25
Levees with 100-Year LOS with an overlap in Austin-Oyster and Lower Brazos HUC-8s	11
Functional	6
In Progress	1
Not Assessed	53
Deficient	1
Non-Deficient	6

(United States Army Corps of Engineers)

Of the 485 dams in the Lower Brazos Planning Region, the deficiency classification is available for 257 dams and is detailed in *Table 1.18.* Less than 10% of dams that have deficiency data available from the State Regulated Dams TCEQ 2021 Report are classified as deficient or in need of replacement.

Table 1.18: Functional Classification of Dams by HUC-8

HUC-8	Deficient	Non-Deficient	Not Assessed (Unknown)	Total
Austin-Oyster	1	5	1	7
Bosque	-	1	2	3
Cowhouse	-	-	46	46
Lampasas	-	9	6	15
Leon	4	34	33	71
Little	-	18	25	43
Lower Brazos	-	1	8	9
Lower Brazos-Little Brazos	5	10	31	46
Middle Brazos-Lake Whitney	4	37	49	90
Middle Brazos-Palo Pinto	1	19	4	24
Navasota	2	28	1	31
North Bosque	3	25	17	45
San Gabriel	1	46	3	50
Yegua	1	2	2	5
Total	22	235	228	485

(United States Army Corps of Engineers)

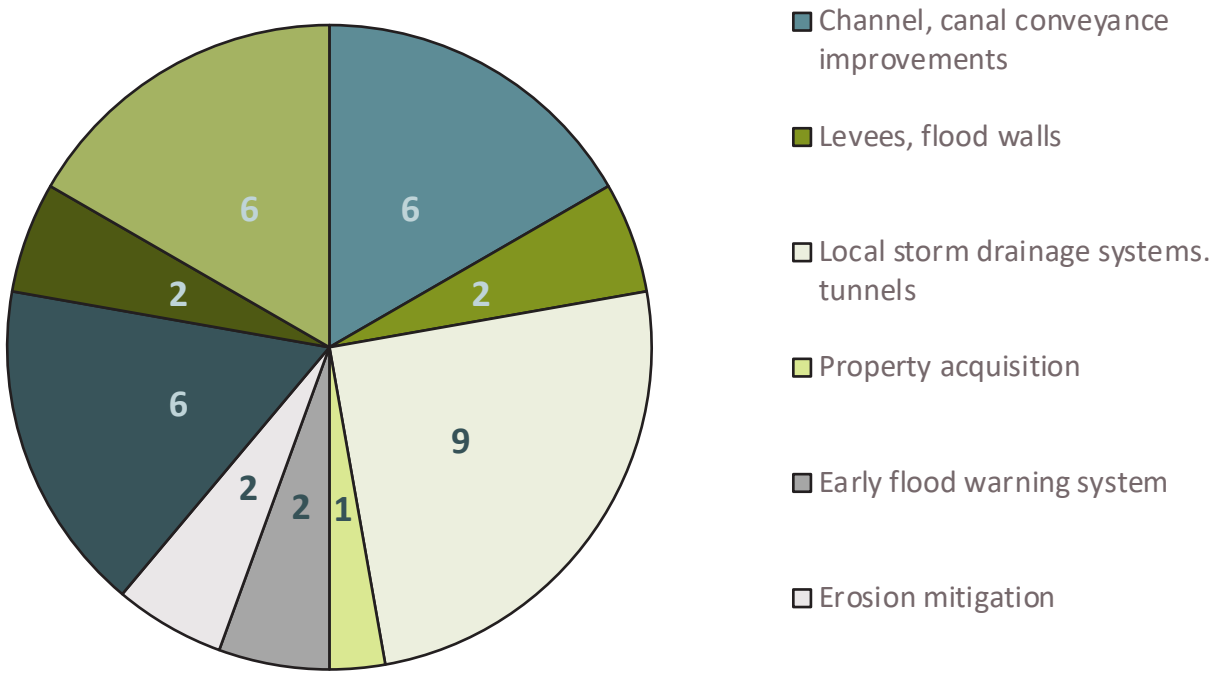
1.4 – Proposed or Ongoing Flood Mitigation Projects

For a thorough flood planning process that considers the flood protection policy and regulatory framework at the local level, it was essential to document the proposed and ongoing flood mitigation projects in the Lower Brazos Planning Region. The data for this section is derived from two primary sources. The first source is the Lower Brazos RFPG – Interest Group Survey, supplemented by direct outreach to interest group contacts. More detailed results are available in the Summary *of* Proposed or Ongoing Flood Mitigation Projects in *Appendix 1.2* and *Map 2* in *Appendix 0*. The second source is existing Hazard Mitigation Plans in the Lower Brazos Planning Region.

1.4.1 Ongoing or Proposed Projects Identified in the Lower Brazos Planning Region's Data Collection Tool

Over 60 communities indicated in the Data Collection Tool that they planned to undertake flood mitigation projects in the coming years. However, there are several gaps in this data set as little data was provided on individual projects. Some communities indicated that they anticipated pursuing a variety of FMPs in the coming years. Almost all the communities responding to the survey question on ongoing or proposed flood management strategies or projects indicated they did intend to pursue more than one type of flood mitigation project. These include projects related to local storm drainage systems, roadway improvements, regional dam improvements, reservoirs and detention areas improvements, sea barriers and revetments, erosion control, and levee improvements. *Figure 1.18* details the distribution of the types of intended flood mitigation projects.

Figure 1.18: Intended Number of Flood Mitigation Projects



(Lower Brazos Basin Community Survey)

Table 1.19 details the frequency with which communities plan on implementing a particular type of flood mitigation. While several project types, like local storm drainage systems and roadway improvements, may be local in nature, many other solutions are more regional in nature, such as regional dams and retention, as well as highway improvements that may involve state agencies.

Table 1.19: Number of Flood Mitigation Projects

Type of Flood Mitigation Project	Number
Channel, canal conveyance improvements	6
Levees, flood walls	2
Local storm drainage systems. tunnels	9
Property acquisition	1
Early flood warning system	2
Erosion mitigation	2
Regional dams, reservoirs, detention, retention basins	6
Roadway and crossing improvements, bridges, culverts	2
Pump station improvements	6
Total	36

(Lower Brazos Basin Community Survey)

These proposed or ongoing flood mitigation projects are derived from survey responses received from communities throughout the basin, including cities, counties, and additional political entities such as levee improvement districts and municipal utility districts. The predominant types of projects being pursued are:

- local storm drainage systems and tunnels
- regional dams, reservoirs, detention, retention basins
- pump station improvements
- channel, canal conveyance improvements

The projects with no interest were nature-based projects, property floodproofing, and sea barriers, walls, and revetments. It is important to note that there may be more ongoing projects than described in the survey since respondents provided information on projects they were pursuing at the time of the survey, but not every ongoing project in the entity. Potential funding sources identified for these projects as part of the RFPG effort include FEMA, Texas General Land Office, Community Development Block Grant-Mitigation, TWDB, and Texas Department of Emergency Management (TDEM), as well as local funding sources from the general fund, taxes, stormwater utility fees, and other fees.

1.4.1.a. Structural Projects under Construction

Information provided in response to outreach efforts is insufficient to provide a complete understanding of structural projects under construction within the entities that responded to the Lower Brazos RFPG –

Interest Group Survey. Entities within Fort Bend County are the only survey respondents that provided information on projects that are under construction. Of the 132 identified proposed or ongoing flood mitigation projects in Fort Bend County, 73 projects reported in the survey have completed the design phase and are in the construction phase.

1.4.1.b. Non-Structural Flood Mitigation Projects Being Implemented

Information provided in response to outreach efforts is insufficient to describe the non-structural flood mitigation projects being implemented within the various entities.

1.4.1.c. Structural and Non-Structural Flood Mitigation Projects with Dedicated Funding

Information provided in response to outreach efforts is insufficient to describe all structural and non-structural flood mitigation projects with dedicated funding. Entities within Fort Bend County are utilizing Hazard Mitigation Grant Program (Hazard Mitigation Grant Program (HMGP)-FEMA/TDEM) funds and FEMA funds.

1.4.1.d. Projects Identified in Hazard Mitigation Plans

In addition to the projects identified in the Lower Brazos Basin Community Survey, the community hazard mitigation plans developed or adopted by communities in the Lower Brazos Planning Region are an essential source of information on future flood mitigation activities. Many non-structural initiatives such as education and citizen awareness, outreach and community engagements, and urban planning and maintenance can be accomplished with lower investment, while an ongoing program of buyouts and acquisitions may be a longer-term and more expensive initiative. Likely, many flood mitigation projects identified by communities have already been completed since the initial hazard mitigation plan was adopted. See Chapter 4 for more details on how projects from Hazard Mitigation Plans were included in the Lower Brazos Planning Region.

1.4.1.e. Potential Benefits of Planned Mitigation Projects

Although most communities did not provide detailed information about their intended projects, there does appear to be substantial awareness of the value of preparing for future flood events. Survey responses and a review of hazard mitigation plans indicate that substantial investment is being made in local drainage, roadway, and flood control infrastructure. Without greater detail regarding the scale, complexity, and location of these projects, it is difficult to quantify the benefit received, but it is anticipated that the inventory of this information will continue to expand in future planning cycles.

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Chapter 2: Flood Risk Analyses

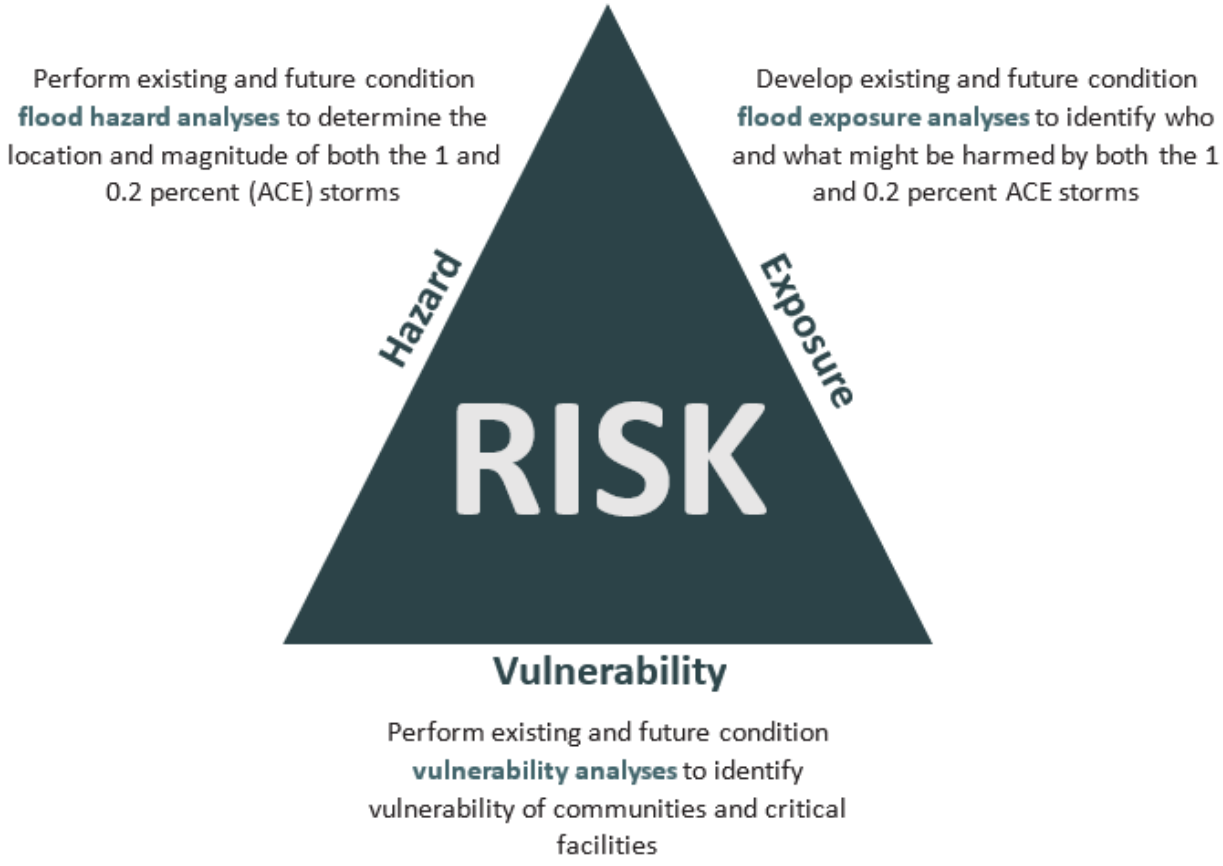
An essential aspect of developing a regional flood plan involves accurately assessing the flood risk. This includes a description of the flood, identifying what is at risk, and estimating the associated impacts. In terms of understanding the environment, the Lower Brazos Regional Flood Plan assessed flood risk for existing and future conditions.

In the Lower Brazos Regional Flood Plan, the existing and future conditions flood risk assessment focused on the following three main components:

1. Flood hazard analyses to determine the location, magnitude, and frequency of flooding,
2. Flood exposure analyses to identify who and what might be harmed within the Lower Brazos Basin; and
3. Vulnerability analyses to identify the degree to which communities and critical facilities may be affected by flooding.

Figure 2.1 below shows the Risk Triangle framework applied to the Lower Brazos Regional Flood Plan Flood Risk Analyses.

Figure 2.1: Flood Risk Analyses Triangle Framework



Task 2A – Existing Condition Flood Risk Analyses

2A.1 Existing Condition Flood Hazard Analysis

The purpose of the existing flood risk analyses was to determine the flood hazard in the Lower Brazos Planning Region to help establish priorities in other tasks in the regional food planning effort. This process contributed toward the general characterization of the Lower Brazos Planning Region's current flood risk and, subsequently, identifying locations at high flood risk and locations with gaps in flood risk data.

2A.1.a. Sufficiency of Existing Conditions for Planning Purposes

In terms of potential flood hazard analysis, existing conditions refer to the hydrologic and hydraulic conditions present when the available data was created. These conditions include current land use, estimated precipitation data, and constructed drainage-related infrastructure. Existing conditions in relation to the Lower Brazos Planning Region do not consider projected changes in rainfall patterns, future land use/population growth, or planned new/improved infrastructure. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) Special Flood Hazard Areas (SFHA) are generally based on existing conditions. The FEMA regulatory SFHA boundaries from these maps are part of the data used for the Lower Brazos Planning Region's existing conditions flood hazard analysis.

Land Use

Land use is an important factor in determining existing conditions flooding limits. It affects the hydrological processes such as evapotranspiration, interception, and infiltration. As urban development (impervious area) is added to a watershed, the hydrologic response is changed, and surface runoff often increases. As demonstrated in Chapter 1, most urban development occurs in the middle and lower portions of the Lower Brazos Planning Region watershed located in Bell, Brazos, Fort Bend, McLennan, and Williamson counties. Land use outside the major population centers within the Lower Brazos Planning Region consists primarily of farming and ranching interspersed with forested areas. Ranching occurs throughout the Lower Brazos Basin, while farming is primarily concentrated in the middle and lower portions of the basin. Localized urban development is primarily confined within city boundaries and the extraterritorial jurisdiction. While not as prolific as urban development, cultivated agricultural and grazed land use still quickens the watershed's response time compared to natural forested ground cover increasing existing flood risk. The rate of development and changes in land use since the initial determination of the flooding limits affect the validity of the analysis for planning purposes. For example, the FEMA's SFHA within the Lower Brazos Basin is based on hydrologic and hydraulic (H&H) analyses performed between the mid-1970s and today. Many older studies may no longer be valid based on land use changes that impact peak flow rates and floodplain inundation limits.

Precipitation

Assessing potential anomalous floods causing precipitation is crucial when planning for existing flood risk conditions. Precipitation, as it relates to flood risk, is commonly analyzed in terms of inches of rainfall that occur within a 24-hour duration. In 1973, the FEMA National Flood Insurance Program (NFIP) set the standard for flood hazard areas based on the 1 percent annual chance exceedance (ACE).

All risk assessments for the State Flood Plan will be based on this recurrence interval in addition to the 0.2 percent ACE. A majority of FEMA's SFHA boundaries within the Lower Brazos Planning Region were developed using hypothetical rainfall data from the *National Weather Service (NWS), Technical Paper No-40/NWS Hydro-35, 1961/1977,* or *The United States Geological Survey Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas, 2004*. Rainfall data was broken down in terms of duration and recurrence interval. In September 2018, National Oceanic and Atmospheric Administration (NOAA) developed updated hypothetical rainfall in Texas based on historical rainfall data in its Atlas 14 study. The NOAA Atlas 14 study results in significant differences between hypothetical rainfall in the lower portion of the Lower Brazos Planning Region's watershed compared to the 1961/1977 and 2004 rainfall data. *Table 2.1* shows the range of rainfall for each data source.

Table 2.1: Lower Brazos Planning Region 1 percent ACE, 24-hour Precipitation

Lower Brazos Watershed	TP40/Hydro 35 Rainfall (inch)	USGS 2004 Rainfall (inch)	NOAA Atlas 14 Rainfall (inch)
Upper Basin	8.8-10.5	8.5-11.0	8.5-11.0
Middle Basin	10.5-12.0	11.0-12.0	11.0-14.0
Lower Basin	12.0-13.5	12.0-14.0	14.0-18.5

Flood Infrastructure

Drainage-related infrastructure is a key element in determining existing conditions of flood risk. Drainage-related infrastructure includes but is not limited to dams, levees, detention/retention ponds, bridges, culverts, low water crossings, tunnels, urban storm drain networks, breakwaters, bulkheads, and revetments. The Lower Brazos Basin has nine dams owned and operated by the United States Army Corps of Engineers (USACE). In addition, the Lower Brazos Planning Region contains nearly 350 Soil Conservation Service minor reservoirs, which control flood waters along the major and minor tributaries. The Brazos River Authority (BRA) owns and operates three reservoirs; however, they are for water supply, not flood control. Many other privately owned and operated dams can also be found in the Lower Brazos Planning Region. There are 16 levee districts within the Lower Brazos Planning Region, with an estimated 59 levee structures protecting flood-prone populations.

While flood control infrastructure mitigates existing flood risk, some older drainage-related infrastructure contributes to flooding. Bridges, culverts, and storm drain systems that were designed and constructed before major land use changes and higher standards were implemented, impound flood water, and overtop during major storm events. The result is increased flood risk to both property and life, which is expanded upon in the existing conditions exposure analysis presented below.

2A.1.b. Existing Hydrologic and Hydraulic Model Availability

Hydrology and hydraulic (H&H) modeling is necessary to determine how water flows over land. It is a crucial element in developing effective flood planning strategies.

Hydrology is the scientific study of the earth's natural water movement with a focus on how rainfall, infiltration, and evaporation affect the amount of flow of water in streams and storm drains. Hydraulics

represents the engineering analysis of the flow of water in streams and infrastructure, such as channels, pipes, and other man-made structures.

Applied since the 1970s, H&H modeling uses computer software applications that simulate the flow of rainfall-runoff over the land to predict the rise of creek, river and lake water levels and potential flooding, as well as test ways to reduce flooding without constructing projects. H&H modeling simulates the flow, frequency, depth, and extent of flooding over land. These models inform decisions about selecting and implementing flood reduction and restoration projects. H&H modeling also satisfies regulatory requirements and ensures that natural, agricultural, and social resources are not damaged by flooding induced by modifications to creeks, rivers, and channels.

Within the Lower Brazos Planning Region's 14 eight-digit Hydrologic Unit Code (HUC)-8 watersheds, hundreds of H&H models were developed for the Lower Brazos Planning Region, spanning from the late 1970s to the present. Most models are associated with detailed effective FEMA floodplains that are available upon request. FEMA has also developed Base Level Engineering (BLE) approximate models, which cover a large portion of the mid-eastern portion of the Lower Brazos basin. BLE models are based on regional regression hydrology and the hydraulic models do not have structures (bridges, culverts, etc.); however, they are based on the latest available Light Detection and Ranging (Lidar) terrain data. This data can be leveraged and supplemented with additional detail as needed for community flood risk needs.

Additional H&H models were also collected from various communities throughout the basin. All the data output from the various modeling efforts was ultimately incorporated through geographic information system (GIS) mapping into the Lower Brazos Planning Region's existing flood hazard layer (floodplain quilt) as described in *Section 2A.1.c. Map 22* in *Appendix 0* shows the model location in the Lower Brazos Planning Region. Many of the models identified for the Lower Brazos Planning Region were created to support the Fort Bend County Master Drainage Plan. This effort created up-to-date 1D/2D models for most of the county. Additional models were sourced from the Sugar Land Master Drainage Plan, which relied heavily on Integrated Catchment Modeling (ICM) to represent the complex storm sewer drainage found throughout the City of Sugar Land.

The cities of Bryan, College Station, Taylor, Stephenville, Waco, and Gatesville were also sources for existing conditions modeling. Although referenced for other purposes, many of the models provided by these entities were focused on generating alternatives for flood hotspots, and subsequently were not intended to provide mapping results. These models were not incorporated into the floodplain quilt. Similarly, models developed by the RFPG under Task 12 efforts were utilized to evaluate potential project alternatives but were not incorporated into the floodplain quilt.

2A.1.c. Best Available Existing Flood Hazard Data

Flooding within the Lower Brazos Planning Region is mostly riverine with coastal influence primarily in Brazoria County to the south, where the area is directly (and frequently) affected by hurricane storms from the Gulf of Mexico. Hurricanes typically fade and downgrade to tropical storms or tropical depressions as they move inland away from the coast. Riverine flooding is mostly from general rainfall

and thunderstorm floods. Flash floods are common from these rainfall events, which can occur within a few minutes or hours of excessive rainfall, exposing millions of dollars in valuable public and private property to flood risk. The largest risk from flash flooding is to people driving across low water crossings, which has resulted in many fatalities within the Lower Brazos Planning Region and across the state. A portion of the Lower Brazos Planning Region lies in the flash flood alley of Texas. *Figure 2.2* shows reported and documented flood events by the county as well as the location band of the flash flood alley.

Even though riverine and coastal-based flooding is the dominant types of flooding in the Lower Brazos Basin, urban flooding data was evaluated for inclusion in the existing floodplain quilt where available. Urban flooding (off-floodplain, pluvial, or surface flooding) is caused by intense local precipitation running-off impermeable surfaces such as paved streets, sidewalks, and structures that overwhelms local drainage systems and overflows small waterways. Consequently, the water may enter buildings and other properties. This flooding often occurs in locations such as historic downtown areas and residential neighborhoods, which either predate floodplain maps and higher design standards or have land use patterns such as urban sprawl.

Existing flood hazard mapping estimation is based on using current land use and precipitation data to estimate hydrologic condition parameters and discharges. This is then used to simulate water surface elevations to create existing floodplain mapping extents.

The TWDB compiled the most current existing flood hazard mapping data from multiple sources to create a comprehensive, single, coherent, continuous quilt of the best available existing floodplain for the Lower Brazos Planning Region. The compiled mapping data was the 1 percent and 0.2 percent annual chance exceedance (ACE) data. The existing floodplain quilt data was then updated with data from FEMA, USACE, United States Geological Survey, and local communities where available.

The primary data sources comprising the existing floodplain data for the Lower Brazos Planning Region are described below:

- Regulatory FEMA Floodplain Data
- Base Level Engineering Data
- TWDB Cursory Floodplain Data
- Local Data Submitted by Entities
- Flood-Prone Areas Related to Reservoirs and Levees

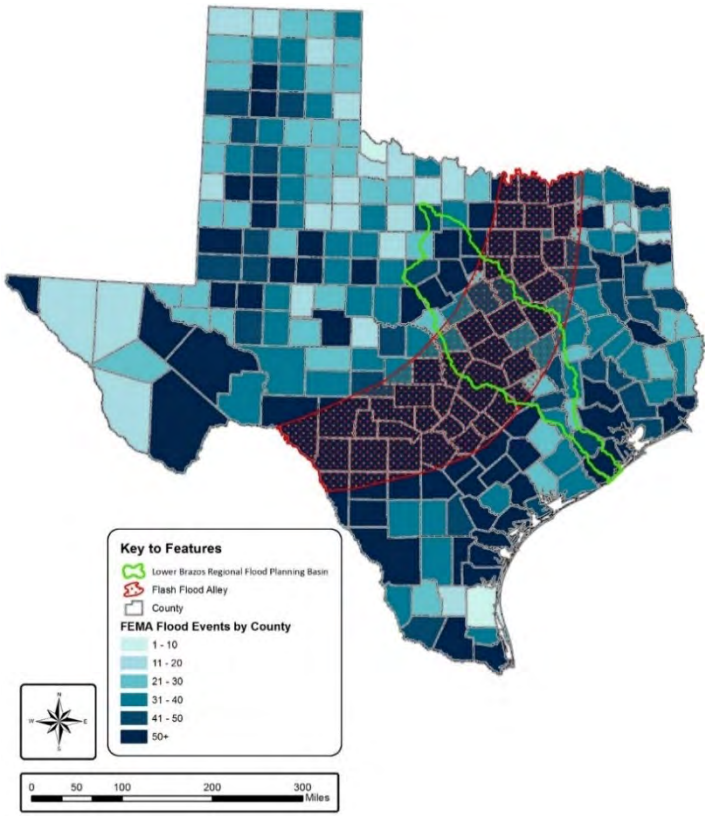
Regulatory FEMA Floodplain Data

The FEMA Flood Insurance Rate Maps (FIRMs) include flood zones that form the basis of regulatory floodplain management for communities and mandatory flood insurance requirements for structures in the mapped special flood hazard area (SFHA) floodplain. A wide range of FEMA data was used in the Lower Brazos Planning Region, including effective FEMA maps, detailed and approximate study areas, and pending and preliminary FEMA maps that will not become effective for several months. However, priority was given heavily to effective, detailed maps. Approximate data was only used when critical to maintain continuous stream connectivity in the mapping.

One Percent Annual Chance Storm Events Floodplains

On FIRMs, FEMA maps both the 1 percent and 0.2 percent ACE flood events. Floodplain data developed for the Lower Brazos Planning Region included only the 1 percent and 0.2 percent ACE events to describe the flood hazards and perform the exposure and vulnerability analyses.

Figure 2.2: Flash Flood Alley



(FEMA/NOAA Storm Data, 1996 – 2019)

The 1 percent ACE has a one in a hundred chance of being equaled or exceeded in any given year and an average recurrence interval of 100 years. Also referred to as the SFHA or 100-year flood, this boundary is mapped as a high-risk flood area subject to a 1 percent or greater annual chance of shallow flooding in any given year, where shallow flooding is usually in the form of ponding or sheet flow with average depths between 1 to 3 feet. Along the coast, these high-risk areas are associated with velocity wave action. In the Lower Brazos Planning Region, coastal wave action only affects Brazoria County. The 1 percent ACE flood areas may also be susceptible to erosion, deposition, and mudflow. It is sometimes referred to as the "Base Flood." It is the national standard used by the NFIP and other Federal agencies to regulate development and require the purchase of flood insurance.

0.2 Percent Annual-Chance Floodplains

The 0.2 percent ACE flood has a 0.2 percent chance of occurring in any given year and is also referred to as the 500-year flood. The 0.2 percent ACE flood refers to areas of moderate flood risk that are not

considered to be in immediate danger from flooding caused by overflowing rivers; areas in the 1 percent ACE with average depths less than 1 foot or with drainages areas less than 1 square mile. It also refers to areas protected by levees from the 1 percent ACE. The 0.2 percent ACE areas are also referred to as Non-Special Flood Hazard Areas (NSFHA).

Other Floodplain Data – FAFDS, BLE, and Cursory Floodplain Data

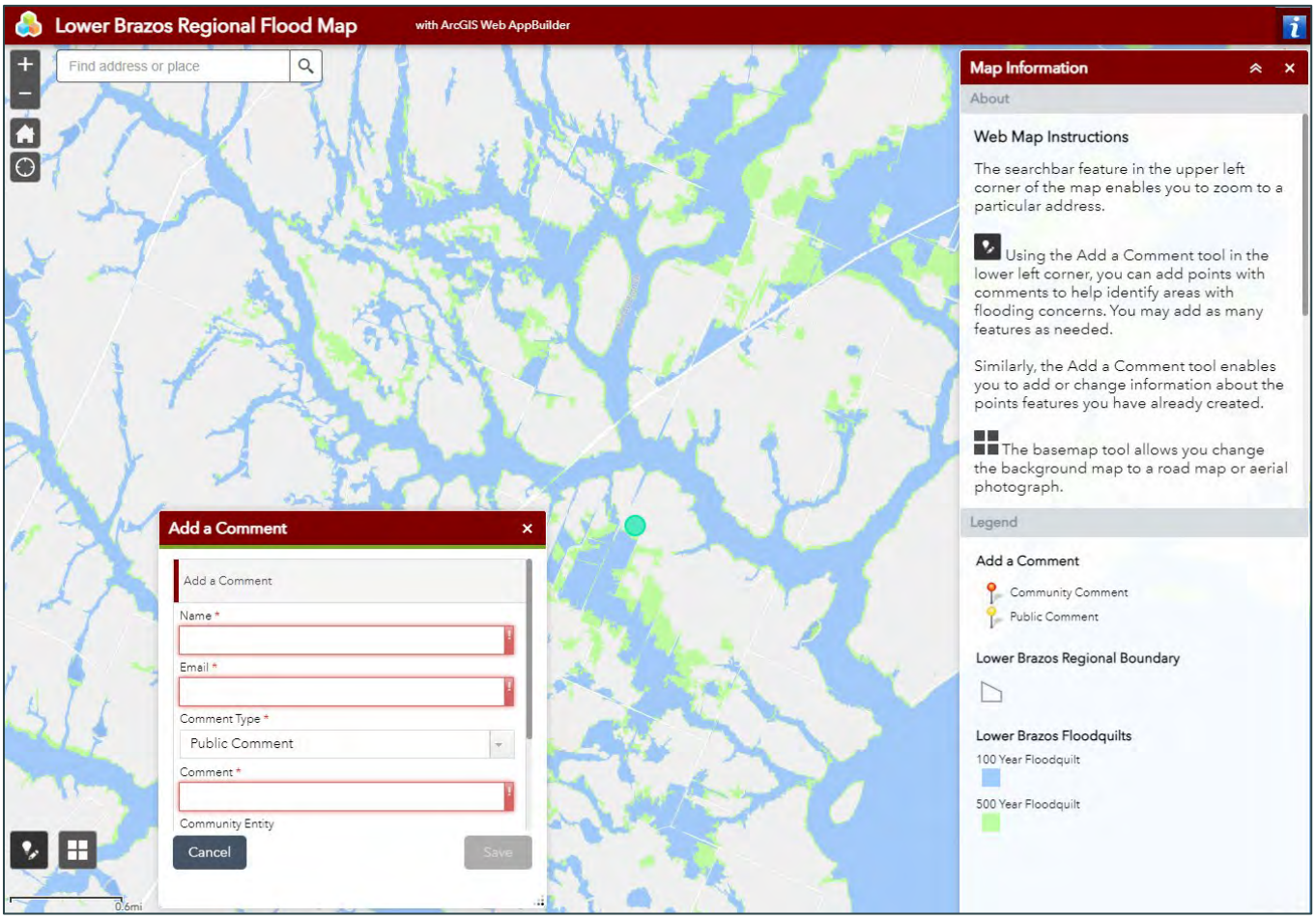
The First American Flood Data Services (FAFDS) represents where only paper-based FEMA data was available and digitally converted. The FAFDS data was not used within the Lower Brazos Planning Region primarily due to age; it was replaced with Cursory Floodplain Data. The FEMA and TWDB's Base Level Engineering study data that produces model-backed approximate studies on a HUC-8 wide level was leveraged to revise the existing floodplain quilt.

The TWDB provided modeled flood data from the 2021 Cursory Floodplain Data set to be used where applicable. The data was developed by a research group, Fathom, at the University of Bristol, England. The cursory data has been peer-reviewed and was found appropriate for use in this initial planning effort. The model is a two-dimensional (2D) hydraulic framework developed at a national scale on 30-M Digital Elevation Models (DEMs). The results have been mapped on 10 feet Lidar for Texas to create statewide flood depth rasters for fluvial, pluvial, and coastal mapping for the 1 percent and 0.2 percent ACE events as well as other frequencies. The fluvial, pluvial, and coastal flood depth rasters from the Cursory Floodplain Data for the Lower Brazos Basin were mosaicked together with the greatest depth where the datasets overlap. The combined rasters were processed into flood polygon boundaries using guidance provided by the TWDB. The Cursory Floodplain Data served as a supplemental dataset for inclusion in the existing flood boundaries; it was primarily used to replace FEMA approximate mapping.

Regional Data Collection and Possible Flood-Prone Areas

A regional online data collection website was created as an outreach tool to work closely with regional entities (counties, municipalities, state and federal agencies, or political subdivisions with flood-related authorities) to gather local flood-risk information. A web mapping application on the data collection tool enabled entities to document other possible flood-prone areas not previously identified as mapped flood hazard areas; this can be seen in *Figure 2.3.* The webmap was available from March 24, 2022 to April 29, 2022 to receive community input. During this timeframe, several public meetings were conducted throughout the Lower Brazos Planning Region to collect data on areas of historic flooding, roads that are frequently overtopped, and past flood claims hot spots.

Figure 2.3: Interactive Flood Map



The Lower Brazos Planning Region's Technical Consultant Team, led by Halff Associates, also collected data related to areas subject to inundation from reservoirs and levee inundation areas. The Natural Hydrography Dataset indicates lake areas subject to flooding, while the United States Army Corps of Engineers has a dataset that indicates leveed areas prone to flooding; these publicly available resources were utilized where available. Data submitted to the Regional Flood Planning Group (RFPG) through the online data collection tool was also added. Cities, counties, entities with flood control responsibilities, and the general public had the opportunity to submit data to the RFPG.

The Technical Consultant Team led by Halff Associates weaved the existing conditions floodplain quilt together using the best available flood hazard data. The existing conditions floodplain quilt was presented at the Lower Brazos RFPG meeting on January 27, 2022, and posted to the Lower Brazos RFPG website for public review and comment on March 24, 2022. The deadline for community, county, entity, and public review and comment on the existing conditions floodplain quilt was April 29, 2022. The various data sources received were compiled according to the TWDB's ranking hierarchy, as shown in *Table 2.2*. The data ranking was based on a quality and coverage extent relative to other datasets. *Appendix 2A.3* shows the floodplain data sources by location developed for the Lower Brazos Planning Region.

Table 2.2: Floodplain Quilt Data Ranking

Ranking	Data Category	Source
1	Local Community Submitted Data	Various Entities
2	National Flood Hazard Layer (NFHL) Pending (Detailed and Approximate Studies)	FEMA
3	NFHL Effective (Detailed Study Only)	FEMA
4	BLE	FEMA
5	Cursory Floodplain Data	TWDB
6	NFHL Effective (Approximate Study Only)	FEMA

Source: The TWDB Technical Guidelines for the Regional Flood Planning and Lower Brazos RFPG Input

The compiled existing floodplain quilt data for the Lower Brazos Planning Region is included in the submittal GIS database layer named "ExFldHazard." *Map 4* in *Appendix 0* shows a GIS coverage map of the comprehensive existing flood hazard layer compiled for the Lower Brazos Planning Region, showing the 1 percent and 0.2 percent ACE floodplains.

The total floodplain area for each county and associated percentage distribution within the Lower Brazos Planning Region are also displayed in *Appendix 2A.1, Figure 2A-2,* and *Table 2A-1.*

To ensure there was no confusion on the purpose and content of the floodplain quilt when displayed to the public through the online webmap or in-person meetings, the following disclaimer was used:

"The floodplain quilt is a compilation of data from multiple sources and is intended to approximate the extent of existing flood risk in the Lower Brazos Region. This data layer is for planning purposes only and is not to be used for any regulatory activities. For regulatory floodplain maps, contact your local floodplain administrator or visit the FEMA Map Service Center at https://msc.fema.gov/portal/home"

Overall, the Lower Brazos Planning Region covers a total land area of approximately 23,400 square miles, with about 22 percent (5,000 square miles) in the existing conditions, 1 percent and 0.2 percent ACE floodplains. Brazoria County has the largest amount of land and the highest percentage of land within the 1 percent and 0.2 percent ACE floodplains. This is due to the county's proximity to the Gulf Coast, where there is relatively flat terrain and coastal flooding coupled with riverine flooding from the Brazos River. Conversely, Fayette and Travis counties have less than 5 square miles within the Lower Brazos Planning Region, resulting in 0 percent of their land within the Lower Brazos Planning Region being in the floodplain.

2A.1.e. Flood Data Gaps

Once the best available comprehensive existing flood data was compiled, data gaps were assessed to identify any remaining areas where flood inundation boundary mapping was missing, lacked modeling or mapping, used outdated modeling or mapping, or had prepared more accurate topographic data since the last map update.

The key factors that were referenced to identify these gaps were:

- counties with no modernized data since the completion of the FEMA Map Modernization initiative
- areas with effective data that is more than 10 years old
- areas where Cursory Floodplain Data was used
- counties significantly impacted by NOAA Atlas 14 rainfall data.
- areas that contain BLE or FEMA NFHL detailed floodplain boundaries were not considered data gaps

The validation status (whether a stream model was new or has updated engineering) was determined, when possible, for the associated H&H models supporting the mapped floodplains using the contributing engineering factors listed earlier. For example, Brazoria, Austin, Waller, and Washington counties located in the southern portion of the Lower Brazos Planning Region were greatly affected by the NOAA Atlas 14, meaning the effective floodplain information is outdated. Due to this, these counties are being reported as data gaps. Fort Bend County, also in the southern portion of the Lower Brazos Planning Region, has new flood risk mapping based on a recent study incorporating Atlas 14 rainfall data. Model-backed (H&H) detailed stream study flood data varied in age and conformance to current technologies, even for modernized county-wide FIRMs. In the urban areas, a large percentage of the H&H model data is outdated (HEC-2 or not in digital format), with only a few models revised recently (HEC-RAS, XPSWMM, etc. and in digital format).

The gap area data is included in the GIS database in a layer named "Fld_Map_Gaps." *Map 5A* in *Appendix 0* shows the identified flood data gaps' locations. Additional detailed data gap maps are shown in the appendices.

While areas were identified within the floodplain quilt as data gaps with outdated information, the compiled existing floodplain quilt still comprised the best available flood hazard datasets for the Lower Brazos Planning Region and was used for the flood risk analysis. Further evaluation of these data gaps for inclusion in Flood Management Evaluations (FMEs) is discussed in Chapter 4.

2A.2 Existing Condition Flood Exposure Analysis

Flooding is common in the Lower Brazos Planning Region (Shown in *Figure 2.2*). Flooding can become a significant hazard when it inundates the built environment and causes direct damage to buildings, critical facilities, crops, or significant injuries and sometimes death to people. Flooding frequency and intensity have been increasing in recent years, often necessitating state and federal relief, which has risen to record levels. The existing condition flood risk exposure analysis leveraged the compiled existing conditions 1 percent and 0.2 percent ACE events in the Lower Brazos Planning Region to determine existing flooding exposure to buildings, critical facilities, and agriculture. Results from the flood exposure analysis were utilized to estimate the impact on socially vulnerable populations or communities discussed in *2A.3 Existing Condition Vulnerability Analysis*.

2A.2.a. Existing Development within the Floodplain

A region-wide inventory of buildings, population, critical facilities, utilities, and agriculture was conducted to assess who and what is at risk. Existing development data leveraged for the Lower Brazos Planning Region came from several data sources. The Homeland Infrastructure Foundation Level Data (HIFLD) and data from the TWDB were the sources of critical facilities data. The Texas Department of Transportation (TxDOT) bridge inventory and roadway data were also used. The TWDB provided building data in November 2021 with the associated population and Social Vulnerability Index (SVI) estimates, which were confirmed and updated where additional information was available.

The 2021 TWDB building dataset was built on available Lidar information (2010 to 2021), Microsoft Artificial Intelligence Version 2 data, and 2021 Open Street Map (OSM) buildings. The 2019 LandScan USA dataset from Oak Ridge National Laboratory (ORNL) was utilized to estimate the population per building for both day and night. The 2018 Centers for Disease Control and Prevention (CDC) SVI dataset was applied at the census tract level.

The 2020 Texas Cropland Data layer was developed by the United States Department of Agriculture (USDA) National Agricultural Statistics Service. The bridge and roadway asset inventory data came from the 2020 TxDOT dataset. Communities and interest groups within the Lower Brazos Planning Region also provided data via the online collection tool.

Results of the detailed analyses of exposure to development within the existing floodplain are presented in *Sections 2A.2c – 2A.4*.

2A.2.b. Proposed and Ongoing Flood Mitigation Projects

Throughout the Lower Brazos Planning Region, ongoing projects have already received design and construction funding and are set to be implemented before the completion of the State Flood Plan. These projects were identified through multiple avenues, including the Flood Infrastructure Fund (FIF) tracking website which was one source used to identify project status. Passed by the Legislature and approved by Texas voters through a constitutional amendment, the FIF program provides financial assistance in the form of loans and grants for flood control, flood mitigation, and drainage projects. Similarly, projects recently funded through mechanisms such as the Community Block Development Grant or Hazard Mitigation Grant were identified as ongoing projects.

Additional proposed and ongoing projects were identified through pre-existing knowledge of flood mitigation efforts throughout the Lower Brazos Planning Region. Through this avenue, two dam projects currently under final design and a study on the potential impact of Lake Limestone on the Navasota River were identified as being underway in the Lower Brazos Planning Region. A tabular report of the proposed or ongoing projects, set to be complete before the installation of the state flood plan, is provided in *Table 2A-2* of *Appendix 2A.1*.

Upper Brushy Creek WCID Projects

In the Upper Brushy Creek Water Control and Improvement District (WCID), several projects were identified from the 2016 Flood Protection Plan and the 2020 Dam Assessment Study to mitigate flooding and ensure aging flood infrastructure continues to perform as intended. These projects are in various

stages of evaluation, design, and construction. Of these, two are currently under design and expected to complete construction before the conclusion of the inaugural Regional Flood Planning cycle.

The Dam 14 project, located in Round Rock, Texas, will utilize several methodologies to repair and rehabilitate the dam on Meadow Lake. These improvements will include fixing cracks in the dam crest, flattening the dam slope to reduce erosion, and refining the auxiliary spillway. The implementation of this project will reduce flood risk in the immediate vicinity of the dam, as well as along the downstream Chandler Branch Tributaries. This project is expected to undergo construction beginning in late 2022 and wrap up in 2023.

The Dam 101 Project is another major effort currently under design in the Upper Brushy Creek WCID. This project is one of three known together as the Lake Creek Flood Mitigation Projects. Also located in the greater Round Rock area, the project aims to construct a new dam along Lake Creek just east of the intersection of IH-45 and FM 620. This mitigation effort is estimated to provide benefits extending approximately five miles downstream of the construction and reduce flood risk to over 1,000 residents, as well as provide better access for emergency vehicles during storm events. Construction is expected to begin in the winter of 2022 and wrap up by the spring of 2025.

Navasota River Study

Another major, ongoing effort impacting the Lower Brazos Planning Region is a study being performed jointly by the Institute for a Disaster Resilient Texas and Texas A&M University. This study is investigating flooding along the Navasota River, downstream of Lake Limestone to the confluence with the Brazos River. Modeling efforts are underway to simulate various changes within the watershed and analyze their effects on flooding along the Navasota River. Results, and associated recommendations based on the conclusions of this effort, are expected to be available in 2023.

2A.2.c. Flood Exposure Due to Existing Levees or Dams

Flood exposure identifies what is at risk due to extreme flooding. This refers to the people, buildings, businesses, infrastructure systems, and associated functions that could be lost to a flood hazard (*FEMA, 2017*). Exposure also refers to the economic value of assets subject to the flood hazard. This section discusses flood exposure due to levees and dams in the Lower Brazos Planning Region.

Levees in the Lower Brazos Planning Region

There are an estimated 59 levees in the United States Army Corps of Engineers (USACE) National Levee Database (NLD) in the Lower Brazos Planning Region. These levees are built parallel to rivers, streams, creeks, and their tributaries as well as lakes and along the coast to protect them from certain levels of flooding. About 68 percent of the levees can be found in the southern portion of the Lower Brazos Planning Region in Austin, Brazoria, Fort Bend, and Waller counties. The remaining 32 percent are scattered throughout the Lower Brazos Planning Region, with a noticeable gap in the western portion.

Levees can be breached during flood events due to overtopping, toe scour, seepage/piping, and foundation instability. The resulting torrent can quickly inundate a large area behind the failed levee with little or no warning, exposing them to extreme flooding effects and consequences.

Levee accreditation is FEMA's recognition that a levee is reasonably certain to contain the base (1 percent annual chance storm events) regulatory flood. To help communities understand the risk behind levee structures, FEMA applies levee accreditation information on FIRMs to show the locations with reduced risks from the regulatory flood event. Approximately 37 percent of the levees in the Lower Brazos Planning Region are accredited. See *Map 3* in *Appendix 0* for the location of deficient levees in the Lower Brazos Planning Region.

On FIRMs, FEMA shows areas mapped behind accredited levees as "Areas with Reduced Risk Due to Levee." When the levee is not accredited, the embankments are categorized as hydraulic significant structures. The area behind the landward side of the levees is not considered to be protected from any flood event and, consequently, exposed to flooding.

USACE leveed-area floodplain data and FEMA's "Areas with Reduced Risk Due to Levee" datasets were incorporated into the existing floodplain quilt dataset for the Lower Brazos Planning Region as "Other Flood-Prone Areas." This data set was primarily added to show potential flood hazards on the landward side of levees.

Levee Exposure Assessment

There are almost 200,000 people who live and work behind the levees in the Lower Brazos Planning Region. A detailed levee exposure analysis describing the populations that would be impacted by levee failure is provided in *Table 2A-3* in *Appendix 2A.1*. The exposure summary was estimated by overlaying the leveed areas within the Lower Brazos Planning Region's existing floodplain quilt with population data. The exposure analyses assumed that even the accredited levee systems might be subject to internal flooding, ponding, and/or structure failures. Hence, exposure assessments include structure and population counts behind the accredited levees under flood-prone areas, as shown in the TWDB-required *Table 3* in *Appendix 2A.2*.

Fort Bend and Brazoria counties have by far the most exposure with respect to levees.

Dams in the Lower Brazos Planning Region

In the Lower Brazos Planning Region, dams and their associated reservoirs are primarily used for water supply, recreation, navigation, electric generation, irrigation, and flood control. According to the USACE National Inventory of Dams and the Texas Commission on Environmental Quality (TCEQ), there are nearly 500 dams in the Lower Brazos Planning Region. Most of these are used for flood control, water supply, recreation, and agriculture.

Dams with flood-related capacity keep floodwaters impounded and either release them in controlled amounts downstream to the river below or store and divert water for other uses. Contrary to this, dams used only for water supply, recreational, and agricultural purposes do not have a dedicated flood control pool to retain runoff from flood events and pass-through runoff from flood events. As such, areas lying adjacent to or downstream of dams are exposed to flooding during flood events and potential consequences if a dam breaks or fails.

The dams in the Lower Brazos Planning Region are 53 years old on average. Dams that are owned and operated by large entities are regularly maintained. However, dams owned and operated by smaller entities or private landowners may need inspections and/or rehabilitation as funding for such activities is often more costly than the property owners can afford.

While FEMA does not show downstream dam breach inundation extents on maps, such data may be available as non-regulatory products in some flood risk projects. The TCEQ requires dam breach inundation mapping for certain dams.

Dam Flowage Easement

Flowage easements are perpetual rights governing areas delineated around a dam, typically owned by government agencies such as the USACE. The dam flowage easements grant these agencies the right to release water from the reservoir under their operation, even if it floods privately owned land. Additionally, the easements grant them the right to prohibit the construction of, or maintenance of, any improvement(s) for human habitation and to approve any other structures constructed on the included property. The purpose of establishing these lines is to identify and protect personal property that would likely be flood-prone during a flood event. These boundaries, therefore, assist in estimating buildings and population affected in areas subject to dam inundation within the Lower Brazos Planning Region. FEMA also shows these flowage easements lie along reservoirs on its FIRMs.

Dam Exposure Assessment

For the Lower Brazos Planning Region's dam exposure analysis, dam inundation areas based on flowage easements were overlaid on buildings and population to estimate the associated hazard potential. The complete dam exposures analysis is provided in *Appendix 2A.1*. *Map 3* in *Appendix 0* shows the locations of the dams classified as non-functional or deficient in the Lower Brazos Planning Region according to the State Regulatory Dams TCEQ 2021 Reports.

There are approximately 800 people who live around the dams in the Lower Brazos Planning Region that fall within the USACE flowage easement. According to *Table 2A-4* in *Appendix 2A.1*, high dam exposures are prevalent in Eastland and Palo Pinto counties.

The State of Texas does not regulate development in high-hazard areas immediately adjacent to or downstream of dams. Many developers purchase properties with small livestock dams classified as low-hazard dams and develop property around lakes and downstream of the dams, creating additional risk. Continued growth in rural areas will result in changes to hazard classification for dams that current residents may not be aware of. Chapter 8 explores recommendations that could help mitigate these issues and reduce flood risk throughout the region.

2A.2.d. Existing Conditions Flood Exposure

This section of the Lower Brazos Regional Flood Plan discusses and summarizes the results of the existing condition flood exposure to existing development. The existing conditions flood exposure analysis considered buildings, population, public infrastructure, critical facilities, roadway crossings, and agricultural areas exposed to the compiled existing conditions floodplain quilt. This section excludes

flood exposure for levees and dams and only applies to the existing conditions of 1 percent and 0.2 percent ACE flood mapping extents in the Lower Brazos Planning Region's floodplain quilt.

Buildings, Critical Facilities, Infrastructure, and Agriculture Exposure Totals by County

For this planning cycle, flood exposure analysis estimated the structure count of buildings, critical facilities, roadway crossings, roadway segments, and agriculture areas potentially exposed to existing flooding by overlaying the existing conditions floodplain quilt developed for the Lower Brazos Planning Region. *Map 6* in *Appendix 0* shows the total number of buildings, critical facilities, low water crossings, and agriculture areas exposed to the existing floodplain quilt. A summary of this information is displayed in *Table 2.3*. The highest counts by far are in Brazoria and Fort Bend counties due to their proximity to the coast and significant populations. The rest of the Lower Brazos Planning Region shows moderate exposure counts.

Table 2.3: Summary of Existing Flood Risk

Flood Risk	Number of Structures	Population	Miles of Roadway	Roadway Crossings	Agricultural Area (sq mi)	Number of Critical Facilities
1 percent ACE	63,060	129,890	3,300	7,500	840	190
0.2 percent ACE	107,720	261,930	4,430	7,800	950	330

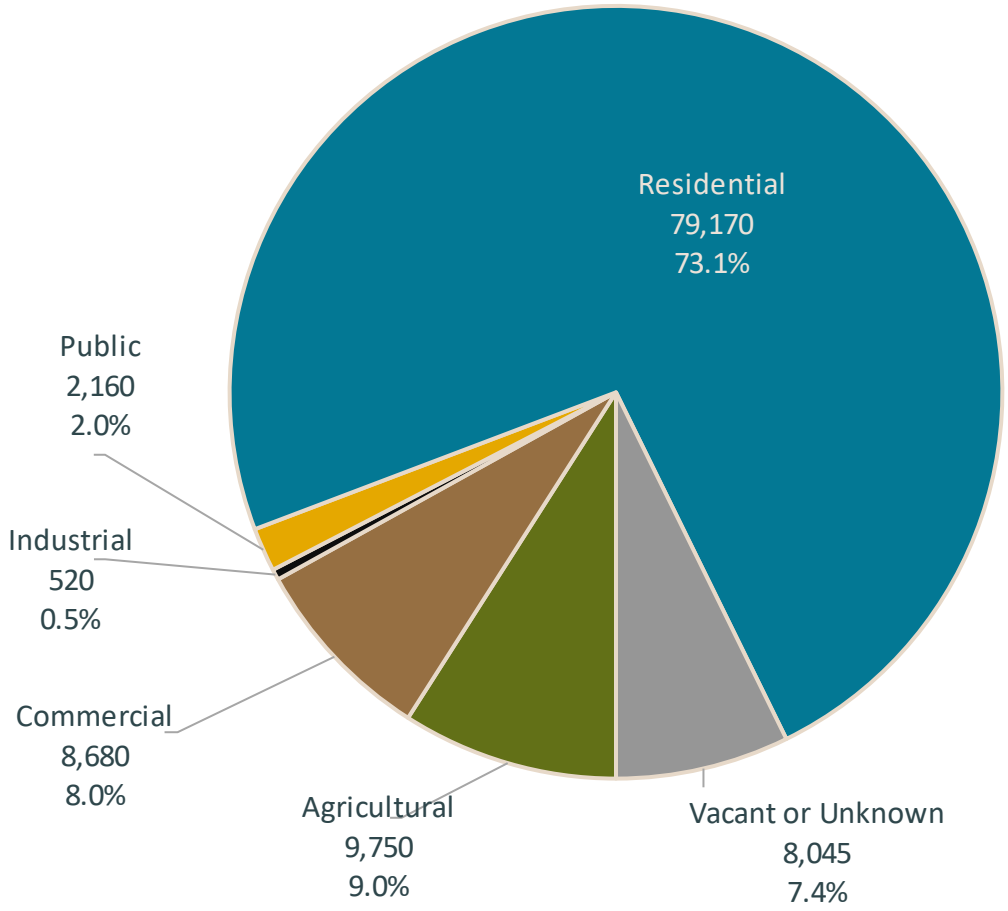
Population Totals by County

Population data (day and night) attributed to the associated buildings and critical facilities was used to summarize the county-wide population exposed to the existing conditions floodplain quilt. The higher of the day or night population was used for the exposure population estimated by county; this can be seen in *Appendix 2A.1 Figure 2A-2*.

Similar to structural risk, high population exposures are primarily concentrated in Fort Bend and Brazoria counties. However, there is also significant risk throughout the Waco area in McLennan County. Due to the population count being higher than the day or night numbers, these numbers assume the worst possible scenario where the maximum number of people present are exposed to the existing floodplain quilt.

Regional building data collected for the Lower Brazos Planning Region was classified into two main categories: residential and non-residential. As shown in *Figure 2.4*, for the structures at the existing 1 percent or 0.2 percent ACE flood risk, around 73 percent are residential buildings, while the remaining 27 percent are non-residential. Buildings classified as vacant are structures for which the building type and/or use could not be determined. Agricultural buildings include any structure used to operate a farm or ranch or process and sell their products.

Figure 2.4: Distribution of Structures at Risk of Flooding by Structure Type



Residential Structures

Residential structure data used in the Lower Brazos Planning Region included single-family homes, townhomes, mobile homes, and multi-family residences like apartments and condominiums. Approximately 892,000 residential building footprints were gathered for the Lower Brazos Planning Region, and an estimated 9 percent of these buildings were exposed to flooding. *Figure 2A-3 Appendix 2A.1* provides graphical representations of the total estimated number of residential structures by county exposed to the existing floodplain quilt. Fort Bend and Brazoria counties have the highest number of residential structures in the floodplain by a wide margin; however, McLennan and Williamson counties also had significantly more at-risk residential structures than the rest of the counties.

Archer, Bastrop, Brown, Callahan, Fayette, and Travis counties show very little residential building exposure because only a very small portion of these counties are within the Lower Brazos Planning Region, most of which are their respective unincorporated areas. Several other largely rural counties also have low numbers of at-risk residential structures.

Non-Residential Structures

Non-Residential inventory data also included agricultural, commercial, industrial, and public buildings. Over 492,000 non-residential building footprints were gathered for the Lower Brazos Planning Region and 6 percent of these buildings are exposed to flooding. The total estimated number of non-residential structures by county exposed to the existing floodplain quilt can be seen in *Figure 2A-4* in *Appendix 2A.1*.

McLennan and Waller counties have over 1,000 agricultural structures, while Brazoria, Fort Bend, and McLennan counties all have more than 1,000 commercial structures at flood risk. Similar to the residential structure analysis, counties with little area within the Lower Brazos Planning Region had low numbers of non-residential structures at flood risk.

Critical Facilities and Public Infrastructure

A critical facility provides services and functions essential to a community, especially during and after a disaster. Critical infrastructure includes all public or private assets, systems, and functions vital to the security, governance, public health and safety, economy, or morale of the state or the nation (*TWDB, 2021*). Critical facilities data for the Lower Brazos Planning Region include fire stations, hospitals, nursing homes, police stations, emergency shelters, schools (Kindergarten through 12th grade), water and wastewater treatment facilities, TCEQ wastewater outfalls, water supply systems (well sites), and superfund sites. Lifeline utility systems data such as petrol storage tanks, power generating plants, as well as natural gas and electric transmission lines were collected for exposure analysis. Critical facilities data were from the TWDB, TCEQ, Railroad Commission of Texas, HIFLD, as well as data from Lower Brazos Planning Region communities.

The existing floodplain quilt was overlaid on the data gathered for critical facilities to estimate the flood exposures. *Appendix 2A.1, Figures 2A-5* provides the total counts of exposed critical facilities to the existing floodplain quilt in the Lower Brazos Planning Region. Over 4,850 critical facilities data were identified for the Lower Brazos Basin and an estimated 6 percent of these facilities are exposed to flooding.

Brazoria and Fort Bend counties in the southern portion of the Lower Brazos Planning Region and McLennan County in the central portion have the highest number of critical facilities with potential flood risk. For Brazoria and Fort Bend counties, this is due to their proximity to the coast, while the risk associated with McLennan County is primarily due to the higher concentration of structures.

Roadway Crossings and Roadway Segments

Transportation line data (roadways and railroads) from TxDOT was used to estimate road and railways crossings at risk of flooding. A combination of available flood depth information from BLE and Cursory Floodplain Data, as well as bridge deck elevation from Lidar data, was used to estimate flood exposure of the road and railroad bridges at stream crossings. Low Water Crossing (LWC) data provided by Lower Brazos Planning Region communities and the TWDB was also used to identify exposed road and railway crossings.

There are over 5,100 low water crossings in the Lower Brazos Planning Region. *Table 2A-5* in *Appendix 2A.1* shows the low water crossing exposure totals per county. Additionally, the miles of road segment exposed to the existing floodplains per county are provided in *Figure 2A-6 Appendix 2A.1*. Fort Bend, Brazoria, and McLennan counties have the highest mileage exposures. However, the distribution of low water crossings differs from many other metrics. Williamson and Bell counties have the highest number of low water crossings, which are more common in the Hill Country portion of the Lower Brazos Planning Region.

Agricultural Area

Crops and livestock data used in the Lower Brazos Planning Region was obtained from the 2020 Texas Cropland Data layer developed by the United States Department of Agriculture (USDA) National Agricultural Statistics Service. In the Lower Brazos Basin, the increasing population continues to have a significant influence on the continued loss of working lands, changing ownership sizes, and land values. This occurs particularly within or in surrounding urban centers like the Waco Metroplex. Large sections of the southern portion of the basin face similar challenges because of development from the neighboring Houston-Galveston area. (*Texas Land Trends, 2022*).

Crops and livestock exposed (dollar exposure from production) to flooding are documented in *Table 2A-6* in *Appendix 2A.1***,** which summarizes estimated exposure values in dollars to the existing floodplain quilt by county. The 2020 FEMA National Risk Index (NRI) data was leveraged to show the value of crops and livestock exposed to flooding. The FEMA NRI uses data from the 2017 USDA CropScape and the Census of Agriculture to document the value of exposed crops and livestock. The CropScape data in dollars was used to calculate crop and livestock production value density per county. The county value is divided by the county's total crop and livestock land area to find its dollar value density (shown in *Equation 2.1*).

Equation 2.1: County Crop and Livestock Value Density

$$AgValueDen_{Co} = \frac{AgValue_{Co}}{AgArea_{Co}}$$

where:

- $AgValueDen_{Co}$ is the crop and livestock value density calculated at the county level (in dollars per square mile)
- $AgValue_{Co}$ is the total crop and livestock production value of the county, as reported in the 2017 Census of Agriculture (in dollars)
- $AgArea_{Co}$ is the total crop and livestock production area of the county (in square miles)

The crop and livestock areas exposed to flooding were determined by overlaying the existing floodplain quilt. Each county's crop and livestock value losses were then calculated as the product of the crop and livestock production value density per county and the associated crop and livestock areas exposed to flooding from the existing conditions floodplain. The value of crop and livestock (production) areas in dollars and exposed areas square miles to the existing floodplain quilt in the Lower Brazos Planning Region can be found in *Appendix 2A.1, Table 2A-6*. Comanche, Falls, McLennan, Milam, and Robertson counties have more than $10,000,000 of agricultural land at a 1 percent annual chance event flood risk. Many of these counties have high densities of agricultural land, making them susceptible to flooding impacts. Fayette and Travis counties had no agricultural exposure in the Lower Brazos Planning Region (less than 1 percent of the land area is in the Lower Brazos Planning Region). The area of exposed agricultural area per county is provided in *Appendix 2A.1, Figure 2A-7*.

2A.2.e. Expected Loss of Function

Severe flood events can result in a loss of function for a community's infrastructures, impacting the systems supported by the infrastructure. The impacts can include disruptions to life, business, and public services that can be essential to a community during and after a flood event. Infrastructure that becomes inundated during flooding events is often non-functional during the event and through the recovery process.

A spatial analysis was conducted in GIS using the best available data and the existing conditions floodplain quilt to generate qualitative estimates of the expected loss of function for the Lower Brazos Planning Region. Metrics were developed to understand the expected loss of function of structures, transportation, health services, water supply, water treatment, utilities, energy generation, and emergency services during a 1 percent ACE. *Table 2A-7* in *Appendix 2A.1* summarizes the results of the expected loss of function analysis for each county within the Lower Brazos Planning Region.

Inundated Structures

Residential structure data used in the Lower Brazos RFPG included single-family homes, townhomes, mobile homes, and multi-family residences like apartments and condominiums. Based on the existing flood exposure analysis detailed above, an estimated 42,650 residential buildings are in the 1 percent annual chance storm event floodplain and potentially lose function during and after storm events. An approximate population of 130,000 is estimated to be exposed to the risk of flooding with loss of function of their residences. Loss of function of residential structures can result in content loss and displacement of residents.

Non-Residential inventory data also included over 28,500 buildings that are exposed to flooding. These buildings are subject to a potential loss of function during storm events and the recovery process. Loss of function of non-residential structures can result in content and inventory loss, potential relocation, and loss of short-term shelters. These impacts all contribute to operating losses for businesses.

Transportation

Transportation line data (roadways and railroads) from TxDOT was used to estimate road and railways crossings at risk of flooding. Based on the existing flood exposure analysis presented above, over 7,000 roadway crossings and 4,000 miles of roadway are at risk in the Lower Brazos Planning Region.

These roadway crossings will likely become impassable and result in a loss of function during significant storm events. The impassable roadways can cause issues for emergency responders and motorists traveling on the roadways. During significant storm events, debris buildup can cause conveyance loss at bridges and exacerbate the risk of road crossings with higher flood waters overtopping the roadways and the potential for debris to overtop the roadway.

Health and Human Services

Health and human services include hospitals, nursing homes, and other services to enhance the health and well-being of the public. Based on the spatial analysis, nine hospitals and 33 nursing homes or assisted care facilities are located within the existing floodplain. Potential loss of function can occur during a flood event for these services due to their location within the floodplain. The loss of function of health and human services can result in loss of available beds, displacement of patients, and a potential loss in the quality of care. Fort Bend County has the highest number of hospitals and nursing homes within the existing floodplain.

Water Supply

Floods can contaminate water supply sources such as wells, springs, and lakes/ponds through polluted runoff laden with sediment, bacteria, animal waste, pesticides, and industrial waste and chemicals. Drinking water wells have the potential to become contaminated during major flooding events, requiring disinfection and cleanup. The TCEQ's Public Water Supply dataset shows 1,957 public water supply wells in the Lower Brazos River Basin, with 351 in the floodplain. Therefore, 18 percent of the public water supply wells in the Lower Brazos River Basin are potentially exposed to flood risk.

Water and Wastewater Treatment

Flooding has the potential to impact water and wastewater treatment facilities and reduce the effectiveness of the facilities. Failure of water and wastewater treatment systems due to flooding may consist of direct losses such as equipment damage and contamination of pipes as well as indirect impacts such as disruption of clean water supply. In the Lower Brazos Planning Region, 300 wastewater outfalls are located within the floodplain. The wastewater treatment facility is likely nearby the outfall and could be within the floodplain resulting in potential flood risk and loss of function.

Energy Generation

The potential failure of power generation plants due to flooding can cause direct losses such as equipment damage and indirect impacts to surrounding facilities due to loss of power. Five power plants are located within the floodplain and potentially have a loss of function during a flood event. The power plants are located throughout the Lower Brazos River Basin, with three located in Bosque County, one in Palo Pinto County, and one in Fort Bend County.

Emergency Services

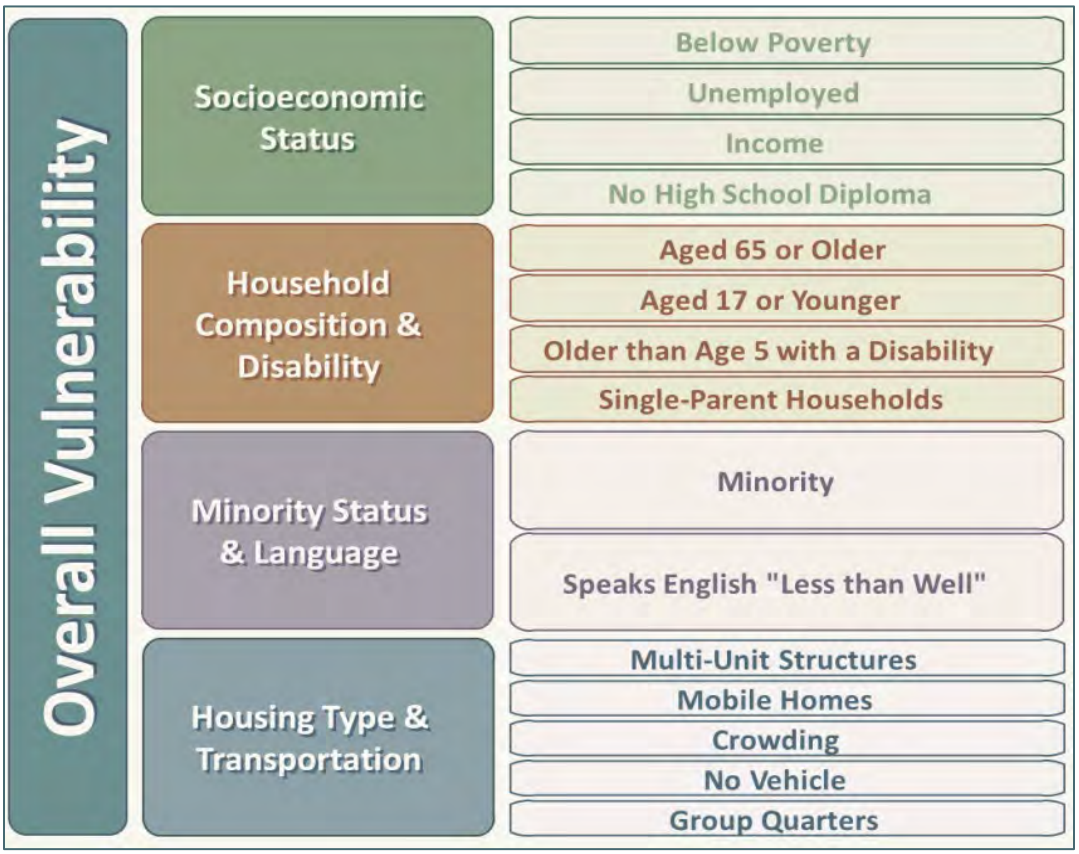
Flood events can disrupt emergency services, causing delays in response times and hindering access to areas such as shelters or locations of emergencies. There are 35 fire stations within the floodplain and they could experience a loss of function during a flood event. A total of 54 emergency shelters are within the floodplain, which could limit access to the facilities in the event of a flood.

2A.3 Existing Condition Vulnerability Analysis

Vulnerability is an assessment of the potential negative impact of the flood hazard on communities and a description of the impacts. This task uses the data from the existing flood exposure analysis to determine the vulnerability of exposed structures and populations to flooding. The existing condition vulnerability analysis uses the 2018 Social Vulnerability Index (SVI) data developed by the U.S Centers for Disease Control and Prevention (CDC). The CDC calculates the SVI at the census tract level within a specified county using 14 social factors, including poverty, housing, ethnicity, and vehicle access, and groups them into four related themes: socioeconomic status, household composition, race/ethnicity/language, and housing/transportation.

Figure 2.5 shows the CDC themes used for SVI calculation. Each census tract receives a separate ranking for each of the four themes and an overall ranking.

Figure 2.5: CDC Vulnerability Metrics



Source: CDC (*https://svi.cdc.gov/Documents/Data/2018_SVI_Data/SVI2018Documentation.pdf*)

2A.3.a. Vulnerabilities of Structures, Agricultural Areas, Bridges, Low Water Crossings, and Critical Facilities

The 2018 CDC Social Vulnerability Index (SVI) data was overlaid with the Lower Brazos Planning Region's buildings, critical facilities, bridges, low water crossings, and agricultural areas to attribute their associated SVI values. The SVI values for all the buildings, critical facilities, agricultural areas, bridges, and low water crossings exposed to the existing conditions floodplain quilt are summarized by county averages and provided in *Appendix 2A.1, Figure 2A-8.*

A community's SVI score is proportional to a community's risk. Social vulnerability is a consequence enhancing risk component and community risk factor that represents the susceptibility of social groups to the adverse effects of natural hazards like floods, including disproportionate death, injury, loss, or disruption of livelihood (FEMA, 2021). An SVI score and rating represent the relative level of a community's social vulnerability compared to all other communities, with a higher SVI score resulting in a higher risk index score (FEMA, 2021)

The analysis shows Fort Bend County has the lowest SVI score in the Lower Brazos Planning Region but has the second-highest number of critical facilities at flood risk. This is primarily due to the higher median incomes across the county and the significant presence of flood mitigation infrastructure boosting the ability of communities within Fort Bend County to respond during a risk event. However, as indicated by the distribution of critical facilities at flood risk, a low SVI does not mean a community has no flood risk. The TWDB considers a threshold of 0.75 as an indicator for highly vulnerable areas. Only Waller County reaches this threshold in the Lower Brazos Planning Region at the county level. *Map 7* in *Appendix 0* shows the county-wide average distribution of SVI with regard to the exposed critical facilities in the Lower Brazos Planning Region. Waller, Somervell, Robertson, Limestone, Grimes, Falls, Eastland, and Brazoria counties all had SVI scores greater than or equal to 0.50.

2A.4 Summary of Existing Conditions Flood Exposure Analysis and Vulnerability

The existing flood risk, exposure, and vulnerability for the Lower Brazos Basin are summarized in *Table 2.3*. As the data shows, Brazoria and Fort Bend Counties experience higher exposure than the majority of the Lower Brazos Region due to a combination of dense population and proximity to both coastal and riverine flooding exposure. McLennan County also trends towards high flood exposure, especially centered around the Waco metropolitan. Conversely, several counties such as Archer, Brown, Callahan, and Fayette, have neglible area and flood exposure in the Lower Brazos Region. Much of the Lower Brazos Region is rural and does not have large numbers of flood exposed population or infrastructure. However, flooding in these areas could cause significant damage by harming farming and ranching land that much of the region uses to generate revenue.

Appendix 2A.2 Table 3 provides the existing flood exposure and vulnerability analysis results per county as outlined in the Technical Guideline for Regional Flood Planning. A geodatabase with applicable layers as well as associated TWDB required maps and figures are provided as digital data.

Task 2B – Future Condition Flood Risk Analyses

The RFPGs were tasked with considering the flood risk change over the Lower Brazos Planning Region. Future condition flood risk analyses considered projected increases in flood hazard areas and the additional people and property exposed.

2B.1 Future Condition Flood Hazard Analysis

The purpose of the future condition flood hazard analysis was to identify the future condition flood hazard area based on a projected increase in impervious cover, anticipated change in rainfall patterns, anticipated change in relative sea level and/or land subsidence, anticipated sedimentation in flood control structures, and other factors that may result in increased or altered flood hazards in the future. Flood exposure and vulnerability analyses were performed based on the future conditions flood hazard layer. Future Condition Flood Hazard areas are shown on *Map 8* in *Appendix 0*.

2B.1.a. Future Conditions Based on "No Action" Scenario

The future conditions flood risk analysis performed for this plan was based on a 30-year "no-action" scenario. This scenario includes continued population growth, current regulations, land use and development trends, potential increases to flood risk from sea level rise, and changes in rainfall patterns. Flood mitigation projects recommended in this plan are not incorporated into the future conditions analysis. The analysis is to be used for planning purposes only and is not intended for regulatory purposes.

Population Growth

Population projections were developed by watersheds (HUC-10) and sub-basins (HUC-8) using the earlier decades of the 50-year county and Water User Group (WUG) population projections developed for the 2022 State Water Plan. The Brazos (Region G) and Region H Water Planning Region overlap the Lower Brazos Flood Planning Region. Although some WUGs cross watersheds and sub-basins, the population projections used in this analysis only correspond within the Lower Brazos Planning Region. The 2022 State Water Plan projects population within the Lower Brazos Planning Region is projected to grow by 51 percent, or 1,448,481 people, from 2020 to 2050. Population projections for each WUG in the Lower Brazos Planning Region can be found in *Appendix 2B.1, Table 2B-1,* and a summary of growth region-wide is shown in *Table 2.4.*

Table 2.4: Population Projections

Region	2020	2030	2040	2050	Percent Growth
Lower Brazos	2,822,674	3,290,547	3,757,180	4,271,155	51%

Anticipated Future Development

The future conditions analysis included distributing projected population growth spatially within the Lower Brazos Planning Region. The TWDB provided population projections at the WUG Level, the same level used in the State Water Plan. The process of deciding where anticipated development would occur

Figtook into consideration regional infrastructure, undeveloped land, natural features, existing flood risk, jurisdictions, and current development trends. The input factors were combined using local knowledge to represent how likely new development could occur throughout the Lower Brazos Planning Region.

Future development was distributed within each WUG based on the following factors (in priority order):

- proximity to recent developments
- proximity to existing developments
- proximity to interstates and highways
- proximity to major local thoroughfares
- proximity to planned highways and local thoroughfares
- wetlands
- flood hazard areas
- areas within city limits or extraterritorial jurisdictions (ETJ)

Future development was restricted in the following areas:

- existing floodways
- existing parks, cemeteries, airports, golf courses
- government-owned land
- existing railroad right of way
- existing road right of way
- existing developments

The 2020 Census informed anticipated population densities, as shown in *Table 2.5*. The high population density was assigned to existing urban centers. Medium-density was used for all areas within 3 miles of existing urban centers (suburbs). Low density was used for the remaining area in the Lower Brazos Planning Region (rural areas).

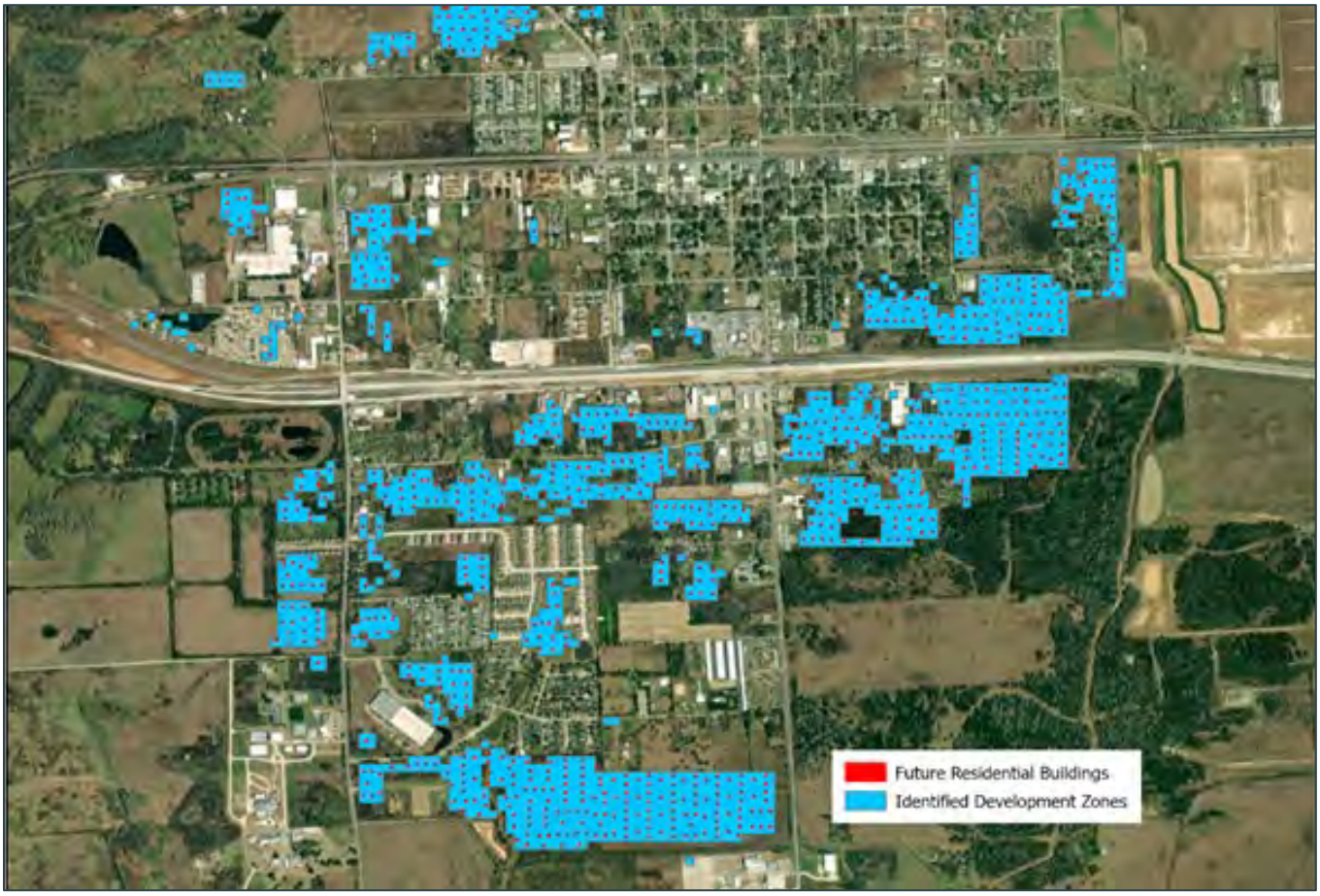
Table 2.5: Approximate Future Population Densities

Population Density	People per Acre
High	20
Medium	12
Low	6

Future development was distributed within each WUG, beginning with the most desirable areas as determined by the factors listed above until all was anticipated population assigned. In heavily developed WUGs, population growth often exceeded land available to develop; in these scenarios, the population over the WUG capacity was transferred to the closest “County-Other” WUG. Areas anticipated to be developed were divided into individual parcels based on population densities from the areas of people per household determined in the 2020 Census. A single residential structure was created at the center of each parcel for inclusion in the future conditions flood risk exposure analysis.

Figure 2.6 illustrates the outcome of the process; the zones identified as potential future development and the predicted layout of residential structures can be seen in this figure. The shaded area follows typical development patterns. Undeveloped land near the major thoroughfares and pockets of vacant land within the city has developed, and additional land on the edge of the existing urban area has also been developed. The shaded areas were then divided into potential future structures based on the population associated with the development.

Figure 2.6: Sample Area of Anticipate Future Development



Sea Level Rise

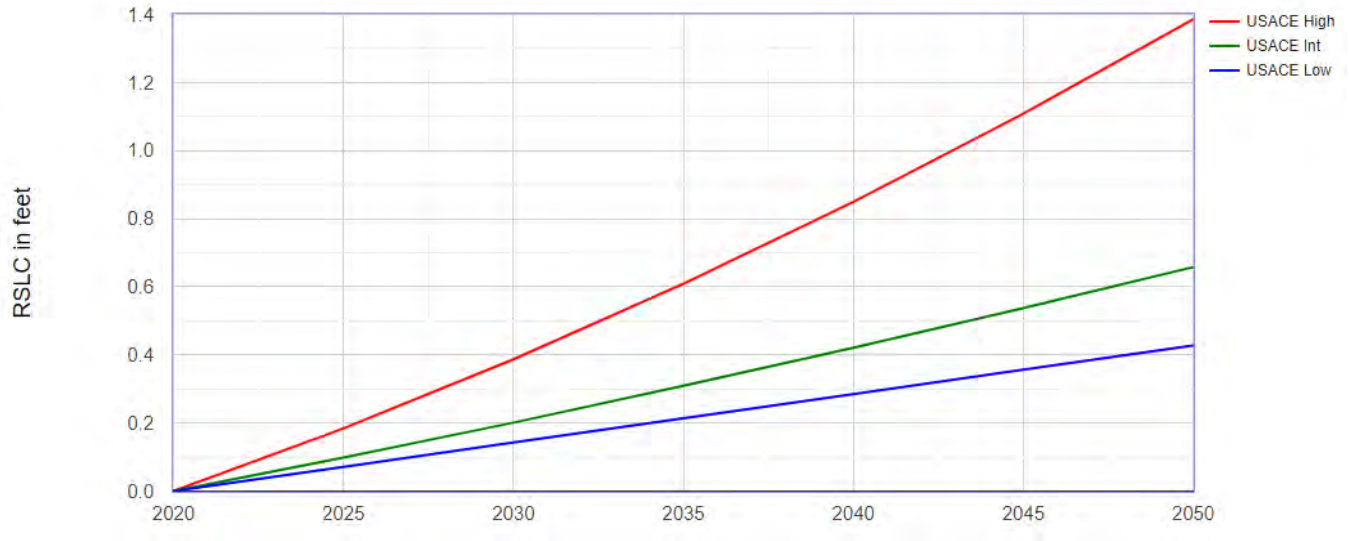
Sea Level Rise (SLR) is an on-going phenomenon where the relative ocean elevation is increasing and encroaching on coastal areas. The Texas State Climatologist, Dr. Nielsen-Gammon, has analyzed the historical SLR and shown that the relative SLR increases at approximately 4.43 millimeters per year (0.44 feet in SLR over 30 years) in the Freeport, Texas measurement station.

The USACE has also developed a tool to calculate the approximate sea level rise for a "high," "intermediate," and "low" scenario (Figure 2.7). The rate computed for the "high" scenario builds from the most recent Intergovernmental Panel on Climate Change (IPCC) and modified National Research Council (NRC) projections for a high rate of SLR. In Galveston Bay, the approximate "high" SLR projected by USACE over the next 30 years is 1.4 feet of SLR. The rate computed for the "intermediate" scenario

builds from the most recent Intergovernmental Panel on Climate Change (IPCC) and modified National Research Council (NRC) projections for a moderate rate of SLR.

In Galveston Bay, the approximate "intermediate" SLR projected by USACE over the next 30 years is 0.66 feet of SLR. The rate computed for the "low" scenario builds from historic rates of SLR to determine the low rate of SLR. In Galveston Bay, the approximate "low" SLR projected by USACE over the next 30 years is 0.43 feet of SLR. The "intermediate" scenario (0.66 feet of SLR) is the recommended estimation of SLR over the next 30 years.

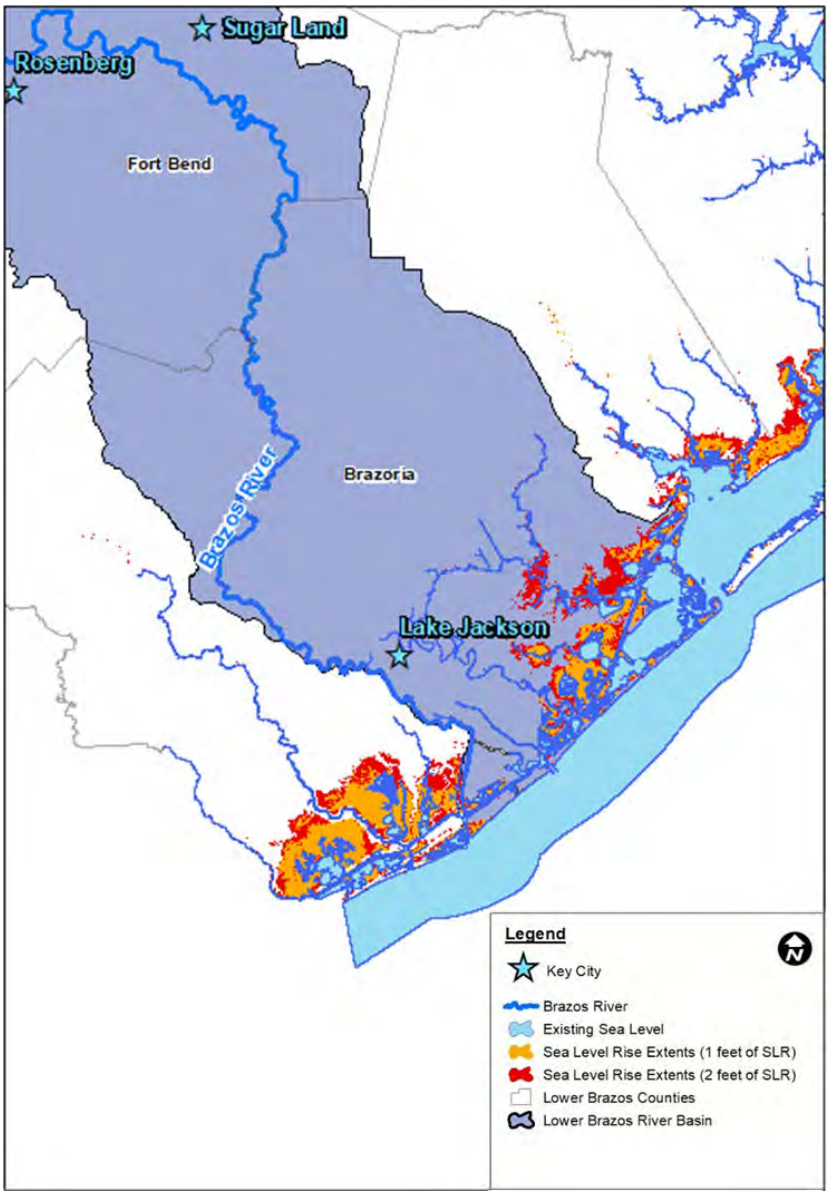
Figure 2.7: Estimated Sea Level Rise in Freeport, Texas from 2020 - 2050



(USACE, 2021)

GIS was used to visualize the influence of SLR from both the intermediate and high scenarios to the Lower Brazos River Basin. *Figure 2.8* shows the influence of SLR in the Lower Brazos River Basin caused by a rise of 1 and 2 feet higher than the Intermediate Scenarios from USACE. The extent of SLR shown in *Figure 2.8* provides a visual reference of the influence of SLR in the Lower Brazos River Basin even though the SLR shown is higher than the predicted values from USACE. While the influence of SLR appears to be localized to the outlet of the Lower Brazos River Basin, the impacts of this rise cannot be neglected. For more information, Sea Level Rise Viewer from NOAA (https://coast.noaa.gov/slr/) can be utilized to visualize the sea level rise, potential coastal flooding impact areas, and relative depths. The influence of SLR on the future conditions of flood hazards should be considered in planning efforts and continuously monitored as additional data becomes available in the coastal areas of the Lower Brazos River Basin.

Figure 2.8: Approximate Influence of Sea Level Rise on the Lower Brazos River Basin



(NOAA, 2022)

Subsidence

Subsidence is the gradual lowering of the ground elevation that can result from changing groundwater levels or increases in sediment loadings. GPS stations are currently monitoring subsidence within the Lower Brazos River Basin near the Gulf Coast, operated by the Harris-Galveston Subsidence District, Fort Bend Subsidence District, University of Houston, Lone Star Groundwater Conservation District, Brazoria County Groundwater Conservation District, Texas Department of Transportation, and other local entities. Land subsidence can occur due to aquifer compaction, drainage of organic soils, underground mining, natural compaction, sinkholes, and thawing permafrost.

Actual land subsidence varies spatially. While the areas near the Gulf Coast have shown to experience subsidence at higher rates, areas further inland tend to show little to no subsidence and do not consider it a concern. The Southern Trinity Groundwater Conservation District, located in the middle portion of the Lower Brazos River Basin, states that subsidence is unlikely to occur in the district, and the aquifers have little potential for compaction and subsidence due to groundwater withdrawals. Looking toward the coastal areas of the Lower Brazos River Basin, historical subsidence has been observed from 1906-2000, with areas in the Lower Brazos Planning Region experiencing subsidence from 1 to 5 feet (*Figure 2.9*).

Future subsidence estimates show further lowering of land within the Lower Brazos River Basin by 2050 (*Figure 2.10*) and range between 1 and 2 feet of additional estimated subsidence. While the area within the Lower Brazos River Basin impacted by subsidence is localized to the coastal areas, long-term monitoring and management of groundwater resources are recommended for future planning to control and prevent further land subsidence.

Figure 2.9: Actual Subsidence in Feet: 1906-2000 (Geodetic Survey Contour Interpretations)

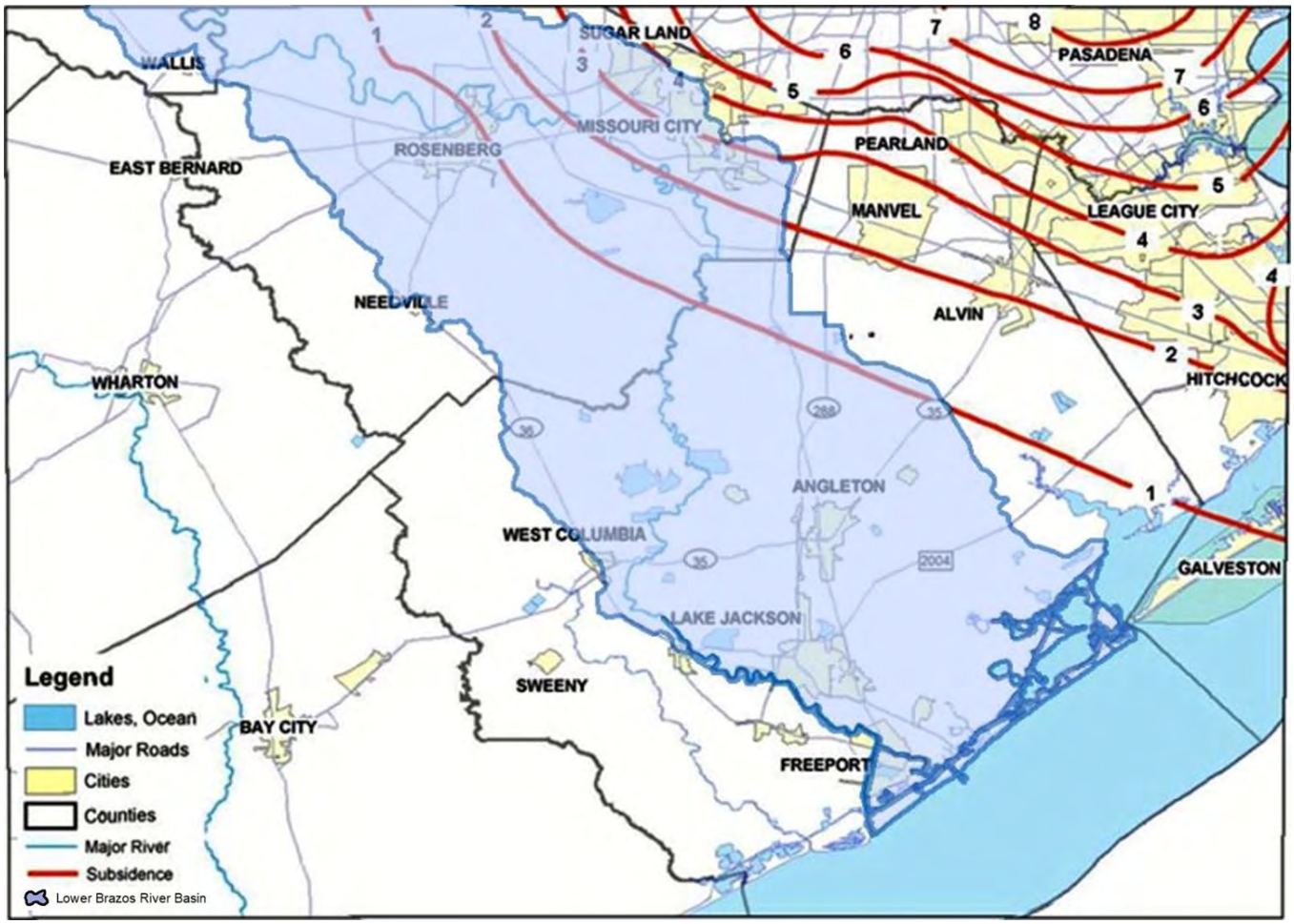
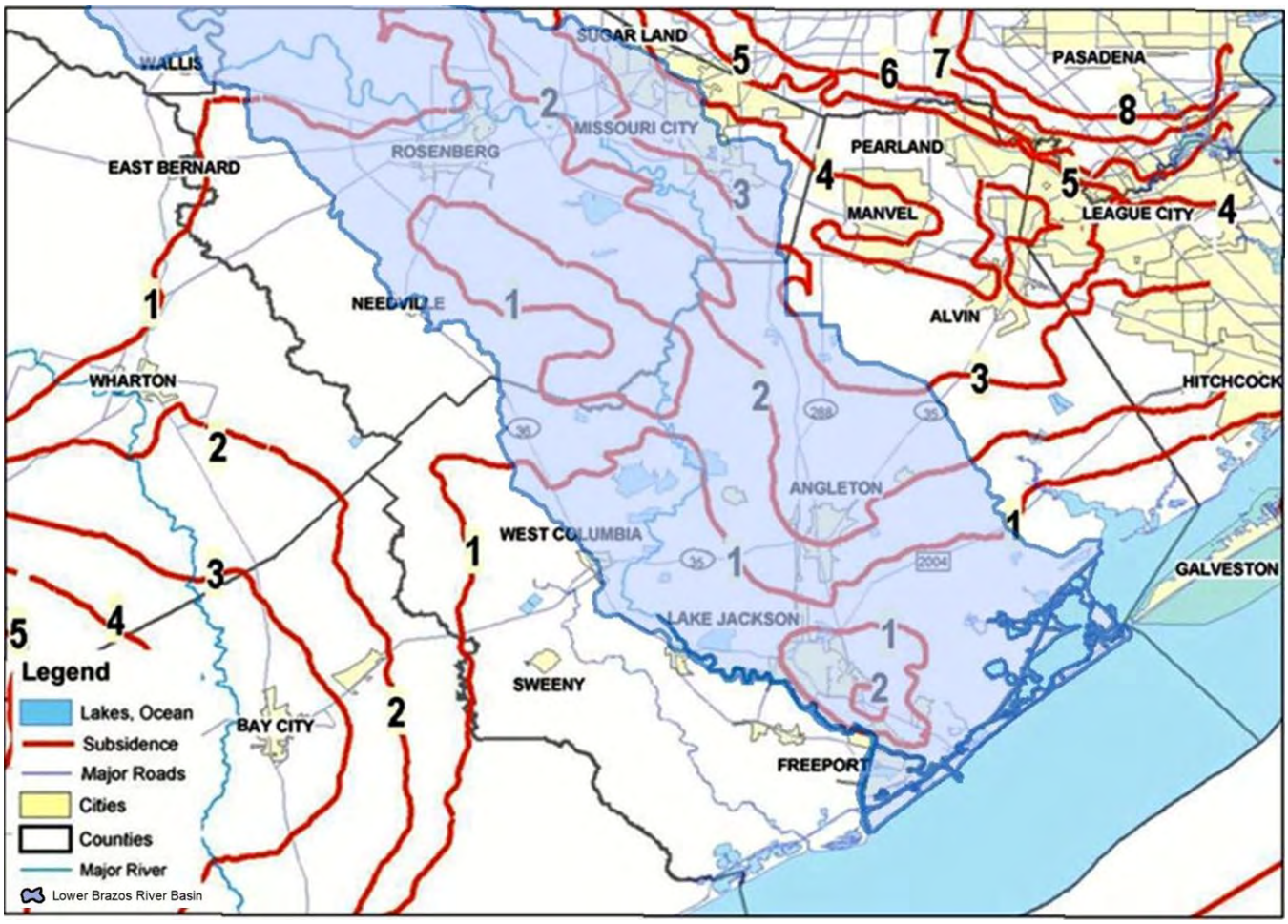


Figure 2.10: Projected Subsidence in Feet: 1906-2050

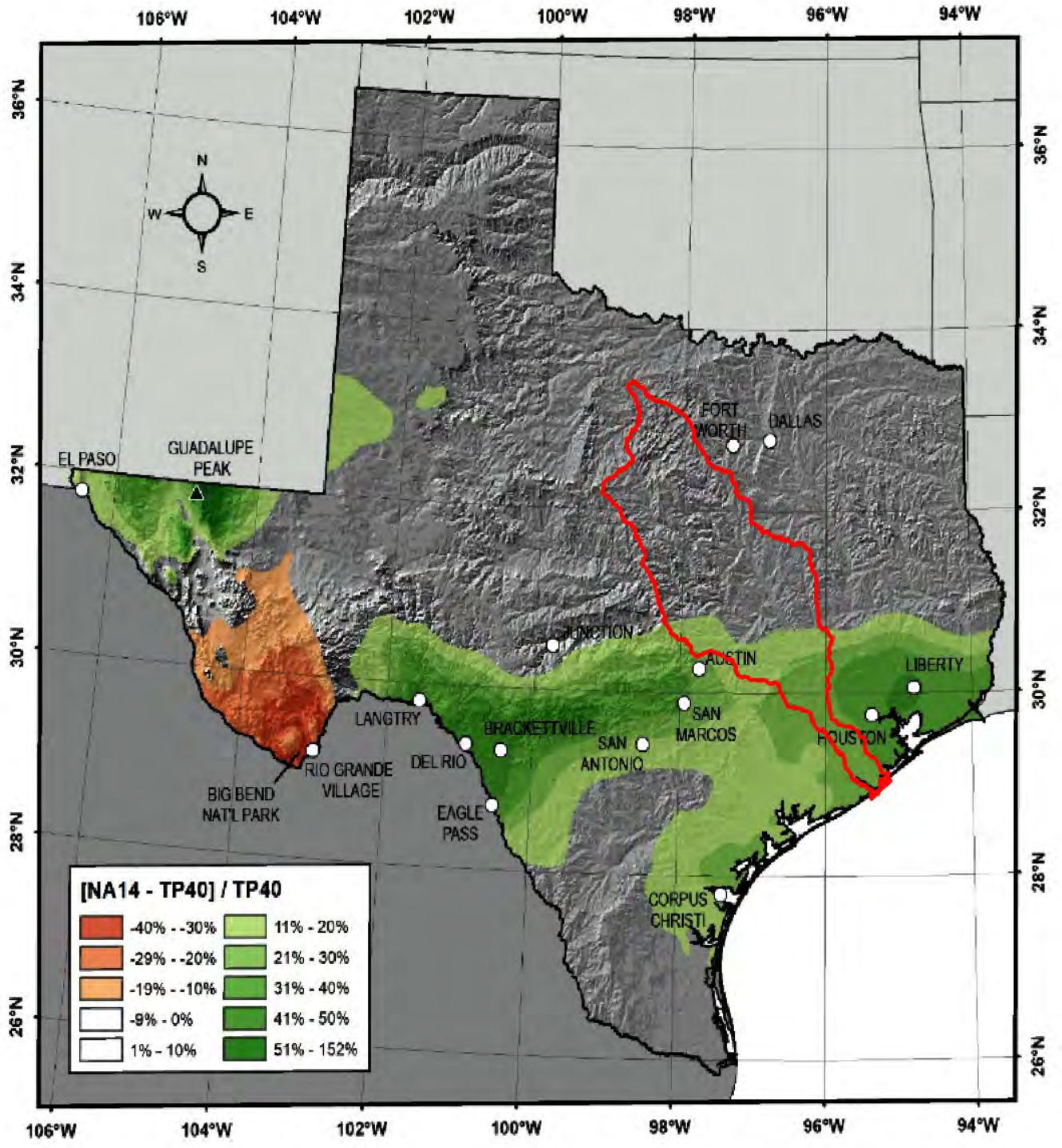


(Northern Gulf Coast Groundwater Availability Model developed by U.S. Geological Survey and 2002 RWPG Pumping Estimates by Regional Water Planning Groups and the TWDB)

Anticipated Changes in Rainfall Patterns and Floodplains

Changing rainfall patterns in the basin significantly contributes to increased flood risk. Two major rainfall atlases have been completed in the Lower Brazos Planning Region. Technical Paper Number 40 (TP-40) was released in 1962 and NOAA Atlas 14 Update to TP-40 was released in 2018. In the 50 years between both publications, the lower end of the basin experienced increases between 20 – 40 percent in rainfall associated with a 1 percent annual chance storm event. *Figure 2.11* shows the statewide historical change in rainfall. The rainfall rates are shown in *Table 2.1*. The Texas State Climatologist report, "Climate Change Recommendations for Regional Flood Planning," states that *climate change may lead to substantial increases in flood vulnerability over and above increases due to greater population.* Increased rainfall in a community without increased mitigation will result in more expansive flood hazard areas.

Figure 2.11: Change in 24-hour 1 percent ACE Rainfall between NA14 and TP-40



(NOAA Atlas 14 Updates to Texas TP-40 Rainfall Frequency Values, 2018)

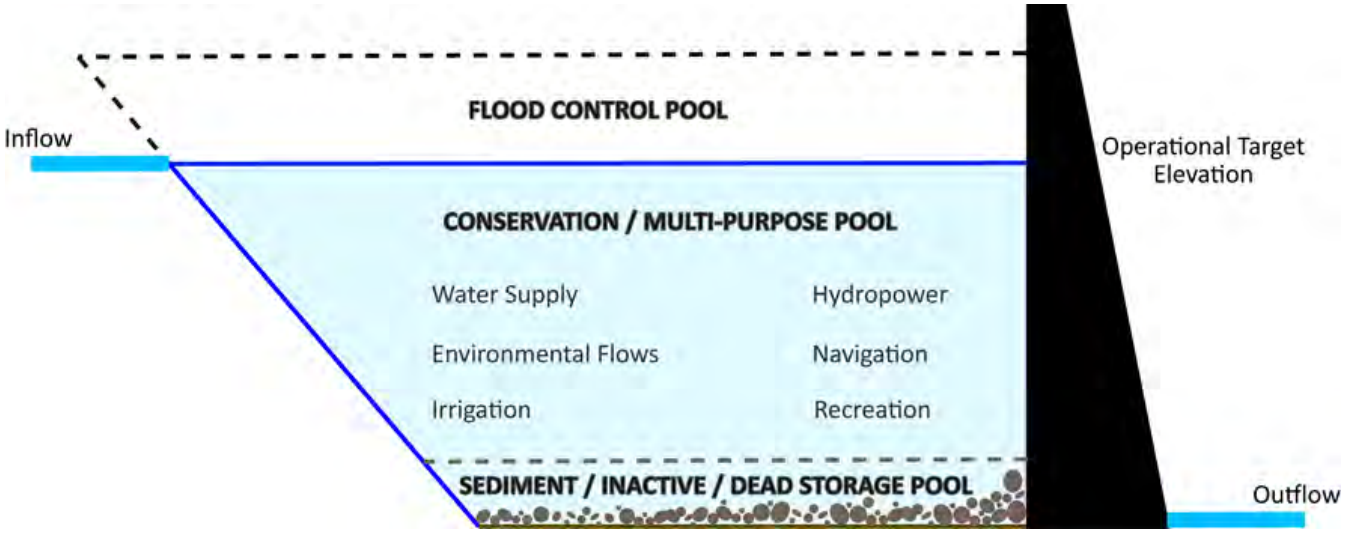
Sedimentation and Major Geomorphic Changes

Erosion, sedimentation, and significant planform changes are major issues in the Lower Brazos Planning Region. Geomorphic changes affect losses in property access, roads, agriculture, and residential structures. Erosion also threatens the integrity of levees systems which protect billions of dollars from flood risk. Further analysis and planning efforts outside the Regional Flood Plan are needed to better understand and address these concerns.

Anticipated Impacts of Sedimentation in Flood Control Structures

In the Lower Brazos River Basin, the most prominent flood control structures at a regional scale are levees, dams, and their associated reservoirs. In general, reservoirs are the facilities that are most susceptible to the impacts of sediment deposition over time within this watershed. *Figure 2.12* shows a section of a typical multipurpose reservoir.

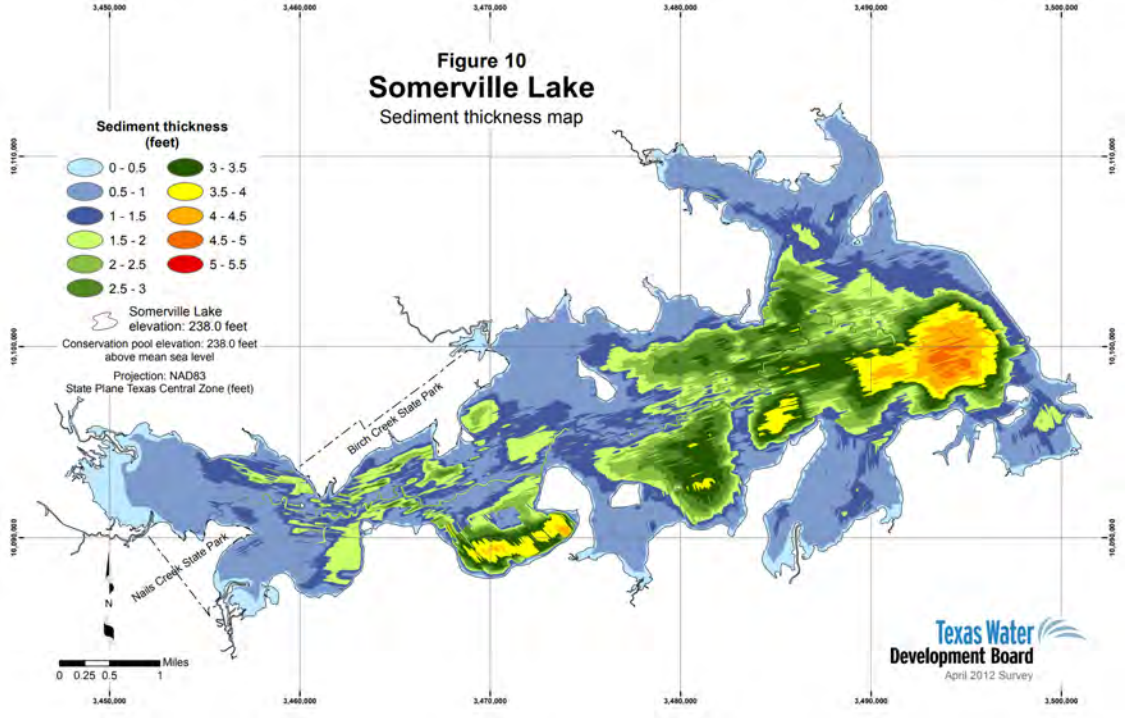
Figure 2.12: Section of a Typical Multipurpose Reservoir



(https://nicholasinstitute.duke.edu/reservoir-reallocation)

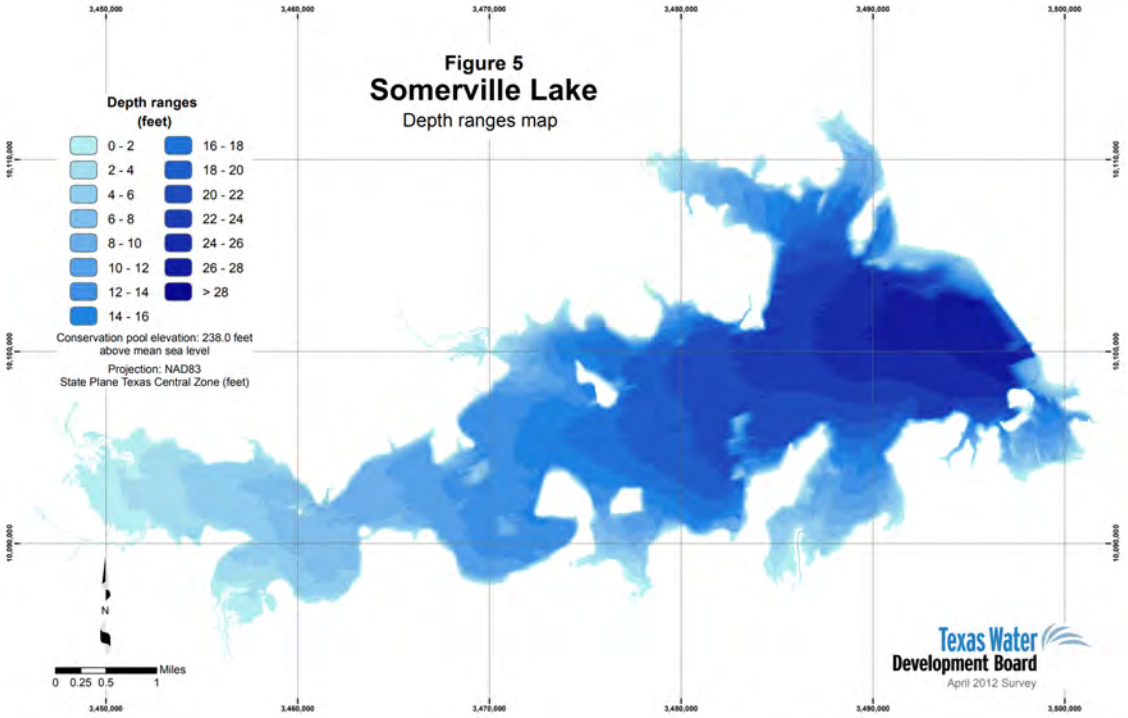
Sedimentation within reservoirs would impact, primarily, the conservation pool, which in most cases provides water supply, and in limited cases, hydropower generation. The regional water plans evaluate the consequences of sedimentation impacting the ability of reservoirs to maintain a steady water supply. The TWDB has performed numerous bathymetric surveys of lakes, which are used to track the progress of sedimentation. *Figure 2.13* shows a map of sediment thickness in Somerville Lake, and *Figure 2.14* shows the water depths below the conservation pool; these maps show that the majority of the sediment has accumulated on the east end (near the dam) where the conservation pool is the deepest, and the shoreline shows the minimal accumulation of sediment. This is consistent with the concept illustrated in *Figure 2.12.* In large reservoirs, it is unlikely for sedimentation to impact the flood control pool (if available) significantly, as the majority of the sediment load will deposit below the conservation pool.

Figure 2.13: Sediment Thickness Map for Somerville Lake



(Volumetric and Sedimentation Survey of Somerville Lake, TWDB, 2014)

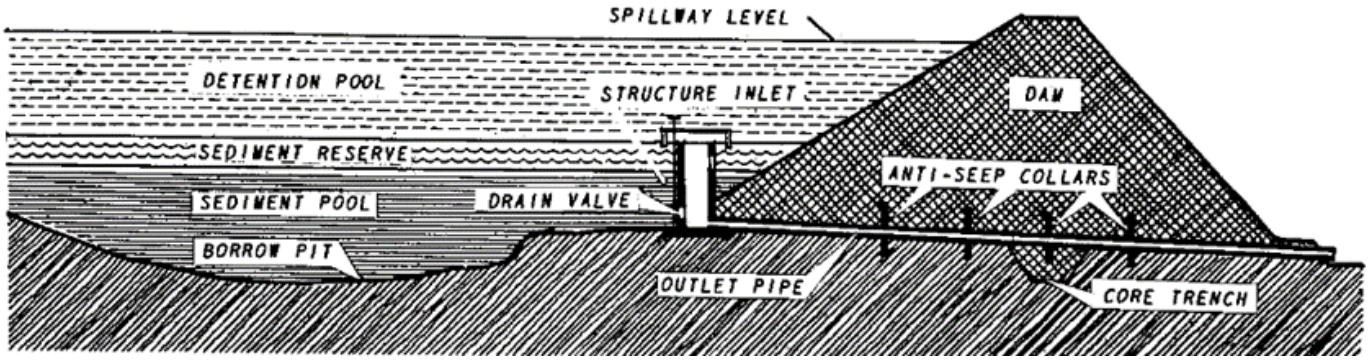
Figure 2.14: Depth Ranges Map for Somerville Lake



(Volumetric and Sedimentation Survey of Somerville Lake, TWDB, 2014)

In the case of NRCS floodwater retarding structures, sedimentation may be considered to have an adverse impact on the structure's flood control performance only when the sediment pool capacity has been depleted and sediment accumulates in the detention pool. *Figure 2.15* shows a section of a typical NRCS flood retarding structure. Periodic maintenance to remove accumulated sediment is recommended to maintain the capacity of the detention pool.

Figure 2.15: Section of a Typical NRCS Floodwater Retarding Structure



(Big Sandy Creek Watershed Work Plan, Soil Conservation Service, 1955)

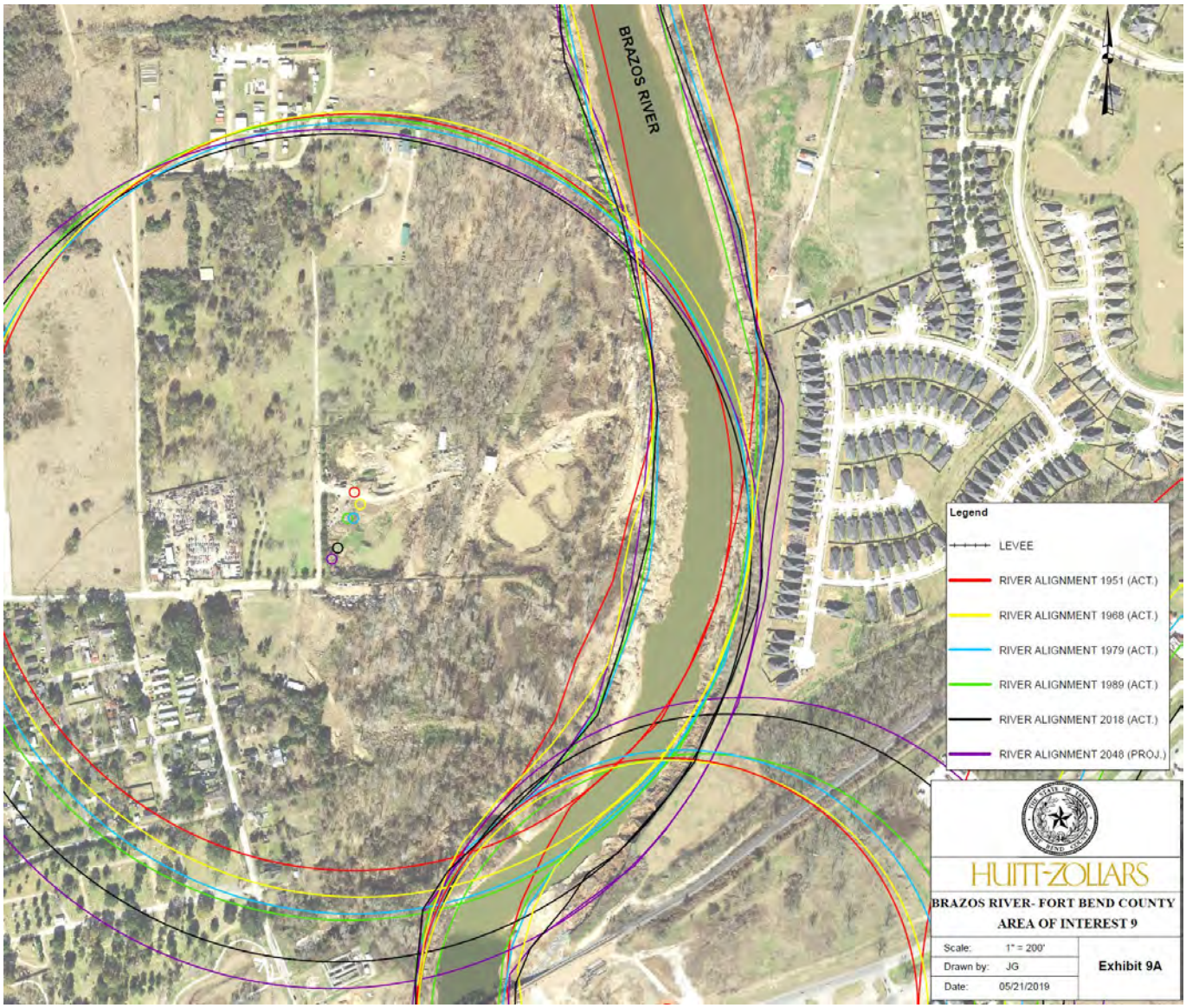
Effects of Geomorphic Changes on Flood Risks

The Brazos River has a long history of geomorphic changes. For example, Oyster Creek in Fort Bend and Brazoria Counties was created due to major geomorphic changes to the course of the Brazos River over thousands of years. In May 2019, Fort Bend County completed the Brazos River Erosion Study, which focused on a geomorphologic analysis at 24 locations on the Brazos River to project the meander migration of the river over the next 30 years. The locations evaluated pose a greater risk to existing infrastructure and population; developing measures to mitigate geomorphic changes would require further evaluation. Compromise of existing levee systems due to erosion along the Brazos River could increase flood risk in those locations.

Figure 2.16 shows the projected meander migration at one of the locations of interest. Areas outside Fort Bend County would benefit from similar assessments to identify locations that pose a risk to existing infrastructure and population. The 2020 Brazos River Flood Risk Management Study completed by the USACE-ERDC analyzed the available methodology for addressing geomorphic changes in the region. The recommended bank stabilization methodologies included direct and indirect approaches. Indirect measures such as permeable or impermeable dikes are common in straight river reaches. Direct bank stabilization methods, including rip-rap blanks or stone toe protection, are common recommendations for the Brazos River, according to the USACE-ERDC.

Further analysis is needed to better understand the impact that future geomorphic changes could have on flood risks.

Figure 2.16: Projected Meander Migration at Example Location of Interest



(Brazos River Erosion Study, Huitt-Zollars, Fort Bend County Drainage District, 2019)

2B.1.b. Available Future Condition Hydrologic & Hydraulic Models

No future condition H&H models or floodplain mapping were available in the Lower Brazos Planning Region for use in Task 2B. As a result, the RFPG had to modify existing conditions data to create future condition flood hazard information; the process for doing so is discussed in *Section 2B.1.c*.

2B.1.c. 1.0 and 0.2 Percent Annual Chance Exceedance Floodplains

The TWDB defined multiple methods for conducting future condition flood hazard analyses where data was unavailable, which apply transformations to existing flood hazard data. Per the Technical Guidelines for Regional Flood Planning, these methods are described below:

- **Method 1:** Increase water surface elevation based on projected percent population increase

- **Method 2:** Utilize the existing condition 0.2 percent ACE flood hazard area as a proxy for the future 1 percent ACE flood hazard area
- **Method 3:** Combination of Methods 1 and 2 or an RFPG-proposed method
- **Method 4:** Request TWDB for a Desktop Analysis

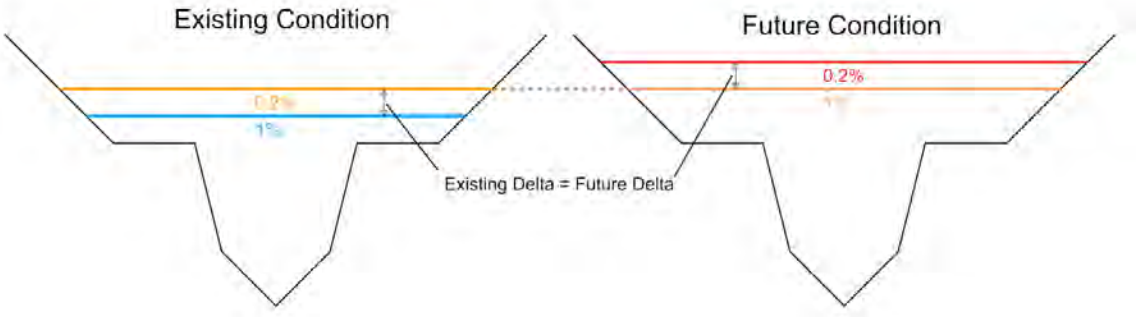
The Technical Consultant Team, led by Halff Associates, submitted a memorandum to the TWDB titled "Task 2B – Future Conditions Flood Hazard Areas" on January 25, 2022, to supplement discussions from the December 14, 2021 RFPG meeting about how Method 2 would be implemented in the Lower Brazos Planning Region. The memo described how horizontal and vertical buffer techniques would be utilized and was sent to obtain full approval of said techniques. As a result of this coordination, Method 2 was selected for implementation in the Lower Brazos Planning Region. The proposed method was accepted by the TWDB on June 7, 2022.

As mentioned above, horizontal and vertical buffers had to be utilized in conjunction with Method 2 to create the 0.2 percent ACE future flood hazard area. Vertical buffers are computed using the vertical difference between existing condition 0.2 and 1 percent ACE WSEL rasters, while horizontal buffers are computed by measuring horizontal widths of the existing condition 0.2 percent ACE flood hazard polygon.

Future Conditions for Areas with Water Surface Elevation Data

For areas with available WSEL data, the future 1 percent ACE WSEL was set to match the existing 0.2 percent ACE WSEL. Then, a vertical buffer was applied to add the existing difference in 0.2 and 1 percent ACE WSEL to the future 1 percent annual chance WSEL to set the future 0.2 percent ACE WSEL. This process is illustrated in *Figure 2.17*.

Figure 2.17: Future Conditions Flood Hazard 1 and 0.2 Percent Annual Chance



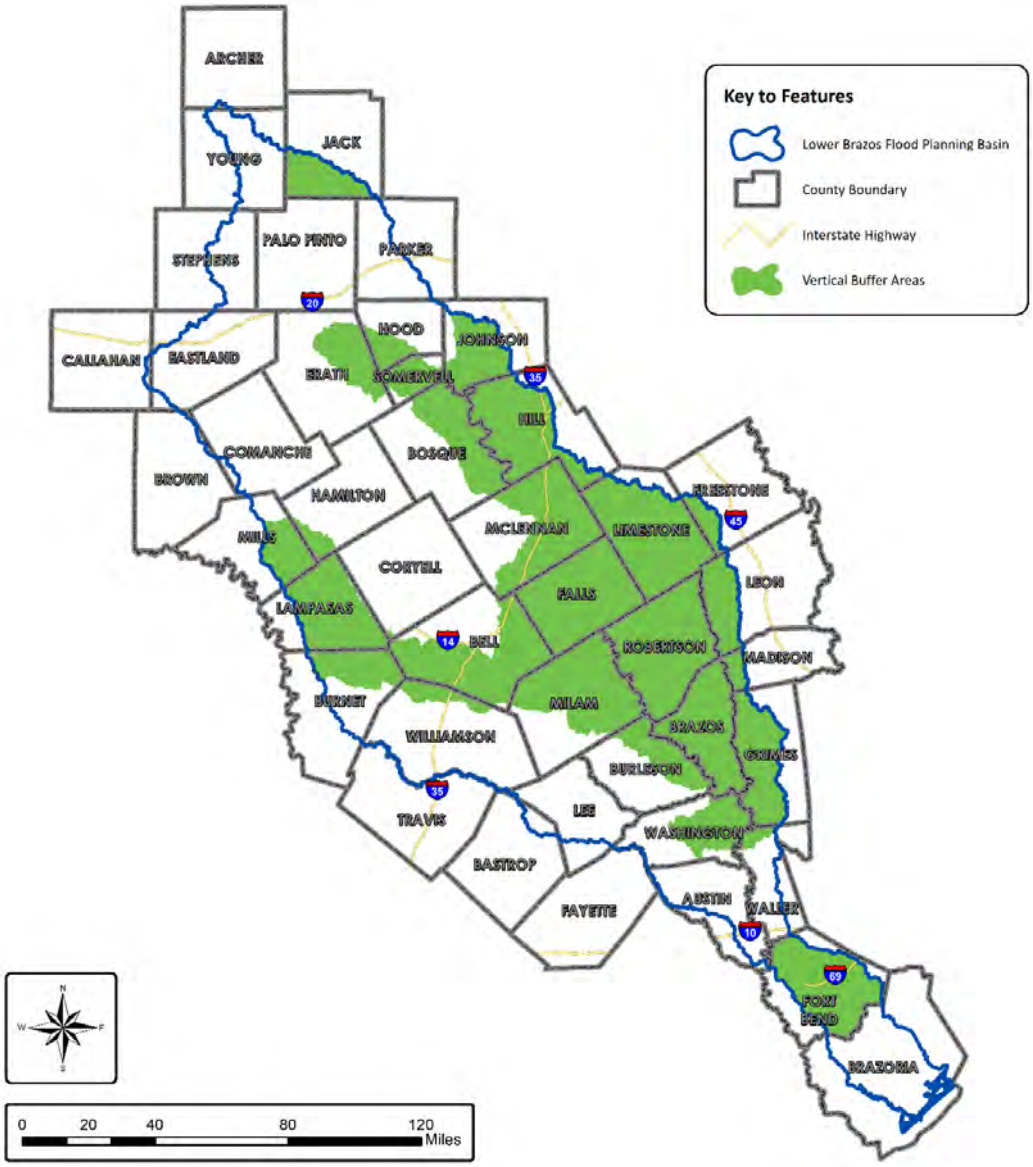
This process provides a more representative estimate of the future condition 0.2 percent ACE flood hazard area than a horizontal buffer, as it considers the elevation of the topography relative to the water surface. Where BLE data could be obtained, this process was implemented. These areas are listed below from south to north and are shown in *Figure 2.18*.

- Lower Brazos-Little Brazos HUC-8 watershed
- Navasota HUC-8 watershed

- Little HUC-8 watershed
- Lampasas HUC-8 watershed
- Middle Brazos-Lake Whitney HUC-8 watershed
- Jack County

Data from ongoing hydrologic and hydraulic modeling efforts conducted by Fort Bend County Drainage District (FBCDD) as a part of the Fort Bend County Drainage Master Plan were provided to the Lower Brazos RFPG. Since this data included WSEL rasters, the same vertical buffer process applied to the BLE data was utilized in areas encompassed by the FBCDD models for consistency. The FBCDD models encompass major streams in Fort Bend County that drain into the Brazos River.

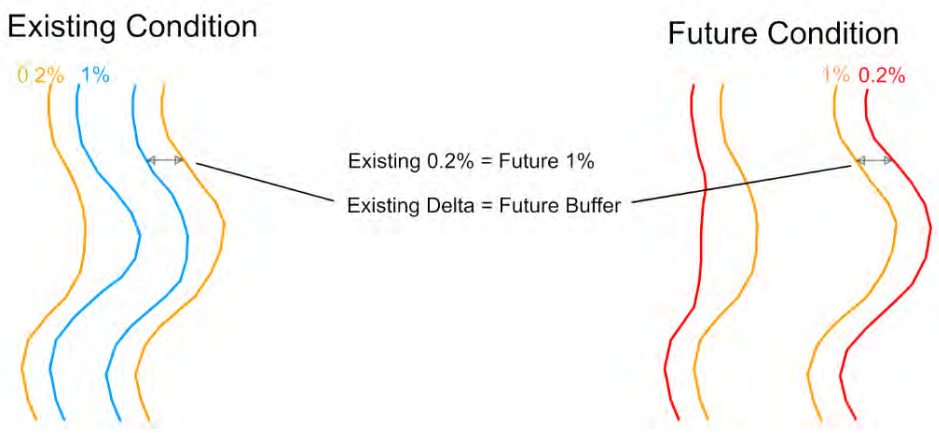
Figure 2.18: Future Conditions Flood Hazard 1 and 0.2 Percent ACE



Future Conditions for Areas without Water Surface Elevation Data

For all other areas not previously discussed, the future 1 percent ACE flood hazard area was set to match the existing 0.2 percent ACE flood hazard area. Then, typical horizontal buffer widths were estimated in each HUC-8 for rivers, major tributaries, and local streams to determine the existing thickness of the 0.2 percent ACE flood hazard area. This buffer was then applied to the future 1 percent ACE polygons to determine the extent of the future 0.2 percent ACE polygons. This process is illustrated in *Figure 2.19*.

Figure 2.19: Future Condition Flood Hazard 1 and 0.2 percent ACE

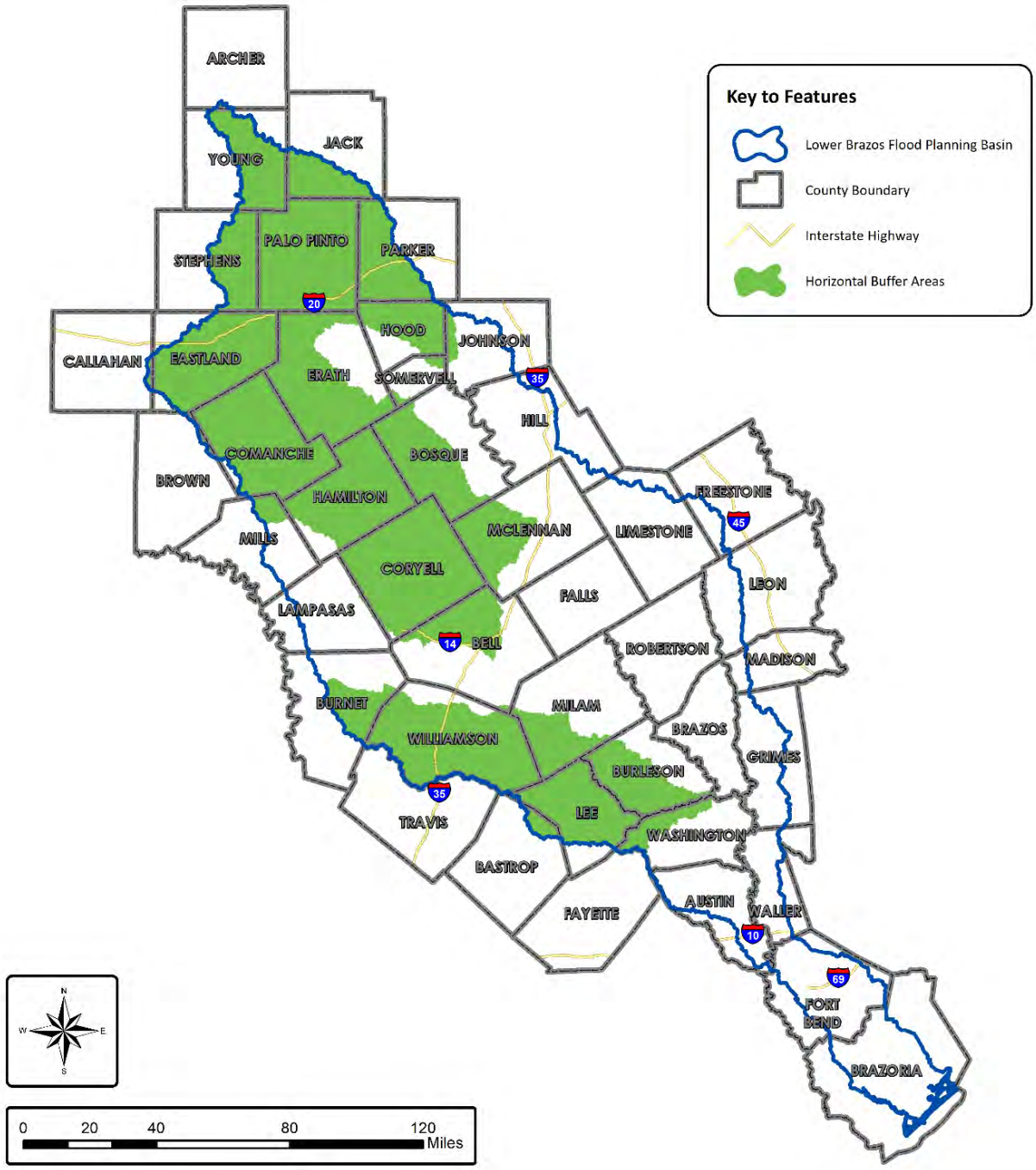


This process was implemented on FEMA and Cursory Floodplain Data, which are spread throughout the Lower Brazos Planning Region. *Figure 2.20* shows some larger areas where horizontal buffers were utilized to calculate the future 0.2 percent ACE flood hazard polygons. These areas and the values used for major rivers, tributaries, and local streams are also listed in *Table 2.6*.

Table 2.6: Horizontal Buffer Values by HUC-8

Watershed HUC-8	Major River Buffer (ft)	Tributary Buffer (ft)	Local Stream Buffer (ft)
Bosque	41	57	8
Cowhouse	-	16	8
Leon	41	33	8
Lower Brazos	-	16	8
Middle Brazos – Palo Pinto	-	66	8
North Bosque	49	33	8
San Gabriel	41	16	8

Figure 2.20: Horizontal Buffer Areas



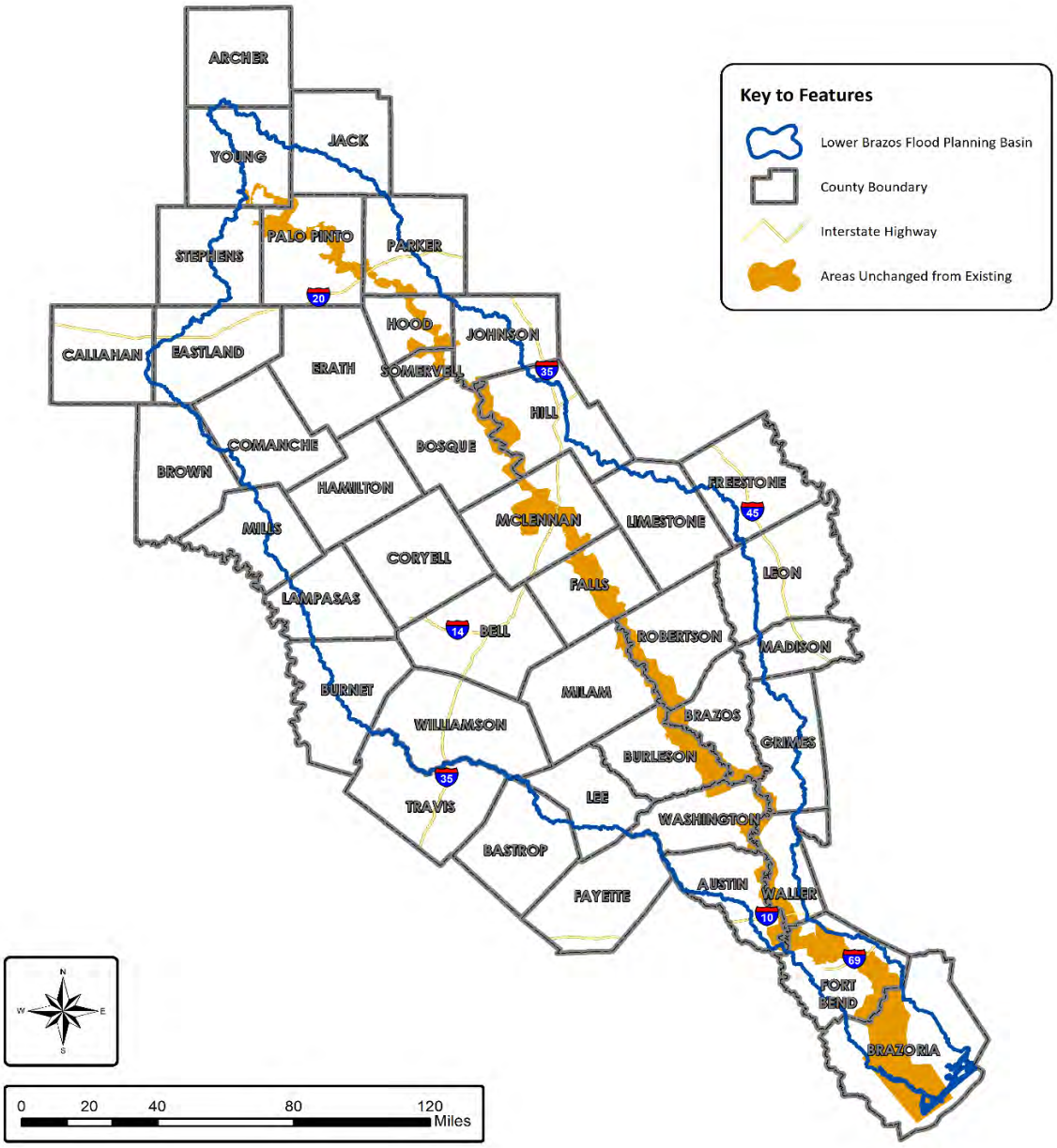
Future Conditions for the Brazos River

Based on coordination between the Technical Consultants, led by Halff Associates, and the RFPG members, it was determined that the flood hazard areas along the main stem of the Brazos River should not be modified from existing to proposed conditions, as shown in *Figure 2.21*, for the following reasons:

- Due to the large size of the watershed, the Brazos River would be less susceptible to localized increases in storms.

- Large flood control reservoirs regulate releases, and larger floodplains result in greater attenuation of flood flows.
- The most recent study of the Brazos River, completed in 2021 by FBCDD, utilized a flood frequency analysis based on a period of record encompassing close to 100 years' worth of records. Drastic changes in discharges would be necessary to significantly increase the 1 and 0.2 percent ACE discharges.

Figure 2.21: Flood Hazard Areas Unchanged from Existing Conditions



Map 8 in Appendix 0 shows future condition flood hazard areas across the Lower Brazos River watershed. *Figures 2B-1* in *Appendix 2B.1* show flood hazard areas for 1 and 0.2 percent ACE by county compared to the complete area of each county in the Lower Brazos Planning Region.

Map 10 in *Appendix 0* shows the changes in flood hazard data from existing to future conditions due to the buffering techniques described above. The increase in 0.2 percent ACE flood hazard area for the Lower Brazos Planning Region is 10 percent, *Table 2.7* summarizes the extent increase region-wide.

Table 2.7: Increase in Flood Hazard Area for Future Condition Compared to Existing Condition

Flood Frequency	Existing Conditions Area (Sq. Mi)	Future Conditions Area (Sq. Mi.)	Increase (Sq. Mi.)	% Increase
1 percent ACE	4,688	5,048	360	8%
0.2 percent ACE	5,173	5,698	525	10%

2B.1.d. Data Gaps

As previously mentioned, no future condition hydrologic and hydraulic models or floodplain mapping were available in the Lower Brazos Planning Region for use in Task 2B. As a result, the entire region is reflected as a gap in inundation boundary mapping in *Map 9*.

2B.2 Future Condition Flood Exposure Analysis

2B.2.a Future Conditions Flood Exposure

Flood exposure for future conditions followed the same methodology as existing conditions as outlined in *Section 2A*. However, residential structures created based on projected future development and population projections were incorporated into the exposure analysis. Existing buildings, roadway crossings, and agricultural areas were maintained in the future conditions analysis. The summary of future flood exposure by county can be found in *Table 5* in *Appendix 2B.2* and *Map 11* in *Appendix 0.* The increase in future conditions exposure compared with existing conditions exposure is summarized in *Table 2.8.*

Table 2.8: Summary of Increased Exposure in 0.2 percent ACE Flood Hazard Area

Feature	Existing Conditions	Future Conditions	Increase
Population	261,925	421,657	159,732
Total Structures	107,719	168,534	60,815
Residential Structures	79,169	134,024	54,855
Non-Residential Structures	28,550	34,510	5,960
Critical Facilities	325	533	208
Roadway Crossing	7,799	7,891	20
Roadway Segments (miles)	4,432	5,639	1,207
Agricultural Area (sq. mi)	945	1,030	85

Buildings, Critical Facilities, Infrastructure, and Agriculture Exposure Totals by County

Future flood exposure analysis included existing and anticipated future development and estimated the number of buildings, critical facilities, low water crossings, roadway segments, and agriculture areas potentially exposed to anticipated future flooding by overlaying the future conditions flood hazard area developed for the Lower Brazos Planning Region. *Table 5* in *Appendix 2B.2* shows the total number of buildings, critical facilities, and agriculture areas exposed to the future flood hazard areas, summarized by the county. The most significant structural exposure in the Lower Brazos Planning Region is found in Brazoria, Fort Bend, and Williamson counties.

Population Totals by County

Population data for the future conditions flood risk exposure analysis accounted for population growth and existing population data. The population associated with existing structures was not altered for the future exposure analysis. As discussed previously, the population of new structures was identified using population projections and population density. Table 2.9 summarizes the population increases between existing and future conditions for counties within the region with the highest at-risk population.

Table 2.9: Counties with the Highest Population Exposure within the 0.2 percent ACE Flood Hazard Area

County	Existing Conditions Population	Future Conditions Population	Increase
Fort Bend	76,202	138,587	62,385
Brazoria	55,016	59,421	4,405
McLennan	48,280	51,580	3,300
Williamson	14,398	51,473	37,075

Similar to structural risk, high population exposures are primarily concentrated in Brazoria, Fort Bend, and Williamson counties. Additionally, McLennan County has a significant population exposed to the anticipated future flood risk. *Figures 2B-2* in *Appendix 2B.1* show the potential future population exposed to 1 and 0.2 percent ACE flood hazard by county compared to the total population for each county in the Lower Brazos Planning Region. The potential future population includes the existing population and projected population.

Per *Table 2.4* in *Section 2B.1.a*, the Lower Brazos Planning Region is expected to grow by 1,448,481 people by 2050 to 4,271,155. Approximately 250,000 people are anticipated to be located within the future 1 percent ACE flood hazard area, and 422,000 within the future 0.2 percent ACE flood hazard area, or 5.8 percent, and 9.8 percent of the total population within the region, respectively. Over 865,000 people are estimated to be located in future flood-prone areas (0.2 percent ACE and flood-prone areas) compared to approximately 459,000 in existing flood-prone areas.

Residential Properties

A total of 318,000 structures are exposed to flooding region-wide within the 0.2 percent ACE; the overwhelming majority of the structures exposed are residential, with a total of 276,000 structures, nearly double than under existing conditions. Similar to the population exposed to flooding, the counties

with the largest number of residential structures exposed to future flood risk include Fort Bend, Brazoria, and Williamson counties. The complete list of residential properties exposed by county is included in *Table 5* in *Appendix 2B.2*. *Figures 2B-3* in *Appendix 2B.1* show potential future residential structures exposed to 1 and 0.2 percent ACE flood hazard by county compared to total residential structures for each county in the Lower Brazos Planning Region. Potential future residential structures include existing and approximate future residential structures. *Table 2.10* summarizes the structure exposure increases between existing and future conditions for counties with the region with the highest at-risk structures.

Table 2.10: Counties with the Highest Structural Exposure within the 0.2 percent ACE Flood Hazard Area

County	Existing Conditions Structures	Future Conditions Structures	Increase
Fort Bend	32,762	53,538	20,776
Brazoria	23,918	25,135	1,217
Williamson	6,186	19,116	12,930
McLennan	8,448	10,804	2,356

Non-Residential Properties

Non-residential structure inventory data included agricultural, commercial, industrial, and public buildings. No additional non-residential structures were included in the analysis due to the uncertainty of where or how many structures could be expected in the future. The exposure of existing non-residential structures is anticipated to increase by 21 percent in future conditions, and the exposure of future non-residential structures is unknown. Of the structures exposed to the future flood hazard area, 80 percent are residential buildings, while the remaining 20 percent are non-residential. Buildings classified as vacant are structures for which the building type and/or use could not be determined.

Critical Facilities and Public Infrastructure

Critical facilities and public infrastructure were analyzed with the future flood hazard areas to determine the future flood risk exposure of these features. No additional features were added to the dataset compiled in the existing conditions flood exposure analysis previously described. The future condition scenario assumes that all new critical facilities are constructed outside the future flood hazard areas, and no exiting critical facilities are retrofitted to decrease the flood risk exposure. An additional 56 critical facilities were identified in the future condition flood exposure analysis that was not previously identified in existing conditions. *Table 2.11* summarizes the change in structural flood exposure for critical facilities in future conditions compared to existing conditions. A summary of all critical facilities in flood-prone areas in *Table 5* in *Appendix 2B.2. Figures 2B-5* in *Appendix 2B.1* show critical facilities exposed to 1 and 0.2 percent ACE flood hazard by county compared to total critical facilities identified for each county in the Lower Brazos Planning Region.

Table 2.11: Counties with the Highest Critical Facilities Exposure within the 0.2 percent ACE Flood Hazard Area

County	Existing Conditions Critical Facilities	Future Conditions Critical Facilities	Increase
Fort Bend	60	110	50
Brazoria	72	74	2
Williamson	11	20	9
McLennan	49	78	29

Roadway Crossings and Roadway Segments

The future flood risk exposure analysis for roadways used only the existing roadway data available from TxDOT. Without considering additional future roads, the future flood risk exposure resulted in a 9.5 percent increase in roadway crossings and a 27 percent increase in miles of inundated roadways. Increases in the flood hazard area have less of an impact on roadway stream crossings as most crossings in the region were identified in the existing conditions analysis. Similar to the existing condition exposure analysis, bridge deck height was not considered in the future condition exposure analysis. Larger flood hazard areas resulted in a significant increase in inundated roadway miles. A summary of all roadway crossings and roadway segments in flood-prone areas is included in *Table 5* in *Appendix 2B.2. Figures 2B-6* in *Appendix 2B.1* show roadway miles exposed to 1 and 0.2 percent ACE flood hazard by county compared to total roadway miles for each county in the Lower Brazos Planning Region.

Agricultural Area

The agricultural area in the Lower Brazos Planning Region was also evaluated to determine future flood exposure. The same area determined in the existing exposure analysis as agricultural was used in the future flood risk exposure analysis. Without altering the agricultural land dataset, the future flood risk exposure resulted in a 7 percent increase in agricultural land in flood-prone areas. Of the 945 square miles of existing agricultural land, approximately 25 square miles are covered by projected future development. *Figures 2B-7* in *Appendix 2B.1* show agricultural land area exposed to 1 and 0.2 percent ACE flood hazard by county compared to the total agricultural land in each county in the Lower Brazos Planning Region.

2B.2.b Potential Flood Mitigation Projects

The existing conditions flood hazard areas were developed using all data made available to the RFPG. Of the proposed and ongoing projects identified in Task 1, no post-project reduced flood hazard areas were provided for inclusion in the future conditions analysis. If reduced flood hazard areas were provided, this information would be incorporated into the base polygon features used to create future flood hazard areas. Without this information, the baseline used for future conditions is the existing conditions flood hazard areas presented in *Task 2A*. Future implemented flood mitigation projects should consider the increased flood risk anticipated over the structure's life.

2B.3 Future Condition Vulnerability Analysis

After identifying areas of future risk and the anticipated people and property exposed to that risk, the vulnerability of those affected people was studied. The vulnerability was assessed using the same methodology as the existing flood risk exposure analysis. All new residential structures developed to account for the projected population were assigned the existing SVI of the census tract. The vulnerability analysis results are summarized by county in *Table 5* of *Appendix 2B.2*. This information is also shown in *Map 12* of *Appendix 0*. *Map 12* also includes the location of critical facilities in the basin identified in the existing conditions flood risk exposure analysis color-coded by their SVI. The highest vulnerability of features in flood-prone areas is found in Falls and Grimes Counties. *Figures 2B-8* in *Appendix 2B.1* visually show the average SVI of features in flood-prone areas by county.

2B.4 Summary of Future Conditions Flood Exposure Analysis and Vulnerability

The future flood exposure analysis anticipates that 57 percent more structures and 61 percent more people are potentially impacted than under existing conditions within the 0.2 percent ACE flood hazard area. The analysis predicts that Fort Bend, Brazoria, Williamson, McLennan, and Brazos counties, respectively, will be the highest exposure counties by structure count in the region by 2050. By this metric, Williamson and Brazos counties experience the highest increase in exposure in the 0.2% ACE flood hazard area from existing to future conditions, as structure counts increase by more than 300% in each of these counties if trends in flood risk and development continue. There is approximately a 9% increase in agricultural areas inundated by the 0.2% flood hazard area. The highest increases in impacted agricultural land occur in less developed areas in the central part of the region. The future flood risk, exposure, and vulnerability for the Lower Brazos Basin are summarized in the TWDB-required *Table 5* of *Appendix 2B.2*. The table provides the results per county of the future flood exposure and vulnerability analysis as outlined in the Technical Guidelines for Regional Flood Planning.

Chapter 3: Floodplain Management Practices and Flood Protection Goals

The Lower Brazos Regional Flood Planning Group (RFPG) solicited local entity and public input in developing floodplain management practices and flood protection goals for the Lower Brazos Planning Region. The data collection effort provided feedback from 73 entities on specific topics, representing 12 percent of the region. Public comment, input, and constructive feedback were taken at the RFPG meetings in July, August, and September 2021. Floodplain management practices and goals were given approval during the October 28, 2021 monthly meeting.

The presented floodplain management standards were developed to both reduce existing flood risk and minimize the creation of future flood risk by encouraging the implementation of consistent floodplain management policies throughout the region. The flood protection goals were developed to ensure the plan's coherence and guide the evaluation and recommendation of flood mitigation needs under Chapter 5.

Implementing these goals and standards will benefit individuals, communities, and the entire region by reducing flood risk and the loss of life and property due to flooding.

Task 3A – Evaluation and Recommendation on Floodplain Management Practices

3A.1 Purpose and Intent

The purpose of this task is to evaluate existing floodplain management practices within the Lower Brazos Planning Region and recommend floodplain management standards that minimize existing flood risks and prevent creating a new flood risk. It is essential to note the RFPG does not have the authority to enact or enforce floodplain management, land use, or other infrastructure design standards. Any standards considered, recommended, and accepted by the Lower Brazos RFPG are intended to encourage implementation by local entities in the Lower Brazos Planning Region with flood-related authority. A summary of existing flood planning documents is provided in Chapter 1. Additionally, Map 13 in *Appendix 0* provides an overview of the existing floodplain management standards in the Lower Brazos Region.

Floodplain management standards fall into two main categories, adoption, and recommendation. Coordination with the RFPG resulted in a consensus that standards produced as part of the flood planning effort should be classified as recommendations for general consideration by entities and communities within the Lower Brazos Planning Region. For context, adopted standards are minimum standards that entities must implement to qualify them for the inclusion of any flood management evaluations (FMEs), flood management strategies (FMSs), or flood mitigation projects (FMPs) in the Regional Flood Plan on their behalf. Although standards for adoption are not proposed for this initial

flood plan, it is conceivable that future updates to the Regional Flood Plans may incorporate standards for adoption.

The recommended standards for consideration are divided into two distinct categories: standards for region-wide recommendation (*Figure 3.1*) and standards recommended for smaller "zones" within the Lower Brazos Planning Region delineated along with Hydrologic Unit Code (HUC)-8 boundaries (*Figure 3.2).*

These categories allow for a broad application of standards and a tailored formulation for capturing flood risk variability, natural hydrography, topography, climatological effects, and demographics throughout the river basin. The different categories of standards are described further in subsequent sections, along with the definitions of each standard. *Table 3.1* provides a summary of the recommended standards for each category.

Table 3.1: Summary of Lower Brazos River Basin Recommended Standards

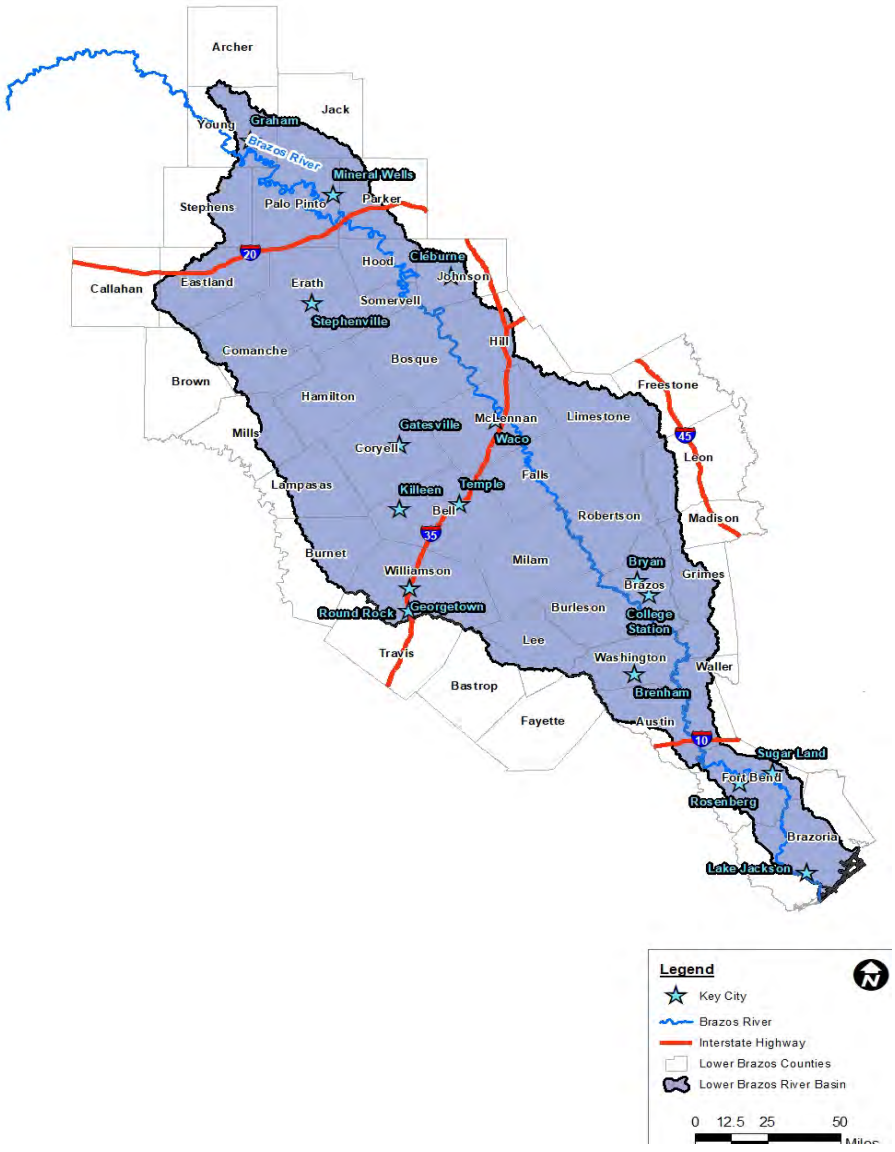
Recommended Standard	Region-wide	Zone 1 "Coastal"	Zone 2 "Upper Coastal"	Zone 3 "Brazos Valley"	Zone 4 "Middle Brazos"
National Flood Insurance Program (NFIP) Participation	X				
Compensatory Storage Requirement in 1 percent (100-year) Annual Chance Event	X				
No Adverse Impacts for the 1 percent (100-year) Annual Chance Event	X				
Improved Flood Response	X				
Improved Flood Risk Awareness/Education	X				
Use of Best Available Rainfall Data		X	X	X	
No Adverse Impacts for the 1 percent (100-year) and 10 percent (10-year) Annual Chance Event		X	X	X	
Form a Voluntary Buyout Program		X			
Long-term Operation and Maintenance Planning of Drainage Infrastructure		X			
Drainage Corridor Preservation			X	X	
Compensatory Storage Requirement in 0.2 percent (500-year) Annual Chance Event				X	X
Requirements for Culvert and Bridge Crossings				X	X

Recommended Standard	Region-wide	Zone 1 "Coastal"	Zone 2 "Upper Coastal"	Zone 3 "Brazos Valley"	Zone 4 "Middle Brazos"
Roadway Requirements within the Floodplain				X	X
Culvert and Bridge Hydrologic and Hydraulic Analysis Requirement				X	X

3A.1.a. Recommended Standards Region-Wide

Region-wide standards for the Lower Brazos Flood Planning Region (*Figure 3.1*) are assumed to be applied to the region and are subsequently described. These standards are recommended by the RFPG.

Figure 3.1: Map of Lower Brazos Planning Region



National Flood Insurance Program (NFIP) Participation

All entities should enact ordinances that meet minimum requirements for NFIP participation and be active NFIP participants in good standing. This standard would only apply to communities not already NFIP participants in good standing (e.g., Hamilton County, Falls County, and a handful of municipalities not in the NFIP). NFIP participation is voluntary; however, it allows for the purchasing of flood insurance, eligibility for federal grants and loans, and federal disaster assistance. For communities to participate in the NFIP program, they must do the following:

- adopt and enforce a flood damage prevention ordinance
- require permits for all types of development in the floodplain
- ensure that building sites are reasonably safe from flooding
- estimate flood elevations not determined by Federal Emergency Management Agency (FEMA)
- require new or substantially improved homes and manufactured homes to be elevated above the Base Flood Elevation (BFE)
- require other buildings to be elevated or floodproofed
- conduct field inspections and cite violations
- require Elevation Certificates to document compliance
- carefully consider requests for variances
- resolve non-compliance and violations
- advise FEMA when updates to flood maps are needed

Compensatory Storage Requirement in 1 Percent ACE Floodplain.

Any reduction in floodplain storage or conveyance capacity within the 1 percent ACE regulatory floodplain must be offset with a hydraulically equivalent (one-to-one) volume of mitigation sufficient to offset the reduction. Floodplains provide critical and beneficial functions for flood storage, natural habitat, and water quality. Fill placed within the floodplain impairs the benefits provided by the floodplain and should be avoided. This standard may be exercised for planned development or fill placement within the 1 percent ACE regulatory floodplain. Such mitigation shall be within the same watershed or at an alternative site that the community's Floodplain Administrator approves. A complete hydrological and hydraulic (H&H) analysis must be submitted to support a request for mitigation outside the developed property boundaries. This requirement may not apply to FEMA-classified flood zones with velocity hazards (FEMA Flood Zone V and VE).

No Adverse Impacts for the 1 Percent ACE

The 1 percent ACE is considered the primary storm for basing no adverse impacts. Incorporating no adverse impacts can help minimize flood damages caused by activities that could adversely impact flood damage to another property or community. This practice is cited in Texas Floodplain Managers Association (TFMA) Higher Standards (TFMA, 2018). This standard will require a complete H&H analysis to be submitted to support the no adverse impact requirement. Considerations should be made by each entity on the best practice for determining no adverse impacts, including the extent of impact consideration, no rise in water surface elevation versus no increase in peak flow, and regional mitigation versus local development mitigation. For reference, examples of no adverse impact determinations are:

- a rise of 0.01 feet on another property is non-permissible and is considered an adverse impact. In addition, any loss in floodplain volume on the property is also an adverse impact.
- an increase in peak flow in the receiving waterway downstream of development is non-permissible and is considered an adverse impact.

Improved Flood Response

This measure includes appropriate efforts to enhance flood notification and communication with emergency response personnel and the public. Efforts to improve flood response can include developing an Emergency Action Plan (EAP) for significant storm events, communication plans to contact residents of emergency situations during storm events, implementation of an emergency response system, and execution of emergency response tabletop exercises. This can improve flood risk communication and mobility (response and evacuation) at large geographic scales.

Improved Flood Risk Awareness/Education

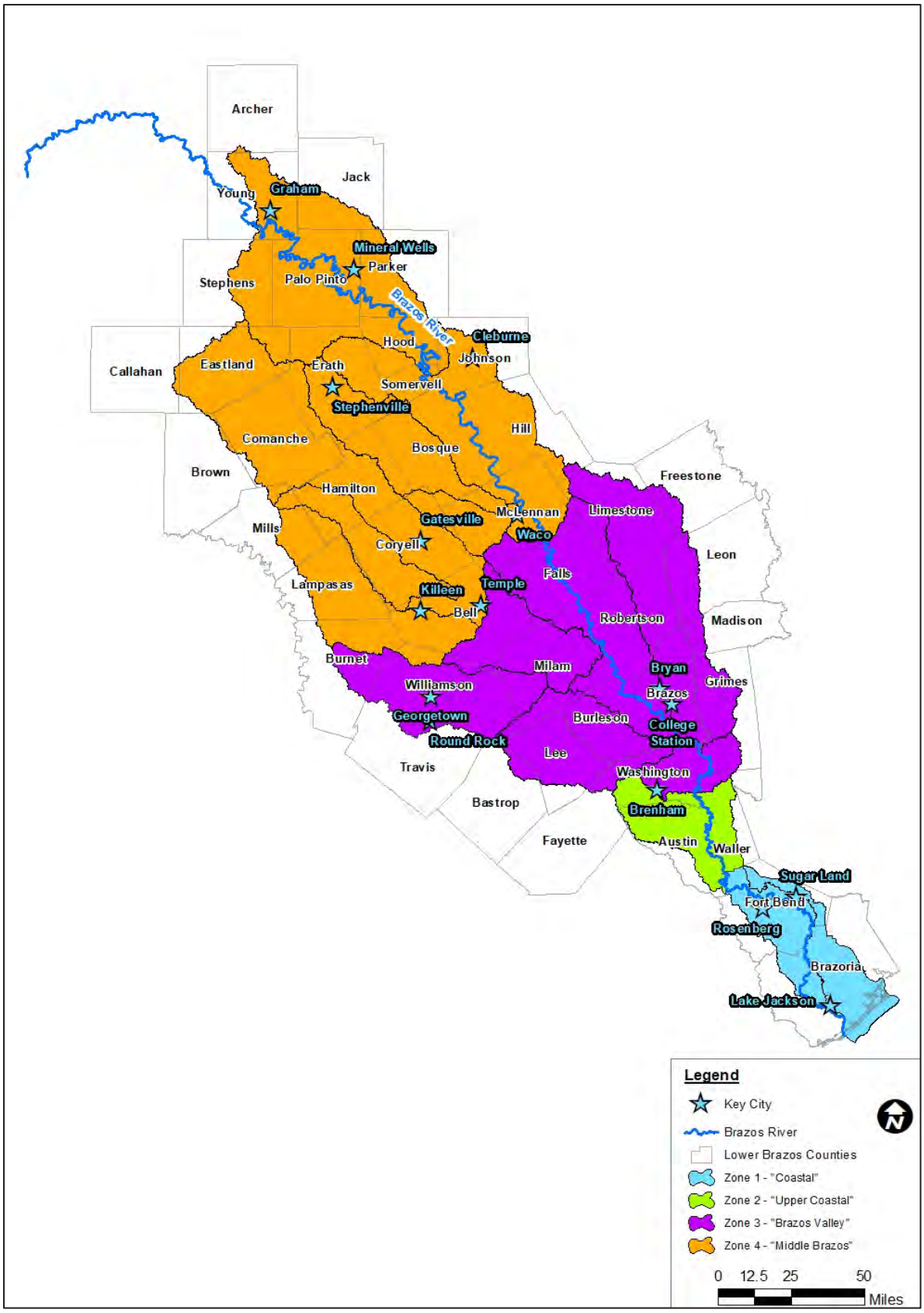
This standard recommends the implementation of flood risk awareness and education within the zone. Flood risk awareness and education can include a website or webinars to increase the public flood risk awareness.

3A.1.b. Recommended Standards by Zone

As shown in *Figure 3.2*, standards are recommended by zone to better tailor recommendations with varying flood risk, natural hydrography, topography, climatological effects, and demographics throughout the river basin. Much of this variation can be attributed to variations in inherent flood risk by rainfall and population growth (urban versus rural communities). The zones were delineated along pre-defined HUC-8 boundaries. *Table 3.1* lists how standards vary by zone. Zone-level standards are as follows.

- Use of Best Available Rainfall Data
- No Adverse Impacts for the 1 Percent and 10 Percent Storm Events
- Formation of a Voluntary Buyout Program
- Long-Term Operation and Maintenance Planning of Drainage Infrastructure
- Drainage Corridor Preservation
- Compensatory Storage Requirement in 0.2 percent Floodplain
- Requirements for Culvert and Bridge Crossings
- Roadway Requirements within the Floodplain
- Culvert and Bridge Hydrologic and Hydraulic Analysis Requirement

Figure 3.2: Lower Brazos Planning Region Zones



Use of Best Available Rainfall Data

Utilize the latest rainfall data as the more conservative rainfall estimates (for regions where applicable) as part of new analysis, design standards, and flood prevention regulations.

No Adverse Impacts for the 1 Percent ACE and 10 Percent ACE

The 1 percent and 10 percent ACEs are considered the primary storm for basing no adverse impacts. Incorporating no adverse impacts can help minimize flood damages caused by activities that could adversely impact flood damage to another property or community. This practice is cited in TFMA's Higher Standards (TFMA, 2018). This standard will require a complete H&H analysis to be submitted to support the no adverse impact requirement. Considerations should be made by each entity on the best practice for determining no adverse impacts, including the extent of impact consideration, no rise in water surface elevation versus no increase in peak flow, and regional mitigation versus local development mitigation. Examples of no adverse impact determinations are provided below for reference.

- a rise of 0.01 feet on another property is non-permissible and is considered an adverse impact. In addition, any loss in floodplain volume on the property is also an adverse impact
- an increase in peak flow in the receiving waterway downstream of development is non-permissible and is considered an adverse impact

Formation of a Voluntary Buyout Program

This practice recommends forming a voluntary buyout program by local entities to assist in reducing flood damage within certain areas of the floodplain. Implementing the program would help improve coastal resiliency and reduce repetitive flood damage.

Long-Term Operation and Maintenance Planning of Drainage Infrastructure

Developing a plan for long-term operation and maintenance of critical drainage infrastructure within each entity is recommended to improve coastal resiliency and reduce flood risk in the zone. This plan should include a defined sustainable funding mechanism to support long-term operation and maintenance. Critical drainage infrastructure can include dams, levees, floodwalls, and any other infrastructure identified as critical by the entity.

Drainage Corridor Preservation

Infrastructure construction should avoid high-risk and sensitive areas such as floodways, floodplains, coastal dunes, and areas downstream of dams, levees, and floodwalls. New buildings should be prohibited within the regulatory floodplain.

Compensatory Storage Requirement in 0.2 percent ACE Floodplain

Any reduction in floodplain storage or conveyance capacity within the 0.2 percent ACE floodplain must be offset with a hydraulically equivalent (one-to-one) volume of mitigation sufficient to offset the reduction. This standard may be exercised for planned development or fill placement located within the 0.2 percent ACE regulatory floodplain. Such mitigation shall be within the same watershed or at an alternative site that that community's Floodplain Administrator approves. A complete H&H analysis

must be submitted to support a request for mitigation outside the developed property boundaries. This requirement does not apply to flood zones with velocity hazards (Zone V and VE).

Requirements for Culvert and Bridge Crossings

Culverts and bridges at arterial roadways, access roads to critical facilities, emergency routes, and evacuation routes should pass the 1 percent ACE with a minimum of 1 foot of freeboard. This standard assists in reducing the number of new low water crossings within the zone.

Roadway Requirements within the Floodplain

New arterial roadways, access roads to critical facilities, emergency routes, and evacuation routes within the regulatory floodplain should be at or above the base flood elevation to provide access for emergency vehicles during a flood.

Culvert and Bridge Hydrologic and Hydraulic Analysis Requirement

New culverts or bridges constructed in the floodway should require a complete H&H analysis.

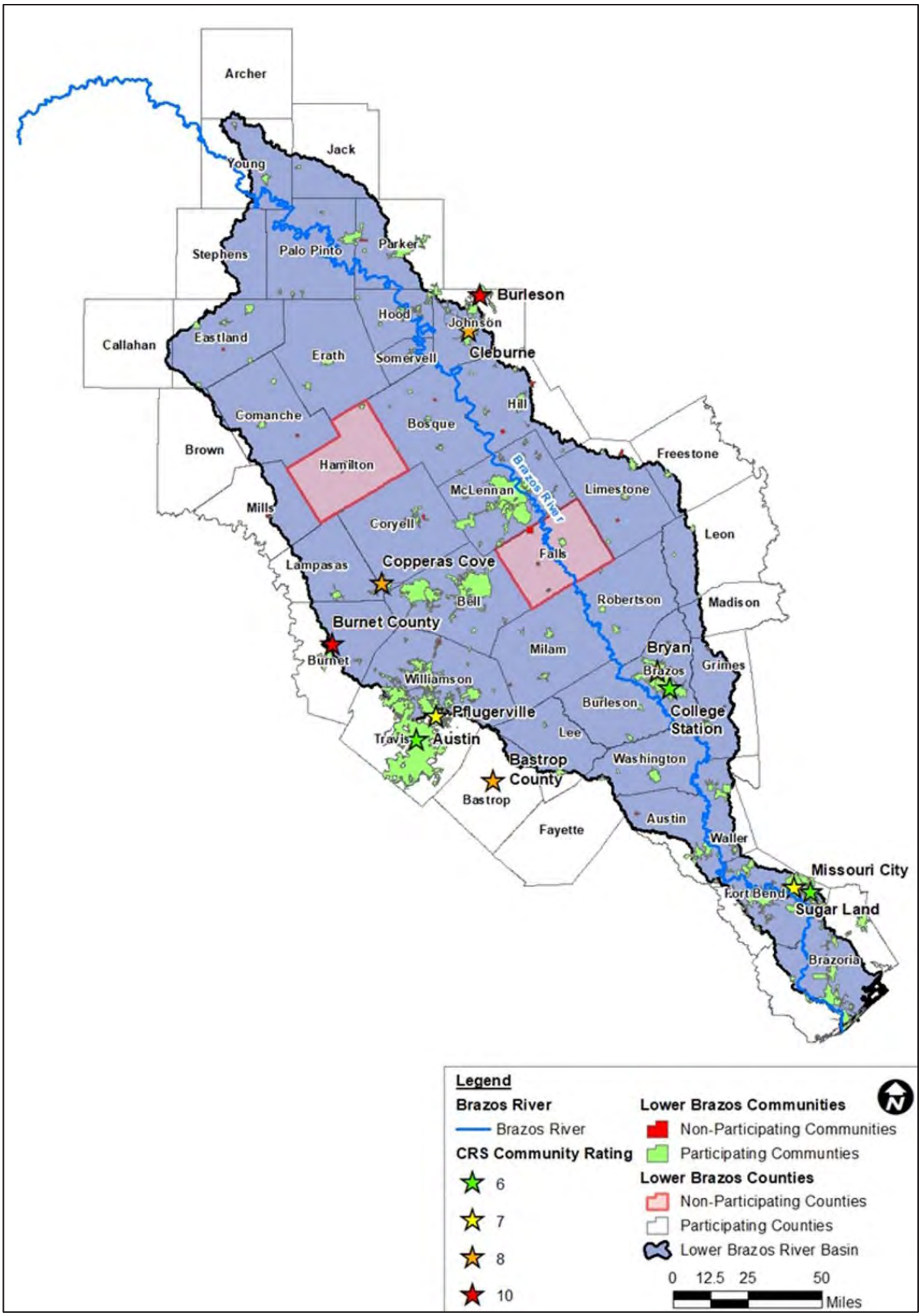
3A.2 Data Collection and Watershed Characteristics

3A.2.a. Data Collection

Several data sources were utilized to inform the determination of floodplain management standards. These sources include survey feedback, existing criteria, standards, programs, regulations, reports, and available TWDB data sources. Survey feedback was gathered to better understand the existing floodplain management practices throughout the region and identify standards that entities within the Lower Brazos Planning Region would like to see included in the Regional Flood Plan. Existing criteria and standards were examined to provide information on existing floodplain management practices for entities that did not provide survey feedback. This information supplemented the data gathered from the survey and provided a better understanding of the entire region in regard to floodplain management practices. The results from this collection are detailed in the TWDB required Table 6, which can be found in *Appendix 3.1*. Reports like the Lower Brazos Flood Protection Planning Study (Halff, 2019) provided information on existing flood hazards in the region. Spatial data provided by the TWDB helped determine characteristics for areas within the river basin that assisted in refining recommended standards tailored to each area.

Entities within the Lower Brazos River Basin provided feedback through a basin-wide survey initiated in July 2021. The survey included questions regarding existing floodplain management practices and considerations for minimum standards across the river basin. The responses provided insight into the existing standards practiced by entities in the basin and suggested minimum standards that the communities would prefer to see implemented. Figure 3.2-2 in *Appendix 3.2* provides the survey responses regarding minimum standards entities within the Lower Brazos River Basin want to see recommended. The total number of entities who responded to the survey was 64.

Figure 3.3: Lower Brazos NFIP and CRS Participation



Existing criteria and standards were analyzed for many of the entities within the region. The existing criteria included drainage criteria manuals, engineering standards, master plans, stormwater management programs, subdivision regulations, and ordinances. Cities had a greater variation in existing criteria, with many having drainage criteria manuals, master plans, and stormwater management programs. Counties primarily had subdivision regulations and stormwater management programs. The criteria vary over the river basin; however, many entities have more stringent floodplain management standards than the minimum standards set by the NFIP. Even though many entities have higher standards, only 11 entities participate in the Community Rating System (CRS). The CRS is a program within the NFIP that recognizes communities implementing standards higher than minimum floodplain management standards, making them eligible for discounted flood insurance premiums. NFIP participating communities and CRS communities are shown in *Figure 3.3*.

The TWDB Technical Guidance provided an outline for developing region-specific floodplain management standards. This included example standards, resources for higher standards, including reports by TFMA and FEMA CRS standards, and considerations to make when developing the standards. The TWDB provided a rich assortment of spatial data, including FEMA flood claims, low water crossings, critical infrastructure, flood control infrastructure, and floodplain quilt. The data was analyzed through a geographic information system (GIS) to highlight specific watershed characteristics for each HUC-8 within the Lower Brazos Planning Region. The metrics calculated were used to help tailor standards to each HUC-8 and regional zone.

3A.2.b. Watershed Characteristics

Each zone has defining characteristics used to tailor recommended standards to help local entities establish preventative measures for reducing flood damage. *Table 3.2* summarizes the characteristics of each zone.

Zone 1 is defined as the Coastal Region nearest the Gulf of Mexico. The zone is comprised of portions of Brazoria County and Fort Bend County. The defining characteristics of this zone are a high number of FEMA flood claims, high NFIP participation, a high number of critical infrastructure within the floodplain, and only a few low water crossings. Over half of the zone is within the 0.2% ACE floodplain. Precipitation estimates for this zone have increased significantly with Atlas 14 revised rainfall data.

Zone 2 is the Upper Coastal Region and is comprised of portions of Austin, Waller, and Washington Counties. The defining characteristics of this zone are a low number of FEMA flood claims, high NFIP participation, a low number of critical infrastructure within the floodplain, and only a few low water crossings. Precipitation estimates for this zone have increased with Atlas 14 revised rainfall data.

Zone 3 is defined as the Brazos Valley Planning Region and is comprised of the central HUC-8s within the river basin. The upstream and downstream boundaries were defined based on existing HUC-8 boundaries. The defining characteristics of this zone are a moderate amount of FEMA flood claims, medium to high NFIP participation, a moderate number of critical infrastructure within the floodplain,

and a significant number of low water crossings. Precipitation estimates for areas within this zone have increased with Atlas 14 revised rainfall data.

Zone 4 is the Middle Brazos Region and is comprised of the northwestern HUC-8s within the Lower Brazos River Basin. The defining characteristics of this zone are a moderate amount of FEMA flood claims, medium to high NFIP participation, a large number of critical infrastructure within the floodplain, and a significant number of low water crossings.

Table 3.2: Lower Brazos "Zone" Characteristics

Zone	Flood Claims	NFIP Participation (% of Entities)	Critical Infrastructure in Floodplain	Low Water Crossings
Zone 1 “Coastal”	12,321	100%	174	7
Zone 2 “Upper Coastal”	63	93%	6	21
Zone 3 “Brazos Valley”	1,884	87%	47	533
Zone 4 “Middle Brazos”	1,705	86%	154	594

Each HUC-8 has defining characteristics used to tailor the zone-specific recommended standards to help local entities establish preventative measures for reducing flood damage. HUC-8s are watersheds for medium-sized rivers delineated by the United States Geologic Survey (USGS). The 14 HUC-8s within the Lower Brazos River Basin vary in size from 422 to 3,200 square miles. *Table 3.3* summarizes the characteristics of each HUC-8. *Figure 3.4* through *Figure 3.6* provide visuals of computed metrics for each HUC-8.

Table 3.3: Lower Brazos HUC-8 Characteristics

HUC-8	Flood Claims	NFIP Participation (% of Entities)	Critical Infrastructure in Floodplain	Low Water Crossings
Austin-Oyster	7201	100%	130	1
Bosque	38	88%	5	19
Cowhouse	2	82%	0	8
Lampasas	173	78%	15	103
Leon	482	88%	21	237
Little	85	94%	3	60
Lower Brazos	5183	97%	50	27
Lower Brazos-Little Brazos	334	88%	14	98
Middle Brazos-Lake Whitney	488	83%	87	107
Middle Brazos-Palo Pinto	465	96%	24	69
Navasota	655	81%	10	106
North Bosque	57	93%	2	51
San Gabriel	714	92%	10	210
Yegua	96	100%	10	59

Figure 3.4: Lower Brazos Flood Claims by HUC-8

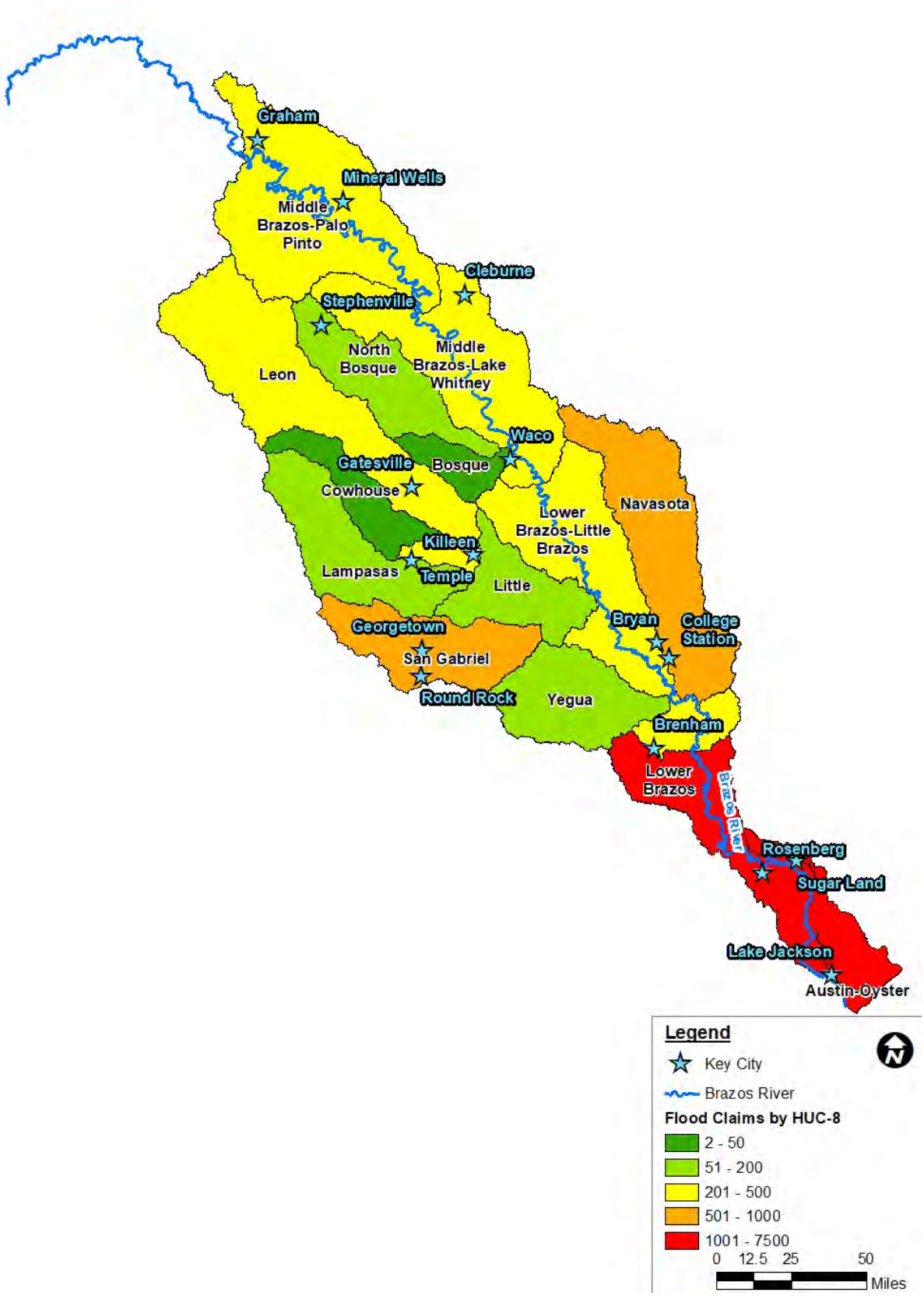


Figure 3.5: Critical Infrastructure within the Floodplain by HUC-8

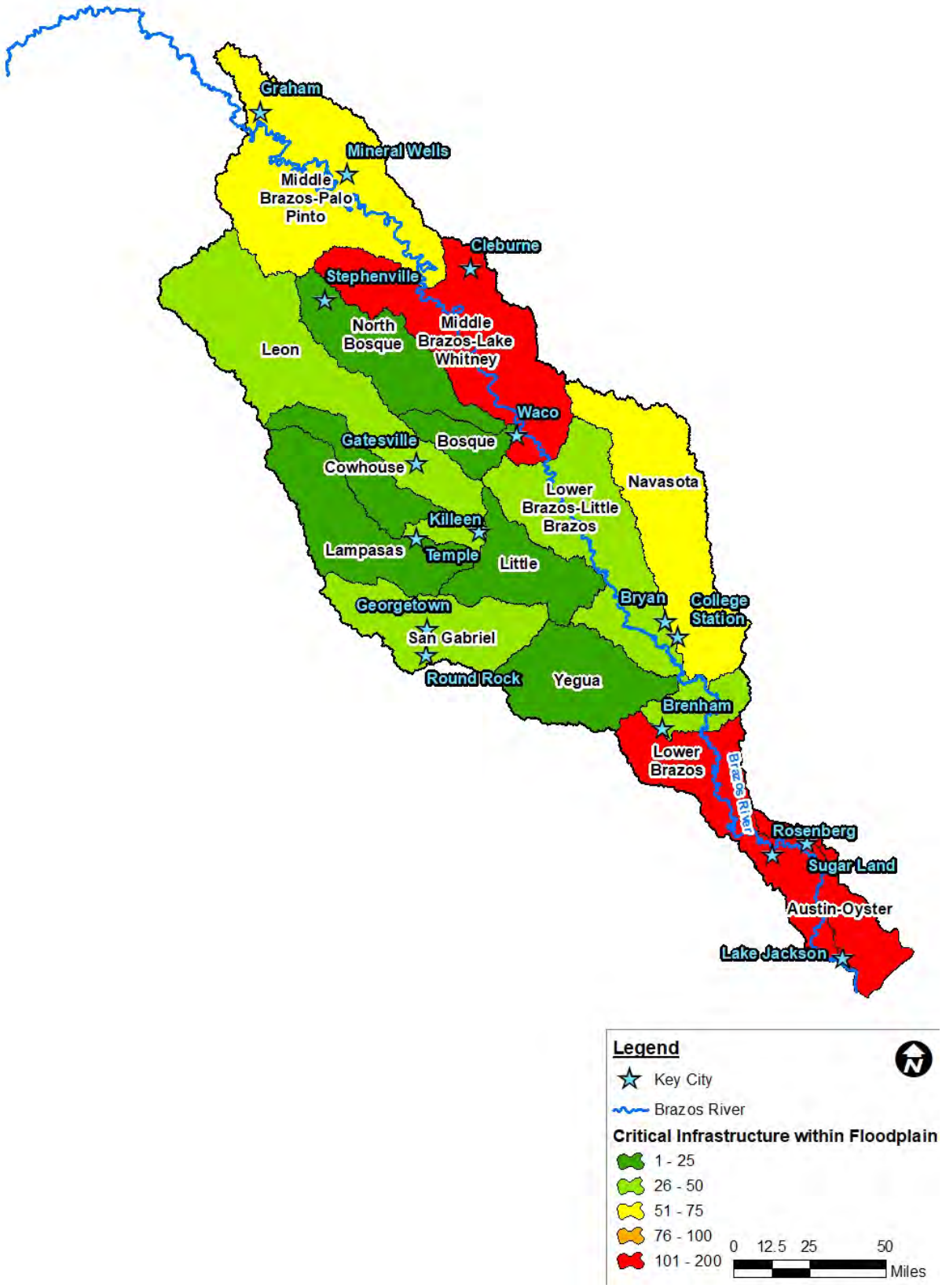
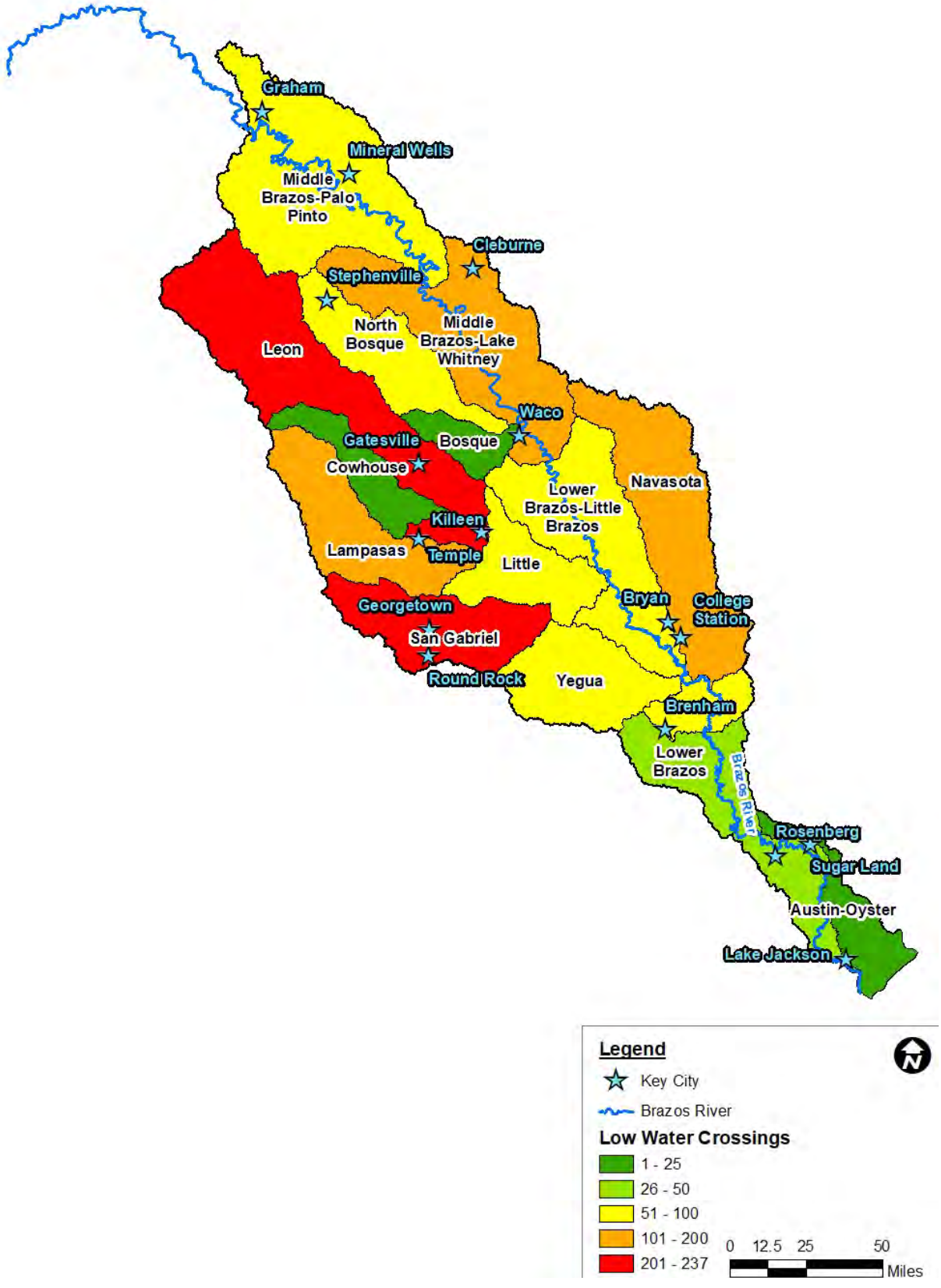


Figure 3.6: Low Water Crossings by HUC-8



Task 3B – Flood Mitigation and Floodplain Management Goals

3B.1 Purpose and Intent

The purpose of this task is to define flood mitigation and floodplain management goals for the Lower Brazos Planning Region, as directed by the RFPG. The intent of these goals is driven by the TWDB in 31 TAC 362.3, "to protect against loss of life and property." To accomplish this task, the TWDB developed six key elements to consider throughout its development:

1. define specific and achievable goals with target years that address risks to life and property,
2. identify any remaining risk after goals are met;
3. organize goals to be easily understood by the public;
4. use the goals to guide the flood mitigation needs analysis and the identification, evaluation, and recommendation of FMEs, FMSs, and FMPs;
5. use the HUC-8 geographic divisions to specify which goals are intended for which region(s); and
6. select which goals should be considered short-term (10 years) and long-term (30 years).

The key elements above are intended to "guide the overall approach and recommendations in the plan and ensure the coherence of the entire plan," according to Exhibit C of the TWDB Technical Guidelines for Regional Flood Planning. Furthermore, these guidelines will influence how the Regional Flood Plan creates and establishes regulatory goals.

Regulatory goals will be used to guide the development of minimum floodplain management standards as well as gauge the effectiveness and necessity of future Flood Management Strategies (FMSs), Evaluations (FMEs), and Projects (FMPs). Therefore, it is essential that these goals meet the intent of the TWDB as stated above, address the needs of the stakeholders, and reflect the unique characteristics and flood risks of the Lower Brazos Planning Region.

Floodplain management compliance and consideration of the goals will provide flood risk benefits to individuals, communities, and the overall Lower Brazos Planning Region as a whole, as well as demonstrate the overall purpose and intent of this Regional Flood Planning Study.

This document presents a list of goals established for the region using the described metrics and approved by the RFPG. Feedback previously received by the RFPG has been incorporated into this document, including finalized goals, their respective feasibility, timeframe, and regions of applicability.

3B.2 Goal Categories

The Lower Brazos Planning Region's Consultant Team, led by Halff Associates, developed goal categories to help provide some clarity as to the general focus and resulting benefits of each specific, measurable goal. The categories and goals were developed with consideration given to the TWDB overarching goal and the survey results. Specific goal statements can be found in

3B.3 Specific Goal Statements. Additional information regarding the development of the goal categories can be found in 3B.4 Goal-Setting Direction and 3B.5 Watershed Characteristics.

Five distinct category categories emerged during the review of potential goals for the region. Below is a description of each category and how it achieves the TWDB goals:

Category 1: Floodplain Management

- Introduce criteria, regulations, or actions that will help reduce the risk of loss of life and the risk of flood damage to properties.
- Encourage those counties or communities with floodplain regulatory authority to take stronger action.
- Mitigate current floodplain risk by promoting responsible development practices and implementing higher standards.
- This category indirectly supports the overarching goal of protecting against the loss of life and property by reducing the increase in future flood risk.

Category 2: Flood Studies and Analysis

- Provide communities with updated flood studies and updated floodplain maps.
- Give communities a more accurate depiction of flood risks in their area through improved flood information.
- This category indirectly supports the overarching goal of protecting against the loss of life and property by providing more flood risk awareness to the public.

Category 3: Mitigation Projects

- Implement mitigation projects, property acquisition, drainage infrastructure improvements, the elevation of structures, or floodproofing of structures.
- This category directly supports the overarching goal of protecting against the loss of life and property by reducing current flood risk.

Category 4: Flood Warning and Readiness

- Improve flood information systems and a community's communication capabilities before, during, and after an emergency event.
- Possible installation of rainfall, stage, and flow gauges throughout the Lower Brazos Planning Region and developing procedures and additional means of rapid and broad communication.
- This category indirectly supports the overarching goal of protecting against the loss of life by keeping the public informed, prepared, and aware of flood risk.

Category 5: Education and Outreach

- Increase public awareness of the possibility of flood damage, types of various flood risks, and the level of flood risk in the Lower Brazos Planning Region.
- Include educating the public about risks associated with traveling through flood waters, how to interpret flood maps, varying risks within a flood zone, and ways communities might mitigate future flood risks.

- This category indirectly supports the overarching goal of reducing loss of life and property by helping people understand and avoid flood risk.

A list of direct potential benefits associated with each goal category is provided in *Table 3.4* for consideration and assistance in selecting a list of effective and well-rounded goals for the Lower Brazos Planning Region.

Table 3.4: Goal Categories and Benefits

Category / Benefits	1. Floodplain Management	2. Flood Studies and Analysis	3. Mitigation Projects	4. Flood Warning and Readiness	5. Education and Outreach
Protect against loss of life	■	■	■	■	⊙
Protect against loss of property	■	■	■	⊙	⊙
Protect infrastructure	■	■	■	⊙	
Protect environment	■	■	■		⊙
Protect water supply	⊙	⊙	⊙	⊙	⊙
Sustain the economy	⊙	⊙	■	⊙	
Design for co-benefits*			⊙		
Increase public awareness	⊙	⊙		■	■
Build community support	⊙	⊙		■	■

Legend: ■ Benefit ⊙ Potential Benefit

*Single project with multiple benefits, i.e., improves floodplain protection and water supply, increases recreation opportunities, habitat preservation, etc.

Based on the benefits listed with each category, the overarching goal of the TWDB, and the feedback from the survey, the goal categories were prioritized to ensure an adequate number of goals for a given category.

1. Floodplain Management
2. Mitigation Projects

3. Flood Studies and Analysis
4. Flood Warning and Readiness
5. Education and Outreach

The priority of the categories is reflected in the number of goals selected for each category. Categories that were given lower priority have fewer goals than those that were ranked higher priority.

3B.3 Specific Goal Statements

Combining the benefit potential of each category from Section 3B.2 with the direction provided by the TWDB, partners and community collaborators, and the characteristics of the basin, a list of 10 goals for the RFPG was developed and listed in *Table 3.5*. These goals were conditionally approved at the monthly board meeting on October 28th, 2021, with textual changes to the goals reflected in this document.

The goals are presented with time frames, levels of achievement, and geographic applicability. The proposed values reflect current data points and what goals can be reasonably achieved during the given timeframe. *Table 3.5*, as well as TWDB Table 11 in *Appendix 3.3*, includes the goals and their metrics, such as where the goal is applicable, how the goal will be measured, and if any residual risk remains even after the stated flood mitigation goal is fully met.

Table 3.5: Lower Brazos Planning Region's Regional Floodplain Goals

ID	Goal	Category	Baseline	Short Term Goal 2033	Long Term Goal 2053
1	Increase the number of counties and communities enrolled in the NFIP	Floodplain Management	Participating Communities - 152 (85%) Participating Counties - 41 (95%)[1]	Communities enrolled – 90% Counties enrolled – 100%	Communities enrolled – 95% Counties enrolled – 100%
2	Increase the number of counties and communities that have adopted higher than NFIP standards, including directing development away from the floodplain	Floodplain Management	39 out of a total of 221 counties and communities have higher standards[2]	Increase the number of counties and communities with higher standards by 10%	Increase the number of counties and communities with higher standards by 40%
3	Increase the number of entities that have adopted the best available data and science for their designs and plans	Floodplain Management	Number of entities that are utilizing the latest data	Establish a baseline measurement	80% of all entities
4	Improve safety at low water crossings by adding warning systems/signage or improving low water crossings in high-risk areas	Mitigation Projects	895 existing low water crossings	Improve 90 low water crossings	Improve 270 low water crossings

[1] The total number of communities in the Lower Brazos region is 178. The total number of counties is 43.

[2] Obtained from the TWDB higher standard survey results.

ID	Goal	Category	Baseline	Short Term Goal 2033	Long Term Goal 2053
5	Reduce the number of structures that are at risk of flooding during the 1% annual chance flood event by both structural (flood infrastructure) and non-structural (elevation, acquisition, relocation, etc.) means	Mitigation Projects	17,732 structures in the floodplain quilt	Reduce risk to 5% of structures	Reduce risk to 15% of structures
6	Reduce the number of critical facilities at risk of flooding during a 1% annual chance of flooding to above the 0.2% annual chance flood event by both structural (flood infrastructure) and non-structural (elevation, buy-outs, relocation, etc.) means	Mitigation Projects	538[3] critical facilities are within the floodplain quilt	Establish the quantity of at-risk critical facilities in the region	Reduce risk to 10% of facilities
7	Increase the accuracy of flood hazard data in the region by performing detailed studies using the best available terrain, land use, and precipitation data to reduce gaps in floodplain mapping	Flood Studies and Analysis	N/A	Establish a baseline measurement	50% data gap reduction

[3] Preliminary information obtained from GIS – additional scrutiny of this data (including if the facilities have existing levels of flood protection) is required

ID	Goal	Category	Baseline	Short Term Goal 2033	Long Term Goal 2053
8	Increase the number of communities with warning and emergency response programs that can detect flooding threats and provide timely warning of impending flood danger	Flood Warning and Readiness	N/A	Establish a baseline measurement	Increase the number of communities with programs by 40%
9	Increase the number of flood gauges (rainfall, stream, reservoir, etc.) in the region	Flood Warning and Readiness	N/A	Evaluate the number of basins in the region and establish a baseline of where additional gauges are needed	Add gauges based on the results of the evaluation (Increase by 30%)
10	Increase public outreach and education activities to improve awareness of flood hazards and the benefits of flood planning in the region[4]	Education and Outreach	N/A	Develop outreach and education program	Majority participation in annual events throughout the basin

[4] Future goals could include real-time flooding and ponding maps, such as the web-based map created by the City of Sugar Land.

3B.4 Goal-Setting Direction

To facilitate goal-setting for the Lower Brazos Planning Region, several sources of information were pulled together to help provide direction. These include the TWDB guidance, survey feedback, and data-defining watershed characteristics.

3B.4.a. The TWDB Goal

The TWDB has directed all the RFPGs to set an overarching goal "to protect against the loss of life and property." The specific goals for the Lower Brazos Planning Region must directly or indirectly contribute to this overarching goal, and the selected goals should be weighted heavily to contribute to this goal directly.

3B.4.b. Lower Brazos Region Data Collection Survey

Another direction point is feedback from various Lower Brazos Planning Region communities and agencies using the Lower Brazos Data Collection Survey, initiated in July 2021. The survey was sent out to all the pertinent jurisdictions in the Lower Brazos Planning Region (Cities, Counties, MUDs, LIDs, etc.). It included questions specifically designed to discern general goals that the entities would like to set or, at least, discern the benefits that the entities would like to see as a result of this Regional Flood Plan. Select questions were pulled from the Data Collection Survey to provide insight into the communities' needs.

Questions and information from the Lower Brazos Planning Region's Data Collection Survey referenced in this section are shown in *Appendix 3.2*.

Based on the survey results, multiple prominent, useful conclusions helped direct the goal-setting process:

1. Entities generally desire to have better flood risk information (flood studies and mapping) to better understand current and future flood risks.
2. The Lower Brazos Planning Region generally has a willingness to implement flood mitigation measures and reduce current flood risk.
3. Communities could take stronger action to promote flood resilience to reduce future flood risk than is currently being undertaken.
4. Stronger enforcement of floodplain management regulations than is currently occurring could be provided by many communities to reduce future flood risk.
5. In areas lower in the region, higher floodplain management standards could be implemented by many communities to reduce future flood risk.

3B.4.c. Establishment of Goal Targets

Each goal was reviewed to determine the applicability to the Lower Brazos Planning Region and whether the goal should be applied on a region-wide basis, a zonal basis[5], or a HUC-8 basis. The Lower Brazos Planning Region varies significantly in terms of population, topography, climate effects, and overall flood risk. Therefore, some rules are better applied on a smaller scale.

The selection of 10- and 30-year goals was determined based upon guidance from the TWDB. In addition, selecting these target dates aligns with other regions, which will help the TWDB measure achievement across the state. Based on the implementation date of 2023, the goal milestones would be achieved in 2033 and 2053, respectively.

Quantities of measurement for each goal have been recommended in this document. However, the values selected are subject to change as additional data become available and finalized. A brief discussion of the selection of each quantity, with limitations, is detailed below.

- **Goal 1:** Percentages were chosen on what could be reasonably achieved. As only two counties do not participate in NFIP, full participation should be achieved in 10 years. It is assumed that not every community will be able to join the NFIP, so the value proposed is reasonably close to 100 percent while still being achievable.
- **Goal 2:** The selected short-term goal is to increase the number of counties with higher-than-NFIP standards by 10 percent and the number of communities by 30 percent. For the long-term goal, the proposed values are an increase in county regulations by 50 percent and communities of 70 percent. Additional research is needed to fine-tune the baseline value presented, including determining the number of communities that currently have higher than NFIP standards and the breakdown between counties and communities.
- **Goal 3:** The short-term component of this task is to establish a baseline value for the number of entities affected by the latest available data. Long-term, the goal is to have 80 percent of entities implementing the best available data in studies or plans produced within their region.
- **Goal 4:** An achievable implementation rate of increased safety standards or complete removal of low water crossings was assumed to be around 10 percent per decade. Both the short-term and long-term goals aim to improve crossings at this pace. This goal only focuses on crossings in the existing floodplain since the number of low water crossings in the 'future floodplain' has not yet been defined.
- **Goal 5:** Structures at risk for flooding during the 1% Annual Chance Event (ACE) will be evaluated to determine where structural and non-structural measures can be implemented to reduce flood risk. Risk reduction to structures was aimed at five percent for the short-term and 30 percent for the long-term. This goal focused on reducing risk due to many structures inside the existing ACE.

[5] The four zones that make up the Lower Brazos region are 1 (Coastal), 2 (Upper Coastal), 3 (Brazos Valley), and 4 (Middle Brazos). For additional information, see the Chapter for Task 3A.

- **Goal 6:** An achievable reduction of critical facilities at-risk was assumed to be at a rate of 10 percent per decade. Consensus will need to be reached on what defines a critical facility. This goal only focuses on critical facilities in the existing floodplain since the number of critical facilities in the "future floodplain" has not yet been defined.
- **Goal 7:** A baseline measurement will be established as the first goal of this task to determine the number of communities with gaps in flood hazard mapping and where maps can be updated with additional information. Evaluation will be required as some areas may not have changed imperviousness or precipitation values since the latest FEMA maps were issued and will not require updates.
- **Goal 8:** A baseline measurement will be established as the first goal of this task to determine the number of communities with established flood warning systems. From there, a 40 percent increase in the number of communities and warning systems was determined to be a reasonable long-term goal.
- **Goal 9:** Numerous rainfall gauges in the region are operated by municipalities, counties, flood control districts, the United States Geological Survey (USGS), and others. The short-term goal for increasing the number of rain gauges will be to establish a baseline measurement and identify where gaps in data should be addressed. From there, additional gauges will be added based on the evaluation results.
- **Goal 10:** An outreach program will be established as part of this goal, and annual events will be calculated to determine participation. The nature of the program will reflect the measurement determined (for example, whether this will be calculated using the number of events or number of participants).

3B.5 Watershed Characteristics

Data was gathered from various sources such as FEMA, TWDB, Texas Department of Transportation (TxDOT), and local entities; it was subsequently organized and analyzed to highlight the unique characteristics and varied flood risks across the Lower Brazos Planning Region. Characterizing the region ensures the development of regional goals purposefully affects the reduction of loss of life and property. Some data analyzed included flood risk mapping, flood claims, location of structures (including critical infrastructure), and floodplain management participation levels. This data will help identify the type and level of flood risk throughout the Lower Brazos Planning Region, specifically to:

- Manage the achievability and appropriateness of each goal
- Appropriately specify the regional application of each goal

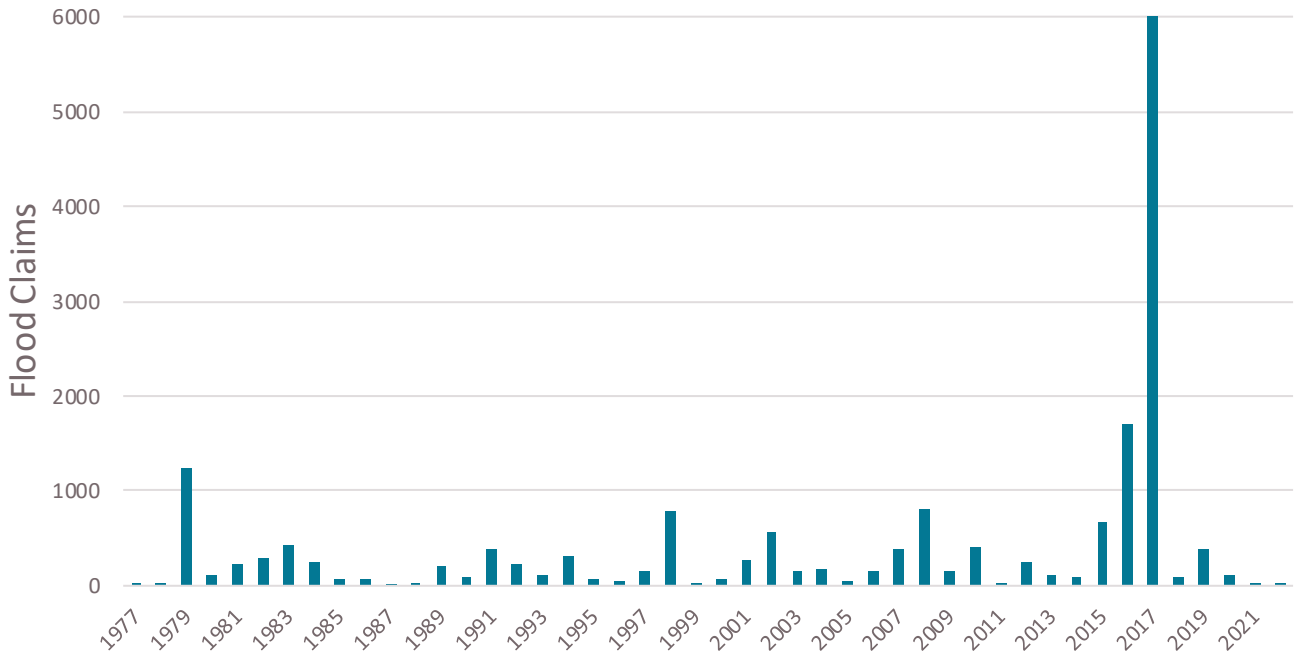
3B.5.a. Population Density

Regional population density is a key metric in determining where most of the population resides in the Lower Brazos Planning Region, as shown in *Figure 1.6: Population Density by Census Tract* in Chapter 1. A larger population typically corresponds with higher flood risk due to increased development and residence in a flood hazard area and increased urbanization, which can exacerbate flooding issues. Mitigation projects implemented in areas of larger population density may see larger benefits due to the number of people and properties the projects will benefit.

3B.5.b. FEMA Flood Claims

Figure 3.7 is a graphical representation of the number of FEMA flood claims per year in the Lower Brazos Planning Region since 1979. The figure details the scale of the magnitude of flood risk throughout the Lower Brazos Planning Region. It can help quantify the level of flood reduction desired for the entire region.

Figure 3.7: Lower Brazos Watershed FEMA Flood Claims by Year

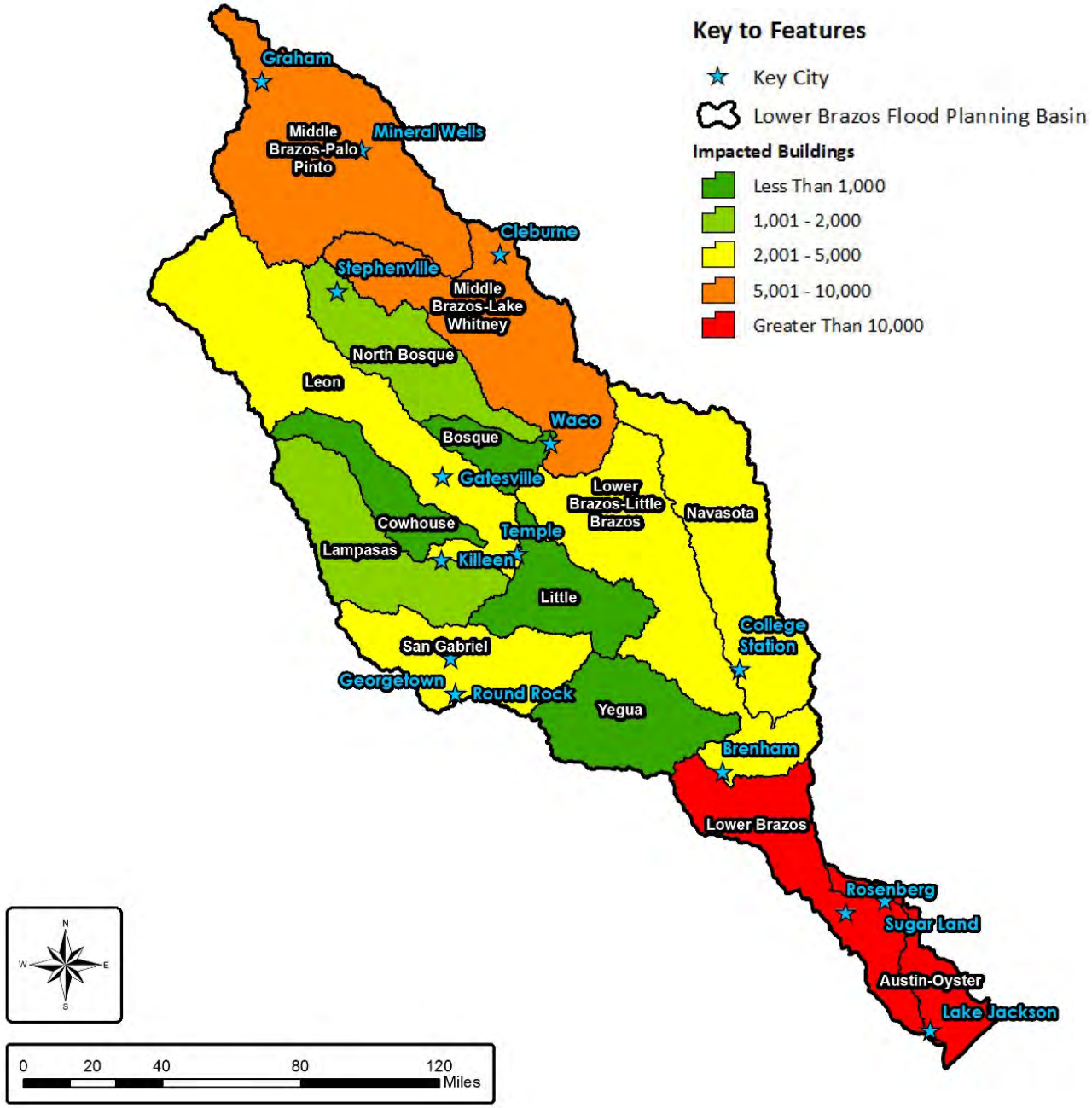


The density map (*Figure 1.14: FEMA Flood Claim Density* in Chapter 1) breaks down the number of FEMA flood insurance claims by HUC-8 regions. These are the total claims from 1979 to 2021. The figure shows the magnitude of flood claims across the Lower Brazos Planning Region and the varying density of these claims. As expected, the flood claim density is highest near heavily populated areas, especially around the Houston area, where the terrain is also relatively flat. However, even some less populated regions still have a significant number of flood claims over the same period.

3B.5.c. Flood Hazard Area Impact

Figure 3.8 details the number of structures in the Lower Brazos Planning Region's flood hazard zone, broken down by HUC-8. Important items include the fact that some structures may be elevated above the base flood elevation, which is not reflected in this map. Additionally, the results are based on the latest floodplain quilt data and are subject to change as more floodplain quilt data is received. However, the figure indicates the varying density across the region of structures currently located in high flood risk areas.

Figure 3.8: Structures Located within Flood Hazard Areas by HUC-8



3B.5.d. Critical Infrastructure

Figure 1.15: Density Map of Critical Facilities in Chapter 1 details a density map of the number of critical structures in the Lower Brazos Planning Region's flood hazard zone. Critical structures include but are not limited to, hospitals, fire and police stations, colleges, nursing homes, and schools. As stated previously, facilities that are elevated above the flood hazard zone are still considered at risk in this figure. The figure indicates the varying density across the region of critical infrastructure currently located in high flood-risk areas.

3B.5.e. NFIP Participation

Participation in the NFIP is highly encouraged by FEMA and is required for property owners to be eligible for flood insurance and federal flood disaster money. *Figure 1.13: NFIP Participation* in Chapter 1 shows the communities and counties both enrolled and not enrolled in the program. The map shows there are still areas where NFIP participation should be encouraged.

3B.5.f. Higher Community Standards

Cities and counties have the authority to establish their own policies, standards, and practices to manage land use in and around flood-risk areas. These communities can adopt and enforce higher standards than the FEMA NFIP minimum standards to better protect people and property from flooding and reflect the unique characteristics of each community or county. Enforcing higher standards is supported and encouraged by FEMA.

According to the TWDB Exhibit C Guidance Document, the term "higher" standard is defined as freeboard, detention requirements, or fill restrictions. FEMA defines a freeboard as additional height above the base flood elevation that serves as a safety factor when determining the elevation of the lowest floor. TFMA performs a Higher Standards Survey annually of cities and counties to document which entities have adopted higher development standards. *Table 3.6* details the community response regarding what regulations are required for floodplain development.

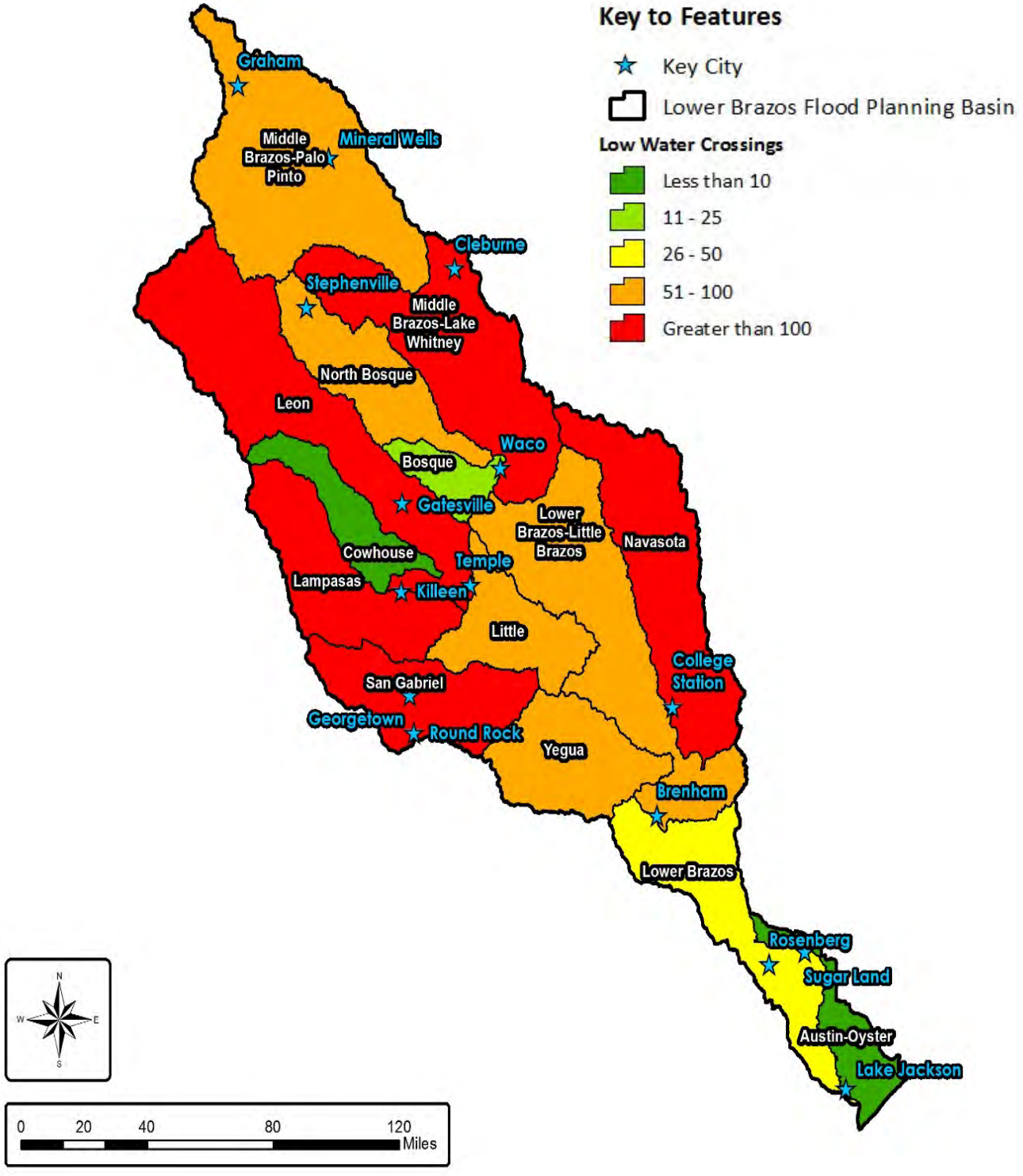
Table 3.6: NFIP Higher Standards

NFIP Higher Standard Required	Count of Entities
At or above current base flood elevation (BFE)	30
BFE + 1 foot (current 1% annual chance event)	16
BFE + 2 foot (current 1% annual chance event)	20
BFE + 2 foot (current 0.2% annual chance event)	2
BFE + 2 foot (future 1% annual chance event)	1
TOTAL ENTITIES ABOVE THE CURRENT BFE	39

3B.5.g. Low Water Crossings

Low water crossings are roadway crossings that can quickly be inundated during a flood event. These areas are important to track because they pose a risk to people who try to cross them during flood events. Often, the depth and speed of the water are underestimated, and people and vehicles may be washed away, causing injury or fatalities. As shown in *Figure 3.9*, the low water crossings are found throughout the Lower Brazos Planning Region but are primarily concentrated in the central portion of the region.

Figure 3.9: Low Water Crossings by HUC-8



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Chapter 4: Assessment and Identification of Flood Mitigation Needs

At the outset, Lower Brazos Regional Flood Plan developed a broad understanding of the planning area with a focus on flood risk (*Chapter 1 – Planning Area Description*) and performed an analysis to identify infrastructure, land, and populations at flood risk and prepare an estimation of the associated impacts (*Chapter 2 – Flood Risk Analysis*). The results of these previous efforts were further analyzed to identify regions with the greatest gaps in flood risk information and regions with the greatest flood risk. The results of this effort are utilized in conjunction with information obtained from public outreach to identify areas or communities with specific flood management or mitigation needs, including flood risk mitigation projects, mitigation evaluations, and management.

The descriptions of the flood mitigation and management categories provided by the Texas Water Development Board (TWDB) are as follows:

- **Flood Management Evaluation (FME):** A proposed flood study of a specific, flood-prone area is needed to assess flood risk and/or determine whether there are potentially feasible FMSs or FMPs.
- **Flood Management Strategy (FMS):** A proposed plan to reduce flood risk or mitigate flood hazards to life or property. Any proposed action that the group would like to identify, evaluate, and recommend that does not qualify as either an FME or FMP.
- **Flood Mitigation Project (FMP):** A proposed project, either structural or non-structural, with non-zero capital costs or other non-recurring costs and, when implemented will reduce flood risk and mitigate flood hazards to life or property.

As a result of these two tasks, maps show the areas of highest flood risk and the most significant information gaps within the region. Additionally, a list and associated maps were created to characterize the potential flood risk mitigation and management needs, or FMEs, FMSs, and FMPs identified for the Lower Brazos Planning Region. These results will be utilized in subsequent Regional Flood Planning tasks.

Task 4A: Flood Mitigation Needs Analysis

This section describes the process adopted by the Lower Brazos Regional Flood Planning Group (RFPG) to conduct the Flood Mitigation Needs Analysis, resulting in identifying areas with the greatest gaps in flood risk information and the areas of greatest known flood risk and mitigation need. The process consisted of a high-level assessment that guided the efforts to identify FMEs, FMPs, and FMSs. *Table 4-1* summarizes the TWDB guidance and factors considered in the Flood Mitigation Needs Analysis.

Table 4-1: TWDB Guidance and Factors to Consider

Guidance	Factors to Consider
Most prone to flooding that threatens life and property	• Buildings within a 1 percent annual chance event (ACE) flood hazard area • Low water crossings • Agricultural and ranching areas in 1 ACE flood hazard area • Critical facilities in 1 percent ACE flood hazard area
Locations, extent, and performance of current floodplain management and land use policies and infrastructure	• Communities not participating in National Flood Insurance Program (NFIP) • Community Rating System (CRS) score • City/County design manuals • Land use policies • Floodplain ordinance(s)
Inadequate inundation mapping	• No Base Level Engineering (BLE) or Zone AE Federal Emergency Management Agency (FEMA) floodplain mapping • Presence of Cursory Fathom Data/FEMA Zone A flood risk data
Lack of hydrologic and hydraulic (H&H) models	• Communities without recent detailed FEMA modeling or models of higher level of detail
Emergency need	• Damaged or failing infrastructure
Existing modeling analyses and flood risk mitigation plans	• Lack of Hazard Mitigation Action plans • Hazard Mitigation plans older than five years
Previously identified and evaluated flood mitigation projects	• Exclude flood mitigation projects already in implementation
Historic flooding events	• Disaster declarations • Flood insurance claim information
Previously implemented flood mitigation projects	• Exclude areas where flood mitigation projects have already been implemented unless significant residual risk remains
Additional other factors deemed relevant by RFPG	• Social Vulnerability Index (SVI)

4A.1: Process and Scoring Criteria

The main objectives of the Flood Mitigation Needs Analysis are to identify the areas of greatest known flood risk and areas where the greatest flood risk knowledge gaps exist. To address the needs identified, FMEs were subsequently identified and recommended by the RFPG.

The Flood Mitigation Needs Analysis compiled data collected in Chapters 1 through 3 to achieve the objectives mentioned above. The data was used to conduct a geospatial assessment by assigning scoring metrics associated with factors listed in *Table 4-1* to different areas of the region. Note that some

factors were excluded from the analysis due to data scarcity, such as locations of identified flooding and pending flood mitigation projects. For the geospatial assessment, Hydraulic Unit Code (HUC)-12 watersheds were selected as the area unit to be scored. A HUC is a unique identifier assigned to watersheds in the United States. As the watersheds get smaller, the number of units used to identify them gets longer. Therefore, the smallest unit of division used to identify a watershed is 12 digits or a HUC-12. The Lower Brazos Planning Region has 560 HUC-12 watersheds, with an average size of 42 square miles. Consideration was made to conduct this analysis at a county level to be consistent with exposure analyses in Chapter 2; however, it was determined that this would not provide a sufficient level of detail for the following reasons:

- Much of the compiled data can be summarized within smaller units than counties, such as HUC-12 watersheds
- FMEs identified and recommended based on results of the Flood Mitigation Needs Analysis target needs more appropriately at a finer scale than the county level
- Utilizing hydrologic boundaries to address flood risk and knowledge gaps is aligned with the overarching plan goal of proposing regional solutions

A total of 13 data categories were used in the geospatial assessment, each with a scoring range determined based on percentiles. Generally, a scoring scale of zero to five was utilized for each category, with higher scores indicating higher need. Due to limited data in several categories, only non-zero values were considered in the scoring ranges. The Flood Map Gap and H&H modeling categories were utilized to locate areas with the greatest flood risk knowledge gaps. The scores across the other 11 data categories were totaled to reveal the areas of greatest known flood risk. Further documentation of the scoring methodology is provided in *Section 4A.2*.

The following sections provide descriptions of all scoring factors and how each HUC-12 watershed was scored. Unless otherwise specified, the 1 and 0.2 percent annual chance storm events polygons from the existing flood hazard spatial layer created in Chapter 2 were utilized in this analysis as inundation mapping. Note that the objective of the Flood Mitigation Needs Analysis is to determine the magnitude of all factors present within a given HUC-12, not necessarily to determine the relative importance of each factor in determining flood risk. Therefore, no weight has been applied to any specific category to emphasize one factor over another, although some exceptions were made by setting the maximum possible scores for several categories to be less than five. These exceptions are explained in detail below.

4A.1.a. Areas Most Prone to Flooding that Threatens Life and Property

Buildings

The building footprints dataset was provided by the TWDB Flood Planning Data Hub. This dataset was utilized in Chapter 2 to determine the total number of buildings in the 1 and 0.2 percent ACE hazard polygons. For the Flood Mitigation Needs Analysis, this category was scored based on the count of these buildings within each HUC-12 watershed. Scoring criteria for this category are shown in *Table 4-2*.

Low Water Crossings

Low water crossings were identified in Chapter 1 and were downloaded from the TWDB Flood Planning Data Hub. For the Flood Mitigation Needs Analysis, this category was scored based on the count of low water crossings in each HUC-12. Scoring criteria for this category are shown in *Table 4-2*.

Agricultural Areas

Agricultural areas have been defined for this task as land used for farming. Impacted agricultural areas are identified in Chapter 2 as intersecting the 1 and 0.2 percent ACE flood hazard areas. The total impacted agricultural area in each HUC-12 was the criteria for assigning points. Scoring criteria for this category are shown in *Table 4-2*.

Critical Facilities

Critical facilities for this assessment include but are not limited to hospitals, schools, and industrial buildings. Existing critical facilities were identified in Chapter 1 and were downloaded from the TWDB Flood Planning Data Hub. This dataset was then utilized in Chapter 2 to determine the total number of critical facilities within the 1 and 0.2 percent ACE flood hazard polygons and areas of unknown flood frequency. This category is scored based on the total number of critical facilities in each HUC-12 identified in Task 2A. Scoring criteria for this category are shown in *Table 4-2*.

4A.1.b. Current Floodplain Management and Land Use Policies and Infrastructure

Communities Not Participating in the NFIP

Communities not participating in the NFIP were identified in Chapter 1. If a community is not participating in the NFIP, all HUC-12s intersected by that community were assigned three points. The scoring criteria for this category are shown in *Table 4-2*.

Communities with a Community Rating System (CRS) score below 10

Communities with a CRS score below 10 were identified using publicly available data from FEMA. A score below 10 indicates that a community has adopted higher standards for floodplain management than the basic requirements for participation in the NFIP, with one being the best possible score. College Station has the lowest CRS score (six) in the Lower Brazos Planning Region, and Missouri City and Sugar Land have the second-lowest CRS score (seven). All HUC-12s intersecting communities with a CRS rating of less than 10 were assigned a score of zero, and the rest were assigned a score of two. Scoring criteria are shown in *Table 4-2*. Note that the scoring for both categories within *Section 4A.1.b* is arranged for the maximum combined score equals five; the scoring was arranged since each category's data are closely related. Furthermore, a community must participate in the NFIP to receive a CRS score.

4A.1.c. Areas Identified as Flood Map Gaps

This analysis was completed using the existing flood hazard layer and areas previously identified as a map gap in Chapter 2. It was assumed that the sources below represented adequate inundation mapping data:

- National Flood Hazard Layer (NFHL) Preliminary Data (zones AE, AH, OH, and VE)
- NFHL Effective Data (zones AE, AH, OH, and VE)
- Base Level Engineering (BLE)

The following inundation mapping data sources were considered lacking in necessary detail in this assessment:

- NFHL Zone A
- First American Flood Data Services (FAFDS)
- Cursory Fathom Data

HUC-12s identified as gaps were assigned a score of five. Note also that some HUC-12s were identified as mapping gaps due to a lack of flood hazard data behind levees and were also assigned a score of five. Scoring criteria for this category are shown in *Table 4-2*.

4A.1.d. Areas Without Hydrologic & Hydraulic Models

Using the existing flood hazard layer created in Chapter 2, HUC-12s were selected that intersect with the 1 percent annual chance storm events flood hazard polygons from the following sources:

- NFHL Preliminary
- NFHL Effective Detailed
- Community Submittal

These mapping sources were assumed to be associated with detailed H&H models. HUC-12s flagged as having no detailed models were assigned a score of five. The main difference between this category and the previous category is that BLE data is considered adequate for mapping purposes but not for modeling purposes. Scoring criteria for this category are shown in *Table 4-2.*

4A.1.e. Areas with Emergency Needs

In the Lower Brazos Planning Region, holistic criteria that define "emergency need" are still being determined. For the purposes of the Flood Mitigation Needs Analysis, the identification of damaged or failing infrastructure was utilized as the only scoring metric. Infrastructure points from Chapter 1 that were previously categorized as being in poor or fair condition, deficient, or non-functional were counted in each HUC-12. Scoring criteria for this category are shown in *Table 4-2*.

4A.1.f. Existing Modeling Analyses and Flood Risk Mitigation Plans

Hazard Mitigation Action Plans (HMAPs) were available for most Lower Brazos Planning Region counties. Therefore, only HMAPs equal to or less than five years old were considered to provide meaningful scoring in this category. Scoring criteria for this category are shown in *Table 4-2*.

4A.1.g. Already Identified and Evaluated Flood Mitigation Projects

Use of projects classified as "proposed" in the ExFldProjs layer from Chapter 1 was considered for this category. The ExFldProjs layer contains projects currently being implemented at stages ranging from funded to under construction. Since a limited number of projects were identified as such, this category was not included in this assessment.

4A.1.h. Historic Flooding Events

Disaster Declarations

Disaster declaration data was obtained in tabular form from FEMA. Using this data, declarations were totaled for each county. Totals from each county were then assigned to HUC-12s based on the locations of watershed centroids. This was done to avoid bias in favor of HUC-12s that overlap multiple counties. This category was scored based on the number of disaster declarations assigned to each HUC-12 watershed. Scoring criteria for this category are shown in *Table 4-2*.

FEMA Claims

To summarize flooding history in the Lower Brazos Planning Region in Chapter 1, publicly available NFIP redacted flood claims were obtained in tabular form from FEMA. All available spatial information within the table was utilized to sum claims within the smallest possible area the claim could have occurred within. This spatial information is:

- Census tracts
- Zip codes
- Counties
- Latitude and longitude grids

Claims were geolocated to areas representing unique combinations of the attributes listed above. Where these polygons crossed HUC-12 boundaries, the total number of claims was split between watersheds based on area. For the Flood Mitigation Needs Analysis, this category was scored based on the count of claims within each HUC-12 watershed. Scoring criteria for this category are shown in *Table 4-2*.

4A.1.i. Already Implemented Flood Mitigation Projects

Use of projects identified as "ongoing" in the ExFldProjs layer from Chapter 1 was considered for this category. However, since only a limited number of projects were identified, this category was not included in this assessment.

4A.1.j. Other Factors - Social Vulnerability Index

Social Vulnerability Index (SVI) refers to the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters or disease outbreaks. In the context of this analysis, SVI is being used as a metric for assessing the vulnerability of communities. The TWDB provided a building footprints spatial layer with SVI values at each feature for use in Chapter 2. For Task 4A, HUC-12 IDs were spatially assigned to each building to calculate average SVI values for each HUC-12. This category was scored to reflect that higher SVI values correlate with a higher flood risk mitigation need since high SVI areas tend to have greater difficulty recovering from natural disasters. Scoring criteria for this category are shown in *Table 4-2.*

Table 4-2: Scoring Criteria

	Score (points)					
Categories	**0**	**1**	**2**	**3**	**4**	**5**
Number of Buildings in Flood-Prone Areas	0	1-8	9-18	19-42	43-122	123+
Number of Low Water Crossings	0	1	2		3	4+
Agricultural Areas in Flood-Prone Areas (Square Miles)	0	0-0.119	0.12-0.299	0.30-0.729	0.73-2.059	2.06+
Number of Critical Facilities in Flood-Prone Areas	0	1		2	3-4	4+
Number of Communities not Participating in NFIP	0			1+		
Number of Communities Participating in CRS with Rating Lower than 10	1+		0			
Identified as a Flood Map Gap	No Map Gap					Gap
Areas without H&H Models	1					0
Damaged or Failing Infrastructure	0	1		2	3	4+
Hazard Mitigation Action Plans	COMPLETE			PARTIAL		NONE
Number of Disaster Declarations	0	6-8	9	10	11-12	13+
Number of FEMA Claims	0	0.01-0.439	0.44-1.209	1.21-4.269	4.27-15.529	15.53+
Social Vulnerability Index	0	0-0.249	0.25-0.339	0.34-0.439	0.44-0.549	0.55+

4A.2: Scoring Methodology

As previously mentioned, percentiles were used to develop the scoring scale for numerical categories, with the 80th percentile receiving a score of five and the 20th percentile receiving a score of one. A sample list of 15 non-zero values in increasing order is shown in *Table 4-3* to illustrate how scores are assigned using this methodology. For these categories, zero values received a zero score and were removed from the array of values used to compute percentiles. This was performed to provide meaningful scoring metrics for categories containing a high percentage of zero values. For example, 464 out of 560 HUC-12 watersheds in the Lower Brazos Planning Region have no identified critical facilities in flood hazard areas. Not excluding zero values would assign zero as the 80th percentile, resulting in a score of five assigned to every HUC-12 with a non-zero value. Therefore, zero values were excluded across the board for consistency since this issue was present in several categories. Adjusted percentile values used to score HUC-12s are shown in *Table 4-3.*

Table 4-3: Scoring Example with Percentiles

	1 (below 20th percentile)			2 (20th to 40th percentile)			3 (40th to 60th percentile)			4 (60th to 80th percentile)			5 (above 80th percentile)		
Values	1	1	2	3	4	4	6	8	9	10	17	19	22	24	31

As an alternative to using percentiles, a scoring system that assigns scores from zero to five that are proportional to the full range of values within each category was considered. However, it was determined that this would not provide a clear picture of needs in the region since watersheds near the coast have significantly higher numerical totals than inland areas. For example, the Lower Oyster Creek watershed has the highest total for flood claims (5,674), which is over four times higher than the second watershed by claims. Similar trends are evident in the buildings and critical facilities categories. As a result, assigning proportional scores to values in each category would produce HUC-12 scores near the coast that would eclipse the rest of the region. For this reason, percentiles were chosen as the best option to avoid downplaying flood risk mitigation needs for large portions of the Lower Brazos Planning Region.

4A.3: Areas with Significant Flood Risk Gaps and Flood Mitigation Needs

As previously discussed, the first goal of the Flood Mitigation Needs Analysis was to identify areas where the greatest flood risk knowledge gaps exist. The Inundation Mapping and H&H modeling categories were utilized to locate these areas. The results of this preliminary assessment show that roughly one-third of the Lower Brazos River watershed has inadequate mapping and no detailed H&H models, as indicated in *Map 14* in *Appendix 0*. The scoring ranges representing each level of severity of flood risk knowledge gaps are included in *Table 4-4.* Most of these areas are in the upper portion of the basin. Specifically, the following major subwatersheds, listed from south to north, contain the most significant gaps in flood risk knowledge:

- Mill Creek
- San Gabriel River
- Leon River
- Bosque River
- Middle Brazos – Palo Pinto

Table 4-4: Scoring Ranges for Severity of Flood Risk Knowledge Gaps

Severity of Flood Risk Knowledge Gap	Score Range
High	4
Medium	1 – 3
Low	0

The second goal was to determine the areas of greatest known flood risk and flood mitigation needs. The scores across 11 of the 13 categories, which exclude those used to determine flood risk knowledge gaps, were totaled to locate these areas. The scoring ranges used to determine the severity of flood risk of a HUC-12 are included in *Table 4-5*. As shown in *Map 15*, located in *Appendix 0*, HUC-12s determined by this analysis to have high flood risk are distributed throughout the Lower Brazos River watershed, with clusters of particularly high risk located in the following areas, listed from south to north:

- Eastland County
- McLennan County
- Williamson County
- Grimes County
- Waller County
- Austin County
- Fort Bend County
- Brazoria County

Table 4-5: Scoring Ranges for Severity of Flood Risk

Severity of Flood Risk	Score Range
High	25 – 41
Medium-High	21 – 24
Medium	18 – 20
Medium-Low	15 – 17
Low	4 – 14

Each of these areas tends to score high in different combinations of risk factors. For instance, areas downstream of Washington and Grimes counties score exceptionally high with regard to buildings and critical facilities in flood-prone areas, disaster declarations, and flood claims. Conversely, watersheds in Williamson County tend to score higher due to damaged or failing infrastructure and low water crossings.

Ultimately, the results of the Flood Mitigation Needs Analysis guided the RFPG's subsequent efforts to address flood risk identification and mitigation needs in the Flood Mitigation Needs Analysis by informing the creation of drainage master plan and regional watershed study FMEs, which is discussed further in *Section 4B.3*. Additionally, studies to assess flood hazards within areas protected by levees were created and assigned the type "Study on Flood Preparedness." The high risk areas identified in *Map 14*, located in *Appendix 0*, informed the creation of regional watershed and internal levee study FMEs. The high risk areas identified in *Map 15*, located in *Appendix 0*, identifies areas where drainage master plan FMEs were created. Since sponsorship support was identified as a prerequisite for recommending needs in Chapter 5, *Map 15* also directed the RFPG's interest group outreach efforts to obtain approval of FMPs, FMSs, and FMEs identified in Task 4B.

Task 4B: Identification and Evaluation of Potential FMEs and Potentially Feasible FMSs and FMPs

4B.1 Purpose and Intent

Task 4B was the first step in gathering and assessing potential FMEs, FMSs, and FMPs. The identification of FMEs, FMSs, and FMPs was guided by identifying flood-prone areas in previous tasks, along with reviewing publicly sourced information and interest groups outreach.

The RFPG utilized multiple avenues to collect studies, reports, models, and other documentation supporting the region's proposed flood management or mitigation efforts. The most promising items were sourced from the Interest Groups Survey, where interest groups provided the Lower Brazos RFPG with the information deemed most important to their current efforts. However, publicly available documentation such as hazard mitigation plans, master drainage plans, and flood protection plans were also analyzed for potential mitigation and management efforts that could be included in the Lower Brazos Regional Flood Plan.

After gathering a substantial amount of information, the RFPG approved an identification process that was used to develop a list of potential FMEs, FMSs, and FMPs.

Finally, each FME, FMS, and FMP was analyzed to determine associated characteristics, existing flood risk, flood risk reduction, and costs depending on the mitigation type. The results of this evaluation were used to help determine which FMEs, FMSs, and FMPs would be recommended for inclusion in the Regional Flood Plan.

4B.2 Information Collection

4B.2.a. Interest Group Survey

As described in Chapter 10, a survey was sent out to public officials (primarily Public Works Directors and City Engineers, City managers, County Commissioners, etc.) throughout the Lower Brazos Planning Region. The primary intent of the survey was to directly source-specific flood management and mitigation needs from various interest groups within the Lower Brazos Planning Region. This allowed the entities to provide flood mitigation ideas to the group, from high-level concepts to detailed design drawings of projects, for evaluation and incorporation into the plan.

Although the responses were reasonably distributed geographically, a minority of them included submittals of flood management or mitigation needs. The entities that did provide specific mitigation needs, along with supporting documentation and data, are concentrated in the southern portion of the Lower Brazos Planning Region. This uneven distribution is assumed to be due to the higher risk of flooding in this portion of the region, causing increased awareness of flood risk and, in turn, increased engagement with flood planning efforts.

When the survey was initially sent out, the cities of Sugar Land, Fulshear, and Sienna submitted data and documentation supporting their identified flood mitigation and management needs. Through this avenue, only around 30 potential FMEs, FMSs, and FMPs were initially identified for further evaluation.

4B.2.b. Other Data Sources

Due to the low participation in the survey (14 percent response rate), few needs were provided directly by regional entities. As a result, several other sources were reviewed to indirectly determine additional needs for the communities throughout the Lower Brazos Planning Region. These other sources included Hazard Mitigation Plans, publicly available Master Drainage Plans, unfunded Community Development Block Grant (CDBG) lists, unfunded Flood Infrastructure Fund (FIF) lists, and Capital Improvement Project (CIP) lists.

Throughout the identification and evaluation process, additional direct outreach with interest groups — targeted to the larger communities that did not respond to the survey — was performed to obtain flood management and mitigation needs in high-population areas where needs were expected. These efforts are described in Chapter 10. As a result, several additional needs were provided directly to the Technical Consultant Team, led by Halff Associates, by additional entities. In total, the City of Bryan, City of College Station, McLennan County, Williamson County, and Fort Bend County Drainage District provided almost 90 flood mitigation and management needs.

4B.2.c. Final List of Sourced Potentially Feasible Needs

In all, over 540 flood mitigation and management needs were collected both directly and indirectly from interest groups. These flood mitigation needs ranged from high-level flood mitigation planning to preliminary design of flood mitigation infrastructure. *Table 4-6* shows the sources reviewed and the number of flood mitigation or management needs from each source.

Table 4-6: Flood Management and Mitigation Needs Sources

Source	Number of Needs*
Survey	30
Direct Outreach	66
Hazard Mitigation Plans	237
Master Drainage Plans	133
Capital Improvement Projects	14
Unfunded Community Development Block Grant	25
Unfunded Flood Infrastructure Fund	2
Flood Protection Plan	38
Total	545

* Some needs were found in multiple sources and are counted by the primary source

The needs sourced directly from interest groups (including the survey) or identified from publicly available master drainage plans typically had the most supporting information, such as H&H modeling, needed to complete the identification and evaluation of flood management and mitigation needs for

this plan. As a result, the level of engagement from interest groups directly impacted the flood management and mitigation needs evaluation.

4B.3 Identification Process

4B.3.a. Initial Screening Process

After extensive data collection, a screening process was used to identify needs that did not align with the regional flood planning purposes/goals and categorize the remaining flood mitigation and management needs. The screening process was developed to ensure that needs are classified appropriately per the definitions of FME, FMS, and FMP provided by the TWDB. The process was also developed to ensure that needs were classified in a manner equitable and consistent across the Lower Brazos Planning Region.

The raw list of collected flood management and mitigation needs was initially screened for relevancy to mitigating existing flood risk. For example, projects related to the water supply without flood mitigation benefits or projects focused on mitigating flood risk associated with future development were discarded.

After this pre-screening effort, the needs were filtered into two categories (FMPs or FMSs) based on whether the need was classified as a single project or multiple projects. Single projects included separate projects that are hydraulically connected and provided a flood risk-benefit to a single service area. Regional needs such as community-wide flood early warning systems or drainage criteria updates were classified as FMSs. The remaining needs, such as structural mitigation projects were initially classified as FMPs. These projects ranged in level of detail from conceptual project ideas to detailed construction drawings.

The FMP and FMS lists were then screened further based on the level of information provided by the source. The TWDB required an exposure and flood risk reduction analysis be performed for all FMPs and some types of FMSs to ensure the implementation would provide sufficient benefits to justify the associated costs.

Additionally, the TWDB required some other metrics to be evaluated to help characterize this balance, including:

- Service area
- Percentage of the project that is a nature-based solution (by cost)
- Water supply benefit
- Project level of service
- No negative impact on neighboring areas

Hydrologic and hydraulic modeling is assumed to be a necessary component to generate a sufficient amount of information to complete this evaluation and, as a result, was a primary metric by which FMPs and FMSs were screened. If modeling was not provided with a provided need, the need was classified as an FME with the assumption that the required data could be obtained by further evaluation of the need.

Note that the FMS category is considered a "catch-all" flood management category intended to capture strategies or ideas that may indirectly reduce flood risk. As a result, some FMSs do not require a quantifiable level of flood risk reduction to still be classified as an FMS. Non-structural actions were considered feasible if they were flood-related and provided a benefit to the community. Some examples of these types of FMSs include drainage criteria updates or education and awareness programs. While neither of these examples have a measurable flood risk reduction benefit, they still provide an indirect benefit to flood risk through policy, education, awareness, and information. If a need was initially classified as an FMS but did not have supporting information, additional screening was completed to determine whether the FMS type required flood risk reduction to be quantified. If not, the need remained an FMS.

A flow chart, shown in *Figure 4.1*, was created to visually summarize the key elements of this process to increase public awareness of how needs were screened for further evaluation. The RFPG approved this process on November 16, 2021.

4B.3.b. Secondary Screening and Reclassification

Flood management and mitigation needs often passed through the screening process several times as more information became available through ongoing research and interest group feedback. Some needs were initially classified as FMPs, assuming that H&H modeling would become available later in the evaluation process. In some cases, these models were not provided by the responsible entities, and the FMP was subsequently reclassified as an FME. Conversely, some needs were initially classified as an FME due to the scarcity of the provided information but were later reclassified as an FMP based on newly available data.

Several FMPs were also reclassified as FMEs based on the hydrologic data that was initially used to develop the projects. If the project was developed using outdated rainfall rates, it was classified as an FME and specifically tagged as needing further hydrologic modeling. This has the greatest impact on regions in the southern portion due to the recent change in rainfall statistics in this area.

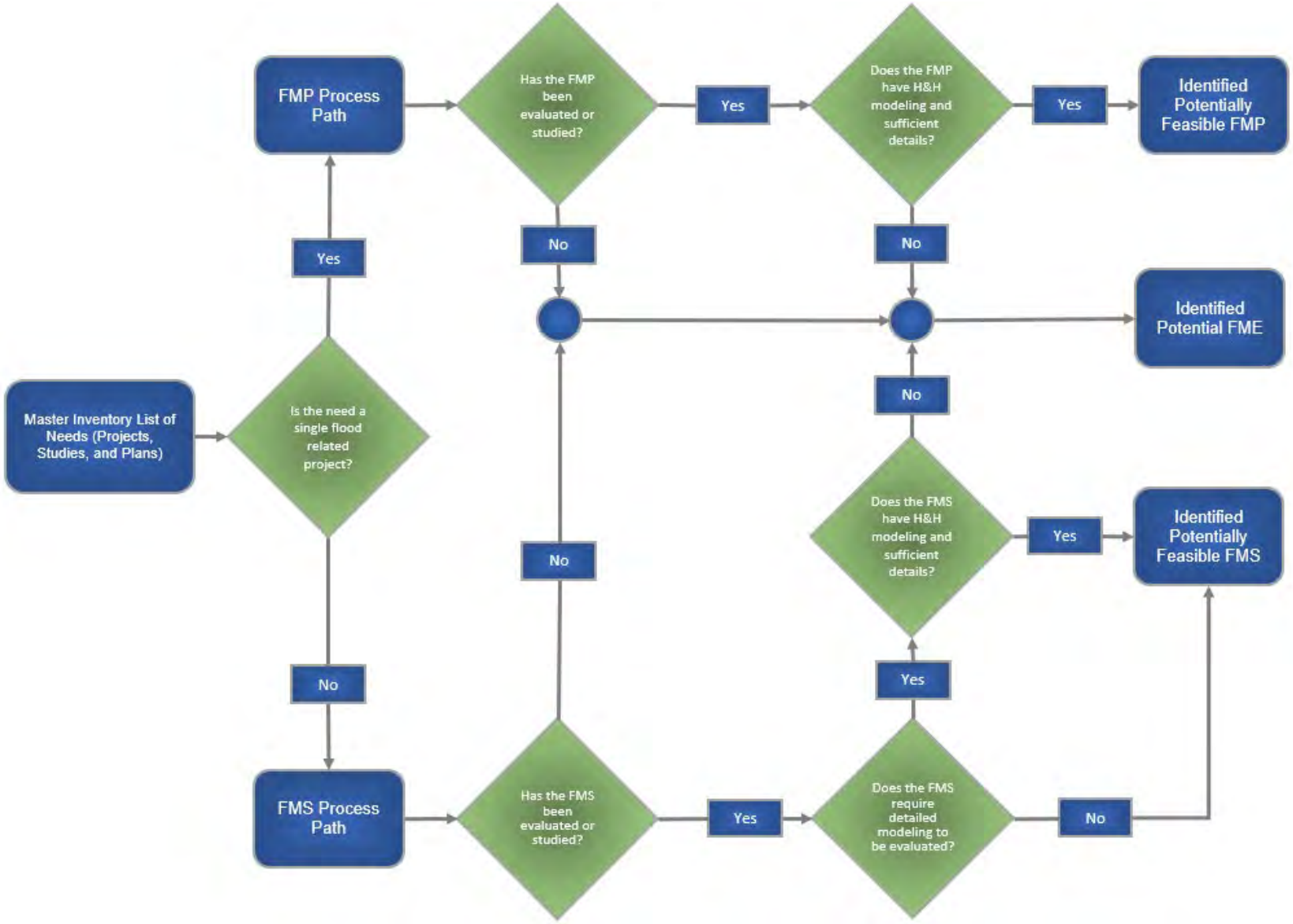
4B.3.c. Geopolitical Boundaries and Flood Planning Regions

Some FMEs and FMSs share a common boundary with geopolitical entities such as city limits or county lines, thus causing the boundary of the FMEs, FMSs, and FMPs to expand outside the Lower Brazos Planning Region. If the majority of an FME or FMS was found to be located outside of the Lower Brazos watershed due to its geopolitical tie, it was removed from the FMEs, FMSs, and FMPs lists and no longer considered an identified need for the plan. These FMEs, FMSs, and FMPs were provided to the relevant neighboring regional flood planning groups for consideration. The communities that were affected are listed in Table 4-7 below. Brazoria County and Young County have been excluded from this process since their boundaries overlap more than two regional flood planning regions. The largest share of the areas for these two entities is located within the Lower Brazos Planning Region.

Table 4-7: FMEs and FMSs Reassigned to Other Regional Flood Plans

Community	Neighboring Regional Plan	Reassigned FME	Reassigned FMS
Archer County	Upper Brazos	-	1
Callahan County	Upper Brazos	-	2
Fort Bend LID #2	San Jacinto	1	-
City of Burleson	Trinity	1	-
City of Fairfield	Trinity	1	-
Freestone County	Trinity	2	2
Jack County	Trinity	1	4
Leon County	Trinity	2	2
Madison County	Trinity	1	2
Parker County	Trinity	2	1
Bastrop County	Lower Colorado	3	1
Brown County	Lower Colorado	-	2
Burnet County	Lower Colorado	1	2
City of Brazoria	Lower Colorado	1	-
Mills County	Lower Colorado	-	1
Total		16	20

Figure 4.1: Identification Process



4B.3.c. FMEs Identified by the RFPG

In addition to identifying FMEs through the data collection efforts described above, the RFPG was also responsible for creating FMEs to address information gaps and identify flood risk needs. To support this activity, the flood mitigation needs analysis conducted during Task 4A identified HUC-12 watersheds with the highest flood risk knowledge gaps and the greatest overall flood risk. To address these needs, drainage master plans were recommended for areas with high flood risk to help mitigate this flood risk, and regional watershed studies were recommended for those areas with the greatest knowledge gaps.

Figure 4.2 below shows areas of the Lower Brazos Planning Region that need further study to close gaps in flood risk knowledge. This information was used to identify the regional watershed studies and studies on flood preparedness within leveed areas mentioned in Section 4A.3. To promote regional solutions and obtain the best return on investment for each study, FMEs were delineated using the smallest appropriate hydrologic area rather than political boundaries. In most cases, study extents were defined by major reservoirs or tributary confluences with larger rivers. As a result of utilizing hydrologic boundaries for study extents, regional watershed study FMEs recommended by the RFPG include some areas that are not specifically noted as having flood risk knowledge gaps.

Figure 4.3 shows areas of the Lower Brazos Planning Region with the most significant overall flood risk based on the factors discussed in Section 4A.3 (also see Map 14 found in *Appendix 0*). HUC-12s with an overall risk score exceeding the 80th percentile were assigned drainage master plan FMEs, which generally follow HUC-12 boundaries. In some cases, two or more HUC-12 areas were combined into a single FME to identify the potential for future FMPs and FMSs to address needs across a broader region.

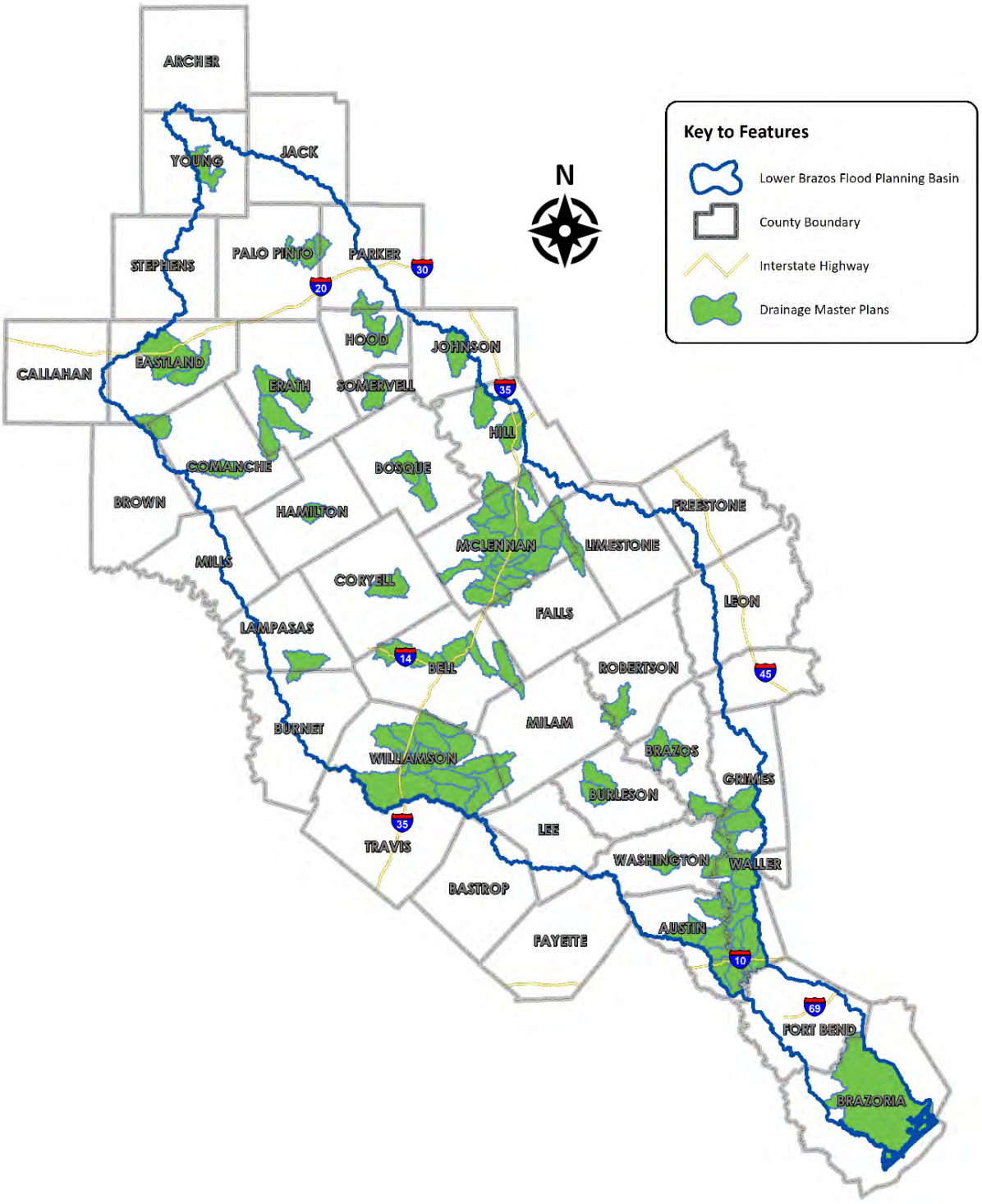
The potential regional watershed studies and drainage master plans were added as FMEs. The list was then checked for overlaps of existing FMEs and created FMEs to ensure that no duplicates covered the same area and need type. FMEs created in the Flood Mitigation Needs Analysis generally had priority over FMEs determined from other sources since they are more regional in scope and have the potential to benefit a larger area. *Table 4-8* lists the different types of FMEs identified due to the Flood Mitigation Needs Analysis.

Table 4-8: Potential FMEs Identified Under Task 4A Needs Analysis

FME Sub-Type	Number
Drainage Master Plans	81
Regional Watershed Studies	39
Study on Flood Preparedness (leveed areas)	4
Total	**124**

Figure 4.2: Regional Watershed Studies Identified by the Lower Brazos RFPG

Figure 4.3: Drainage Master Plans Identified by the Lower Brazos RFPG



4B.3.d. Regional Flood Plan Amendment

The Lower Brazos RFPG was granted additional funding from the TWDB to amend the Final Lower Brazos Regional Flood Plan. This amendment consisted of two tasks intended to identify, evaluate, and recommend additional FMPs and incorporate them into the existing Final Lower Brazos Regional Flood Plan report and associated data.

To complete this amendment process, the Lower Brazos RFPG used two avenues to gather additional flood mitigation and management needs. The first was an additional round of outreach. This effort allowed for communities who were completing studies during the development of the Regional Flood Plan to submit their resulting projects for consideration. Additionally, the RFPG approved the Technical Consultant Team to perform evaluations to develop several projects. These evaluations consisted of performing regional watershed studies identified in Task 4A to develop FMPs that would help address flood risk in the studied areas, performing additional modeling and benefit cost analysis on FMEs to elevate them to FMPs, and assessing the need for gauging and flood warning throughout the Lower Brazos Region. Memorandums describing the results of these studies can be found in Appendix 4.5 and 4.6.

After completing the amendment tasks, and additional 22 flood mitigation and management needs were provided by local entities and 15 flood mitigation and management needs were developed by the RFPG for inclusion in the Lower Brazos Regional Flood Plan.

4B.3.e. Infeasible FMPs

Based on guidance from the TWDB and direction from the Lower Brazos RFPG, projects with a drainage area of less than a square mile that did not have sponsorship support were classified as infeasible since they did not conform to the spirit of a "regional" flood plan. Therefore, 68 FMPs were classified as infeasible, as seen in *Appendix 4.4*.

4B.3.f. Final List of FMEs, FMPs, and FMSs

The final list of potential FMEs, FMPs, and FMS included in the plan for further evaluation in Chapter 5 is listed in *Table 4-9*.

Table 4-9: Final Number of Identified FMEs, FMPs, and FMSs

Need Type	Number
Flood Mitigation Evaluations	423
Flood Mitigation Projects	57
Flood Management Strategies	139
Infeasible Flood Mitigation Projects	68
Total	**687**

The distribution of FMEs, FMPs, and FMSs throughout the Lower Brazos Planning Region can be seen in *Maps 16, 17, and 18, respectively,* in *Appendix 0*.

Each category had a different set of metrics by which the needs were evaluated. For instance, FMEs are evaluated based primarily on study cost and existing flood risk within the study area. In contrast, FMPs

are evaluated not only by project cost and existing flood risk but also by a reduction in flood risk. Even less so, FMSs predominately do not require information on flood risk or flood risk reduction. The final classification is important to the flood plan because it determines how the need is evaluated and how it will be presented.

4B.4 Potential FME Evaluation

4B.4.a. FME Types Overview

Needs classified as FMEs were further classified into "types" and "sub-types" to help determine the costs necessary to complete each respective study and facilitate future prioritization and selection. The two broader categories, Watershed Planning and Engineering Project Planning, are based on the scope of the study.

Much of the Lower Brazos Region has Base Level Engineering (BLE) modeling or other existing data – as discussed in Chapter 2 – that could be leveraged to reduce the amount of work needed to close flood risk knowledge gaps and determine flood risk mitigation efforts. Where BLE is available, certain FMEs could improve upon existing BLE models by enhancing hydrology and adding hydraulic features to provide more detail as needed. Additionally, there are ongoing Category 1 FIF studies throughout the Lower Brazos Region. In these areas, the potential FMEs could utilize the results of those ongoing FIF studies, so that efforts are not duplicated.

Watershed Planning

Watershed planning FMEs characterize those evaluations that are more regional in scope and focused on reducing flood risk information gaps or developing flood mitigation projects for an entire watershed or community.

The **Drainage Master Plans (DMPs)** subtype is an evaluation that estimates flood risk for the entirety or portion of a watershed—sometimes confined to a specific community and its political boundaries—and develops food risk management and mitigation recommendations that will mitigate flood risk. These studies typically identify needs within a community, including FMEs, FMPs, and FMSs.

The **Regional Watershed Studies** subtype is an evaluation that estimates flood risk throughout an entire watershed and can encompass several communities within the watershed. These studies often cover larger areas than a DMP and may not result in the identification of flood mitigation projects like a DMP. Typically, flood risk mapping products are developed as part of this study to be used for regulatory guidance and enforcement.

Engineering Project Planning

Engineering Project Planning FMEs characterize those evaluations that are more specific to individual or multiple connected projects that serve a single benefit area within a community. These studies either include updates to the supporting modeling data or further evaluation of a project. As mentioned above, many of these FMEs were initially classified as FMPs but later reclassified as FMEs due to a lack of modeling or other supporting information needed to complete flood risk reduction evaluations.

Engineering Project Planning FMEs are broken down into three sub-types depending on the level of evaluation needed to upgrade an FME to an FMP.

The **Feasibility Assessment** sub-type is an evaluation of a specific, unstudied high flood risk area with the goal of developing alternatives to mitigate the identified high flood risk. Feasibility assessments include estimated design and construction costs and the flood risk reduction associated with the alternatives. Evaluations of this kind typically require the development of H&H models to establish existing conditions and determine proposed conditions and flood risk benefits associated with the project. Once completed, the study will give planners a better understanding of the options to mitigate flood risk at a specific location, along with estimated costs and benefits associated with a given alternative. It will also help prioritize a given alternative with other community needs and facilitate implementation.

The **Preliminary Engineering** sub-type is an evaluation of an identified FMP to better determine the flood risk reduction benefits associated with the FMP. This evaluation typically requires the development of, or significant revisions to, H&H modeling to determine flood risk reduction associated with the project and also includes the completion of a detailed cost estimate. Once completed, the study will give planners a better understanding of the cost and benefit associated with a given project, help them prioritize that project with other community needs, and facilitate implementation.

The **Update H&H Modeling** sub-type evaluates an already developed FMP where the underlying modeling data is outdated. To be upgraded to an FMP, this FME H&H modeling needs to be updated. These updates typically include updating rainfall information or other underlying data such as other changes in hydrology, terrain, land cover, land use, etc.

Studies on Flood Preparedness

Studies on Flood Preparedness are FMEs that analyze specific flood risks of a community and determine how well the community is prepared to respond or how well the existing infrastructure can handle the flood risks. Dam failure analyses and emergency evacuation plans make up the majority of this category.

Table 4-10 outlines the different types, and sub-types of FMEs, the general category description for each sub-type, and the number of FMEs identified for each category. A full list of the identified FMEs can be found in *Appendix 4.1, Table 12*.

4B.4.b. Critical Assessment Information

FMEs are intended to be identified and recommended for areas with higher-than-average flood risk and where areas do not have planned flood mitigation projects or do not have sufficient flood risk information. Since FMEs focus on developing better information or evaluating projects, they do not typically provide any immediate flood reduction benefit. As a result, the evaluation of FMEs focuses on general information about the FME as well as existing flood risk information within the study area. The following metrics were identified for each potential FME, depending on the amount of available information for a given area:

- General description and location of FME, including impacted HUCs, counties, and watersheds
- Sponsor(s) who will manage the project; along with other entities that may have oversight

- Estimated study cost and potential funding sources (local, state, and federal)
- Associated RFPG approved flood management and mitigation goals (described in Chapter 3B) to ensure the FME meets the goals of the plan
- Determination on whether the FME meets an emergency need
- Associated flood risks within the study area include:
    - Estimated number of structures (residential and critical facilities) at flood risk
    - Estimated population at flood risk
    - Estimated road and low water crossings at flood risk
    - Estimated farm and ranch land at flood risk
- Existing or anticipated models

A few of the generic metrics—description, type, location, area, sponsors, and entities with oversight for each FME—were provided by reports, studies, or other sources that indicated the need of the FME. However, some of the metrics required more analysis than available in the source documentation, such as cost to perform the evaluation, existing flood risk within the study area or likely benefit from the study, and determination of whether the evaluation meets an emergency need.

Evaluation Cost Estimate

An estimate of costs to complete an evaluation was determined for each FME. The TWDB guidance defines the cost estimate for FMEs as a "planning level" cost that describes whether the study would utilize existing hydraulic and hydrologic models or depend on existing information. Some FMEs submitted by entities for inclusion in the Regional Flood Plan included planning level cost estimates. However, most of the FMEs that were either collected or created as part of Task 4B do not have estimated costs. Costs had to be developed for these FMEs.

Per the TWDB guidance, the following costs are required to be considered if applicable:

- Associated non-engineering studies (floodplain regulation development; flood authority or revenue-raising studies; public awareness program)
- Engineering/technical/feasibility studies (H&H modeling/mapping; identification of potential flood risk reduction solutions; BCA and alternative analyses; project design; construction engineering)
- Surveying; geotechnical; testing

To estimate study costs while ensuring an accurate comparison between FMEs, a consistent process was developed for all FMEs based on key FME characteristics such as FME sub-type, study area, and estimated project construction cost. For the **Watershed Planning FME** types (Drainage Master Plans and Regional Watershed Studies) and studies on Flood Preparedness types, costs to complete the FMEs were estimated based on records of costs to complete past evaluations of similar types. From this record, a cost-to-study area relationship (i.e., "curve") was developed. These relationships were used to estimate study costs for watershed mapping FME types based on the area of the FME. The FME areas were delineated manually based on the source description of each FME and estimated using the watershed that contributes runoff to the flood risk point — or region of interest.

Table 4-10: FME Types

FME Type	FME Sub-Type	Description	Number of FMEs Identified
Watershed Planning	Drainage Master Plan	An assessment of a watershed or community to estimate flood risk and recommend flood management and flood mitigation needs with a focus on potential flood mitigation projects.	125
Watershed Planning	Regional Watershed Studies	An assessment of a watershed with the intent to develop better flood risk information that can include both regulatory and non-regulatory flood risk mapping.	60
Engineering Project Planning	Feasibility Assessment	Develop flood mitigation project alternatives for a discrete high flood risk area, estimate construction costs for the alternatives, and determine flood reduction benefits for the alternatives. Evaluation will require the creation of H&H modeling.	32
Engineering Project Planning	Preliminary Engineering	Further evaluation of an identified potential flood mitigation project, validate construction costs, and determine flood reduction benefits for the project. Evaluation will require the creation of H&H modeling.	132
Engineering Project Planning	Update H&H Modeling	Updates or refinement of previously created models that support a potential flood mitigation project to include the best available data.	45
Studies on Flood Preparedness		Analysis to determine community risk and preparedness in infrastructure failure or severe storm events.	29
		Total	423

Costs for **Preliminary Engineering FME** sub-types were estimated using a methodology focused on the scope and type of project being evaluated rather than the study area. This methodology was chosen to account for the complexity of the design associated with the specific project. Therefore, instead of using the study area for the project to estimate study costs, project construction costs were used to estimate study costs. Construction costs were provided in the supporting documentation for all FMEs classified as Preliminary Engineering. The FME study cost was then estimated as a percentage of the construction rated on a curve, with higher-cost projects having a lower percentage of study cost to construction and lower-cost projects having a higher percentage.

Projects with no associated cost within the source material were classified as **Feasibility Assessment FME** sub-types. Because of this, FME study costs for this sub-type were estimated based on the study area using the cost-to-area curve developed for drainage master plans.

The **Update H&H Modeling FME** sub-type costs were estimated using a flat rate methodology. The costs to update H&H modeling and re-evaluate the projects were estimated using rates-based records of costs to complete modeling updates of similar types and scope. However, similar to the cost estimates for Engineering Project Planning, costs were estimated based on the construction cost of the project. The studies were separated into three categories based on the cost of the project—small, medium, and large—and flat study costs were assigned to each. *Table 4-11* lists the costs associated with each size study and the range of area that is included for each size category.

Table 4-11: Update H&H Modeling Costs

Project Cost Range (Millions $)	Estimated Cost
< 0.5 (Small)	$50,000
0.5 - 10 (Medium)	$100,000
> 10 (Large)	$300,000

The above processes were used consistently for all FMEs regardless of the cost information provided within the source documentation. This ensured that the cost estimate calculated for each FME was based on a consistent and equitable methodology.

The estimated costs associated with each FME depend on broad, high-level assumptions. The FME costs estimated as part of this plan are for high-level planning purposes only. Further evaluation will be required to develop more detailed and accurate cost estimates.

Many needs were originally classified as FMPs based on the descriptions provided in the source material. However, due to a lack of modeling or other supporting information, the FMPs had to be reclassified as FMEs for further evaluation to develop the missing information. However, as a result of this reclassification the associated cost for the need was recalculated to represent the cost of performing additional analysis, as explained above. Due to the advanced state of many of these FMEs, estimated construction costs had already been determined, but were no longer being represented in the associated costs. To preserve this information, a separate column was used to track construction costs associated with advanced FMEs.

Existing Flood Risk

A flood risk analysis was completed for each FME to provide additional context to the scope and extents of the FME, along with an estimate of the flood risk level within the study area that could potentially be mitigated with the implementation of flood mitigation projects or management strategies.

The flood risk datasets created in Chapter 2 were leveraged as a baseline for at-risk infrastructure. The flood risk data was heavily based on the floodplain quilt developed under this task. The FME study area was used to define the limits of flood risk and the at-risk infrastructure located within the FME boundary was used to calculate the following metrics:

- Estimated number of structures at flood risk
- Residential structures at flood risk
- Estimated population at flood risk
- Critical facilities at flood risk
- Number of low water crossings at flood risk
- Estimated number of road segment closures
- Estimated length of roads at flood risk (miles)
- Estimated farm and ranch land at flood risk (acres)

This methodology was used consistently for all FMEs regardless of the information provided within the source documentation. This ensured that the associated flood risk calculated for each FME was based on a consistent and equitable dataset.

Emergency Need Classification

The term "emergency need" is not currently defined by the TWDB and was to be determined by each individual region. For the Lower Brazos Planning Region, the following criteria were decided upon by the RFPG to determine projects, strategies, and evaluations that met emergency needs:

- **Remove severe repetitive loss properties that were deemed to meet an emergency need.** Severe repetitive loss properties repeatedly flood, causing significant difficulties for property owners. The National Flood Insurance Reform Act of 2004 defined severe repetitive loss as: "a single-family property (consisting of one to four residences) that is covered under flood insurance by the NFIP and has incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage, with the amount of each claim payment exceeding $5,000 and with the cumulative amount of such claims payments exceeding $20,000; or for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property".
- **Remove critical facilities from the one percent ACE area** through various types of mitigation, including but not limited to acquisition, demolition, or elevation, floodproofing or retrofitting, and through infrastructure projects that would improve roads or bridges that cause critical facilities to be inaccessible.

Since FMEs do not execute any sort of flood mitigation, none were classified as meeting an emergency need.

4B.5 Potentially Feasible FMP and FMS Evaluation

4B.5.a. FMP Types and Overview

The FMP category encompasses many types of flood risk mitigation projects. Both structural and non-structural efforts can be considered projects as long as they have non-zero capital costs or other non-recurring costs. Although the TWDB allows for this extensive scope to encompass projects, not all of the project types were identified within the Lower Brazos Planning Region.

Most of the FMPs identified for the region were sourced from the Fort Bend County Master Drainage Plan which consists of mitigation alternatives for each major watershed throughout the county. The projects identified from this plan were similar in type and scope, primarily focusing on channel improvements and detention mitigation as needed. Additional projects were identified in both McLennan County and the City of Bryan. The FMPs identified for these locations are much more localized, targeting specific flood hot spots and proposing a solution such as property acquisition or crossing improvements.

Nineteen additional projects were provided by local communities and eleven additional projects were identified in the Amendment process through the regional watershed studies across the Lower Brazos Region.

Table 4-12 outlines the number of FMPs identified by project type in the Lower Brazos Planning Region. A full list of the identified FMPs can be found in *Appendix 4.2, Table 14*. Although there are a limited number of identified FMPs, many of the identified FMEs represent projects that have not yet been fully evaluated.

Table 4-12: FMP Classifications

FMP Type	Description	Number of FMPs Identified
Structural: Low Water Crossing or Bridge Improvements	Structural improvements to bridges, culverts, and other road infrastructure to lessen flood risk to transportation routes.	17
Structural: Regional Channel Improvements	Improvements such as expansion, addition of lining, and implementation of banks to existing channels used for conveyance. Creation of new channels to divert water from flood-prone areas and ensure the confluence of channels does not cause overflow.	26
Structural: Regional Detention	Creation of detention ponds to mitigate channelization and current flood risk by delaying the conveyance of stormwater.	1
Structural: Storm Drainage Improvements	Creation of or improvement to existing storm drain systems to provide flood relief along transportation routes and nearby buildings.	4
Structural: Comprehensive Drainage Improvements	Implementation or improvement of several, varied improvement types such as storm drain systems, berms, ditches, detention, and crossing structures intended to work in unison to mitigate flooding.	8
Non-Structural: Property Easement or Acquisition	Property buyouts to remove structures identified as being at flood risk that would be difficult, expensive, or impractical to mitigate for flood risk by other means.	1
	Total	57

4B.5.b. FMS Types and Overview

The FMS category is the broadest, including most flood mitigation or management efforts that do not fit into the types described previously. FMS listings cannot have associated capital costs but may have re-occurring or non-capital costs. These guidelines make the FMS category ideal for regulatory and big-picture flood mitigation efforts.

FMSs were identified uniformly throughout the Lower Brazos Planning Region. Hazard Mitigation Plans, and other publicly available documentation, provided significant insight on large-scale, flood management ideas that are prevalent throughout the region.

The types of potentially feasible FMSs identified for the Lower Brazos Planning Region can be seen in Table 4-13. A full list of identified FMSs can be found in *Appendix 4.3, Table 13*.

Table 4-13 FMS Types

FMS Type	Description	Number of FMSs Identified
Education & Outreach	Programs or initiatives aiming to educate the public on the hazards and risks of flooding.	1
Flood Measurement & Warning	Programs and initiatives to ensure entities are aware of current flood risk and conditions, such as installation of flood risk signage, programs to ensure regulation compliance, and creation of databases to consolidate flood risk data.	15
Infrastructure Projects	Big picture ideas for extensive flood infrastructure improvements throughout a community.	27
Property Acquisition & Structural Elevation	Buyouts or elevation of all structures with designated hazard levels such as one percent annual chance storm event floodplain, repetitive loss structures, or structures downstream of dams.	17
Regulatory & Guidance	Updates or creation of new ordinances, development codes, design standards, maintenance codes, etc. to prevent the creation of new flood risk or mitigate current flood risk.	28
Other	Other initiatives or big pictures ideas for specific flood mitigation or management strategies.	51
	Total	139

4B.5.c. Critical Assessment Information

FMPs and certain FMSs are intended to be identified and recommended for areas with higher-than-average flood risk. Since FMPs focus on reducing flood risk, they typically need to provide a high level of immediate flood reduction benefit to be feasible. This is also true for certain types of FMSs. As a result, the evaluation of FMPs and FMSs—as part of this plan—focuses on general information about the FMP or FMS as well as existing flood risk information within the study area and flood reduction benefit associated with the FMP or FMS.

The following metrics were considered for each identified potential FMP and structural FMSs, depending on the amount of available information for a given area:

- General description and location of FMP or FMS, including impacted HUCs, counties, and watersheds
- Sponsors who will manage the project or strategy along with other entities that may have oversight
- Estimated costs and potential funding sources (local, state, and federal)
- Associated RFPG approved flood management and mitigation goals (described in Chapter 3B) to ensure the FMP or FMS meets the goals of the plan
- Determination on whether the FMP or FMS meets an emergency need
- Associated flood risk within the study area
- Existing or anticipated models

A few generic metrics—description, type, location, area, costs, sponsors, and interested parties for each FMP or FMS—were provided by reports, studies, or other sources that indicated the need for the FMP or FMS. However, some of the metrics required more analysis than available in the source documentation, such as existing flood risk within the FMP or FMS service area, expected flood risk reduction when the project or strategy is implemented, a determination on whether the project or strategy meets an emergency need, how the FMP or FMS contributes or impacts water supply if the FMP or FMS has negative impacts to neighboring areas or resources, a benefit-cost-ratio, and potential funding sources.

Estimated Capital Costs of FMPs and FMSs

The source documentation for FMPs included estimated capital costs. These estimates were utilized and adjusted, when necessary, to account for inflation to 2020 dollars.

Most FMSs are only developed to a conceptual planning level and cannot be accurately assigned a cost estimate. Further evaluation of these FMSs is needed to define the scope such that a more specific cost estimate can be developed. An exception is the Regulatory and Guidance FMS, which is estimated to be $400,000 to update regulations for each county identified as needing regulatory updates. Other categories were not provided a cost.

The estimated costs associated with each FMP and FMS depend on broad assumptions or source documentation that could not be thoroughly vetted. The FMP and FMS cost estimated as part of this plan are for high-level planning purposes only. Further evaluation will be required to develop more detailed and accurate cost estimates.

Comparison of Estimated Benefits of Potentially Feasible FMSs and FMPs

All of the identified FMSs are high-level and general in scope. They consist of updates to regulations, public outreach and education efforts, and broad identification of potential infrastructure improvements which have largely undefined extents and effects. This uncertainty makes it difficult to quantify what is being addressed by the strategy without severely overestimating both flood risk and benefits. Therefore, the flood risk and flood risk reduction evaluation was limited to FMPs. Some of the infrastructure improvement FMSs may be refined further in future cycles to become future FMPs or FMEs.

To ensure consistency throughout the analysis process, each assessment component was approached the same way for each identified FMPs. This consistency allows for the estimated benefits associated with the individual FMPs to be comparable.

Estimated benefits were determined using provided hydraulic and hydrologic models, results maps, or values provided as part of the source documentation. A comparison of existing and proposed conditions was used to determine the flood risk reduction benefits associated with each FMP. A list of the flood risk metrics that were evaluated for each FMP is provided in *Table 4-14*.

Table 4-14: FMS and FMP Benefit Analysis

Category	Existing Risk	Reduction in Risk
Structures	Estimated number of structures at 1 percent ACE flood risk	Number of structures with reduced 1 percent ACE flood risk
Structures	Estimated number of structures at 1 percent ACE flood risk	Number of structures removed from 1 percent ACE flood risk
Structures	Estimated number of structures at 1 percent ACE flood risk	Number of structures removed from 0.2 percent ACE flood risk
Structures	Residential structures at 1 percent ACE flood risk	Residential structures removed from 1 percent ACE flood risk
Structures	Critical facilities at 1 percent ACE flood risk	Critical facilities removed from 1 percent ACE flood risk
Population	Estimated population at 1 percent ACE flood risk	Estimated population removed from 1 percent ACE flood risk
Roads	Number of low water crossings at flood risk	Number of low water crossings removed from 1 percent ACE flood risk
Roads	Estimated number of road closures	Estimated reduction in road closure occurrences
Roads	Estimated length of roads at 1 percent ACE flood risk (mi)	Estimated length of roads removed from 1 percent ACE flood risk (miles)
Agricultural Land	Estimated farm and ranch land at 1 percent ACE risk (acre)	Estimated farm & ranch land removed from 1 percent ACE risk (acre)

Other benefits analyzed for the FMPs would include the overall change in service capacity from pre-project to post-project and estimated reduction in fatalities or injuries if the project or strategy was implemented. However, these metrics were difficult to determine with the modeling results. Unless stated directly in the source documentation, these items were left unidentified for many of the FMPs.

Emergency Need Classification

The term emergency need is not currently defined by the TWDB and was to be determined by each individual region. For the Lower Brazos Planning Region, the following criteria were decided upon by the RFPG to determine projects, strategies, and evaluations that met emergency needs:

- **Removing severe repetitive loss properties that were deemed to meet an emergency need.** Severe repetitive loss properties repeatedly flood, causing significant difficulties for property owners. The

National Flood Insurance Reform Act of 2004 defined severe repetitive loss as: "a single-family property (consisting of one to four residences) that is covered under flood insurance by the NFIP and has incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage, with the amount of each claim payment exceeding $5,000 and with the cumulative amount of such claims payments exceeding $20,000; or for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property".

- **Remove critical facilities from the one percent annual chance storm events** area through various types of mitigation, including but not limited to acquisition, demolition, or elevation, floodproofing or retrofitting, and through infrastructure projects that would improve roads or bridges that cause critical facilities to be inaccessible.

FMSs and FMPs were classified as meeting an emergency need if meeting any of the criteria listed above.

Contributions to Water Supply

All potentially feasible FMPs and FMSs were screened for potential impacts on water supply. This review identified no projects or strategies having the potential to contribute to water supply in the Lower Brazos Planning Region. Potential negative impacts to water supply are analyzed in Chapters 5 and 6.

Nature-Based Solutions

The TWDB encourages the RFPGs to consider nature-based methods of flood risk reduction. The Lower Brazos Region considered solutions to be nature-based if the intent of the strategy or project was to create or protect green infrastructure. This definition is quite broad and includes many different types of flood risk reduction efforts including the preservation of open spaces, incorporation of wetlands into structural mitigation, and utilizing vegetation to prevent erosion and other geomorphic changes. These solutions provide additional benefits to the communities and wildlife surrounding the area. Improvements to air quality, water quality, creation of habitats, and quality of life benefits can all be byproducts of the implementation of nature based solutions.

In the Lower Brazos Planning Region, none of the 57 potentially feasible FMPs include nature-based flood mitigation solutions. Of the 139 FMSs, 10 were identified as including a nature-based solution to flooding. Within this set of strategies, eight involve preservation and creation of open space, and two involve stabilizing erosion through planting and supporting natural vegetation. In addition to flood mitigation, these nature-based strategies have the potential to provide environmental and social benefits such as improvements to air quality, water quality, and the creation of recreational space for communities.

No Negative Impact

The TWDB *Technical Guidelines* for Regional Flood Planning require demonstrating that each identified FMS or FMP will not negatively affect a neighboring area, based on the best available data. Demonstrations of no negative impact must reference the one percent annual chance events water surface elevations (WSELs) and peak discharges in pre-project and post-project conditions.

It is important to note the criteria listed below have no regulatory implications at a local, state, or federal level due to the approximate nature of flood planning. For flood planning efforts, a determination of no negative impact can be established if a project or strategy does not increase the inundation of residential and commercial buildings and structures. Additionally, all of the following requirements, per the TWDB *Technical Guidelines*, should be met to establish no negative impact, as applicable:

1. Stormwater does not increase inundation in areas beyond the public right-of-way, project property, or easement.
2. Stormwater does not increase the inundation of storm drainage networks, channels, and roadways beyond design capacity.
3. The maximum increase of one-dimensional (1D) Water Surface Elevation must round to 0.0 feet (< 0.05ft) measured along the hydraulic cross-section.
4. The maximum increase of two-dimensional (2D) Water Surface Elevations must round to 0.3 feet (< 0.35ft) measured at each computational cell.
5. The maximum increase in hydrologic peak discharge must be < 0.5 percent measured at computational nodes (sub-basins, junctions, reaches, reservoirs, etc.). This discharge restriction does not apply to a 2D overland analysis.

Non-structural FMPs can be determined to have no negative impact on neighboring areas by default. These projects do not propose physical changes to the floodplain and resulting flood hazard areas, which eliminates the potential for increases in one percent annual change storm events discharges or WSELs. Instead, these project types reduce flood exposure by removing individuals and property from flood hazard areas. Similarly, one Property Acquisition FMP reduces flood risk by removing structures from areas prone to flooding.

Similarly, a significant portion of FMSs can also be determined to have no negative impact on neighboring areas without a detailed supporting analysis due to being non-structural in nature. These types of FMSs are listed below:

- Education and outreach (1)
- Early flood warning systems (15)
- Property acquisition and structural elevation (17)
- Regulatory and guidance (28)
- Others include maintenance, restoration, land use policies, sign installation, etc. (2)

To demonstrate no negative impact at a planning level, restoration, preservation, and maintenance activities encompassed by the "other" strategy type will be assumed to retain the present function of natural or built flood infrastructure. Therefore, these strategies demonstrate no adverse impact on the basis of not significantly altering the physical environment.

For structural FMPs and FMSs, reports were checked for certified statements by an engineer registered in the State of Texas that the associated project or strategy would not cause negative impacts upstream, downstream, or within the project area in events up to and including the one percent annual chance

events. For FMPs and FMSs without these certifications, H&H models were reviewed for negative impacts as defined in the TWDB *Technical Guidelines*. As previously mentioned, many structural FMPs and FMSs without accompanying models were reclassified as Preliminary Engineering FMEs.

Benefit-Cost Analysis Determination

One of the most concise ways to compare and prioritize proposed projects is using a benefit-cost ratio (BCR), which measures the benefits a project achieves compared to the required implementation cost. BCRs greater than one indicates that there are more associated benefits than costs over the life of the proposed project.

Many different processes can be used to determine the BCR for a project, each looking at different types of benefits and costs and weighing their importance on a different scale. For this analysis, the TWDB provided benefit-cost analysis (BCA) tool was selected to develop BCRs for projects or strategies when BCRs were not provided in the source material. The BCA tool was selected due to its alignment with the information already required by the TWDB to evaluate the FMPs. The benefits provided to commercial and residential structures, critical facilities, streets, utilities, agriculture, water supply, and recreation are balanced by the construction cost, right-of-way acquisition costs, utility relocation costs, operation and maintenance costs, and the lifespan of the proposed project to determine if the benefits outweigh the costs.

In some cases, the benefits provided by flood risk reduction to structures and agricultural areas were the driving factors behind the BCA calculation. For these FMPs, the resulting BCR had little sensitivity to the inclusion of street flooding reductions. Since the calculation of road reduction benefits requires many detailed assumptions, including EMS travel times and routes, it was not evaluated for projects that had structural risk reduction as the primary benefit. However, some of the FMPs for the Lower Brazos Planning Region were specifically targeted at improving roadway crossings so neighborhoods could be accessed during storm events. For these, the reduction in street flooding was the driving factor for the BCA tool, so it was calculated.

Structural flood risk reduction was determined using the hydraulic modeling results associated with each FMP. The pre-project flood depth rasters provided by the modeling results were intersected with the structure database provided by the TWDB to determine the level of flooding a structure experiences during a flood event. To account for the elevation of the top of slab of a typical slab-on-grade structure above the adjacent grade, 6 inches of flood depth was removed from each structure. The same process was performed using the post-project flood depth information provided by the modeling results. The difference in flood depths from pre-project to post-project was used to estimate the reduction of damages to the structure using the damage costs provided by the TWDB BCA tool.

Ultimately, the dollar per inch reduction in flood depth for each structure was estimated based on the square footage and the type of structure. Given that the BCA process is a planning-level effort, some generalizations were accepted to simplify the BCR calculating process. Residential structures were grouped into small, medium, and large-sized structures to match the BCA tool classifications. Each structure was categorized based on the measured square footage of each structure shape as provided in the structure database. Non-residential structures were generalized into broad categories of the type of

industry the building serves (commercial, industrial, public, etc.). This was done to align the existing industry-type attributes assigned to the structures, as provided by the TWDB, to the BCA tool classifications. The TWDB tool then calculated the value provided by the mitigation using the structure square footage, industry classification, and the provided flood reduction. For instance, fast food restaurant damage costs provided in the TWDB BCA tool closely resembled the average cost of damages for all commercial structures provided in the BCA tool. Therefore, all commercial buildings were classified as fast-food restaurants to achieve an average damage cost.

A similar process was performed for agricultural land, except the depth of flooding was not considered. The TWDB also provided the agricultural land classification as a raster dataset. This dataset included two agricultural regions: farmland and ranchland. Approximate dollar per acre estimates were associated with each type of land. Farmland was considered a low-value crop based on the average crop type for the Lower Brazos Planning Region (corn, rice, sorghum, etc.), and ranchland was considered a hay-type value crop. Values for each are based on the average crop yield values for each category taken from the Texas Almanac. Ranchland was assumed to be a hay-type value crop based on the primary assumption that, during a flooding event, livestock can be transported away from flood risk.

To determine the benefits provided by reducing flood risk to streets, the modeling results were intersected with the roadways. Pre- and post-project depths and miles of roadway exposed to flooding were calculated. In the event that access to a neighborhood was completely restricted by the flooding, emergency medical service delays, the number of houses inaccessible, and the duration of inaccessibility were calculated. These metrics helped capture the larger impacts caused by the flooded streets, and the TWDB BCA tool calculated the associated monetary benefits and costs.

Some FMPs only included flood risk-benefit simulations for the one percent annual chance event. Therefore, the BCA considered only this event. Even if only one storm event was analyzed, all known sources of flooding were incorporated into the analysis. For many of the FMPs in Fort Bend County, modeling results of flood events along the Brazos River were used in conjunction with modeling of local rivers and tributaries to determine the extents of flooding. The FMPs sourced from the Fort Bend County Master Drainage Plan for this area are not intended to mitigate Brazos River flooding, although they provide significant benefits in localized flooding events. Due to this, many of the benefits provided by the FMPs are superseded by the Brazos River floodplain, and the resulting BCRs are very low.

The calculated benefits depend on broad assumptions—as stated above—regarding the value of structures, agricultural land, and other factors. The costs and BCRs developed as part of this plan are for high-level planning purposes only, and further evaluation and modeling will be required to develop a more extensive and detailed BCR for each FMP.

Potential Funding

The RFPG researched funding mechanisms for FMEs, FMSs, and FMPs. While potential funding is assessed in more detail in Chapter 9, the Lower Brazos RFPG considers the funding mechanisms below to encompass the widest variety of needs:

- Stormwater Utility – Local

- TWDB Flood Infrastructure Fund (FIF) – State
- TWDB Clean Water State Revolving Fund (CWSRF) – State
- FEMA Building Resilient Infrastructure and Communities (BRIC) – Federal
- FEMA Flood Mitigation Assistance Grant Program (FMA) – Federal
- HUD Community Development Block Grant – Mitigation (CDBG-MIT) - Federal

The State of Texas provides municipalities the opportunity to establish a stormwater utility fee, which is a legal mechanism used to generate revenue to finance an individual municipality's cost to provide and manage stormwater services. Typically, stormwater utility revenues fund local drainage and maintenance projects, making this funding source particularly suitable for FMSs that involve recurring costs. Establishing a stormwater utility fee can be difficult as it is often considered by residents as a tax. Counties do not have the authority to establish a stormwater utility to fund drainage improvement projects.

At the state level, the TWDB FIF provides financial assistance for a wide variety of flood-related projects, including planning evaluations and studies. Since priority is given to projects that include multiple jurisdictions, FIF is an ideal funding mechanism for regional solutions. The CWSRF is another TWDB funding source that supports similar flood mitigation activities. The CWSRF is less oriented toward hydrologic and hydraulic studies and more oriented toward mitigation activities. Since both programs appropriate funding from planning level activities to design, they are suitable mechanisms for FMEs, FMSs, and FMPs.

At the federal level, the FEMA FMA appropriates funds to applicants with FEMA-approved HMAPs to support activities that mitigate severe repetitive loss. Additionally, CDBG-MIT was created in 2018 to fund activities to reduce future losses in areas affected by qualifying disasters in 2015, 2016, and 2017. Lastly, the FEMA BRIC program provides funding to applicants with FEMA-approved HMAPs for a broad range of mitigation activities. Since these programs prioritize flood hazard reduction, they are suitable for FMPs.

The specified federal funding options have varying local cost shares, making them suited for FMPs at varying scales. While BRIC grants have the highest local cost share of these programs at 25 percent, priority is given to applications with local shares that exceed this baseline. This may make BRIC a suitable option for smaller projects that benefit multiple entities. FMA has a local share that varies from 0 percent to 25 percent depending on the degree to which the application benefits repetitive loss structures, which may make FMA a suitable option for projects that benefit areas with a high number of flood claims as identified by previous tasks. CDBG-MIT has no required local share, which would simplify funding of projects with widespread, regional benefits.

Chapter 5: Recommendation of Flood Management Evaluations, Flood Management Strategies, and Associated Flood Mitigation Projects

The recommendation of Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) is a direct advancement of the information collected and evaluated in Chapter 4 Task 4B. This list of potential FMEs, FMSs, and FMPs developed in Chapter 4 was further analyzed and screened to determine which mitigation and management needs should be recommended in the Regional Flood Plan.

Although several hundred mitigations and management efforts were collected and evaluated in Task 4B, not all align with the goals and purpose of the Regional Flood Plan. The Regional Flood Planning Group (RFPG) considered the region's needs, the overarching purpose of the Regional Flood Plan, and the guidance provided by the Texas Water Development Board (TWDB) to develop an equitable approach to recommend FMEs, FMSs, and FMPs. This chapter discusses the metrics used by the RFPG to determine recommendation status and summarizes recommended mitigation and management efforts.

5.1 – Recommendations

The RFPG had several discussions about metrics needed for flood mitigation or management to fulfill the Regional Flood Plan's intent. These discussions considered two main components of the needs: the type of evaluation, strategy, or project being proposed and how the need was identified. These two components guided the RFPG in determining the regionality of the impact of the need and the proposed sponsor's level of interest and urgency in actually performing or implementing the mitigation or management effort. After analyzing the distribution of the needs with regard to these components, as well as others, the RFPG was able to determine metrics that should be met for a need to be recommended.

Additionally, the TWDB provided the following guidance on what should be recommended:

- FMSs and FMPs to mitigate the 1 percent annual chance event (ACE) flood where feasible
- FMEs that are most likely to result in the identification of potentially feasible FMSs and FMPs
- FMSs and FMPs may not negatively impact a neighboring area.

These standards for recommendation were considered where applicable.

5.1.1 Regional Benefit and Location

5.1.1.a. Benefit Area

A key point of discussion throughout the recommendation process was ensuring that the recommended FMEs, FMSs, and FMPs provide regional benefits. The TWDB guidance encourages FMSs and FMPs only

to be considered for inclusion in the Regional Flood Plan if they have contributing drainage areas of greater than 1 square mile except in "instances of flooding of critical facilities or transportation routes or for other reasons, including levels of risk or project size, determined by the RFPG." On May 25th, 2023, the Lower Brazos RFPG approved specific guidance principles for FMPs with a contributing drainage area of less than 1 square mile to be potentially included in the Lower Brazos Regional Flood Plan. If any of the following guidance principles are met, an FMP may be recommended within the Lower Brazos Regional Flood Plan regardless of drainage area.

1. The FMP provides flood mitigation benefits to a critical facility as defined by the TWDB, FEMA, or the State of Texas.
2. The FMP removes an established TxDOT evacuation route from flood risk.
3. The FMP removes a low water crossing within the TWDB dataset that is a singular ingress or egress point from flood risk.
4. The FMP falls within a high flood risk HUC as defined by the analysis completed under Task 4A.
5. The FMP provides benefits to a repetitive loss structure.

5.1.1.b. Combination of FMEs, FMSs, and FMPs

Some sponsors brought forth several small flood mitigation and management needs. Individually, these needs were localized and did not meet the previously discussed drainage area requirement. However, when combined, they often exceeded 1 square mile of drainage area. Several discussions were held to determine when it would be appropriate to combine these needs and boost the benefit area. It was decided that the following metrics must be met for mitigation and management needs to be combined:

- hydraulically connected and have interlocking drainage areas
- sponsor of the needs must provide approval for the combinations proposed

If both conditions were met, the mitigation and management needs were considered for combination. This type of consolidation was largely done for Preliminary Engineering and Feasibility Assessment FMEs, which considered the development of several consecutive projects along the same stream or channel segment. FMEs considering localized storm sewer projects were mainly left uncombined due to the lack of hydraulic connection between the different proposed networks.

5.1.1.c. Flood Mitigation or Management Type

Another way to identify flood mitigation and management needs that may not provide regional benefit was determined by looking at the proposed mitigation type. Several identified needs were localized. Although these needs are important and can potentially reduce flood risk if implemented, they do not satisfy the purpose and intent of a regional flood plan. Specifically, maintenance and inspection programs were considered the local entity's responsibility and not a strategy that could provide benefits outside of the political boundaries in which they were proposed. The proposed flood mitigation and management needs (shown in *Table 5.1*) were not recommended as individual needs in the Regional Flood Plan. These needs were generally identified as potentially feasible FMSs.

Table 5.1: Localized Flood Mitigation and Management Types

Flood Mitigation or Management Type	Description
Maintenance Programs	Recurring maintenance efforts to remove debris or sediment from local storm infrastructure
Public Awareness Programs	Programs targeted at increasing public participation in the National Flood Insurance Program (NFIP) or other flood-related programs and exercises
Inspection Programs	Formation of system, team, and schedule to regularly inspect flood infrastructure to determine potential degradation that could lead to failure

5.1.1.d. Flood Mitigation or Management Location

Flood mitigation and management needs located along the border of the Lower Brazos Planning Region were given special consideration. Some flood mitigation and management needs identified had benefit areas that extended into multiple regions. As mentioned in Task 4B, if the majority of any individual need fell into a neighboring region, then it was removed from the Lower Brazos Planning Region list and sent to the associated RFPG's for consideration. If the need had the majority of its benefit area within the Lower Brazos Planning Region, it was determined that it would be considered for a recommendation if all the other requirements were met.

5.1.2 Latest Data

The RFPG determined in Chapter 3 that a key standard that should be carried forth in the Lower Brazos Planning Region is using the best available data when developing criteria, projects, or mapping. Both the recommended standards and goals established in Chapter 3 reflect the necessity of using the latest data, including rainfall statistics, to generate equitable and accurate estimations of flood risk during modeling efforts. This concept was applied to the recommendation process for FMEs, FMPs, and FMSs to ensure consistency throughout the plan. Any flood mitigation or management needs developed before 2019 were examined to establish whether they require updates to include current data.

This evaluation was primarily important for FMPs. Using outdated data could cause modeling results to indicate that proposed projects would provide more benefit than they truly would. Additionally, the equitable comparison of FMPs, especially when looking at flood risk reduction and benefit-cost ratios (BCRs), would be impossible if they were not held to the same standard. However, the RFPG did not want to completely disregard flood management and mitigation needs if the proposed solution was outdated. FMPs flagged as needing updates to include the best available data were demoted to hydrologic and hydraulic (H&H) modeling FMEs. These FMEs were recommended for inclusion within the plan as long as they met all of the other established requirements.

5.1.3 Sponsorship

The metric that kept the largest amount of flood mitigation and management needs from being recommended was the need for explicit sponsorship approval.

5.1.3.a. TWDB Guidance

A sponsor is defined in the TWDB *Technical Guidelines* as an entity or multiple entities responsible for "financing and implementing" a flood mitigation or management need. The identified sponsor would be responsible for executing and administrating the need. The funding necessary to carry out a proposed need could be from various sources, including grants, and does not have to be directly funded by the identified entity. Additionally, the recommendation of a need does not indicate an entity's obligation to complete the identified strategy, project, or evaluation.

In a Technical Consultants Call hosted by the TWDB on May 24th, 2022, it was confirmed that explicit sponsorship approval is not required for an FME, FMS, or FMP to be included in the Regional Flood Plan. However, if a sponsor explicitly requests that the flood mitigation or management need is outdated or should not be included in the plan, this must be respected. The RFPG is only responsible for attempting to contact the identified sponsor to indicate the intent to include the flood mitigation or management need in the Regional Flood Plan.

Additionally, the TWDB indicated the RFPGs could list themselves as sponsors for any flood mitigation or management needs for which they could not identify sponsors but wanted to recommend for inclusion within the plan.

5.1.3.b. Lower Brazos Planning Region's Sponsorship Requirements

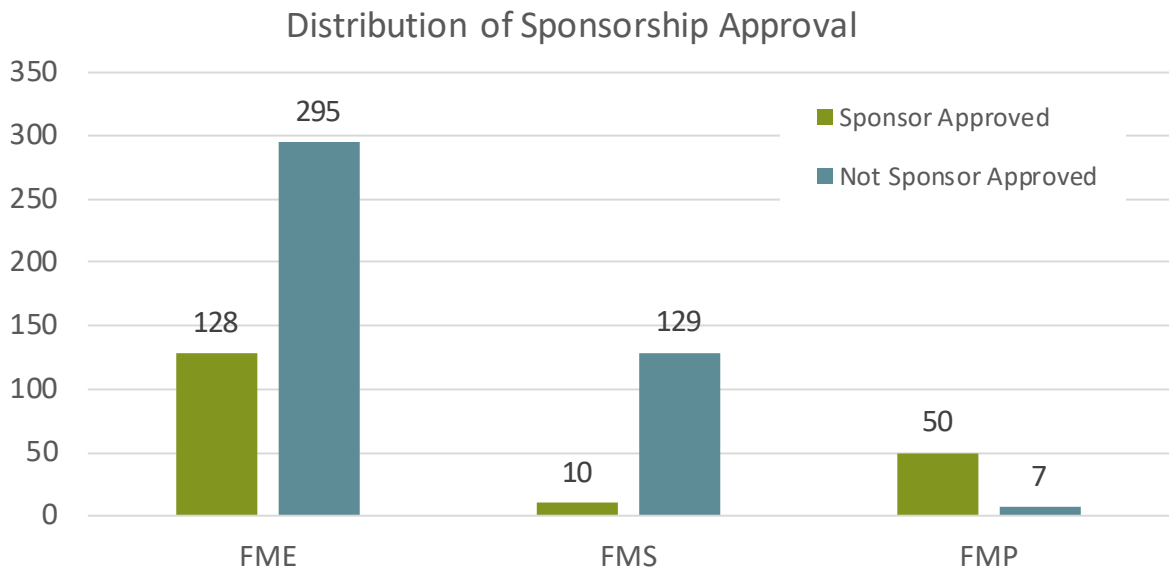
The Lower Brazos RFPG discussed the guidance on sponsorship provided by the TWDB. Several concerns with the allowable usage of sponsorship were identified.

For needs with an identified sponsor that was not responsive to the outreach performed, several potential causes were identified. The lack of response could indicate that the sponsor did not understand the purpose and importance of incorporating their needs into the Regional Flood Plan, did not have the resources to provide the requested information or approval, or may not have as severe of a need for flood mitigation. Without coordination with the identified sponsor, there is no way to be confident that the need or solution identified still exists. Recommending flood mitigation or management efforts associated with a sponsor may create the perception that there is a risk where there is not or that there are potential projects underway that are not actually being developed.

The FMEs developed in Task 4A included identified sponsors. However, the scope and extent of the identified flood mitigation and assessment needs made aligning interest groups with these evaluations difficult and imprecise. Since the FME boundaries cover multiple communities and counties, it would be beneficial if multiple entities were to coordinate to oversee and procure funding for the evaluation. The RFPG considered the possibility of naming itself as a sponsor for these needs; however, the implications of naming the RFPG as a sponsor for these needs were concerning to the group. Although the TWDB intended this label as a placeholder to indicate support for flood mitigation or management needs, it could create confusion about the role of the RFPG within the regional and state flood planning process by implying that the group has the authority to carry out projects within the Lower Brazos Planning Region.

Due to these concerns, the Lower Brazos RFPG decided on April 28th, 2022, not to recommend any flood mitigation or management needs that did not have explicit sponsorship approval. An FME, FMS, or FMP was considered to have sponsorship approval if the need was brought forth directly by an entity or if verbal or written approval was obtained for a need's inclusion during outreach efforts. *Figure 5.1* shows the distribution of sponsorship approval for the identified FMEs, FMSs, and FMPs.

Figure 5.1 Sponsorship Summary



5.1.3.c. Outreach Efforts

Many FMEs, FMSs, and FMPs were collected through research performed by the Technical Consultant Team. This research included public documentation such as hazard mitigation plans, master drainage plans, and flood protection plans that indicated the need for specific flood mitigation projects or evaluations. These ideas were collected and included within the initial list created in Task 4B, characterizing flood needs throughout the Lower Brazos Planning Region. Once these needs were collected and evaluated, the identified associated sponsors were contacted to request any additional information they may possess pertaining to the needs. However, not all of these outreach attempts were successful. Many identified sponsors could not confirm the identified need was still present or that the proposed solution was still feasible.

Additional FMEs were identified in Task 4A. Specific outreach to sponsors regarding these FMEs was not performed. Potential sponsors were identified; however, since many of the identified Task 4A FMEs adhere to watershed boundaries instead of political boundaries, sponsorship would likely need to be shared by multiple entities for each FME.

5.1.4 Recommendation

The Lower Brazos RFPG met on May 26th, 2022, and approved the proposed lists of recommended FMEs, FMSs, and FMPs; 118 of the 582 collected FMEs, FMSs, and FMPs were recommended.

During the public comment period on the Draft Regional Flood Plan, several sponsors submitted comments supporting FMEs, FMSs, and FMPs that were on the not-recommended list. The RFPG considered the submitted comments on October 27th, 2022, and approved 129 of the 582 collected listings for recommendation.

During the amendment process, several additional flood mitigation and management needs were identified and recommended. The RFPG considered the additional FMEs, FMSs, and FMPs on May 25th, 2023, bringing the total number of recommended needs to 145 of 619 collected needs.

5.2 – Recommended FMEs

5.2.1 FME Recommendation Approach

The RFPG identified and evaluated 423 potential FMEs as described in Chapter 4. The FMEs that meet the requirements set by the TWDB and the additional metrics decided upon by the Lower Brazos RFPG were recommended. To ensure that the need was truly present and had public backing, explicit sponsorship approval was required for recommendation. Additionally, a study area of at least 1 square mile was a prerequisite to screen out FMEs that would not provide regional benefits. FMEs in close proximity to one another were only combined if they provided hydraulically interconnected benefits. All recommended FMEs were aligned with regional floodplain management and flood mitigation goal as developed in Chapter 3. Recommended FMEs will work towards developing potentially feasible flood mitigation projects and strategies for inclusion in a future planning cycle. Much of the Lower Brazos Region has Base Level Engineering (BLE) modeling or other existing data – as discussed in Chapter 2 – that could be leveraged to reduce the amount of work needed to close flood risk knowledge gaps and determine flood risk mitigation efforts. Where BLE is available, certain FMEs could improve upon existing BLE models by enhancing hydrology and adding hydraulic features to provide more detail as needed. Additionally, there are ongoing Category 1 FIF studies throughout the Lower Brazos Region. In these areas, the potential FMEs could utilize the results of those ongoing FIF studies so that efforts are not duplicated.

The recommended FMEs consist of six types:

1. **Regional Watershed Studies:** Studies focused on generating new mapping or otherwise increasing knowledge of flood risk throughout an entire watershed, typically a Hydraulic Unit Code (HUC)-8.
2. **Studies on Flood Preparedness:** Studies focused on generating emergency action plans or determining the risk associated with catastrophic events or failure of flood infrastructure (such as dams or levees).
3. **Drainage Master Plans:** Evaluation of flood risk with the intent to identify flood-prone areas and begin developing potential FMPs or FMSs.
4. **Feasibility Assessments**: Evaluation of a previously identified flood-prone area to identify a feasible flood mitigation solution.
5. **Preliminary Engineering:** Continued evaluation of a proposed flood mitigation solution to develop it to the point of becoming an FMP.

6. **Hydraulic and Hydrologic Analysis:** Modeling updates to a previously developed FMP to implement current data, including new rainfall statistics, terrain, or land use.

A detailed description of the types and how FMEs were classified can also be found in Task 4B.

5.2.2 Summary of Recommended FMEs

In total, 423 potential FMEs were presented to the RFPG for recommendation. Of these, 97 were recommended by the Lower Brazos RFPG. Almost $30 million in flood mitigation and management needs and 19 locations are represented by these recommended evaluations. *Figure 5.2* shows the associated sponsors of the recommended FMEs, and *Figure 5.3* and *Map 19* in *Appendix 0* show the distribution of FMEs throughout the region. A summary of the recommendations is presented in *Table 5.2*. One-page fact sheets for each recommended FME can be found in *Appendix 5.5*, and a table of the recommendations and their evaluations can be found in *Appendix 5.1*. Many of the recommended FMEs only lack a few necessary details to qualify as FMPs. The Preliminary Engineering and Hydraulic and Hydrologic Analysis type FMEs were developed enough to have estimated construction costs associated. By definition, an FME cost only represents the cost required to complete analysis and design; for this reason, a separate tracking category was created for potential construction costs of FMEs. There is $558 million in associated construction costs for the recommended Lower Brazos Planning Region's FMEs.

Table 5.2: Summary of Recommended FMEs

FME Type	Number of Identified FMEs	Number of Recommended FMEs	Cost of Recommended FMEs
Regional Watershed Studies	60	15	$5,343,000
Studies on Flood Preparedness	29	2	$1,000,000
Drainage Master Plans	125	5	$1,774,000
Feasibility Assessments	32	13	$4,850,000
Preliminary Engineering	132	42	$13,058,000
H&H Analysis	45	20	$3,554,000
Total	**423**	**97**	**$29,579,000**

Figure 5.2: Sponsorship of Recommended FMEs

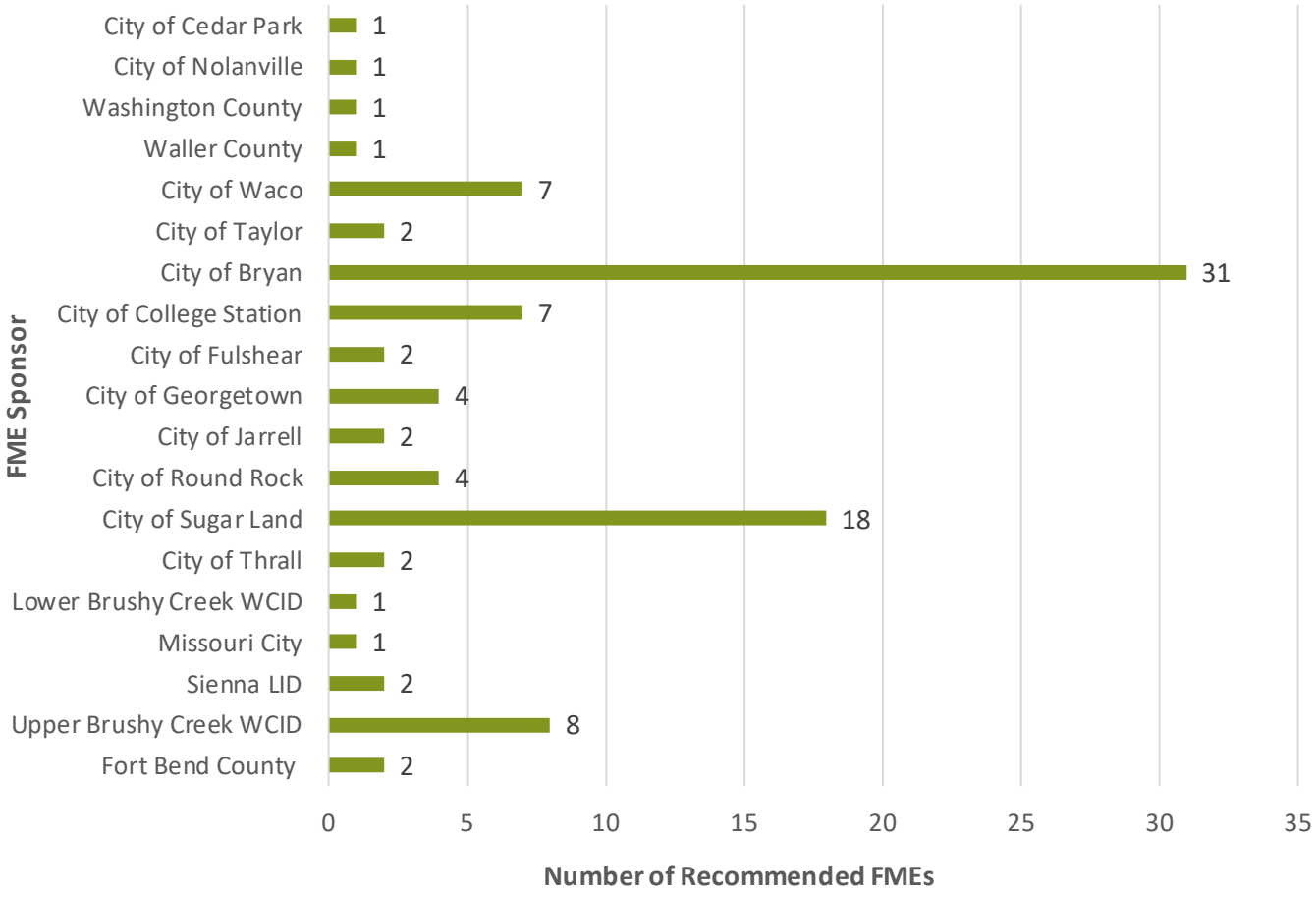
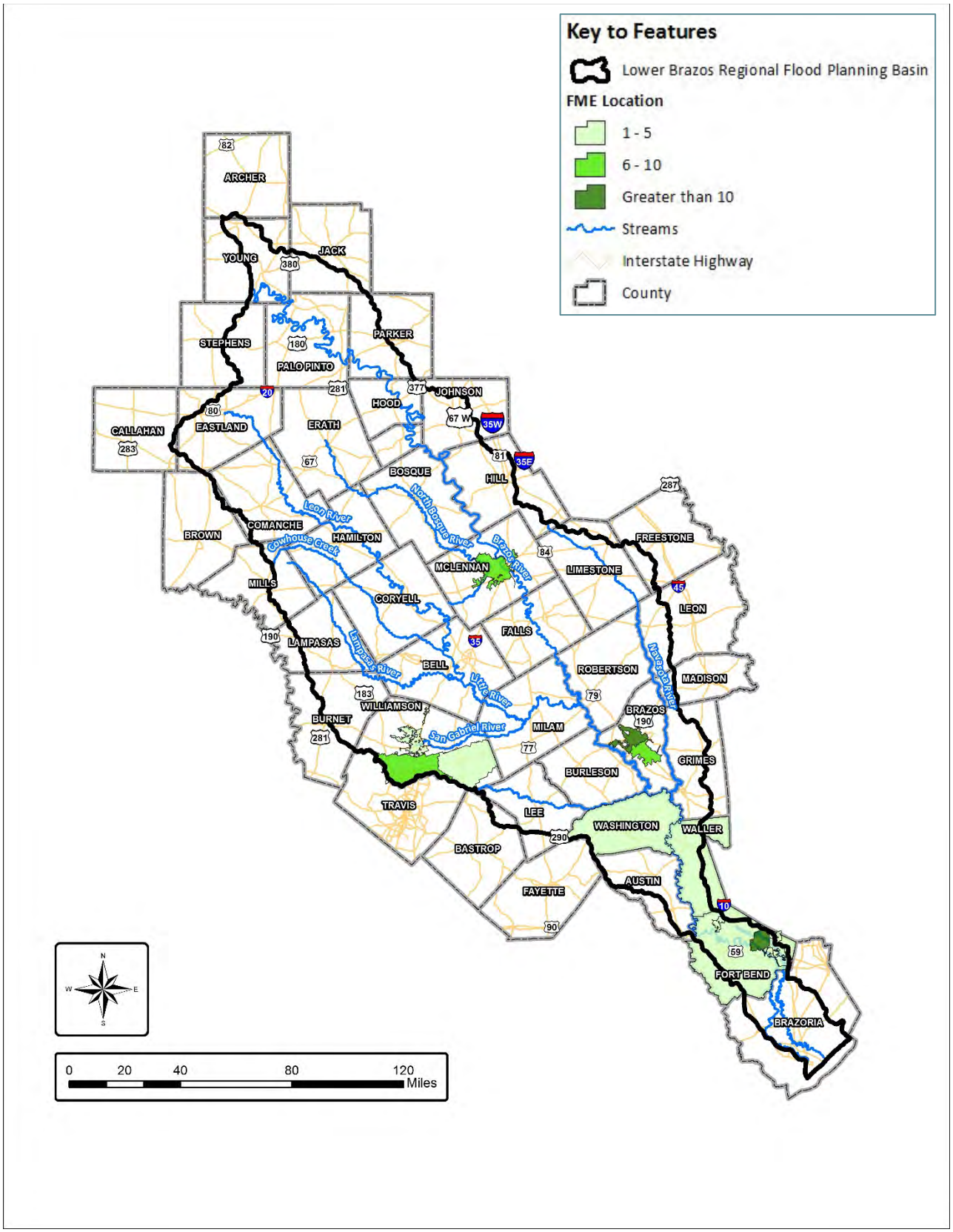


Figure 5.3: Distribution of Recommended FMEs



5.3 – Recommended FMSs

5.3.1 FMS Recommendation Approach

The Lower Brazos Planning Region identified several types of FMSs. These strategies consist of "big picture" ideas that do not need the same level of study as FMEs or have the same level of detail as required for FMPs. Many of the collected FMSs were identified through publicly available Hazard Mitigation Plans. These plans have some similar entries across the counties and region; many align closely with the goals and standards set forth by the Lower Brazos Planning Region. However, most identified sponsors were not responsive to outreach, and the FMSs were subsequently not recommended. The TWDB guidance encourages the recommendation of FMSs that mitigate for the 1 percent annual chance event. Since the nature of FMSs is strategic, the level of mitigation could not be explicitly confirmed. However, the FMSs could potentially provide benefits for the 1 percent annual chance event and beyond, depending upon their development. The following five types of FMSs were recommended:

1. **Flood Measurement and Warning:** Implementation of early flood warning systems, including stream gauges and monitoring equipment, to alert officials when flooding may be imminent.
2. **Infrastructure Projects:** Large strategies, including erosion control and entity-wide infrastructure improvements, made up of a network of potential projects working together to provide flood relief.
3. **Property Acquisition and Structural Elevation:** Elevation or acquisition of all structures within a flood hazard area.
4. **Regulatory and Guidance:** Formation of new drainage entities to manage flood control or/and updates to drainage manual criteria and ordinances to ensure best practices are implemented.
5. **Other:** Other strategies such as flood resilience efforts and developing entities or departments to manage flood risk.

Other types of FMSs were identified throughout Task 4B, but due to lack of sponsorship, they were not recommended as part of the Lower Brazos Regional Flood Plan. Descriptions of these types of FMSs can be found in Chapter 4.

5.3.2 Summary of Recommended FMSs

In total, 139 FMSs were collected through outreach to interested parties and the examination of publicly available documentation. Of these, ten were recommended by the Lower Brazos RFPG. Around $360 million is estimated to be needed for the erosion projects in Fort Bend County, and an additional $14 million is estimated for the City of Waco property acquisitions. The remaining FMSs do not have estimated costs at this time. As the ideas behind the FMSs develop further, additional associated costs will likely be identified. The cost estimations provided as part of this effort are approximations of the level of effort required to execute the strategies as proposed. *Figure 5.4* shows the associated sponsors of the recommended FMSs, and *Figure 5.5* and *Map 21* in *Appendix 0* show the distribution of the FMSs throughout the Lower Brazos Planning Region. A summary of the recommendations is presented in

Table 5.3. One-page fact sheets for each recommended FMS can be found in *Appendix 5.6,* and a table of the recommendations and their evaluations can be found in *Appendix 5.3*.

Table 5.3: Summary of Recommended FMSs

FMS Type	Number of Identified FMSs	Number of Recommended FMSs	Cost of Recommended FMSs
Education and Outreach	1	0	N/A[1]
Flood Measurement and Warning	15	2	$1,000,000
Infrastructure Projects	27	2	$360,500,000
Property Acquisition and Structural Elevation	17	2	$2,400,000
Regulatory and Guidance	28	1	$500,000
Other	51	3	$2,000,000
Total	**139**	**10**	**$366,400,000**

[1] Enough information was not available to determine the extent of these FMSs and to develop an estimated cost to implement.

Figure 5.4: Sponsorship of Recommended FMSs

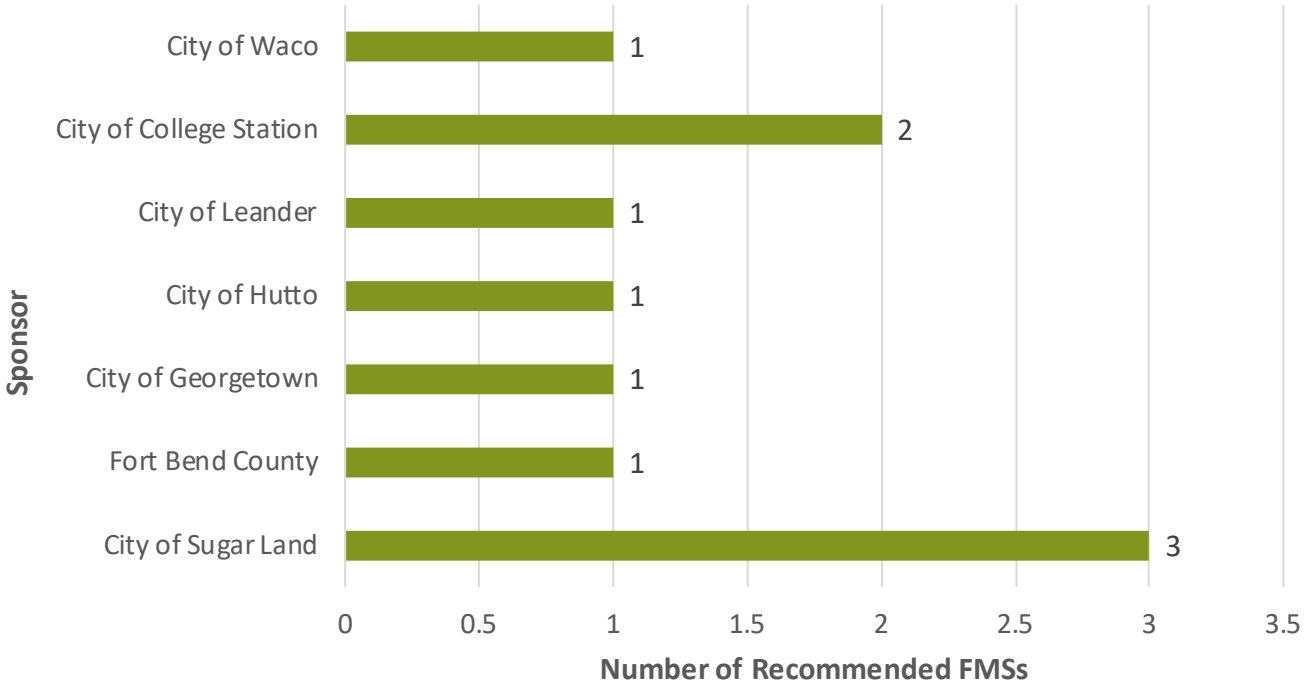
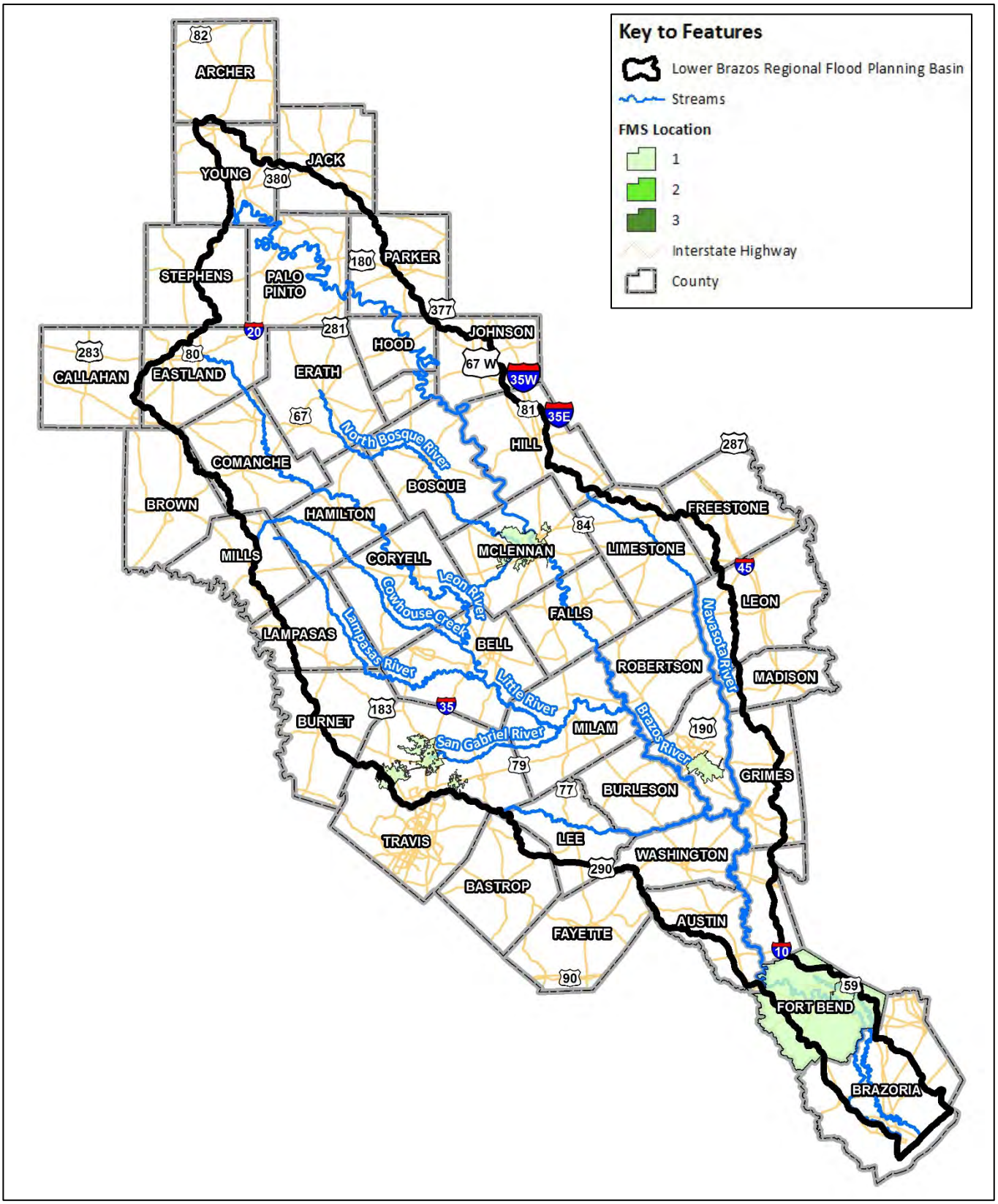


Figure 5.5 Recommended FMS Distribution



5.4 – Recommended FMPs

5.4.1 FMP Recommendation Approach

The recommendation of FMPs was a simpler process than for the other categories. Without a sponsor providing the RFPG with supporting models and project details, the FMPs could not be evaluated to the extent required by the TWDB. If a flood mitigation or management effort was initially identified as an FMP, but supporting modeling and data were never obtained, it was demoted to an FME, assuming that more evaluation would be necessary to provide the required evaluation metrics. The only FMPs with supporting data that lacked sponsorship support were those developed under the amendment tasks by the Technical Consultant Team. Outreach was performed to give potential sponsors an opportunity to engage and provide their support for the FMPs developed for their communities. However, not all sponsors were interested or supportive of the proposed projects. FMPs developed under this effort that did not receive explicit sponsorship support were not recommended.

All identified FMPs provided flood mitigation benefits for the 1 percent annual chance storm event and were determined to have no negative impacts on neighboring areas as required by the TWDB. No negative impacts for all recommended FMPs were determined based on signed and sealed statements submitted by the engineers originally responsible for modeling the projects or evaluating supporting models. These documents are provided in Appendices 5.9 and 5.10.

Additionally, FMPs were evaluated based on the drainage area requirements. The application of this screening process removed one FMP from the recommended list. The types of FMPs that were recommended in the Lower Brazos Regional Flood Plan are described below:

1. **Low Water Crossings or Bridge Improvements:** Structural improvements to bridges, culverts, and other road infrastructure to lessen flood risk to transportation routes.
2. **Regional Channel Improvements:** Improvements such as expansion, the addition of lining, and implementation of banks to existing channels used for conveyance. Creation of new channels to divert water from flood-prone areas and ensure the confluence of channels does not cause overflow.
3. **Regional Detention Improvements:** Creation of detention ponds to mitigate channelization and current flood risk by delaying the conveyance of stormwater.
4. **Levees:** Creation of a levee to form a barrier between flood waters and locations with severe flood risk.
5. **Storm Drainage Improvements:** Creation of, or improvement to existing, storm drain systems to provide flood relief along transportation routes and nearby buildings.
6. **Comprehensive Drainage Improvements:** Implementation or improvement of several varied improvement types such as storm drain systems, berms, ditches, detention, and crossing structures intended to work in unison to mitigate flooding.
7. **Property Easement or Acquisition:** Property buyouts to remove structures identified as being at flood risk that would be difficult, expensive, or impractical to mitigate for flood risk by other means.

8. **Low Water Crossings or Bridge Improvements:** Structural improvements to bridges, culverts, and other infrastructure surrounding roads to lessen flooding across the road.

5.4.2 Summary of Recommended FMPs

5.4.2.a. Overview

In total, 57 FMPs were collected through outreach to interested parties, examination of publicly available documentation, and the development of FMPs by the Technical Consultant Team during the amendment process. Of these, 49 were recommended by the Lower Brazos RFPG. One proposed FMP was not recommended due to having a drainage area of less than 1 square mile and not meeting any of the additional guidance principles outlined by the RFPG. A total of 7 FMPs were not recommended due to a lack of local sponsor support.

The recommended FMPs are scattered throughout the Lower Brazos Region, representing 9 locations and over $4 billion in funding needs. *Figure 5.7* and *Map 20* in *Appendix 0* show the distribution of the FMPs throughout the region. A summary of the recommendations is presented in *Table 5.4*. *Figure 5.6* Sponsors of Recommended FMPs shows the associated sponsors of the recommended FMPs. One-page fact sheets for each recommended FMP can be found in *Appendix 5.7*, and a table of the recommendations and their evaluations can be found in *Appendix 5.2*.

Table 5.4: Summary of Recommended FMPs

FMP Types	Number of Identified FMPs	Number of Recommended FMPs	Cost of Recommended FMPs
Low Water Crossing or Bridge Improvements	17	10	$28,272,000
Regional Channel Improvements	26	25	$3,603,269,000
Regional Detention	1	1	$8,699,000
Storm Drainage Improvements	4	4	$9,419,000
Comprehensive Drainage Improvements	8	8	$643,007,000
Property Acquisition	1	1	$600,000
Total	**57**	**49**	**$4,293,266,000**

Figure 5.6 Sponsors of Recommended FMPs

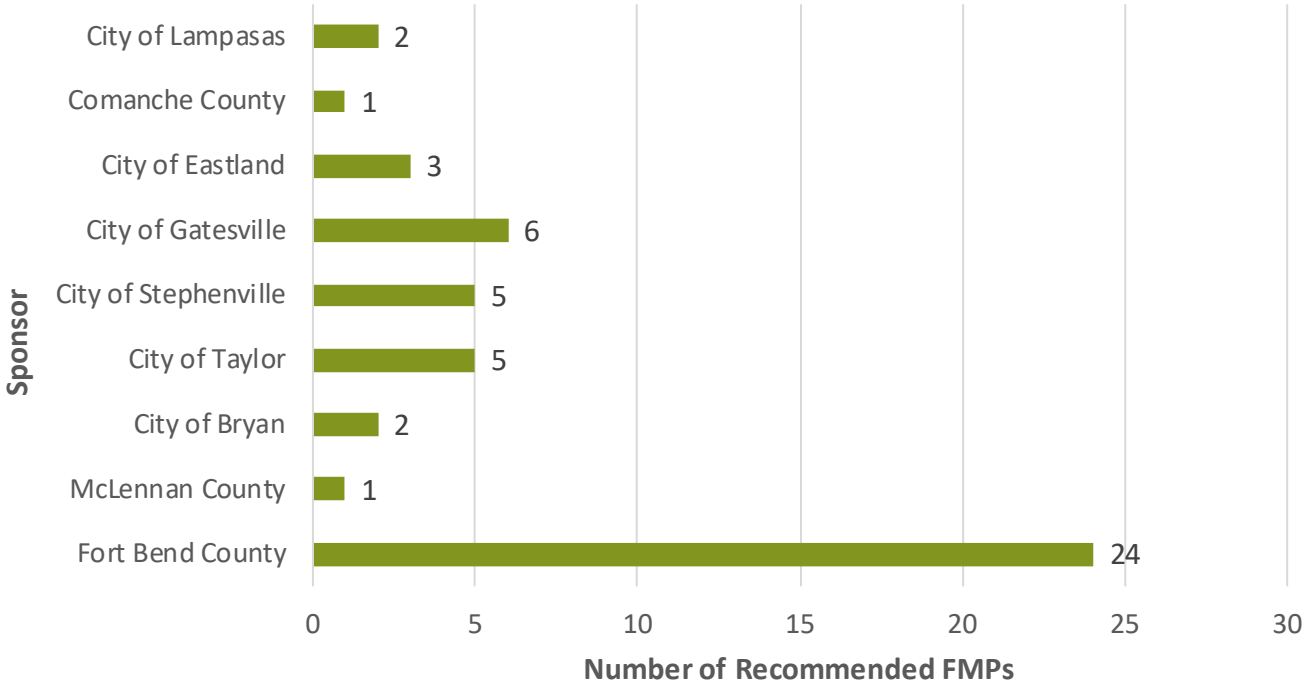
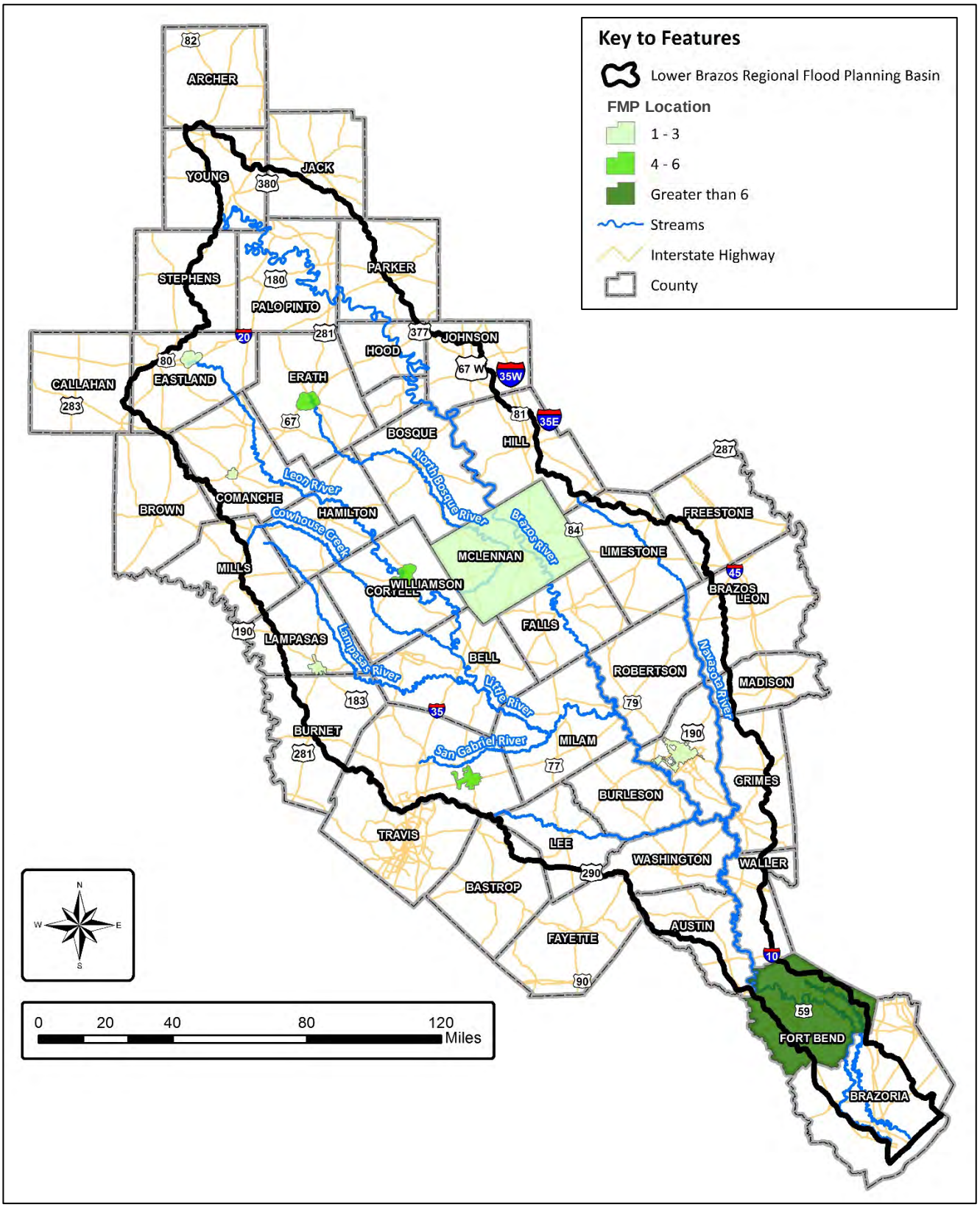


Figure 5.7 Recommended FMP Distribution



5.5 – Not Recommended FMEs, FMSs, and FMPs

As mentioned previously, the Lower Brazos Planning Region determined that several criteria must be met for flood mitigation, or management need to be recommended within the Regional Flood Plan. These metrics were applied to ensure that the recommended needs provided regional benefits and were supported on a local level, and, therefore, more likely to be carried forward and implemented.

However, many FMEs, FMSs, and FMPs that were not recommended as part of the Lower Brazos Regional Flood Plan may still provide flood reduction or mitigation if implemented. For example, the FMEs generated in *Task 4A – Flood Mitigation Needs Analysis* were not recommended due to lack of sponsorship but are highly indicative of flood-prone areas and areas of unknown flood risk. The not recommended lists of FMEs, FMSs, and FMPs have merit and should be explored by local entities when possible. Ongoing outreach is recommended, especially during the infancy of the Regional Flood Plan, to ensure that entities are aware of the plan's importance in addressing their flood mitigation needs and getting funding for their identified flood mitigation projects and studies. Additionally, if entities express support for not recommended FMEs, FMSs, and FMPs that do not currently have sponsor approval, they may be considered for recommendation during future flood planning cycles. *Table 5.5* summarizes the FMEs, FMSs, and FMPs that were not recommended for the Lower Brazos Regional Flood Plan. A detailed list of these items is in *Appendix 5.4*.

Table 5.5: Summary of Not Recommended FMEs, FMSs, and FMPs

Classification	Number Not Recommended	Reason for Recommendation Status*	Associated Costs
FME	294	No official sponsor approval was obtained.	$211,461,000
FME	32	The study area is less than 1 square mile.	$3,850,000
FMS	129	No official sponsor approval was obtained.	Not enough information was available to determine the extent of these FMSs and to develop an estimated cost to implement
FMP	1	The project drainage area is less than one square mile and does not meet guidance principles.	$669,000
FMP	7	No official sponsor approval was obtained.	$21,179,000
Total	**463**		**$237,159,000**

*Some flood mitigation and management needs may have multiple reasons for not being recommended.

In total, 463 flood mitigation and management needs were identified but not recommended as part of the Lower Brazos Regional Flood Plan. Of these, 430 were not recommended due to insufficient explicit sponsorship approval. Although there are many reasons that identified interest groups may not have responded to outreach, in some cases, it may indicate the lack of flood risk and mitigation needs in those areas.

5.6 – Evaluation of Recommended FMPs and FMSs

Although all collected FMEs, FMSs, and FMPs were evaluated, as previously explained in Chapter 4, the recommended FMPs and FMSs had some additional metrics examined. Ensuring that the recommendations did not cause any negative impacts to neighboring areas was critical to adhere to the plan's goals and the state flood planning process as a whole. Additionally, the recommendations were looked at closely for any potential interactions with the water supply, guaranteeing that their implementation would not cause any adverse effects on this metric.

FMPs were then evaluated for all benefits and costs on a detailed level. This assessment will provide the basis for the ranking process implemented by the TWDB to present the recommended projects to the State Legislature. Since the TWDB will only be requesting funding for the recommended FMPs, only these need to be evaluated to the level of detail explained below.

5.6.1 Water Supply Interactions

No recommended FMPs or FMSs were identified as having the potential to contribute to or negatively impact water supply since the projects and strategies do not propose modifications to aquifers or water supply reservoirs.

5.6.2 Negative Impact Identification

As previously mentioned**,** no negative impact can be determined if a project or strategy does not increase the inundation of infrastructures such as residential and commercial buildings and structures. A detailed definition of negative impacts is provided in Section 4B.5.c. Of all the identified strategies and projects, only six strategies were flagged as having the potential to negatively impact a neighboring area. These strategies involve improving or elevating low water crossings, which requires further analysis to ensure that proper mitigation is implemented to offset the reduction or expansion of channel conveyance. Ultimately, no recommended FMP or FMS was identified as having the potential to negatively impact a neighboring area.

The FMPs recommended in the Lower Brazos Region have signed and sealed supporting documentation, but the no negative impact statements included in the documentation are not always explicitly stated in a way that ensures that the requirements set forth by the TWDB are being met. To ensure that the projects are in fact meeting the TWDB no-impact requirements, the models for several of the FMPs were evaluated in further detail. Following the guidance provided by the TWDB in Exhibit C, the models were checked for any increases in the max water surface elevations equal to or greater than 0.05 ft from existing to proposed conditions. Additionally, the inundation extents were checked to ensure that there are no increases in inundation extents outside of public right-of-way, project property, or easement or

any inundation of storm drainage infrastructure beyond its capacity. These conditions were met for all the recommended FMPs. Peak flows at computational nodes were also checked for any increases. Several of the proposed projects increased conveyance capacity of the respective conveyance systems, resulting in higher peak flow rates. However, water surface elevations associated with these conveyance systems did not increase over the TWDB minimum requirements due to changes in hydrograph time-to-peak from existing to proposed conditions or increased hydraulic capacity in the conveyance system, allowing it to convey the increased flow rate. As a result, these flow increases were considered acceptable and should not be considered a negative impact. Finally, FMPs on creeks that feed into the Brazos River directly were considered to not create a negative impact, even if the flow increased. Due to the Brazos River's substantially large watershed size, increases in flow from the tributaries are likely to occur well before the Brazos River crests and, in turn, unlikely to affect the max water surface elevations or inundation limits associated with Brazos River flows. The method and supporting data, such as models and signed and sealed reports, used to verify that the recommended FMPs will not cause negative impacts are described in Appendix 5.10.

Each FME, FMP, and FMS should be continually evaluated and maintained during the final design and construction to ensure that, when implemented, the flood mitigation strategy or project will not have an adverse impact. It is also important that regular maintenance of these projects and strategies be implemented to ensure that the infrastructure operates as intended. Poor operation and maintenance can result in drainage infrastructure losing its functionality which, in turn, increases the potential negative impacts.

5.6.3 Additional Project Details Evaluation

5.6.3.a. Overview

The FMPs recommended for inclusion in the Lower Brazos Regional Flood Plan required additional evaluation efforts beyond the information produced to determine benefit-cost ratios (BCRs) and the metrics required for the Task 4B TWDB-required tables. These details will provide the baseline data for the TWDB to compare the projects equitably within the State Flood Plan and determine prioritization for funding and presentation to the State Legislature. The evaluation process looks at many metrics that could potentially be used to determine the benefits and impacts caused by implementing the FMPs. Some categories rely on qualitative assessments of the FMPs, in contrast to the purely quantitative analyses during previous Tasks. The full table of project details can be found in *Appendix 5.8.*

Much of the general project data required for the evaluation had been gathered previously. However, two classifications were determined for each project: FIUP (Flood Intended Use Plan) Project Category and Rural Applicant Classification. The definitions and classification process for both of these can be found in the TWDB 2020 Flood Intended Use Plan and are briefly described below (www.twdb.texas.gov/financial/programs/fif/doc/2020_Flood_Intended_Use_Plan.pdf).

FIUP Project Category describes the development stage of a project or study.

- **Category 1:** Planning of entire watersheds to inform the development of structural and non-structural mitigation strategies

- **Category 2:** Planning, acquisition, and design efforts in relation to an identified flood mitigation project
- **Category 3:** Projects that have already received federal funding contingent on matching with local funds
- **Category 4:** Projects that can be implemented quickly and will immediately protect life and property

All the FMPs recommended for the Lower Brazos Planning Region are aligned with Category 2.

A project classifies as a Rural Applicant if any of the following conditions are met:

- all entities within the project benefit area are outside metropolitan statistical areas and have populations < 10,000
- district or municipality with a service area of 10,000 or less in population
- county in which no urban area exceeds 50,000 in population

Roughly half of the recommended FMPs were identified as rural applicants.

5.6.3.b. Severity Evaluation

To understand the severity of risk in the existing conditions of the project area, the average depth of flooding for structures was calculated. The flood depths (raster format) obtained from the models were used to find the depth of flooding adjacent to each structure. These flood depths were then adjusted by 6 inches to reflect the difference between Light Detection and Ranging (lidar) elevations and the finished floor elevations of structures, which are typically elevated above the existing topography. The average flood depth at the structures was calculated and used to compare the severity of flooding under existing conditions.

The affected population was another metric determined to characterize the existing needs. This helped account for the potential overestimation of severity due to the presence of uninhabited structures at flood risk. To determine community need, the population within the floodplain was compared to the total population of the affected community. The sponsor of the FMP was determined to represent the affected community, and the entire population of that jurisdiction was used as the baseline.

5.6.3.c. Flood Risk Reduction Evaluation

To determine the flood reduction benefits provided by implementing the proposed FMPs, the number of structures removed from 1 percent ACE flood risk was considered. This metric was previously calculated in Task 4B and contributed to the BCR calculations. The flood depths associated with the proposed conditions (including the implementation of the projects) were utilized to see how many structures previously identified as being flooded were no longer within the floodplain. The percentage of at-risk structures shown as having been removed from flood risk in proposed conditions was calculated for each FMP.

Additionally, any structures that were provided with some level of flood risk reduction for the 1 percent ACE were considered. Damages associated with the flood depths pre-and post-project were determined.

These calculations were pulled from the BCR spreadsheet provided by the TWDB, used previously in Task 4B. The percent decrease in these damages represented the amount of reduction benefit provided.

The number of critical facilities removed from flood risk was also determined. A similar process was used to determine the existing and proposed flood risk conditions for critical facilities as was applied to the structure data set. However, no adjustment factor was applied to the depths due to the variation in what is included within the critical facilities data set. Data points representing facilities such as water and wastewater treatment plants and power plants may be damaged by any flooding depth.

Benefits associated with increasing access to transportation were also considered. Not only were pre- and post-flood depths on roadways used to determine the rating for this category, the classification of the road with flood benefits was also considered. The Texas Department of Transportation road classifications emphasized major collectors, principal arterials, and interstates, as all are major thoroughfares for emergency vehicles.

5.6.3.d. Life and Safety Evaluation

Many different components were considered to characterize the risk of fatalities or injuries caused by flooding. An area hazard rating was calculated by considering the depth, velocity, and land use at key points of flood concern. This metric helped inform the potential for debris to be carried with flood waters, increasing the risk of loss of life due to flooding. An area vulnerability rating was also determined. This factor was based on the speed of flood onset, the presence of flood warning mechanisms, and the nature of the area. Together, these metrics indicated the ability of residents to evacuate a flood-prone area. Finally, when available, narratives divulging historic loss of life in a project area were used to scale the ratings. All these factors determined the risk of loss of life within a project area.

Another indication of the risk to the community is the Social Vulnerability Index (SVI). This rating is determined by the Centers for Disease Control and Prevention (CDC) by census tract. It is defined as characterizing the ability of a community to respond to a disaster. Factors considered include education levels, economic status, and access to transport. When a project benefit area intersected multiple census tracts, the SVI was calculated by weighting the areas of the different census tracts within the project area.

5.6.3.e. Other Benefits Evaluation

Although providing flood mitigation benefits is the primary goal of the recommended projects, other types of benefits were considered where applicable. Projects that achieve multiple benefits can save money and time and encourage using creative and innovative solutions.

Environmental benefits provided by implementing the recommended FMPs were another interaction that was considered. The following categories were considered:

- **Water Quality:** Implementation of vegetation or flood infrastructure that could provide improvements to water quality or reduction of risk to water and wastewater treatment plants that could prevent overflow during storm events

- **Cultural Heritage:** Reduction of flood risk to an identified Texas Historical Commission site
- **Habitat, Biodiversity, and Ecology:** Preservation or creation of habitats, wetland areas, or wildlife corridors.
- **Air Quality:** Creation of open space or recreation areas or addition of vegetation that improves air quality
- **Natural Resources:** Protection of natural resources
- **Agricultural Resources/Properties:** Reduction of flood risk to agricultural property
- **Soil Quality, Erosion, and Sedimentation:** Stream armoring or reduction in water velocities to improve stream stabilization

For the Lower Brazos Planning Region's recommendations, several of these environmental benefits were identified, including reduction of flood risk to wastewater plants and THC sites, creation of open space and recreation areas, reduction of flood risk to agricultural areas, and reduction in water velocities.

Similar to environmental benefits, the FMPs were also examined for the contribution of nature-based solutions to the FMP. Several types of mitigation solutions would have qualified as being nature-based, such as creating wetlands or urban parks, restorations, or reforestation efforts. However, none of the projects recommended in this plan proposed these design components.

As mentioned previously, potential benefits provided to water supply through the flood mitigation projects identified were explored. However, for the FMPs recommended for the Lower Brazos Planning Region, there was determined to be no interaction with the water supply.

Finally, other benefits were reviewed in the broadest sense possible. Any improvements to public establishments, from recreation centers to hospitals; improvements to transportation features such as parking lots and bike paths; potential economic impacts from the relief provided to businesses; economic and environmental benefits associated with project resilience and sustainability; and many other indirect benefits were considered. For the recommended FMPs, the primary associated benefits were recreational and transportation benefits. Pedestrian and bike trails would be constructed alongside many of the proposed channel improvements, supplying communities with additional recreational and transportation outlets. Additionally, projects aimed at improving low water crossings would be accompanied by repaving and re-grading the affected roads providing additional transportation benefits

5.6.3.f. Other Impacts Evaluation

An extensive effort was made to identify drawbacks associated with implementing the FMPs beyond the estimated cost. This analysis helped identify potential indirect costs or negative impacts that help characterize whether the benefits outweigh the impacts.

Recurring costs associated with the recommended FMPs were not incorporated into the initial cost estimates. To ensure an accurate cost representation was considered, operation and maintenance (O&M) costs were estimated and evaluated as part of collecting the project details. The qualifications of those performing the O&M efforts and how the O&M costs compare to the overall estimated cost were considered. For most of the recommended FMPs, O&M costs accounted for less than 1% of the overall

estimated project costs. However, the experience and capacity of the sponsors to perform O&M vary from experienced drainage authorities to smaller entities that may not have drainage-dedicated staff.

Obstacles that could hinder or create additional costs to the implementation of the recommended FMPs were also considered. Three primary categories were examined: the number of permits required to begin construction (local, federal, and state), the number of reviews needed to approve the projects (Texas Commission on Environmental Quality (TCEQ) standards reviews and others), and the number of property acquisitions needed to implement the project. Many of the FMPs recommended for the Lower Brazos Planning Region are large efforts that require significant permitting and property acquisition.

Additionally, environmental impacts were reviewed for each recommended FMP. This analysis was a mirror of the environmental benefits analysis described previously. The same categories were considered, looking instead at how the proposed projects may cause negative effects. Several of the recommended FMPs were identified as including work within a watershed identified by TCEQ's Watershed Action Planning as being an impaired or special interest area. This flagged the FMPs as having potential impacts on water quality. Additionally, work proposed in wetlands and the need to acquire agricultural property flagged many of the recommended FMPs as potentially impacting natural and agricultural resources.

5.6.3.g. Summary of Project Details

This extensive evaluation of the recommended FMPs for the Lower Brazos Planning Region provides much of the necessary information for the ranking process used by the TWDB to compare the recommended FMPs in the State Flood Plan. However, the analysis results in *Appendix 5.8* of this plan do not indicate any final ranking or prioritization by the RFPG. The numbers and details provided are only intended to characterize and evaluate the associated costs and benefits of the FMPs recommended for inclusion in the Lower Brazos Regional Flood Plan.

Chapter 6: Impact and Contribution of the Regional Flood Plan

The Lower Brazos Regional Flood Planning Group (RFPG) was tasked with summarizing the impacts and contributions the Regional Flood Plan is expected to have if the plan is implemented as recommended. The following sections describe the impacts and contributions of this plan to various aspects of water resources. Implementation of the plan as recommended assumes that all recommended flood mitigation projects (FMP), flood management strategies (FMS), and flood management evaluations (FME) are fully funded and completed. Additionally, avoidance of future flood risk due to policy recommendations and potential future recommendations of all identified projects, strategies, and evaluations are described in this chapter since many potential FMPs, FMSs, and FMEs only require sponsor approval to be recommended by the Lower Brazos RFPG.

Task 6A – Impacts of the Regional Flood Plan

The overall impacts of the Regional Flood Plan include potential benefits to areas:

- At risk of flooding
- Structures and populations in the floodplain
- Low water crossings
- Water supply
- Impacts on the environment, agriculture, recreational resources, water quality, erosion, sedimentation, and navigation

This chapter describes the processes undertaken by the RFPG to summarize the benefit of the Regional Flood Plan if fully implemented.

The impact of the plan also includes how future flood risk will be avoided through the implementation of recommended improvements to the region's floodplain management policies. Direct and indirect benefits of other FMPs, FMSs, and FMEs not currently recommended are also discussed. These details highlight the importance of public involvement, especially at the entity level, and support in maximizing the plan's effectiveness during amendment periods and future cycles.

6A.1 Relative Reduction in Flood Risk

The impacts of the plan on existing flood risk were determined based on a before-and-after (regional flood plan implementation) comparison of the same type of information provided in Chapter 2. The recommended projects were developed and analyzed outside of the regional flood planning process and were only analyzed for the 1 percent annual chance event. Since none of the recommended projects were analyzed for the 0.2 percent annual chance event, metrics were only provided to summarize benefits in the 1 percent annual chance event. The quantitative comparison of 1 percent annual chance exceedance data with and without the plan illustrates how much the region's existing flood risk will be reduced by implementing the plan as recommended by the RFPG.

6A.1.a. Reduction in Flood Risk Identification Needs

In Chapter 2, 33 percent of the Lower Brazos Planning Region was identified as needing flood risk identification or updates to existing flood risk information. After the completion of recommended FMEs, 28 percent of the region area will need flood risk identification, a reduction of 1,172 square miles (5 percent). *Figure 6.1* represents the existing and remaining gaps in flood risk information compared to the overall area in the region. *Figure 6.2* shows the location of existing gaps in flood risk information, identified FMEs, and recommended FMEs. Although the RFPG identified additional FMEs in Chapter 4, most were not recommended due to a lack of sponsor response. More information on the process used to recommend FMEs is included in Chapter 5.

Figure 6.1: Gaps in Flood Risk Information After Implementation of Regional Flood Plan

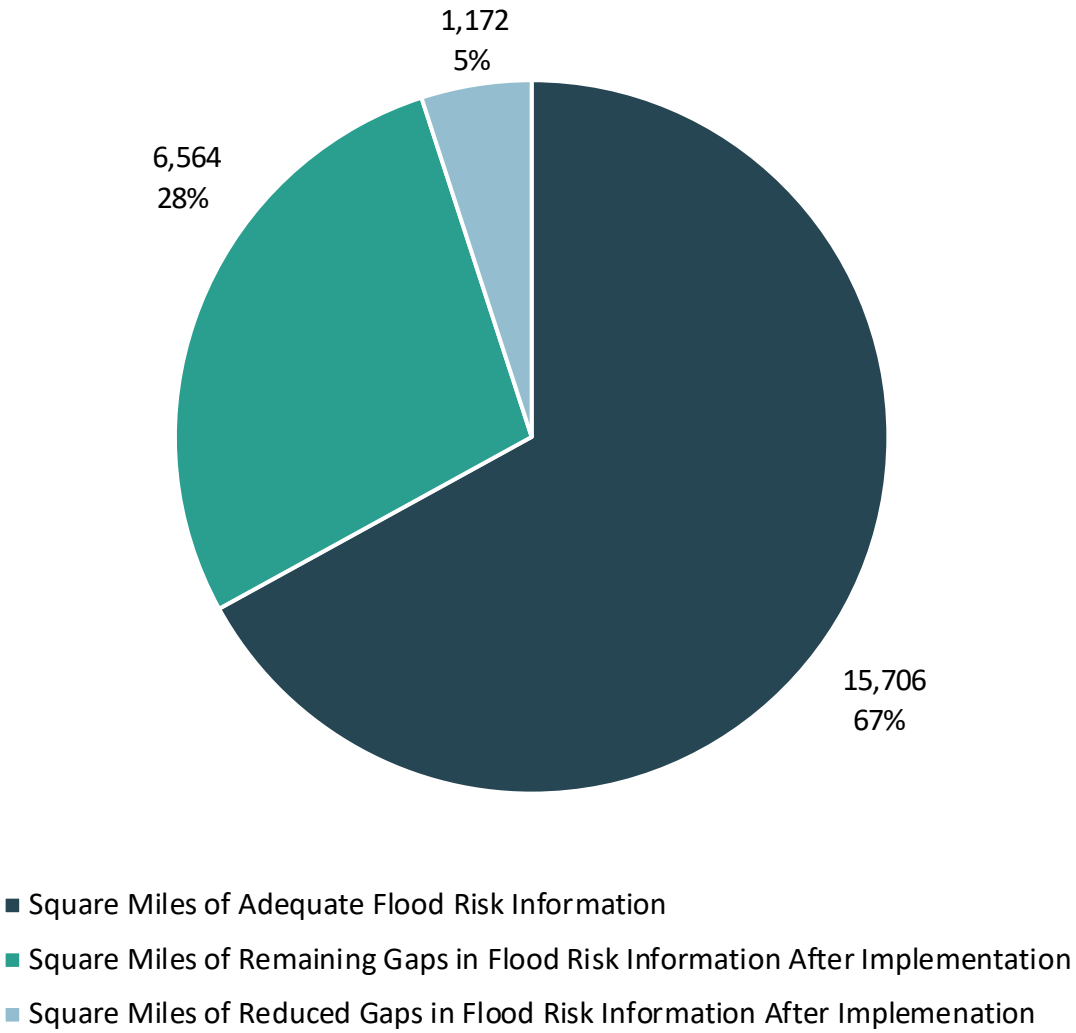
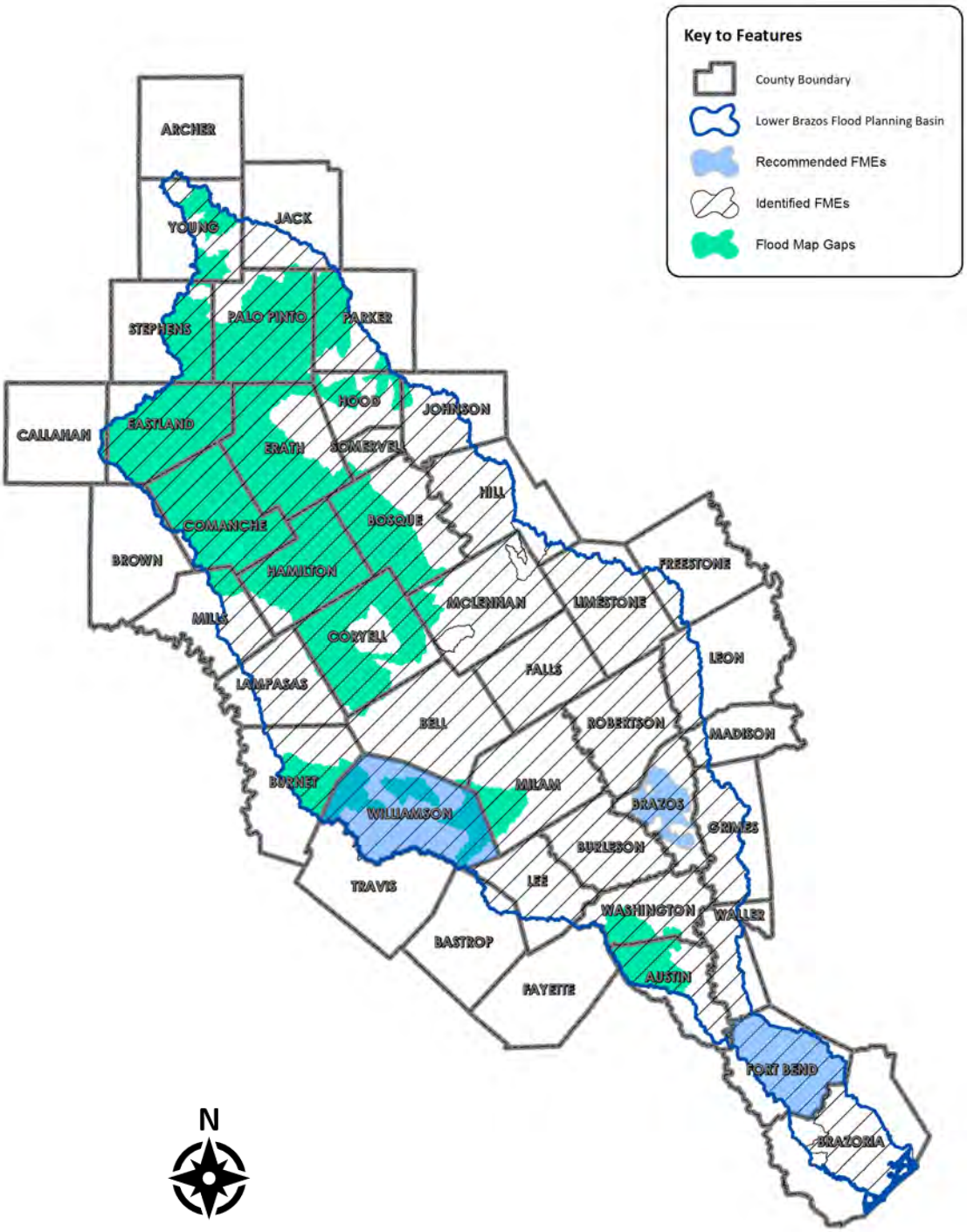


Figure 6.2: Impact of Plan on Flood Risk Information Gaps



6A.1.b. Reduction in Flood Risk Exposure

When implemented, FMPs positively impact or benefit flood risk exposure by removing or reducing population and property from flood risk. The Lower Brazos RFPG recommended 49 FMPs for implementation, and these projects consist of crossing improvements, regional channel improvements, and comprehensive drainage improvements, among others. *Table 6.1* summarizes the benefit to people and property expected if the FMPs in the regional flood plan are implemented as recommended.

Table 6.1: Summary of Impact on People and Property After Implementation of Recommended FMPs

Flood Exposure Region-wide	Existing Conditions 1% ACE*	After Implementation 1% ACE	Reduction in Exposure 1% ACE
Total Structures	63,056	59,074	3,982
Residential Structures	42,646	39,263	3,383
Critical Facilities	187	168	19
Population	129,888	118,803	11,085
Low Water Crossings	7,500	7,495	5

* 2020 conditions

6A.1.c. No Negative Impact

As proposed, implementing the recommended FMPs will not negatively impact neighboring areas within or outside the Lower Brazos Planning Region according to their respective reports and/or models. All recommended FMPs were previously modeled to ensure "no negative flood impact" on upstream, downstream, or neighboring areas. These impact analyses were conducted outside the flood planning process and performed using regional planning level data. The local sponsor will ultimately be responsible for ensuring the final project design has no negative flood impact before initiating construction.

6A.2 Other Impacts

The sections below describe the anticipated impacts of the plan on each of the following categories: socioeconomic, recreation, environment, agriculture, recreational resources, water quality, erosion, sedimentation, and navigation.

6A.2.a. Socioeconomic Impacts

Disadvantaged socioeconomic status can limit access to resources which could hinder response and recovery from flood events. Flooding not only results in damaged infrastructure and destroyed property but also has an adverse social impact on affected citizens. Short- and long-term impacts on physical and mental health result in changes to the livelihoods of affected citizens, creating greater socioeconomic disparity.

The recommended projects provide watershed-wide benefits to areas with Social Vulnerability Index (SVI) values ranging from 0.05 to 0.87. The SVI indicates the relative social vulnerability of a census tract between zero and one, with higher values indicating greater vulnerability. Watershed planning can contribute to the Lower Brazos Planning Region's ability to prepare for, respond to, and recover from flood events. Reducing socioeconomic disparities through implementing measures to create equity can

be initiated through planning. This is done by ensuring that vulnerable populations have the same access to resources and social infrastructure as those unaffected by flooding.

6A.2.b. Recreational Impacts

Using natural or man-made bodies of water for recreation is highly valued in the Lower Brazos Planning Region and throughout Texas. Many waterfront parks are spaces that are designed to be flooded with minimal damage during storm events. These floodplains and wetlands can support tourism, recreation, and freshwater fisheries.

Recreational benefits can also accompany flood mitigation projects. Along the Brazos River, many flood-control reservoirs are utilized for recreation, including boating and fishing. The FMPs recommended by the RFPG will not impact recreational use in these areas. In Fort Bend County, pedestrian and bike trails will accompany channel improvement FMPs, providing mobility and recreational benefits in tributary watersheds. Erosion prevention efforts included in the regional flood plan also provide recreational benefits since all land within the streambed is state-owned property and can be used for camping, fishing, or picnicking. The recommended FMS, Project Brazos, provides recreational benefits in Fort Bend County by protecting streambeds and adjacent communities from erosion.

Additionally, the list of recommended FMSs includes developing a property acquisition program in the cities of College Station and Hutto. These strategies would provide recreational benefits by opening opportunities for creating common gathering spaces for the respective communities.

While parks and camping areas are a valuable asset to the region, there are potential disadvantages to using the floodplain and waterfront parks for recreation. Recreational bodies of water can become dangerous to use when damaged due to flooding. Therefore, consideration must include adequate warning systems for individuals using these facilities.

6A.2.c. Environmental Impacts

The property acquisition FMSs previously mentioned will remove structures from flood risk through demolition and, by doing so, would benefit the environment by eliminating the release of pollutants associated with flooded homes. Although it is unknown what the cities' intended use for the land is after demolition, one possible use would be as local park space, which would benefit the environment by promoting the development of habitats for native plant and animal species.

While land acquisition and development regulations can have positive impacts on the environment, structural projects recommended in the plan have the potential to harm wetland ecosystems in undeveloped land that frequently receives nutrients from flooding. During detailed design phases of recommended projects, consideration of maintaining the natural conditions of these ecosystems should be made through implementing hydraulic connections between the floodplain and improved infrastructure. In some cases, additional permitting could be required.

6A.2.d. Agricultural Impacts

Flooding or excess precipitation can wash nutrients downstream or result in the loss of crops due to excessive moisture. Livestock can be swept away, drowned, or injured by flood waters, or exposed to

contaminated flood waters, resulting in health issues. After the implementation of the Regional Flood Plan, 54 square miles of farming or ranching agricultural land is anticipated to be removed from the 1 percent annual chance flood hazard area as a result of recommended FMPs in Fort Bend County, which will reduce the risk of damage to cropland and excessive transport of fertilizers. The existing and future conditions can be seen in *Table 6.2*. While mitigation projects will primarily provide benefits to agricultural land and water quality, they also have the potential to negatively impact the natural process of nutrient transport in the wide floodplains of Fort Bend County. Ultimately, since farming does not reflect the land's natural condition, and soils rely on human activity for nutrients instead of natural processes, the drawbacks of protecting agricultural land from flooding are likely to be outweighed by the benefits.

Table 6.2: Summary of Impact on Agriculture Region-wide After Implementation of Regional Flood Plan

Flood Exposure	Existing Conditions 1% ACE*	After Implementation 1% ACE	Reduction in Exposure 1% ACE
Agricultural Land (Sq. Mi)	837	783	54

* 2020 conditions

6A.2.e. Water Quality Impacts

Water quality concerns within the Lower Brazos Planning Region are high nutrient loads, high bacterial and salinity levels, and low dissolved oxygen. Mitigating flooded agricultural land mentioned in the previous section will address nutrient load issues by reducing quantities of fertilizer conveyed in runoff.

The list of recommended FMSs includes floodproofing lift stations and manholes within the City of Georgetown. Additionally, the recommended FMPs provide widespread reductions in water surface elevations and inundation. Both floodproofing and structural projects mitigate the overflow of sanitary lift stations in a flood event, preventing the release of untreated sewage that can harm water quality in the region. These strategies and projects can also reduce the disruption of raw water treatment.

6A.2.f. Erosion and Sedimentation Impacts

The list of recommended FMSs includes Project Brazos, which will primarily benefit erosion issues along the main stem of the Brazos River. This strategy includes stabilization efforts for 11 identified locations throughout Fort Bend County where critical infrastructure, such as accredited levees, highways, or historic sites, are at risk of damage due to migration of the Brazos River, which has been accelerated by recent flooding. Implementation of this strategy will reduce erosion and sedimentation along the Brazos River and potentially avoid significant future losses to public infrastructure, buildings, and vulnerability to levees.

6A.2.g. Navigation Impacts

Historically, the Brazos River was navigable from the Gulf Coast to Washington County for approximately 250 miles. Today, the Brazos River is no longer used for navigation purposes. The implementation of recommended FMPs and FMSs in the Regional Flood Plan will not impact navigation on the Brazos River.

6A.3 Avoidance of Future Flood Risk

The following sections illustrate how additional future flood risks (that might otherwise arise if no changes were made to floodplain policies, etc.) will be avoided by implementing the Regional Flood Plan. Impacts of the plan on existing flood risk that also impact future flood risk are not included in the discussion.

6A.3.a. Floodplain Management Policy Future Impacts

Floodplain management recommendations and goals were established by the RFPG as a part of Chapter 3. While most of the Regional Flood Plan focuses on the current cycle, Chapter 3 established a long-term vision for target metrics that subsequent cycles of the plan should achieve. Of the 10 goals set forth by the RFPG, the floodplain management goals presented in Chapter 3 (*Appendix 3.3 Table 11*), listed below, will be most impactful in helping communities in the region avoid increases in flood hazard exposure.

- Increase the number of counties and communities that are enrolled in the National Flood Insurance Program (NFIP)
- Increase the number of counties and communities that have adopted higher than minimum NFIP standards, including directing development away from the floodplain
- Increase the number of entities that have adopted the best available data and science for their designs and plans

Regulation of development, implementation of higher standards, and use of the best available data are all interdependent strategies for avoiding potential increases in flood exposure over time. "Higher standard" is defined by the *Technical Guidelines for Regional Flood Planning* as freeboard requirements, detention requirements, or fill restrictions. Higher standards provide a factor of safety to account for future uncertainty in identified flood risk. Yet, in order to set higher standards, foundational standards should be set through NFIP participation, and flood risk should be accurately identified through reliable and robust methods. The goals listed above will be realized through the execution of FMSs recommended in each planning cycle.

6A.3.b. Flood Management Strategy (FMS) Future Impacts

The RFPG identified FMSs encompassing 27 counties in the region from publicly available Hazard Mitigation Plans (HMPs) that are directly aligned with the goal of implementing higher standards in the Lower Brazos Planning Region. These strategies are assigned the type "Regulatory and Guidance." Through the development regulations mentioned in the previous section, the Regulatory and Guidance FMSs have the potential to reduce flood risk for newly constructed buildings in the Lower Brazos Planning Region.

Based on the future flood hazard analysis from *Task 2B* in Chapter 2, over 480,000 new structures are projected to be constructed across the region to accommodate population growth over the next 30 years. Potential flood risk can be reduced, and resiliency could be increased for many of these structures by communities adopting higher floodplain management criteria and standards. While many FMSs related to updated floodplain management criteria were identified, none were recommended by the

RFPG due to a lack of sponsor response. While the RFPG does not recommend these FMSs, documentation of the strategies in HMPs implies the potential for their recommendation in subsequent amendments or cycles of the plan.

In addition to reducing the risk for newly constructed buildings, higher standards also help communities avoid additional future flood risks through the following regulations:

- Mitigating impacts on receiving waterways from development due to increased runoff conveyance, which also stabilizes erosion and sedimentation in natural channels
- Preserving floodplain capacity by requiring compensatory storage for all fill-in 1 percent or 0.2 percent ACE flood hazard areas
- Incentivizing development away from flood hazard areas, which protects the natural environment and water quality
- Higher freeboard requirements and improved resilience through requiring the design of extreme event overflows

6A.3.c. Flood Management Evaluation (FME) Future Impacts

As shown in *Figure 6.2*, FMEs in the form of regional watershed studies were identified across the Lower Brazos Planning Region to address gaps in flood risk information as a part of *Task 4A*. While these evaluations are not recommended by the RFPG due to a lack of sponsor approval, their future recommendation during subsequent amendments or cycles of the plan could result in an increase in quantified flood exposure, as defined in Chapter 2. While an increase in quantified exposure may not indicate progress in fulfilling the plan's stated goals at first glance, identifying new flood exposure through state-of-the-art studies is a critical step in proposing solutions in the form of FMPs. Implementation of regional studies in a consistent manner throughout the Lower Brazos Planning Region facilitates the following future benefits:

- Better understanding of flooding sources and the frequency of flooding
- Equitable assessment of flood exposure throughout the Lower Brazos Planning Region during future planning cycles
- Widespread availability of existing conditions modeling for evaluation of future FMPs
- Regional hydrologic study extents will facilitate future FMPs that focus on regional mitigation rather than a prioritization of benefits within specific political jurisdictions

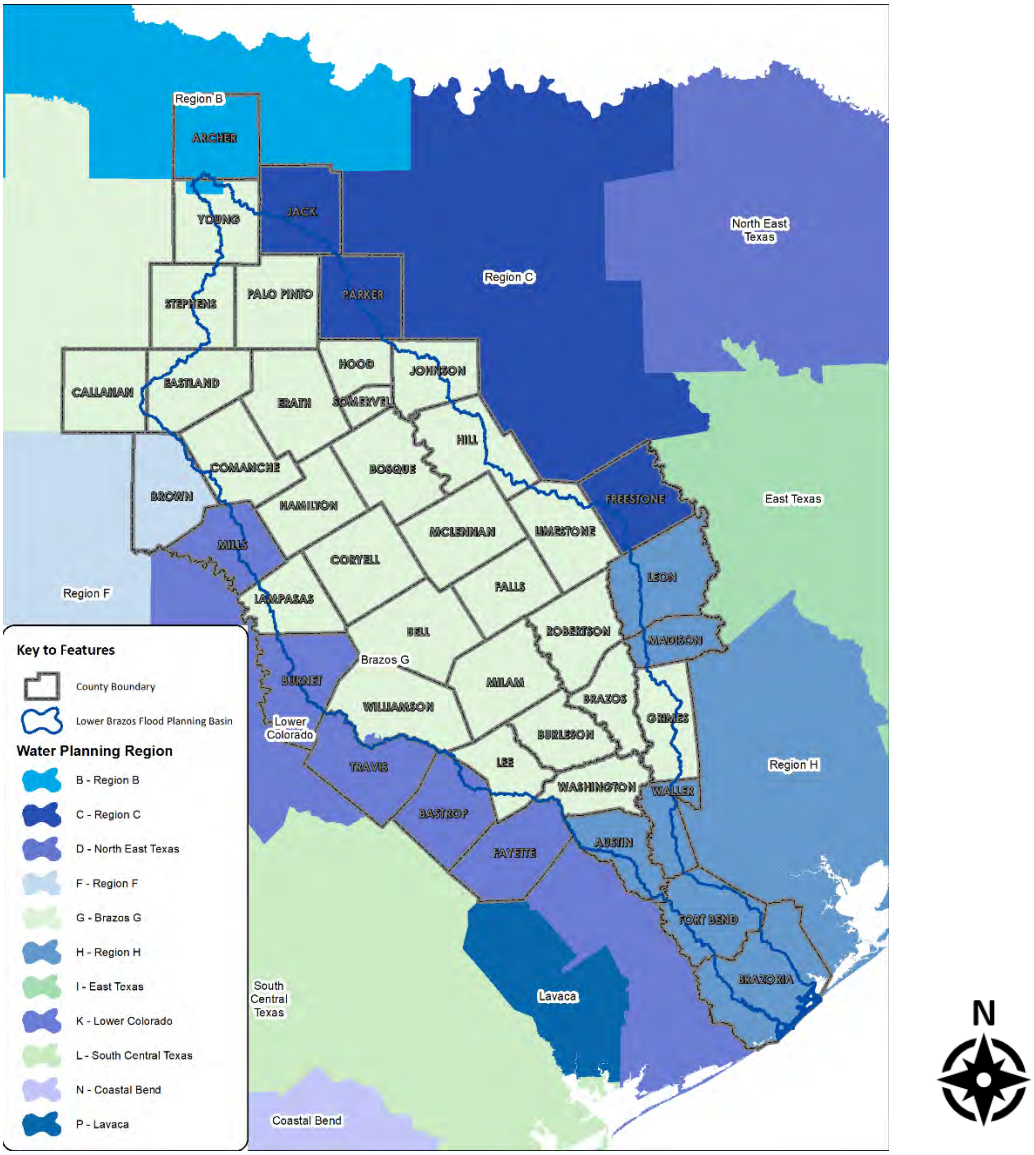
In summary, avoidance of future flood risk begins with identifying this risk through new studies. Beyond addressing the immediate need to close knowledge gaps, the execution of regional watershed studies created by the Lower Brazos RFPG will provide a foundation for effective FMP identification and recommendation in future planning cycles.

Task 6B – Contributions to and Impacts on Water Supply

Regional Flood Plans must include a region-wide summary and description of the contribution that the Regional Flood Plan would have to water supply development, including positive and negative impacts of the flood plan on the State Water Plan. The Lower Brazos Planning Region covers portions of the Brazos G, Lower Colorado (Region K), Region H, Region F, and Region C Water Planning Regions. *Figure 6.3* shows all Regional Water Planning Areas and the Lower Brazos Flood Planning area.

The Lower Brazos RFPG coordinated with each of these planning groups as a part of the flood planning process. No FMPs or FMSs recommended in the Lower Brazos Regional Flood Plan, if implemented, would contribute to or negatively impact and/or reduce the water supply in any of the water planning regions.

Figure 6.3: Water Planning Areas and Lower Brazos Planning Region



Chapter 7: Flood Response Information and Activities

The following chapter summarizes the flood response preparation information and activities in the Lower Brazos Planning Region using demographic, historical, projected, and statistical data from the previous chapters and implementing data from the survey responses. The scope of work states that the Regional Flood Planning Group (RFPG) "shall not perform analyses or other activities related to planning for disaster response or recovery activities." Therefore, this chapter summarizes the information obtained and provides general recommendations regarding flood response activities.

7.1 – Types of Flooding in the Lower Brazos Planning Region

Five types of floods impact the Lower Brazos Planning Region: coastal floods, flash floods, pluvial floods, riverine floods, and urban floods. The two most common are riverine and flash floods. Riverine flooding tends to be more widespread, encompassing vast swaths of land, while flash floods tend to be more dangerous as they can occur suddenly and without warning. The Lower Brazos Planning Region is prone to each flood type below, depending on the location within the region:

- A coastal process such as waves, tide, storm surge, or heavy rainfall from coastal storms creates a flood, referred to as Coastal flooding. **Coastal flooding** tends to be the most extreme when the storm surge is high.
- **Flash floods** are floods caused by heavy rainfall over a relatively short period of time. The flood water can be very powerful, making it extremely dangerous. Flash floods can occur within a few minutes or hours of excessive rainfall or a dam or levee failure, making them unpredictable.
- **Pluvial floods** happen when flooding is independent of an overflowing body of water due to extreme rainfall on internal drainage systems such as storm sewers or ditches. The most common example is when the drainage system is overwhelmed, and the excess water floods into the streets.
- **Riverine floods** occur when rainfall runoff overwhelms the channel capacity and overtops the riverbank. This overtopping then spills the water onto the nearby land. Riverine flooding can be widespread and can cause dams and levees to break and overwhelm nearby areas
- **Urban flooding** is flooding caused by excess runoff water in developed areas, where the water doesn't have anywhere else to go. Urban flooding is primarily due to excessive rain falling on impervious surfaces.

With the Lower Brazos Planning Region's vulnerability to multiple types of flooding, it is key to prepare, respond, recover, and mitigate flood-related impacts. This chapter will look at the region's entities' individual roles, what types of plans are in place to provide the framework that dictates the region's capabilities, and what actions can be implemented to promote healthy floodplain management practices.

7.2 – The Nature and Types of Flood Response Preparations

There are four phases to emergency management, as shown in *Figure 7.1*:

- **Flood Mitigation:** The implementation of actions, including both structural and non-structural solutions, to reduce flood risk to protect against the loss of life and property.
- **Flood Preparedness:** Actions, aside from mitigation, taken before flood events to prepare for flood response activities.
- **Flood Response:** Actions taken during and in the immediate aftermath of a flood event.
- **Flood Recovery**: Actions taken after a flood event involving repairs or other actions necessary to return to pre-event conditions.

Figure 7.1: The Four Phases of Emergency Management

For example, when a severe rain event is projected to occur, steps are taken for **preparedness**: disaster preparedness plans are reviewed, drills and exercises are performed, an essential supply list is created, and potential vulnerabilities are assessed. During the **response** phase, disaster plans are implemented, search and rescues may occur, and low water crossing signs may be erected. In the **recovery** phase, evaluation of flood damage, rebuilding of damaged structures, and removing debris occur. The most critical step of the four phases of emergency management is **mitigation**.

Hazard Mitigation is any sustained action taken to reduce or eliminate the lasting risk to life and property from hazard events. It is an ongoing process that occurs before, during, and after disasters and seeks to break the cycle of damage and restoration in hazardous areas.

Flood mitigation is the primary focus of the Regional Flood Planning process and plan development efforts regarding identifying and recommending Flood Management Evaluation (FME), Flood Management Strategy (FMS), and Flood Mitigation Project (FMP) by the RFPG. The plan may also include flood preparedness FMEs, FMSs, and FMPs.

For example, when a severe rain event is projected to occur, steps are taken for **preparedness**: disaster preparedness plans are in place, drills and exercises are performed, an essential supply list is created, and potential vulnerabilities are assessed. Examples of preparedness actions include installing disaster warning systems, purchasing radio communications equipment, or conducting emergency response training.

During the **response** phase, disaster plans are implemented, search and rescue activities may occur, and/or low water crossing signs may be erected. Response examples include addressing immediate flood needs through actions such as installing 'road closed' barriers at low water crossings, putting up signage on overtopped roads, or using sandbags to divert water.

In the **recovery** phase, evaluation of flood damage occurs. Examples of recovery activities include comprehensive debris management, performing emergency repairs to roads and bridges, rebuilding damaged structures, and restoration of utilities.

The most important step of the four phases of emergency management is **mitigation**. Examples of mitigation actions include planning and zoning, floodplain protection, property acquisition and relocation, and road drainage improvements such as adding culverts, increasing culvert sizes, raising roadbeds, or public outreach projects. Mitigation aids in breaking the cycle of damage and repair after flood events.

7.2.1 Actions and Preparations

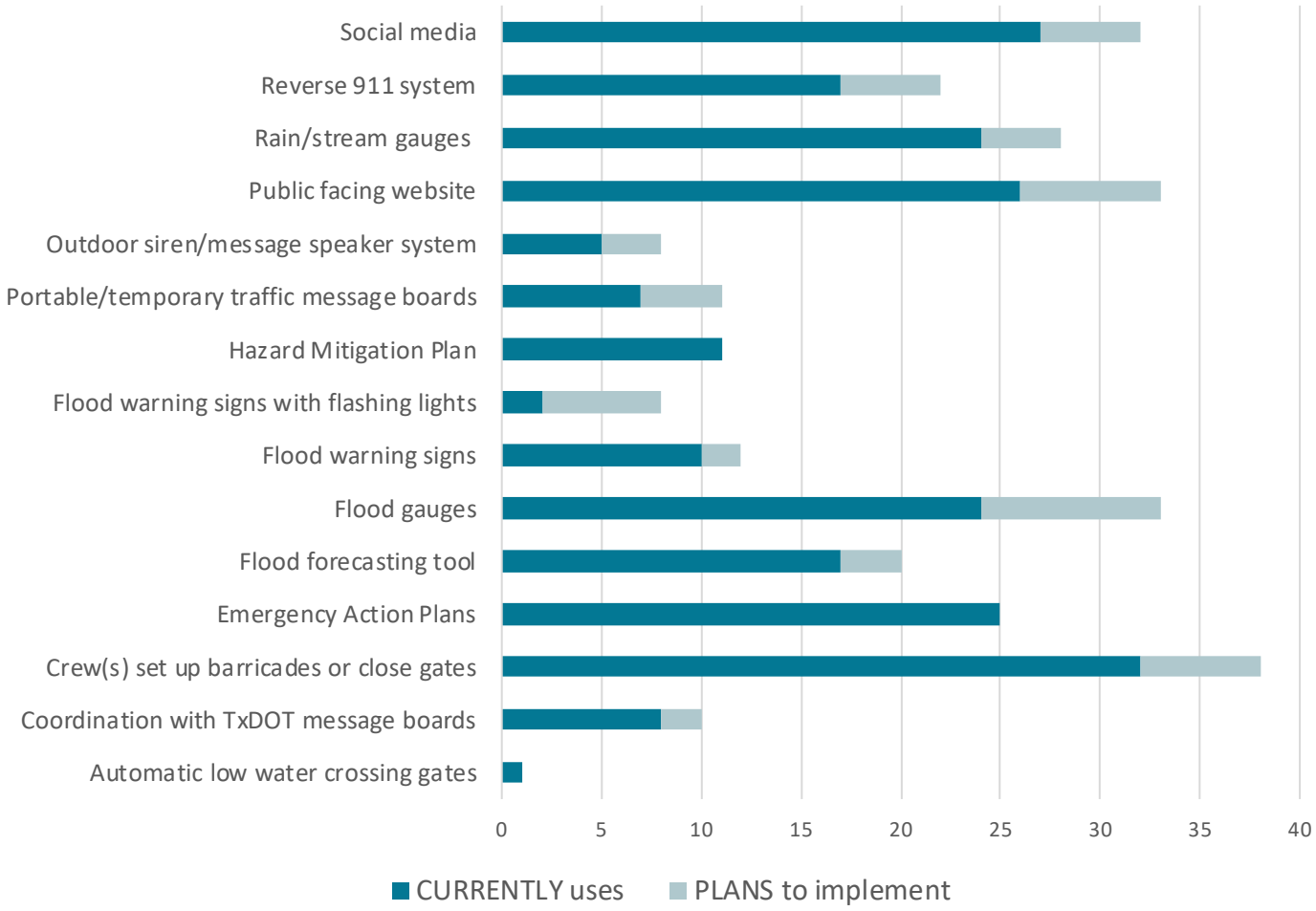
Reviewing Hazard Mitigation Plans can be useful in evaluating types of actions and projects to implement in the mitigation process. In addition to mitigation, these actions can be implemented to aid in the region's preparedness, response, and recovery capabilities.

Below are mitigation actions taken from Hazard Mitigation Action Plans in the Lower Brazos Planning Region:

- Buyout/acquisition/elevation projects
- Drainage control and maintenance
- Education and awareness for citizens
- Equipment procurement for response
- Erosion control measures
- Flood insurance education
- Flood study/assessment
- Infrastructure improvement
- Installation/procurement of generators
- Natural planning improvement
- Outreach and community engagement
- Technology improvement
- Urban planning and maintenance

Many of the flood response measures listed above align with the Lower Brazos Planning Region's outreach survey data shown in *Figure 7.2.* Data from the survey indicated that several of the actions or measures listed were in place or planned for implementation in the next five years. These actions include obtaining and utilizing flood warning signs, implementing the reverse 911 system, utilizing a public-facing website, mobilizing crews to set up barricades or close gates, applying social media engagement, creating Emergency Action Plans, and obtaining and utilizing flood gauges.

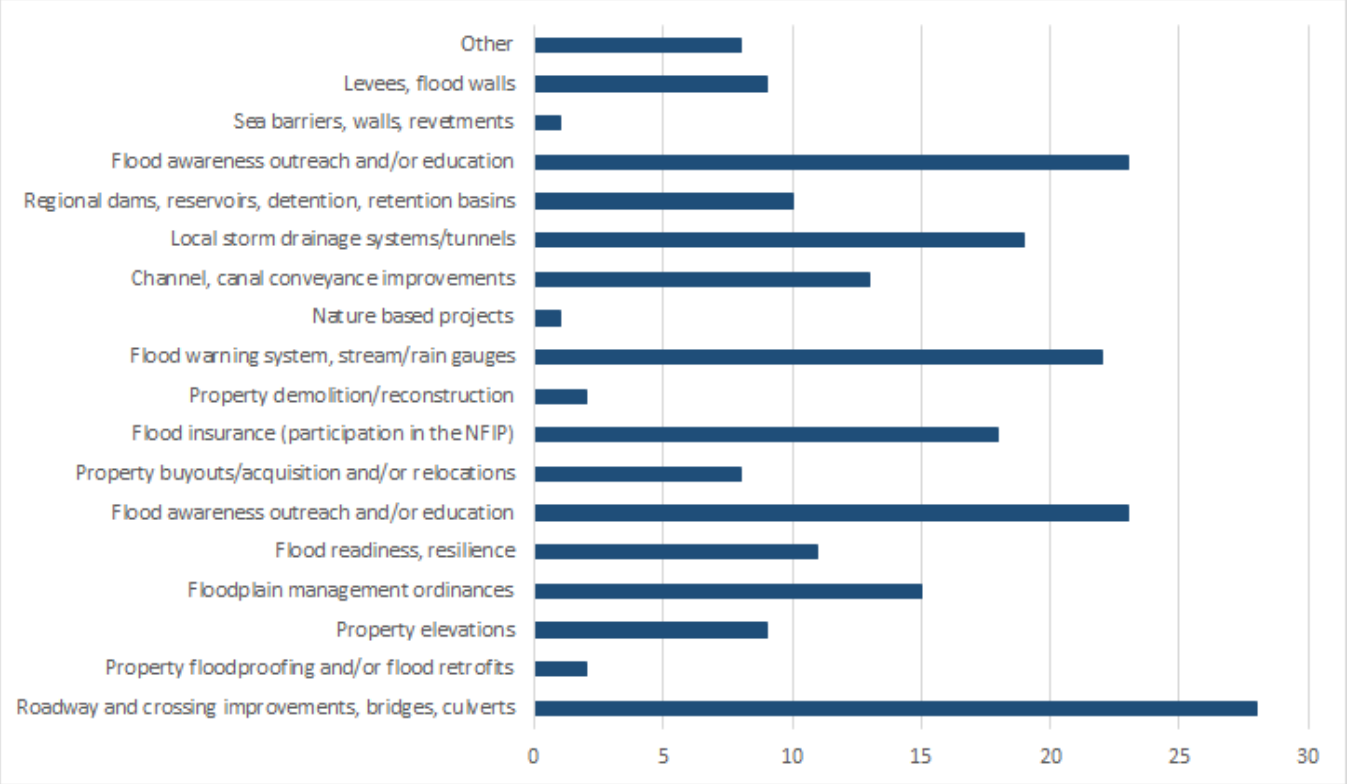
Figure 7.2: Lower Brazos Planning Region's Flood Response Measures



(Lower Brazos Planning Region Outreach Survey)

Per responses from the Lower Brazos Planning Region outreach survey, the top current, ongoing, or proposed projects include several roadways and crossing improvements such as bridges and culverts, and significant flood awareness outreach and education efforts. Additional efforts include developing flood warning systems and implementing stream and rain gauges. This can be seen in *Figure 7.3*.

Figure 7.3: Flood Management Strategies and Flood Mitigation Projects



(Lower Brazos Planning Region Outreach Survey)

Many of these mitigation and preparatory actions are done in conjunction with the relevant entities who put these actions into practice. The entities below are responsible for implementing flood preparedness, flood response, and flood recovery actions.

7.3 – Relevant Entities in the Lower Brazos Planning Region

The purpose of flood risk management is to help prevent or reduce flood risk by using either structural or non-structural means or a combination of the two. Responsibility for flood risk management is shared between Federal, State, and local government agencies, private-sector entities, and the general public. The various interested parties contacted to provide data via the Lower Brazos Planning Region's outreach survey were listed: Cities, Counties, Councils of Government (COGs), Districts such as MUDs, SUDs, etc., and State and Federal Agencies. Listed below are the various contributing entities and partners.

Ag Extension Agents are employed by land-grant universities and serve the citizens as experts or teachers on the topic of Agriculture. Ag extension agents can provide valuable information on preparation and recovery from flood events to agricultural entities. The Lower Brazos Planning Region has a significant agricultural footprint, including farming, forestry, and ranching-making working closely with Ag Extension Agents crucial to prevent losses.

Cities, or Municipalities, generally take responsibility for parks and recreation services, police and fire departments, housing services, emergency medical services, municipal courts, transportation services (including public transportation), and public works (streets, sewers, snow removal, signage, and so forth). There are 178 municipalities within the Lower Brazos Planning Region. In the aftermath of a flood event, Cities and Counties coordinate to provide recovery services for residents, including but not limited to debris cleanup, providing vital resources such as freshwater, medical care, and shelter, buyout programs for flooded properties, and local infrastructure improvements to mitigate future risk. Cities and Counties can provide long-term resiliency through the successful implementation of mitigation projects to reduce the impact of floods.

The major responsibilities of the 44 Lower Brazos Planning Region **County** governments include providing public safety and justice, holding elections at every level of government, maintaining Texans' most important records, building and maintaining roads, bridges, and in some cases, county airports, and providing emergency management services and health and safety services, collecting property taxes for the county and sometimes for other taxing entities, issuing vehicle registration and transfers, and registering voters.

The eight regional **Councils of Governments (COGs)** in the Lower Brazos Planning Region are voluntary associations representing member local governments, mainly cities and counties, that seek to provide cooperative planning, coordination, and technical assistance on issues of mutual concern that cross jurisdictional lines. COGs can serve as a resource for flood data, flood planning, and flood management. When recovering from a flood event, COGs can serve as a valuable resources by providing information, services, and toolkits for residents. COGs facilitate recovery through public engagement and community outreach, the planning of and implementation of regional infrastructure projects, and the development of plans to aid in recovery and resilience. Three Lower Brazos Planning Region COGs, including the Capital Area Council of Governments, Central Texas Council of Governments, and Houston-Galveston Area Council, received Community Development Block Grants for Disaster Recovery (CDBG-DR) allocated by the United States Department of Housing and Urban Development (HUD) for Hurricane Harvey housing recovery assistance. These funds are for housing, infrastructure, and planning through state and local programs.

A portion of the Lower Brazos Planning Region, as part of the North Central Texas Council of Governments (NCTCOG), is the **Public Works Emergency Response Team** (PWERT). This team was created to provide aid during an emergency or disaster when local public works are overwhelmed. In addition, NCTCOG provides a Local Disaster and Recovery Framework and Toolkit, which includes post-disaster recovery checklists, local plan templates, as well as other documents to facilitate in the recovery process.

The Texas Water Development Board's (TWDB) mission is to lead the state's efforts to ensure a secure water future for Texas and its citizens. The TWDB provides water planning, data collection and dissemination, financial assistance, and technical assistance services to the citizens of Texas. The TWDB is statutorily responsible for administering the regional water planning process and preparing and adopting the state water plan every five years. Additionally, the TWDB offers a variety of cost-effective loan and grant programs that provide for the planning, acquisition, design, and construction of water-related infrastructure and other water quality improvements.

The **Federal Emergency Management Agency** (**FEMA**) is an agency of the United States Department of Homeland Security (DHS), initially created in 1977. While on-the-ground support of disaster recovery efforts is a major part of FEMA's charter, the agency provides state and local governments with experts in specialized fields to respond to disasters. The agency provides funding for rebuilding efforts and relief funds for infrastructure by directing individuals to access low-interest loans. In addition, FEMA provides funds for training response personnel throughout the United States and its territories as part of the agency's preparedness effort.

A **Flood Control District** is a special-purpose district created by the Texas Legislature and governed by County Commissioners Courts. It is a government agency established to reduce the effects of flooding.

Dams and Levees are owned and operated by individuals, private and public organizations, and the government. The responsibility for maintaining a safe dam rests with the owner. A dam failure resulting in an uncontrolled reservoir release can have a devastating effect on persons and property downstream. The owners must be part of the flood planning process to ensure collaborative and cohesive flood planning.

The **National Weather Service (NWS)** mission is to provide weather, water, and climate data, forecasts, warnings, and impact-based decision support services to protect life and property and enhance the national economy. NWS provides flash flood indicators through watches, warnings, and emergency notices.

- **Flash Flood WATCH** is issued when conditions look favorable for flash flooding. A watch usually encompasses several counties. Action plans should be considered at this stage should water begin to rise.
- **Flash Flood WARNING** is issued when dangerous flash flooding happens or will happen soon. A warning is usually a smaller, more specific area. This can be due to excessive heavy rain or a dam/levee failure. Preparations must be made to act quickly as flood waters may rise rapidly.
- **Flash Flood EMERGENCY** is issued for the exceedingly rare situations when extremely heavy rain is leading to a severe threat to human life, and catastrophic damage from a flash flood is happening or will happen soon. Emergency officials typically report life-threatening water rises resulting in water rescues/evacuations.

The **National Oceanic and Atmospheric Administration (NOAA)** is a scientific and regulatory agency within the United States Department of Commerce that forecasts weather, monitors oceanic and atmospheric conditions, charts the seas, conducts deep-sea exploration, and manages fishing and protection of marine mammals and endangered species in the U.S. In addition to forecasting potential storm events, NOAA's National Center for Environmental Information (NCEI) provides historical data that can help communities determine their future probability of flood events and is key in the planning and mitigation process. NOAA's Office of Coastal Management is key in providing information, technology, and flood management strategies.

The **General Land Office (GLO)** is the oldest state agency in Texas. The GLO manages state lands, operates the Alamo, helps Texans recover from natural disasters, helps fund Texas public education through the Permanent School Fund, provides benefits to Texas Veterans, and manages the vast Texas coast. GLO, through the Community Development and Revitalization division, aids communities in rebuilding, restoring critical infrastructure, and mitigating future damage through resilient community planning. The GLO administers both Community Development Block Grant Disaster Recovery (CDBG-DR) and Mitigation (CDBG-MIT) funds from the U.S. Department of Housing and Urban Development (HUD) on behalf of the State of Texas. These funds are critical elements in recovery and mitigation in the Lower Brazos Planning Region.

River Authorities or Districts are public agencies established by the state legislature. These agencies are given authority to develop and manage the waters of the state, including groundwater, within their jurisdictional area. The Lower Brazos Planning Region has seven River Authorities that each has the power to conserve, store, control, preserve, utilize, and distribute the waters of a designated geographic region for the benefit of the public. The largest River Authority in the Lower Brazos Planning Region is the Brazos River Authority, along with the Trinity River Authority, San Jacinto River Authority, Red River Authority, North Harris County Region Water Authority, North Fort Bend Water Authority, and the Lower Colorado River Authority accounting for small geographical areas.

Daily river forecasts are issued by the 3 **River Forecast Centers (RFCs)** using hydrologic models based on rainfall, soil characteristics, precipitation forecasts, and several other variables. Some RFCs, especially those in mountainous regions, also provide seasonal snowpack and peak flow forecasts. Forecasts benefit a wide range of users, including agriculture, hydroelectric dam operation, and water supply resources. The forecasts can provide essential information on river levels and conditions. West Gulf River Forecast Center serves a large portion of the Lower Brazos region.

The **Texas Division of Emergency Management (TDEM)**, a division of the Texas Department of Public Safety (DPS), coordinates state and local responses to natural disasters and other

emergencies in Texas. TDEM is intended to ensure the state and its local governments respond to and recover from emergencies and disasters and implement plans and programs to help prevent or lessen the impact of emergencies and disasters.

TDEM's Recovery and Mitigation divisions work closely with local jurisdictions, state agencies, and federal partners to ensure Texans successfully navigate recovery processes and become more resilient to future disasters. The Disaster Recovery Task Force was created to assist jurisdictions that an emergency or disaster has impacted to recover more efficiently by starting the recovery process early in the response phase.

There are six TDEM regions within Texas each with Assistant Chiefs and District Coordinators. They serve as the Division's field response personnel stationed throughout the state. They have a dual role as they carry out emergency preparedness activities and coordinate emergency response operations. In their preparedness role, they assist local officials in emergency planning, training, and exercises and developing emergency teams and facilities. They also teach a wide variety of emergency management courses. In their response role, they deploy to incident sites to assess damages, identify urgent needs, advise local officials regarding state assistance, and coordinate the deployment of state emergency resources to assist local emergency responders. As seen in *Figure 7.4,* the Lower Brazos Planning Region is mostly in TDEM Region 6, with some counties in Regions 1, 2, and 5.

Figure 7.4: Texas Department of Emergency Management Regions

The **Texas Department of Transportation** (**TxDOT**) is a government agency often associated with the construction and maintenance of the state's highway system; however, the agency is also

responsible for overseeing aviation, rail, and public transportation systems. TxDOT can provide real-time road closure and low water crossing information during and after a flood event. Users can access this data through TxDOT's Drive Texas website: https://drivetexas.org.

Texas Public Works Emergency Response Council serves as a Statewide database of response assets available for a response as requested to man-made and natural disasters thru mutual aid. They serve to support and promote statewide emergency preparedness, disaster response, mutual aid assistance, and training for Public Works Agencies and seek to provide a system allowing jurisdictions impacted by disaster to request assistance through a standardized process.

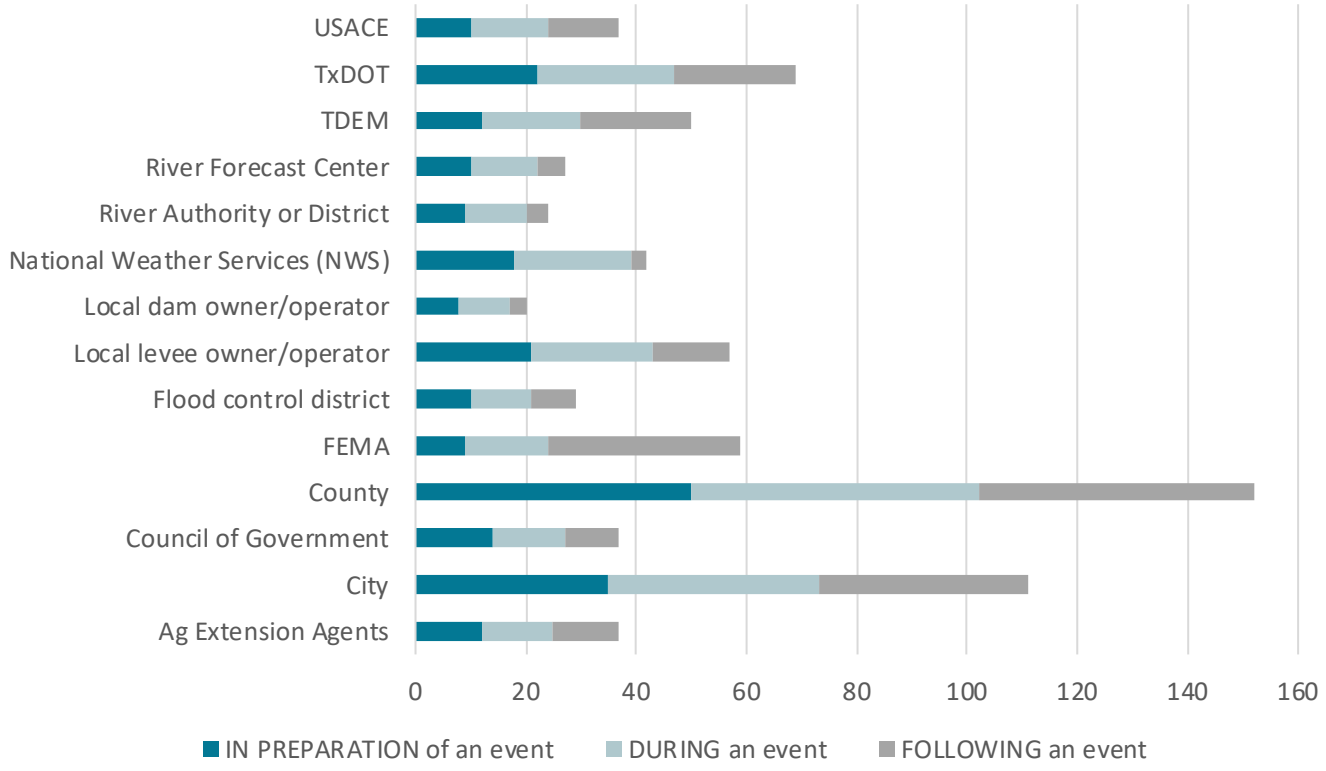
Texas Association of Regional Councils assists state and federal partners by coordinating and improving regional homeland security preparedness, planning, and response activities across jurisdictional boundaries. The Texas Department of Emergency Management works with the regional councils to ensure that all regional and local emergency plans are up-to-date and compliant with Texas Government Code. Regional councils also work with TDEM in the event of a disaster within their region to access state resources in a timely manner.

The **U.S. Army Corps of Engineers (USACE)** is important to the nation's military. The agency is responsible for a wide range of efforts in the United States, including addressing safety issues related to waterways, dams, and canals, environmental protection, emergency relief, hydroelectric power, and much more. USACE owns and operates several large flood control reservoirs in the Lower Brazos Planning Region. USACE is composed of several divisions, with the Lower Brazos Planning Region being in the Southwest Division and the Galveston and Fort Worth Districts.

The USACE Flood Risk Management Program (FRMP) works across the agency to focus the policies, programs, and expertise of USACE on reducing overall flood risk. This includes the appropriate use and resiliency of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, floodproofing, etc.) reduce the risk of loss of life, reduce long-term economic damages to the public and private sector, and improve the natural environment.

In the Lower Brazos basin, coordination with the entities listed above is essential before, during, and after a flood event. As indicated by the Lower Brazos Planning Region outreach survey in *Figure 7.5*, the entities in which coordination is most important at each stage in a flood event are as follows: county, city, TxDOT, FEMA, and levee owner/operators with all other entities accounting for much smaller responses.

Figure 7.5: Lower Brazos Planning Region's Coordinating Entities



(Lower Brazos Planning Region's Outreach Survey)

7.3.1 Emergency Information

There are various means by which data can be collected and disseminated in a flood event. They can include gathering data via rain and stream gauge instruments and sending out emergency flood information through text or recorded messaging.

Two types of gauges used are rain gauges and stream gauges. A rain gauge is a meteorological instrument to measure precipitation in a given amount of time. Stream gauging is a technique used to measure the discharge, or the volume of water per unit time, of a stream at a particular location. The height of water in the stream channel, known as a stage or gage height, can be used to determine the discharge in a stream.

In addition to the National Weather Service, local news stations or radio stations are vital in relaying real-time information about inclement weather and flooding to local residents. They can also alert residents to low water crossing closings, dam or levee breaches, and other potential dangers. They can also flood watches, warnings, and emergency notifications.

An Emergency Notification System is a software that provides alert messages during an emergency. Messages can interrupt radio and television to broadcast emergency alert information. Messages cover a large geographic footprint, including the entirety of the Lower Brazos Planning Region. Emergency

message audio/text may be repeated twice, but Emergency Alert System (EAS) activation interrupts programming only once, then regular programming continues.

A reverse 911 system allows an agency to pull up a map on a computer, define an area and send a recorded phone message to each business or residence in that area. It can provide data to residents on flood dangers in their area.

School emergency alert systems are tools that allow schools to communicate quickly to staff, students, first responders, and others to take appropriate action in the event of an emergency. Various versions of this tool are used in schools throughout the region, from daycares to K-12 grades and universities. Messages may include important announcements about school events or emergencies, such as inclement weather and local flooding.

7.4 – Plans to be Considered

7.4.1 State and Regional Plans

The State Hazard Mitigation Plan effectively reduces losses by reducing the impact of disasters upon people and property. However, mitigation efforts cannot completely eliminate the impacts of disastrous events; the plan endeavors to reduce the impacts of hazardous events to the greatest extent possible. As with Regional Hazard Mitigation Plans, the State Hazard Mitigation Plan is to be updated every five years and is currently being updated. This new cycle will also update the plan to be an Enhanced State Hazard Mitigation Plan by demonstrating that the State of Texas has developed a comprehensive mitigation program, effectively uses available mitigation funding, and can manage the increased funding.

The State Hazard Mitigation plan evaluates, profiles, and ranks natural and human-caused hazards affecting Texas as determined by the frequency of an event, economic impact, deaths, and injuries. The plan:

- Assesses hazard risk
- Reviews current state and local hazard mitigation and climate adaption capabilities
- Develops strategies and identifies state agencies (and other entities) potential actions to address needs

The Regional Emergency Preparedness Program is one of the largest and most effective programs of its kind nationwide. Bringing together urban, suburban, and rural jurisdictions, the program facilitates information sharing, collaboration, and cooperation between jurisdictions in a politically neutral and supportive environment. The Regional Preparedness Program accomplishes this through networking, standardization of policy and procedures, and coordination efforts with interest groups.

7.4.1.a. Local Plans

In 2021, the Lower Brazos Planning Region requested local emergency management and emergency response plans that were publicly available. Some emergency plans are protected by law and unavailable to the public. In addition to the plans provided by local entities, the Lower Brazos Planning

Region also obtained Emergency Management Plans, Hazard Mitigation Plans, and other regional and local flood planning studies from the county and local jurisdictions. An emergency management plan is a course of action developed to mitigate the damage of potential events that could endanger an organization's ability to function. Such a plan should include measures that provide for personnel safety and, if possible, property and facilities.

The Lower Brazos Basin has several regional plans and regulations that provide the framework that dictates a community's capabilities in implementing mitigation and preparedness actions. An up-to-date Hazard Mitigation Action Plan is key in assessing risk and developing mitigation actions or projects. While each county has had a Hazard Mitigation Plan, 20 out of 30 county plans and one COG plan are currently approved by FEMA, as they are to be updated on a five-year cycle. As seen in *Table 7.1*, five plans are being updated, with one plan's approval pending, and five counties have expired plans.

Table 7.1: Lower Brazos Planning Region Hazard Mitigation Plans Statuses

Jurisdiction	HMAP Status
Archer County	Plan Approved
Austin County	Plan Approved
Bastrop County	Plan in Progress
Bosque County	Plan Approved
Brazoria County	Plan in Progress
Brazos County	Plan Approved
Burleson County	Approvable Pending Adoption
Burnet County	Plan Expired
Central Texas Council of Governments (CTCOG)	Plan Approved
Erath County	Plan Approved
Falls County	Plan Approved
Fort Bend County	Plan Approved
Freestone County	Plan Approved
Grimes County	Plan in Progress
Hill County	Plan Approved
Hood County	Plan Approved
Jack County	Plan Approved
Johnson County	Plan in Progress
Lampasas County	Plan Expired
Lee County	Plan Expired
Leon County	Plan Approved
Limestone County	Plan Approved
Madison County	Plan Expired
Palo Pinto County	Plan Approved
Parker County	Plan Approved
Robertson County	Plan Approved
Somervell County	Plan in Progress
Waller County	Plan Approved

Jurisdiction	HMAP Status
Washington County	Plan Approved
Williamson County	Plan Expired
Young County	Plan Approved

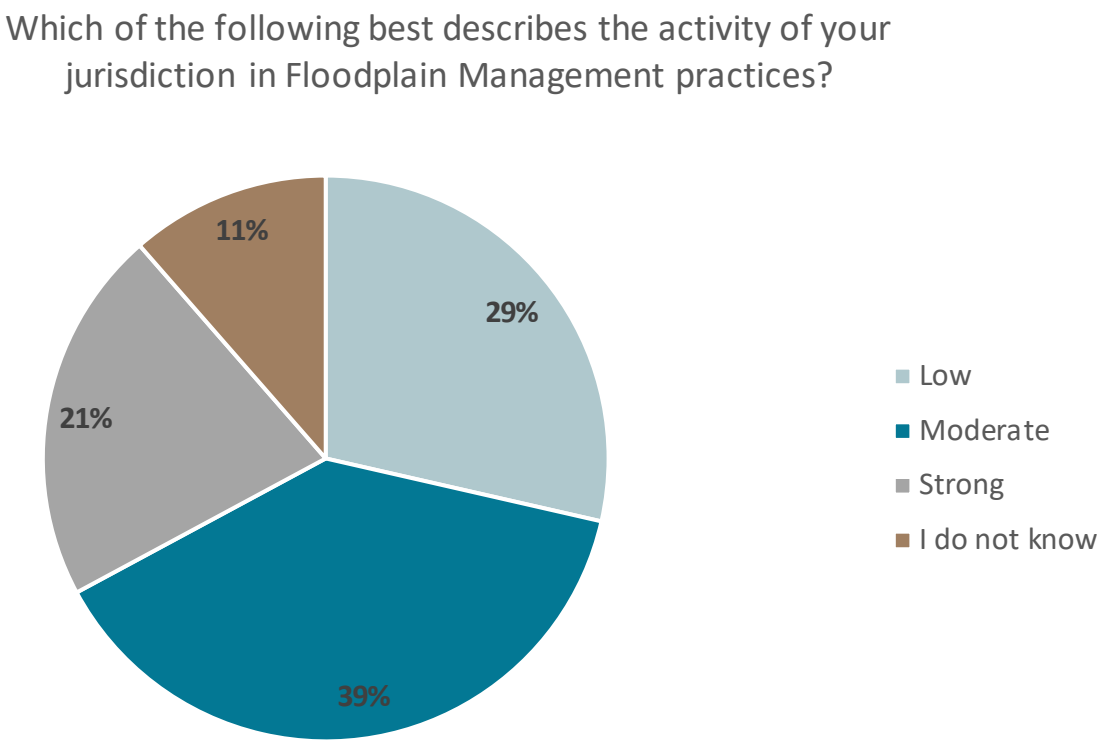
Hazard mitigation planning reduces loss of life and property by minimizing the impact of disasters. It begins with state, tribal, and local governments identifying common natural disaster risks and vulnerabilities in their area. After identifying these risks, they develop long-term strategies for protecting people and property from similar events. Mitigation plans are vital to breaking the cycle of disaster damage and reconstruction.

In the private sector, an emergency action plan (EAP) is a document required by the Occupational Safety and Health Administration (OSHA) standards. An EAP aims to facilitate and organize employer and employee actions during workplace emergencies. They are an essential element in emergency management for critical facilities. EAPs for dams are essential in identifying potential emergency conditions and specifying preplanned actions to be followed to minimize property damage and loss of life.

A watershed master plan helps understand and address existing flooding, erosion, and water quality problems. It can help prepare for future challenges and address existing flood-prone areas. Watershed Master Plans help educate the public and influence decision-makers regarding land use changes, investment in capital projects, and modifications to development regulations within the basin.

When asked which of the following best describes the activity of each respective jurisdiction in Floodplain Management practices, only 21 percent of survey respondents indicated that their jurisdiction maintained strong practices. Per *Figure 7.6*, there are improvements to be made to floodplain management practices, and improvements to these practices can be implemented at all four phases of emergency management.

Figure 7.6: Lower Brazos Floodplain Management Practices



(Lower Brazos Planning Region's Outreach Survey)

Aligning common goals and objectives in the Lower Brazos Planning Region can facilitate the efficiency of plans and actions. Having more robust floodplain practices in local jurisdictions and regionally creates a more robust flood mitigation approach and promotes good floodplain management practices.

The Lower Brazos Planning Region's ability to prepare, respond, recover, and mitigate disaster events is determined by several factors. Creating plans that establish the region's ability to implement the four phases of flood management, coordinating with the necessary entities in the preparation of, during, and in the aftermath of an event, and acknowledging the actions sustained to promote resiliency are all critical elements in creating and maintaining good floodplain management practices.

Chapter 8: Administrative, Regulatory, and Legislative Recommendations

According to 31 Texas Administrative Code 362.3, the RFPG shall include legislative recommendations considered necessary and desirable to facilitate flood management planning and implementation to protect life and property. The RFPG discussed administrative, regulatory, and legislative issues during the Flood Planning effort. The RFPG considered regional input provided through a region-wide survey shortly after the Lower Brazos Planning Region planning efforts began.

As part of the flood planning efforts, recommendations can include alterations to the legislation associated with flood planning throughout the state and regulatory or administrative features associated with flood-related activities. Recommendations may also be proposed to further the flood planning effort, such as desired support or data from the Texas Water Development Board (TWDB) or other state entities.

8.1 – Legislative Recommendations

Being a part of the State Flood Planning effort has allowed the RFPGs, Sponsors, and Technical Consultants to interact with various entities. There are trends and occurrences throughout a large portion of Texas. Some of these trends and occurrences are positive and should be encouraged, while others may need to be reconsidered or updated to benefit the entity, region, and/or state. During this Regional Flood Planning process, RFPGs have the opportunity to see the effects of current state legislation and the need for further action. Therefore, the RFPG proposes the following changes, shown in *Table 8.1*, for consideration.

Table 8.1: Legislative Recommendations for the Lower Brazos Planning Region

ID	Recommendation Statements	Reason for Recommendation
8.1.1	Direct State funding to counties to maintain drainage and stormwater infrastructure in unincorporated areas	Counties have floodplain and drainage-related responsibilities without a consistent way to fund projects.
8.1.2	Develop state strategies to aid in acquiring federal funds	Projects for entities in Texas do not compete well with some federal funding programs. For example, Federal Emergency Management Agency (FEMA)'s Building Resilient Infrastructure and Communities (BRIC) grant requires statewide building codes to improve the application score.

ID	Recommendation Statements	Reason for Recommendation
8.1.3	Develop state funding to assist dam owners with the costs associated with repairing, maintaining, and upgrading dam structures	Urban areas now surround dams that were originally constructed in rural areas. The potential impact of flood damages resulting from dam failure has increased significantly with age and development. Often, private and/or local entities do not have the funding to maintain or repair these dams.
8.1.4	Provide funding and/or technical assistance to develop regulatory floodplain maps	Several entities with outdated maps or no mapping are not able to fund the projects necessary to update or create accurate depictions of flood risk.
8.1.5	Provide funding and/or technical assistance to update drainage criteria and development standards	Up-to-date drainage criteria and development standards at the county level improve resiliency and prevent additional flood risk. However, many entities do not have the funding to update criteria and standards.
8.1.6	Provide funding and/or technical assistance to perform or update flood planning and/or master drainage planning studies	Many communities and entities do not have up-to-date studies or plans that reflect growth or updated rainfall data. Up-to-date master drainage plans can help communities identify drainage needs and develop conceptual solutions to reduce flood risk. These studies can update future regional flood planning cycles and respond to disaster funding opportunities.
8.1.7	Provide alternative funding sources; Expand eligibility and use of funding for stormwater and flood mitigation solutions (Local, State, Federal, Public/Private Partnerships, etc.)	Flood mitigation studies/projects do not generate revenue, making them more challenging to fund locally. Funding sources could utilize different financial/economic benefit metrics for projects that do not generate revenue.
8.1.8	Provide additional funding to enable the continued function of RFPGs during the interim timeframe between the planning cycle	In the interim of the planning cycles, not only could RFPGs continue adding Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) to the Regional Flood Plan, but they could also implement RFPG-sponsored flood management activities, outreach, and stay informed on regional flood-related occurrences.

ID	Recommendation Statements	Reason for Recommendation
8.1.9	Extend Local Government Code, Title 13, Subtitle A, Chapter 552 to allow counties the opportunity to establish and collect drainage utilities/fees in the unincorporated areas	Counties have floodplain and drainage-related responsibilities in the State of Texas. Currently, counties cannot establish and collect stormwater utility fees, thus limiting their ability to fund stormwater or drainage projects, despite having the responsibility.
8.1.10	Grant counties additional authority to regulate land use, especially in unincorporated flood-prone areas downstream of dams	Regulation of development in flood-prone unincorporated areas by counties will aid in the prevention of additional flood risk.
8.1.11	Establish a levee safety program similar to the dam safety program	Levees are often constructed to protect a specific commodity; however, they do not have a safety program like dams, despite being an equal flood risk.

8.2 – Regulatory or Administrative Recommendations

The RFPG has also developed recommendations of a regulatory or administrative nature concerning existing procedures, state entities, or state/regional regulations. These recommendations, shown in *Table 8.2*, are suggested changes to existing standards, state-controlled entities, or procedures.

Table 8.2: Regulatory or Administrative Recommendations

ID	Recommendation Statements	Reason for Recommendation
8.2.1	Simplify all funding application processes and criteria as well as the management and reporting process required once funding is awarded	Current funding applications require significant time and resources to prepare a project for consideration, as well as complete the application itself, especially for jurisdictions with limited resources. Thus, jurisdictions that may need the funding the most typically do not apply for current opportunities, despite having need. Once funding is awarded, the management process can be time-consuming, and some communities may choose not to pursue funding due to the management and reporting requirements.
8.2.2	Review and revise, as necessary, all state infrastructure entities' (i.e., TxDOT) standards and practices for legislative and regulatory compliance with stormwater best practices	State entities should be aware of the drainage and stormwater standards in the areas where they are active. State entities shall consider local regulations when local regulations are higher than State minimum criteria.

ID	Recommendation Statements	Reason for Recommendation
8.2.3	Develop resources for and educate local and regional officials regarding the respective entities' ability/authorization to establish and enforce higher development standards	Local and regional officials are often unaware of their authority to establish and enforce stormwater regulations *(Texas Local Government Code Title 7, Subtitle B.; Texas Water Code Chapter 16, Section 16.315).* Flooding and drainage components of local and regional officials' training are often inadequate for their level of responsibility.
8.2.4	Provide measures to allow and encourage jurisdictions to work together toward regional flood mitigation solutions	Flooding does not recognize jurisdictional boundaries. Allowing and encouraging entities to work together towards common flood mitigation goals would benefit all involved, including state agencies.
8.2.5	Develop a publicly available statewide database and tracking system to document flood-related fatalities and injuries	High flood-risk areas should be tracked and reported to address the health, safety, and welfare of the public. Doing so would increase awareness of the area so that the public could be aware of the risks, and elected officials and decision-makers could institute solutions to reduce the risk.
8.2.6	Provide financial or technical assistance to smaller/rural jurisdictions	The former Office of Rural Affairs/Texas Department of Rural Affairs was intended to assist and work with rural entities; however, the department was disbanded. Actions such as maintaining a department specifically for smaller/rural entities, incentivizing consultants to pursue work for smaller or rural entities, or adjusting BCAs to rank small/rural entities equally are all ideas towards this goal.
8.2.7	Revise the scoring criteria for funding associated with stormwater and flood-related projects that benefit agricultural and other activities	The traditional benefit-cost analysis tools prevent agricultural projects from competing with municipal benefit-cost ratios.
8.2.8	Revise inspection criteria for high-hazard at-risk dams	Recommend a statewide criticality assessment for high hazard dams to identify dams with a high likelihood of failure and high population at-risk and inspect these dams with greater frequency. This would inform Texas Commission on Environmental Quality on dam safety on which dams to inspect more often than the standard five years.

ID	Recommendation Statements	Reason for Recommendation
8.2.9	Address the concern of "takings" regarding floodplain development regulations, comprehensive plans, land use regulations, and zoning ordinances	Jurisdictions should be allowed to regulate development responsibly, reducing future flood risk exposure without fearing legal action by property owners.

8.3 – Flood Planning Recommendations

The RFPG has identified several issues that the TWDB should consider in making the planning process more streamlined and effective for each individual region. The following recommendations, as sown in *Table 8.3*, should be considered to improve the regional flood planning process in future planning cycles.

Table 8.3: State Flood Planning Recommendations

ID	Recommendation Statements	Reason for Recommendation
8.3.1	Update the scope of work, guidance documents, rules, checklists, etc., based on the adjustments and lessons learned made to these planning documents during the first cycle of planning	During the first cycle of the State Flood Plan, multiple amendments and additions to the TWDB documents and the TWDB's interpretation of its documents occurred. Moving forward, the TWDB documents provided at the onset of each new planning cycle should reflect what is ultimately required of the RFPGs.
8.3.2	Develop a fact sheet and/or other publicity measures to encourage entities to participate in the regional flood planning effort	Many entities were unaware of the regional and state flood plan efforts despite the RFPG outreach efforts.
8.3.3	Host "lessons learned" discussions with RFPG members, sponsors, and technical consultants following the submittal of the final regional plans	Opening dialogue among these participants to discuss proposed improvements to the regional planning process will streamline and improve future regional flood planning cycles. Some entities are still requesting information regarding the flood planning process and do not understand the benefits of participating.
8.3.4	Develop an amendment process to efficiently amend approved regional flood plans to incorporate additional recommended FMEs, FMSs, and FMPs and allow the RFPG to advance the recommended FMEs to FMPs	Amending the Regional Flood Plan may be an extensive process. Amendments to move FMEs to FMPs and incorporate new flood management solutions should have a quicker turn-around time to include them in the Regional Flood Plan efficiently. Recommend utilizing the Regional Water Planning amendment process as a go-by.

ID	Recommendation Statements	Reason for Recommendation
8.3.5	Reduce the amount of information required to escalate potentially feasible FMEs to FMPs; Align required information to be similar to what is required for design/construction funding	Some of the data currently requested for FMPs is more detailed than traditional planning level data. Therefore, certain FMPs had to be submitted as FMEs or FMSs despite having sufficient data to produce a project. The RFPs should focus on meeting the minimum requirement to produce funding rather than spending time and money on the project design.
8.3.6	Revise the criteria for the "No Adverse Impact" Certification required for FMPs	The current criteria give thresholds for increases in flow, water surface elevation, and inundation extents. Though helpful, the current criteria do not consider projects that exceed these thresholds but account for the impact through design or downstream accommodations.
8.3.7	Streamline the data collection requirements, specifically those identified in Task 1. Focus on collecting the most useful data for the regional flood plan development	This first round of planning proved that very few entities have the data requested as part of the flood planning process readily available in a geographic information system (GIS) format. Of those entities who did have GIS data, most were unable to share that information. As a result, some of this data was not used or was used minimally to develop potentially feasible and recommended FMEs, FMPs, and FMSs.
8.3.8	Provide statewide data and a methodology to determine infrastructure functionality and deficiencies in the next cycle of the Flood Planning Process; Consider the lack of readily available local data when developing the methodology	Most entities do not have information regarding the functionality and deficiency of their infrastructure. Some fields required by the TWDB-required tables in the Regional Flood Plans are based on data unavailable to entities without extensive fieldwork. A statewide database with this information would be useful to all entities.
8.3.9	Review and revise the geodatabase submittal attributes and elements	Normalizing the geodatabase with relationships would allow for cross-referencing data elements and attributes. More domains for attributes need to be developed.
8.3.10	Use FEMA's Social Vulnerability Index (SVI) when available instead of the Centers for Disease Control and Prevention (CDC)'s SVI in future planning cycles	FEMA's SVI is more relevant to flood resiliency and risk than the CDC's SVI. SVI should not be the primary component considered when allocating funding.

ID	Recommendation Statements	Reason for Recommendation
8.3.11	Use consistent Hydraulic Unit Code (HUC) reporting requirements throughout the TWDB-required tables	The RFPG guidance requires HUC-8 in some tables, HUC-10 in other tables, and HUC-12 in other tables. Some tables require multiple HUCs to be provided. The RFPG recommends that the TWDB require HUC-8 in all TWDB-required tables for consistency and to correspond to FEMA's base level watershed planning granularity.
8.3.12	Develop a statewide bridge inventory with bridge deck elevations	The availability of statewide Light Detection and Ranging (LiDAR) provides the opportunity to more accurately describe the risk at riverine crossings (i.e., overtopping elevation). Creating a statewide database outside of flood planning would further simplify this data.
8.3.13	Improve flood risk identification and exposure process regarding building footprints and population at risk by including first-floor elevations of structures	While the building footprints are helpful, it is difficult to determine the extent of flood risk per structure without first-floor elevations. If the structure is sufficiently elevated above the base flood elevations (BFE), for example, the footprint still shows the structure in the floodplain, and the corresponding population is considered "at-risk" though the structure meets National Flood Insurance Program (NFIP) standards.
8.3.14	Update state rainfall every 10 years in cycle with the State Flood Plan	Use similar statistical process and same data as NOAA, but on a more predictable and frequent schedule. Regular updates should help avoid large swings in data.

8.4 – Funding Opportunity Recommendations

The RFPG is responsible for providing potential funding opportunity recommendations to the TWDB. These ideas could include "new municipal drainage utilities or regional flood authorities that could fund the development, operation, and maintenance of floodplain management or flood mitigation activities in the region."

Responders to the data collection survey indicated the use of stormwater utility fees, bond programs, ad valorem taxes, and the general fund to sponsor projects in their regions. Non-local funding sources include the Hazard Mitigation Grant Program through FEMA and the Texas Division of Emergency Management (TDEM), Pre-Disaster Mitigation through FEMA, Cooperating Technical Partner funds through FEMA, Flood Protection Planning Grants through TWDB, United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), and Flood Mitigation Assistance through FEMA. No additional funding sources were identified in the Lower Brazos Planning Region during this planning cycle.

Chapter 9: Flood Infrastructure Financing Analysis

The Texas Water Development Board (TWDB) requires each regional flood planning group (RFPG) to assess and report on how sponsors propose to finance recommended flood management evaluations (FMEs), flood management strategies (FMSs), or flood mitigation projects (FMPs). This effort's primary aim is to understand local sponsors' funding needs and what role the state should have in financing the recommended FMEs, FMSs, and FMPs. In the Lower Brazos Planning Region, 16 entities were surveyed regarding the funding of recommended actions they are sponsoring. These entities include cities, counties, and regional authorities. The complete list of actions recommended by the Lower Brazos Regional Flood Planning Group (RFPG) is included in Chapter 5.

9.1 – Sources of Funding for Flood Management Activities

Communities across the Lower Brazos Planning Region utilize a variety of funding sources for their flood management efforts, including local, state, and federal sources. This section discusses some of the most common avenues of generating local funding and discusses various state and federal financial assistance programs available to communities. *Table 9.1* summarizes the local, state, and federal sources discussed in this chapter and characterize each by the following three key parameters:

- State and federal agencies involved, if applicable
- Assistance with grants, loans, or both
- Classified as regularly occurring opportunities or are only available after a disaster

9.1.1 Local Funding

Through the initial interest group outreach efforts, the Lower Brazos RFPG sought to understand the landscape of local funding for flood efforts in the Lower Brazos Planning Region. A portion of smaller, more rural communities that responded reported that they did not have any local funding sources for flood management activities. Those communities that reported local funding indicated the use of general funds, dedicated fees, such as stormwater or drainage utility fees and bonds. A community's general fund (for cities or counties) revenue stems from sales, property, and other taxes and is typically the primary funding mechanism used by a government entity to support most departments and services such as police, fire, parks, trash collection, and local government administration. Due to the high demands on this fund for many local needs, there is often not a significant amount available for funding flood management activities from the general fund.

This section primarily focuses on the funding mechanisms available to municipalities and special purpose districts, as a large majority of the FME, FMS, and FMP sponsors are these types of entities. Funding avenues for other entities, such as river authorities, are not discussed in detail.

Table 9.1: Common Sources of Flood Mitigation Funding in Texas

Source	Federal Agency	State Agency	Program Name	Grant (G)	Loan (L)	Post-Disaster (D)
Federal	FEMA	TDEM	**Hazard Mitigation Grant Program (HMGP)**	G		D
Federal	FEMA	TWDB	**Flood Mitigation Assistance (FMA)**	G		
Federal	FEMA	TDEM	**Building Resilient Infrastructure and Communities (BRIC)**	G		
Federal	FEMA	TDEM	**Pre-Disaster Mitigation (PDM)**	G		
Federal	FEMA	TCEQ	**Rehabilitation of High Hazard Potential Dam Grant Program**	G		
Federal	FEMA	*TBD*	**Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM)**		L	
Federal	FEMA	TDEM	**Public Assistance (PA)**	G		D
Federal	HUD	GLO	**Community Development Block Grant – Mitigation (CDBG-MIT)**	G		D
Federal	HUD	GLO	**Community Development Block Grant Disaster Recovery Funds (CDBG-DR)**	G		D
Federal	HUD	TDA	**Community Development Block Grant (TxCDBG) Program for Rural Texas**	G		
Federal	USACE		**Partnerships with USACE, funded through Continuing Authorities Program (CAP), Water Resources Development Acts (WRDA), or other legislative vehicles***			
State	EPA	TWDB	**Clean Water State Revolving Fund (CWSRF)**	G**	L	
State		TSSWCB	**Structural Dam Repair Grant Program**	G		
State		TWDB	**Flood Infrastructure Fund (FIF)**	G	L	

Source	Federal Agency	State Agency	Program Name	Grant (G)	Loan (L)	Post-Disaster (D)
State		TWDB	**Texas Water Development Fund (Dfund)**		L	
State		TSSWCB	**Operation and Maintenance (O&M) Grant Program**	G		
Local		TSSWCB	**Flood Control Dam Infrastructure Projects - Supplemental Funding**	G		
Local			**General fund**			
Local			**Bonds**			
Local			**Stormwater or drainage utility fee**			
Local			**Special-purpose district taxes and fees**			

**Opportunities to partner with the United States Army Corps of Engineers (USACE) are not considered grant or loan opportunities but shared participation projects where USACE performs planning work and shares in the construction cost.*

***The CWSRF program offers principal forgiveness, similar to grant funding.*

Dedicated fees such as stormwater or drainage fees are an increasingly popular tool for local flood-related funding. Municipalities can establish a stormwater utility (sometimes called a drainage utility), which is a legal mechanism used to generate revenue to finance a city's cost to provide and manage stormwater services. To provide these services, municipalities assess fees to users of the stormwater utility system. Impact fees, collected from new development to cover a portion of the expense to expand stormwater systems necessitated by the new development, can also be used as a source of local funding for flood-related efforts. Based on the initial interest groups outreach effort, the cities of Brenham, Hewitt, Killeen, and Troy are communities that collect stormwater fees in the Lower Brazos Planning Region. No entities identified as potential sponsors for recommended actions of the plan collect dedicated fees for flood management.

Special districts are another source of local funding to support flood management efforts. A special district is a political subdivision established to provide a single public service (such as water supply, drainage, or sanitation) within a specific geographic area. Examples of these special districts include Levee Improvement Districts (LID), Water Control and Improvement Districts (WCID), Municipal Utility Districts (MUD), Drainage Districts (DD), and Flood Control Districts (FCD). Each of the different types of districts are governed by state laws, which specify the authorities and process for creating a district. Districts can be created by various entities, from the Texas Legislature and the Texas Commission on Environmental Quality to county commissioners' courts or city councils. Depending on the type, the

districts may be able to raise revenue through taxes, fees, or issuing bonds to fund flood and drainage-related improvements within a district's area. There are numerous special districts in the Lower Brazos Planning Region. Specifically, Fort Bend County Drainage District (FBCDD), Upper Brushy Creek WCID, Lower Brushy Creek WCID, and Sienna LID have been identified as potential sponsors for recommended actions of the plan.

Lastly, municipalities and counties can issue debt through general obligation bonds, revenue bonds, or certificates of obligation, which are typically paid back using any of the previously mentioned local revenue-raising mechanisms. Based on the initial interest groups outreach effort, 18 entities in the Lower Brazos Flood Planning Region indicated that bonds are a local funding source for flood management. Of the entities identified as potential sponsors for recommended actions of the plan, FBCDD and Upper Brushy Creek WCID indicated that bonds could be used to collect the local share of funding for projects, strategies, and evaluations.

Overall, local governments have various options for raising revenue to support local flood-related efforts; however, each avenue presents its own unique challenges and considerations. It is important to note that municipalities have more authority to establish various revenue-raising options than counties. Of the communities with access to local funding, the amount available is generally much lower than the total need, leading local communities to seek out state and federal financial assistance programs.

9.1.2 State Funding

Today, communities have a broader range of state and federal funding sources and programs available due to new grant and loan programs unavailable five years ago. There are two primary state agencies currently involved in providing state funding for flood projects: the Texas Water Development Board (TWDB) and the Texas State Soil and Water Conservation Board (TSSWCB). *Figure 9.1* summarizes the response of local communities in the Lower Brazos Planning Region when asked what state and federal funding sources have been obtained to pay for the implementation of flood management activities. Thirty out of 85 respondents indicated that they obtained funding for flood management beyond local means, many of which listed multiple sources. It is important to note that state and federal financial assistance programs discussed herein are not directly available to homeowners and the general public. Local governments apply on behalf of their communities to receive and implement funding for flood projects in their jurisdiction.

The TWDB's Flood Infrastructure Fund (FIF) is a new funding program passed by the Texas Legislature and approved by Texas voters through a constitutional amendment in 2019. Since its inception, the FIF has committed $406 million to 126 active and completed projects. The program provides financial assistance from low or no-interest loans and grants (cost match varies) to eligible political subdivisions for flood control, flood mitigation, and drainage projects. FIF rules allow for a wide range of flood projects, including structural and non-structural projects, planning studies, and preparedness efforts such as flood early warning systems. **After the first State Flood Plan is adopted, only projects included in the most recently adopted state plan will be eligible for funding from the FIF**. FMEs, FMSs, and FMPs recommended in this Regional Flood Plan will be included in the overall State Flood Plan and thus be eligible for this funding source. In the Lower Brazos Planning Region, the FIF was the most commonly

referenced state funding avenue utilized by entities responding to the initial stakeholder survey results. Additionally, multiple entities specified that they obtained funding through the Category 1 FIF application (Flood Protection Planning for Watersheds).

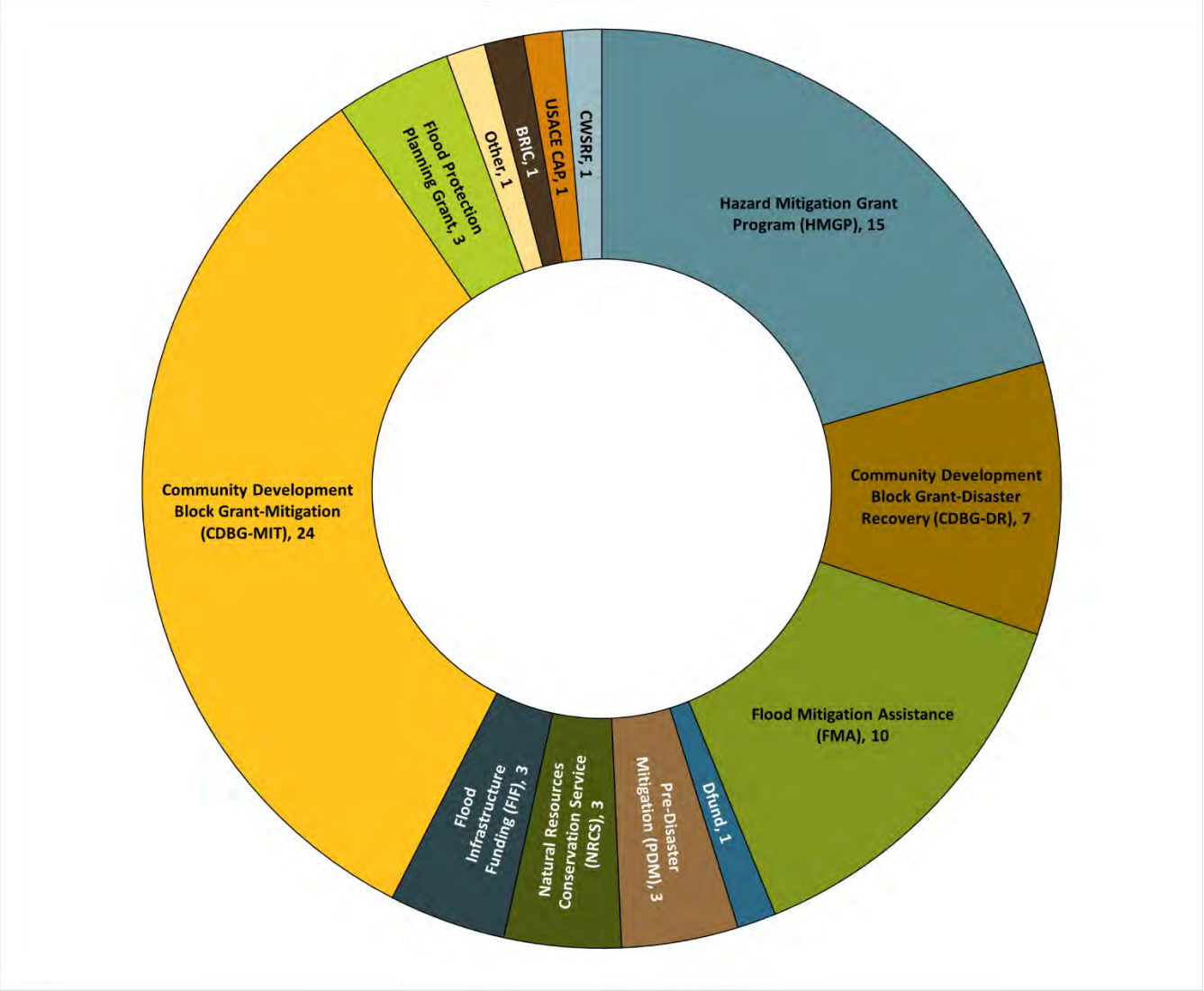
The TWDB also manages the Texas Water Development Fund (DFund) program, which is a state-funded streamlined loan program that provides financing for several types of infrastructure projects to eligible political subdivisions. This program enables the TWDB to fund projects with multiple eligible components (water supply, wastewater, or flood control) in one loan at low market rates. Financial assistance for flood control may include structural and non-structural projects, planning efforts, and flood warning systems. Based on the initial interest group survey results, the DFund has been utilized by the City of Gatesville in the Lower Brazos Planning Region.

The Texas State Soil & Water (TSSWCB) has three state-funded programs specifically for flood control dams: the Operation and Maintenance (O&M) Grant Program; the Flood Control Dam Infrastructure Projects - Supplemental Funding program; and the Structural Repair Grant Program. The O&M Grant Program is a grant program for local soil and water conservation districts (SWCD) and certain co-sponsors of flood control dams. This program reimburses SWCDs 90 percent of the cost of an eligible operation and maintenance activity as defined by the program rules; the remaining 10 percent must be paid with non-state funding. The Flood Control Dam Infrastructure Projects - Supplemental Funding program was newly created and funded in 2019 by the Texas Legislature. Grants are provided to local sponsors of flood control dams, including SWCDs, to fund the repair and rehabilitation of the flood control structures and to ensure dams meet safety criteria to adequately protect lives downstream. The Structural Repair Grant Program provides funds for 95 percent of repair costs on dams constructed by the United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS). This program also provides match funding for federal projects through the Dam Rehabilitation Program and the Emergency Watershed Protection (EWP) Program of the Texas NRCS. The initial interest group survey results indicate that no Lower Brazos Planning Region entities have utilized these funding sources.

9.1.3 Federal Funding

Federal funding currently accounts for a large share of total available funding for flood projects throughout the state due to greater access and availability for large funding amounts from the federal government when appropriated by Congress. As indicated in *Figure 9.1,* most funding sources referenced by entities in the initial interest group survey are federal programs. Out of 30 respondents that obtained funding from non-local resources, 28 entities utilized federal programs. Commonly utilized funding programs administered by seven different federal agencies are discussed in this section. The funding for these programs originates from the federal government, but for many of the programs, a state agency partner plays a key role in the management of the program. Each funding program has its own unique eligible applicants, project types, requirements, and application and award timelines.

Figure 9.1: State and Federal Funding Sources Utilized by Entities in the Lower Brazos Planning Region



9.1.3.a Federal Emergency Management Agency (FEMA)

Common FEMA-administered funding programs include Flood Mitigation Assistance (FMA), Pre-Disaster Mitigation (PDM), Building Resilient Infrastructure and Communities (BRIC), Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM), Rehabilitation of High Hazard Potential Dam (HHPD) Grant Program, Hazard Mitigation Grant Program (HMGP), the Public Assistance (PA) Program, and the Cooperating Technical Partners (CTP) Program.

Under the Hazard Mitigation Grant Program (HMGP), FEMA provides funding to state, local, tribal, and territorial governments to rebuild from a recent disaster in a way that reduces or mitigates future disaster losses in their communities. The program is administered in Texas by the Texas Division of Emergency Management (TDEM). Funding is typically a 75 percent federal grant with a 25 percent local match. While the program is associated with Presidential Disaster Declarations, the HMGP is not a disaster relief program for individual disaster victims or a recovery program that funds repairs to public property damaged during a disaster. The key purpose of HMGP is to ensure that the opportunity to take

critical mitigation measures to reduce the risk of loss of life and property from future disasters is not lost during the reconstruction process following a disaster. This program was the most commonly referenced funding source in the initial interest group survey for the Lower Brazos Planning Region; half of the respondents who obtained non-local funding for flood management activities have utilized HMGP.

Flood Mitigation Assistance is a nationally competitive grant program that provides funding to states, local communities, federally recognized tribes, and territories. FMA is administered in Texas by the TWDB. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program. Funding is typically a 75 percent federal grant with a 25 percent local match. Projects mitigating Repetitive Loss and Severe Repetitive Loss properties may be funded through a 90 percent federal grant and 100 percent federal grant, respectively. FEMA's FMA program now includes a disaster initiative called Swift Current. The program was released as a pilot initiative in 2022 and explored ways to make flood mitigation assistance more readily available during disaster recovery. Similar to traditional FMA, the program mitigates repetitive losses and substantially damaged buildings insured under the NFIP. One-third of the initial interest group survey respondents that have obtained funding for flood management activities through state or federal programs have utilized FMA.

The Pre-Disaster Mitigation (PDM) grant makes funding available to state, local, tribal, and territorial governments to reduce risks from various natural hazards, including flooding. PDM is administered in Texas by TDEM. Funding is typically a 75 percent federal grant with a 25 percent local match, with smaller, more vulnerable communities eligible for up to a 90 percent federal and 10 percent local split. Brazoria, Falls, and Grimes counties have indicated through the initial interest group survey that they have received funding through this grant.

The Building Resilient Infrastructure and Communities (BRIC) is a new nationally competitive grant program implemented in 2020. The program supports states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. BRIC is administered in Texas by TDEM. Funding is typically a 75 percent federal grant with a 25 percent local match. Small, impoverished communities and U.S. Island territories may be funded through a 90 percent federal grant and 100 percent federal grant, respectively. According to the initial stakeholder survey, the Town of Holiday Lakes has obtained funding through this program.

Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) is a new revolving loan program enacted through federal legislation in 2021 to provide needed and sustainable funding for hazard mitigation projects. The program is designed to provide capitalization grants to states to establish revolving loan funds for projects to reduce risks from disaster, natural hazards, and other related environmental harm. At the time of the publication of this plan, the program does not yet appear to be operational and has not yet been implemented in Texas.

FEMA's Rehabilitation of High Hazard Potential Dam (HHPD) Grant Program, administered in Texas by the Texas Commission on Environmental Quality (TCEQ), provides technical, planning, design, and construction assistance in the form of grants for the rehabilitation of eligible high hazard dams. The cost-share requirement is typically no less than 35 percent state or local share. According to the initial

interest group survey, no entities in the Lower Brazos Planning Region have received funding through this program.

FEMA's FEMA Public Assistance (PA) program provides supplemental grants to state, tribal, territorial, and local governments and certain types of private non-profits following a declared disaster so communities can quickly respond to and recover from major disasters or emergencies through actions such as debris removal, life-saving emergency protective measures, and restoring public infrastructure. Funding cost-share levels are determined for each disaster and are typically not less than 75 percent federal grant (25 percent local match) and typically not more than 90 percent federal grant (10 percent local match). In Texas, FEMA PA is administered by TDEM. In some situations, FEMA may fund mitigation measures as part of the repair of damaged infrastructure. Generally, mitigation measures are eligible if they directly reduce future hazard impacts on damaged infrastructure and are cost-effective. Funding is limited to eligible damaged facilities located within PA-declared counties. According to the initial interest group survey, no entities have received funding through this program.

The Cooperating Technical Partners (CTP) program is an effort launched by FEMA in 1999 to increase local involvement in developing and updating Flood Insurance Rate Maps (FIRMs), Flood Insurance Study reports, and associated geospatial data in support of FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) Program. To participate in the program, interested NFIP-participating communities, state or regional agencies, universities, territories, tribes, or non-profits must complete training and execute a partnership agreement. Working with the FEMA regions, a program participant can develop business plans and apply for grants to perform eligible activities. The CTP program is not strictly a funding mechanism by definition, but participation in the program facilitates funding opportunities as well as updating of regulatory flood hazard information. In the Lower Brazos Planning Region, Texas A&M and the Texas A&M AgriLife Extension are CTPs.

9.1.3.b Housing and Urban Development (HUD)

HUD administers the following three federal funding programs: Community Development Block Grant – Mitigation (CDBG-MIT), Community Development Block Grant – Disaster Recovery (CDBG-DR), and Community Development Block Grant for Rural Texas (TxCDBG).

The Community Development Block Grant – Mitigation (CDBG-MIT) is administered in Texas by the Texas General Land Office (GLO). Eligible grantees can use CDBG-MIT assistance in areas impacted by recent disasters to carry out strategic and high-impact activities to mitigate disaster risks. The primary feature differentiating CDBG-MIT from CDBG-DR is that, unlike CDBG-DR, which funds recovery from a recent disaster to restore damaged services, systems, and infrastructure, CDBG-MIT funds are intended to support mitigation efforts to rebuild in a way that will lessen the impact of future disasters.

Following a major disaster, Congress may appropriate funds to the Department of Housing and Urban Development (HUD) under the Community Development Block Grant – Disaster Recovery (CDBG-DR) program when there are significant unmet needs for long-term recovery. Appropriations for CDBG-DR are frequently very large, and the program provides 100 percent grants in most cases. The CDBG-DR is administered in Texas by the GLO. The special appropriation provides funds to the most impacted and distressed areas for disaster relief, long term-recovery, restoration of infrastructure, housing, and

economic revitalization. More than 40 percent of initial interest group survey respondents that have obtained funding for flood management activities through state or federal programs have utilized either CDBG-MIT or CDBG-DR.

The Community Development Block Grant for Rural Texas (TxCDBG) provides annual grants on a formula basis to small, rural cities and to counties to develop viable communities by providing decent housing and suitable living environments and expanding economic opportunities principally for persons of low- to moderate-income. Funds can be used for public facilities such as water and wastewater infrastructure, street and drainage improvements, and housing. In Texas, the CDBG program is administered by the Texas Department of Agriculture (TDA). Based on the initial stakeholder survey, no Lower Brazos Planning Region entities have received funding through the TxCDBG.

9.1.3.c United States Army Corps of Engineers (USACE)

The USACE works with non-federal partners (states, tribes, counties, or local governments) throughout the country to investigate water resources and related land problems and opportunities and, if warranted, develop civil works projects that would otherwise be beyond the capability of the non-federal partner(s). Partnerships are typically initiated or requested by the local community to their local USACE District office. Before any project or study can begin, USACE determines whether there is an existing authority under which the project could be considered, such as the USACE Continuing Authorities Program (CAP), or whether Congress must establish study or project authority and appropriate specific funding for the activity. New study or project authorizations are typically provided through periodic Water Resource Development Acts (WRDA) or another legislative vehicle. Congress will not provide project authority until a completed study result in a recommendation of a water resources project, conveyed via a Report of the Chief of Engineers (Chief's Report) or Report of the Director of Civil Works (Director's Report). Opportunities to partner with USACE have not considered grant or loan opportunities but shared participation projects where USACE performs planning work and shares in the construction cost. USACE also has technical assistance opportunities, including Floodplain Management Services and the Planning Assistance to States program, available to local communities. According to the initial interest group survey, the City of West Columbia is the only entity in the Lower Brazos Planning Region that has conducted a project or study under the USACE CAP.

9.1.3.d U.S. Environmental Protection Agency (EPA)

The Clean Water State Revolving Fund (CWSRF) provides financial assistance in the form of loans with subsidized interest rates and opportunities for partial principal forgiveness for planning, acquisition, design, and construction of wastewater, reuse, and stormwater mitigation infrastructure projects. Projects can be structural or non-structural. Low Impact Development (LID) projects are also eligible. The CWSRF is administered in Texas by the TWDB. Based on the initial stakeholder survey, the Central Texas Council of Governments has obtained funding through this program.

9.1.3.e U.S. Department of Agriculture (USDA)

The USDA's Natural Resources Conservation Service (NRCS) provides technical and financial assistance to local government agencies through the following programs: Emergency Watershed Protection Program, Watershed Protection and Flood Prevention Program, Watershed Surveys and Planning, and Watershed

Rehabilitation. The Emergency Watershed Protection (EWP) program, a federal emergency recovery program, helps local communities recover after a natural disaster by offering technical and financial assistance to relieve imminent threats to life and property caused by floods and other natural disasters that impair a watershed. The Watershed Protection and Flood Prevention Program helps units of federal, state, local, and tribal government protect and restore watersheds; prevent erosion, floodwater, and sediment damage; further the conservation development, use and disposal of water; and further the conservation and proper use of land in authorized watersheds. The Watershed Surveys and Planning program focuses on funding watershed plans, river basin surveys and studies, flood hazard analyses, and floodplain management assistance aimed at identifying solutions that use land treatment and non-structural measures to solve resource problems. Lastly, the Watershed Rehabilitation Program helps project sponsors rehabilitate aging dams that are reaching the end of their design lives. This rehabilitation addresses critical public health and safety concerns. The USDA also offers various Water and Environmental grant and loan funding programs, which can be used for water and waste facilities, including stormwater facilities, in rural communities. The City of Hempstead, Pecan Grove MUD, and Upper Brushy Creek WCID indicated in the initial interest group survey that they have obtained funding through the NRCS.

9.1.3.f Special Appropriations

When the need is large enough, Congress may appropriate funds for special circumstances such as natural disasters or pandemics. A few examples of recent special appropriations from the federal government that can be used to fund flood-related activities are discussed in this section.

In 2021, the American Rescue Plan Act (ARPA) provided a substantial infusion of resources to eligible state, local, territorial, and tribal governments to support their response to and recovery from the COVID-19 pandemic. Coronavirus State and Local Fiscal Recovery Funds (SLFRF), a part of ARPA, delivers $350 billion directly to state, local, and tribal governments across the country. Some of the authorized uses include improving stormwater facilities and infrastructure. Although not a direct appropriation to local governments like ARPA, the 2021 Infrastructure Investment and Jobs Act (IIJA), also called the Bipartisan Infrastructure Law (BIL), authorizes over $1 trillion for infrastructure spending across the United States and provides for a significant infusion of resources over the next several years into existing federal financial assistance programs as well as the creation of new programs.

9.1.4 Barriers to Funding

As opposed to other types of infrastructure, flood projects do not typically generate revenue, and many communities do not have steady revenue streams to fund flood projects, as noted in Section 9.1.1. Consequently, communities struggle to generate funds for local match requirements or loan repayment. Complex or burdensome application or program requirements and prolonged timelines are barriers to accessing state and local financial assistance programs. Of those communities able to overcome these barriers, apply for funding, and generate local resources to match requirements, the high demand for state and federal funding, particularly for grant opportunities, means that need outstrips supply, leaving many local communities without the resources they need to address flood risks. Through participation in

the initial interest group survey, entities in the Lower Brazos Planning Region identified several barriers to obtaining funding for flood management activities:

- Lack of knowledge of funding sources
- Lack of expertise to apply for funding
- Lack of local funds available for local match requirements
- Not meeting the requirements of the program

Of the 31 respondents that mentioned specific difficulties in obtaining funding, 19 entities indicated that they do not meet the requirements of the programs, and 11 entities indicated that they lack knowledge of what funding sources exist. These barriers were the two most common in the Lower Brazos Planning Region. Conversations with several communities in the region show that areas of high flood exposure but low social vulnerability have difficulty meeting application requirements. This issue will likely require further effort to ensure that these communities can obtain funding for flood management. The Social Vulnerability Index (SVI) is utilized in the plan as a proxy for resilience to natural disasters. SVI is defined in Section 2A.3 of Chapter 2 and summarized by county in Map 7 in *Appendix 0.*

Regarding lack of local funding, knowledge, or expertise, each of these barriers can be mitigated through public involvement in the regional and state flood plans, as RFPGs can efficiently assist entities with their flood management needs rather than leaving it up to communities using local resources that may not be available. Generally, many previously mentioned difficulties in obtaining state and federal funds will be improved by implementing the Regional Flood Plans in Texas.

9.2 – Flood Infrastructure Financing Analysis

9.2.1 Flood Infrastructure Financing Survey Methodology

The flood infrastructure financing analysis required obtaining relevant information from sponsors of the recommended FMEs, FMSs, and FMPs with capital costs. This effort's primary aim was to understand local sponsors' funding needs and propose the role state and federal programs should have in financing the recommended FMEs, FMSs, and FMPs.

The RFPG collected information from sponsors by creating a survey via email. An example of the sponsor survey is shown in *Figure 9.2.*

Figure 9.2: Example of the Flood Infrastructure Financing Survey

Dear Vanessa Shrauner –

On behalf of the Lower Brazos Regional Flood Planning Group (RFPG), we are reaching out because City of Jarrell is listed as a potential sponsor for one or more Flood Mitigation Project (FMP), Flood Management Evaluations (FMEs) or Flood Mitigation Strategies (FMSs) that will be recommended for implementation in the Region 8 Lower Brazos Regional Flood Plan (RFP).

We need your input to estimate how much State or Federal funding assistance your community may need to implement the actions that have been identified. The table below lists the actions for which your community has been identified as a potential sponsor, along with the estimated costs of implementation. Recommended solutions must be included in the RFP to be eligible for potential future State funding but inclusion in the plan does not guarantee State funding.

Please reply to this email and fill out the drop-down menu in the table for each of your Flood Mitigation Projects, Evaluations and/or Strategies. There is no commitment associated with being a sponsor for an action in the RFP. This is a high-level planning exercise to determine flood risk and flood mitigation funding need across Texas. If we do not receive a response, we will assume that 100% of the cost for that action will need funding (including State, Federal and/or other funding).

Flood Mitigation Action ID	Flood Mitigation Action Type	Flood Mitigation Action Name	Flood Mitigation Action Description	Flood Mitigation Action Estimated Total Cost	Sponsor Funding	
					Anticipated Source of Sponsor Funding	Percent Funding Anticipated to be Provided by Sponsor
81000934	FME	Low Water Crossing Monitoring & Mitigation	Install automated warning devices or elevate 2 low water crossings on CR 305.	$217,000	Choose an item.	Choose an item.
81000936	FME	Lift Station Floodproofing	Flood proof city lift stations or improve culverts to lessen flood risk.	$217,000	Choose an item.	Choose an item.

For more information regarding the specific Flood Mitigation Actions listed in the RFP, visit the following link: Region 8 - Draft Planning Documents. Additional information about the regional flood plan can be found on the Lower Brazos RFPG website.

We kindly request a reply **no later than Thursday, June 17, 2022** in order to meet the State's legislative deadline for flood planning. Thank you for your input on this important project.

As part of the survey, a personalized table of recommended FMEs, FMSs, and FMPs was generated for each sponsor. The table included the identification number, type, name, description, and total estimated cost for each FME, FMS, and FMP listed. For FMSs lacking accurate cost estimates, input was solicited from the potential sponsor. After receiving the email, sponsors could provide the financing information, a percentage of the project to be financed by the sponsor, and other funding needed for each FME, FMS, and/or FMP.

Options for anticipated sources of sponsor funding included:

- Taxes
- General revenue
- Dedicated revenue inclusion fees
- Entity budget/funds
- Donations
- Bonds/other financing
- Other
- TBD

The Flood Infrastructure Financing survey was sent to 16 sponsors of recommended FMEs, FMSs, and FMPs with capital costs identified. Five of the 16 entities surveyed responded, representing a response rate of 31 percent.

9.2.2 Flood Infrastructure Financing Survey Results

Overall, there is an estimated $4.6 billion in state and federal funding projected to be needed to implement the recommended evaluations, strategies, and projects in the Lower Brazos Regional Flood Plan. This number represents the total cost of all recommended FMEs, FMSs, and FMPs shown in Appendices 5.1, 5.2, and 5.3 but does not reflect the amount of funding needed to mitigate all risks in the region and solve flooding problems in their totality. This number simply represents the funding needs for the specific, recommended studies, strategies, and projects in this cycle of regional flood planning. *Appendix 9.1* presents the survey results for each FME, FMS, and FMP. The response rate for the survey does not represent a significant percentage of respondents. It, therefore, does not accurately represent the total need for state and federal funding in the Lower Brazos Planning Region. To conservatively estimate remaining funding needs, the Lower Brazos RFPG will assume no local cost share for entities that did not respond to the survey. With additional time provided in the second cycle of regional flood planning, it is anticipated that a greater response rate may be obtained.

Chapter 10: Adoption of Plan and Public Participation

Public outreach and participation played a crucial role in developing the first planning cycle of the State Flood Plan. Not only has this feedback been important for identifying and confirming flood risk and project needs in the state, but collecting data for these communities and entities has been critical to developing a successful plan. The Texas Water Development Board (TWDB) allocated funding provided by the legislature in early 2020 for each of the 15 new flood planning regions within the state to specifically focus on tasks covering public participation and flood planning development for their respective basins. In September 2021, the TWDB allocated additional funding to prioritize outreach and data collection efforts for each flood planning region.

The Lower Brazos Regional Flood Planning Group (RFPG) has utilized various methods to reach the public about the development of the first flood plan for the region. A regional website and email address were developed early on by the planning group's Sponsor, the Brazos River Authority (BRA), to provide a robust tool to inform and communicate with the public on the progress of the Lower Brazos Regional Flood Plan. The planning group's Sponsor provided project updates via social media and sent out monthly email blasts to their customers within the Lower Brazos Planning Region, as well as those signed up to receive project information about the flood plan.

The Lower Brazos RFPG held monthly public meetings to discuss project task updates. The public was provided the opportunity to speak at the beginning of each meeting. In addition to the online public outreach survey, the Lower Brazos RFPG conducted a public roadshow in five different cities across the basin to reach the communities in person. The Lower Brazos RFPG has complied with the Texas Open Meeting Act and Public Information Act requirements while developing the 2023 Lower Brazos Regional Flood Plan.

10.1 – Lower Brazos RFPG Communications

10.1.1 New Regional Website and Email Address

To effectively communicate with the entities and communities throughout the Lower Brazos Basin, the Brazos River Authority developed a website for the Lower Brazos RFPG (lowerbrazosflood.org). This website has been an important tool used to publicize the following:

- Upcoming monthly RFPG meetings, including a virtual meeting option with a link to Microsoft Teams;
- 'Current Events' section on the home page, which highlights monthly updates on the planning process and draft documents for the public to review and provide comments;
- Frequently asked questions (FAQ) about the flood planning process for Texas and the Lower Brazos Planning Region;
- Meeting archive containing past meeting details, including agendas, supporting documentation, information flyers, audio recordings, and meeting minutes;

- Flood risk map available for electronic data collection;
- Portal to upload entity data for the regional plan in a secure manner;
- Links to other flood-related state and federal agencies; and,
- Method to submit public comments for a particular agenda item and/or submit a question(s) to the BRA and Lower Brazos RFPG.

In addition, the planning group's Sponsor created a regional email address (LBFlood@brazos.org) to simplify the process for the public contacting them and/or submitting questions to the Lower Brazos RFPG.

10.1.2 Social Media

In addition to using the Lower Brazos RFPG website to publicize meetings and events, the BRA leveraged social media (i.e., Facebook, Twitter, Instagram) to notify and update the public. For each of the monthly RFPG meetings, a colorful and informative flyer was developed by the Halff Associates Team for the BRA to post on their social media accounts for the Lower Brazos RFPG (see examples of meeting flyers in *Appendix 10.3*). For the public roadshow, a 'Save the Date' flyer was initially created and posted on social media in advance that summarized all five open house meeting dates and locations; individual roadshow flyers were then developed to publicize each of the meeting locations closer to the date of the event (reference *Confirm location* for copies of the roadshow flyers). Email blasts that publicized important meetings and event details were typically sent out one to two weeks in advance by the BRA to their database of customers, as well as those signed up to receive notifications about the Lower Brazos RFPG.

10.2 – Targeted Outreach

10.2.1 Interest Group Survey

10.2.1.a. Interest Groups Identified

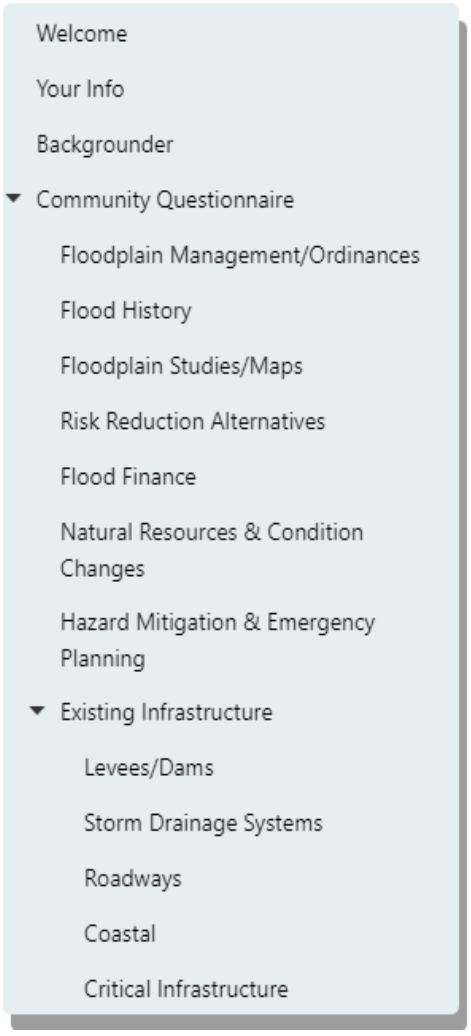
To ensure public input was received and incorporated into the Regional Flood Plan, the TWDB identified specific scope items requiring the RFPGs to engage with public officials with flood related responsibilities. For the Lower Brazos Planning Region, a survey was one of the methodologies used to fulfill this requirement and gather data upfront to characterize flooding needs and efforts.

A list of entities and individuals identified to have some flood-related authority or interest was compiled, and contact information was gathered. Public officials such as floodplain managers, city engineers, mayors, and representatives of special interest districts (such as municipal utility districts and levee improvement districts) made up the majority of the list created. Over 550 interest groups were identified to represent the 43 counties and almost 200 municipalities within the Lower Brazos Basin. Additionally, any member of the public that registered for flood planning updates through the website was added to the contact list. This list formed the target audience for the public outreach survey.

10.2.1.b. Survey Overview

The Technical Consultant Team developed the public outreach survey to be a comprehensive questionnaire working to identify background information, current flood risk, flood-related resources, and existing flood infrastructure within a community. *Figure 10.1* shows the categories encompassed by the 65 questions included in the survey. A copy of the entire questionnaire can be found in *Appendix 10.1*.

Figure 10.1: Stakeholder Survey Topics

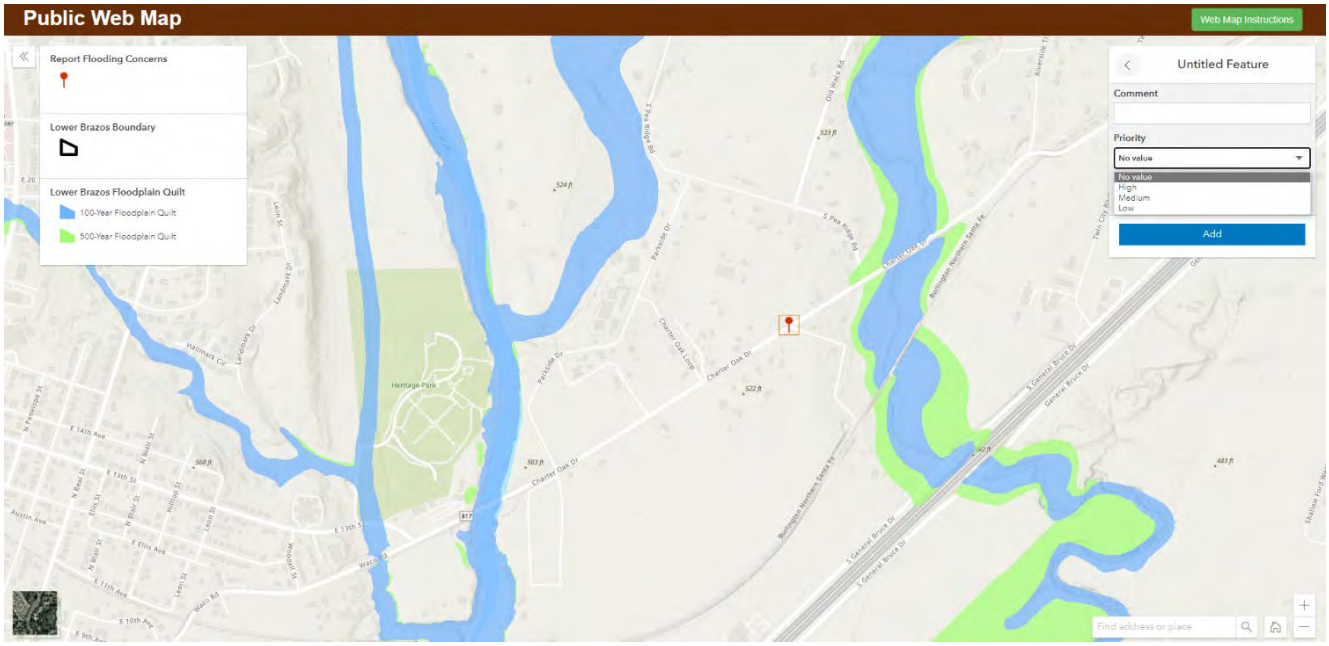


Some questions included opportunities for individuals to upload relevant data, including information about current floodplain management practices and ordinances, studies backing ongoing flood mitigation efforts, or documentation regarding flooding and flood infrastructure conditions in their community.

In addition to the survey provided to the interest groups, an interactive web map was available to all members of the public for input. Users could drop pins at locations where they had knowledge of flood

concerns. Comments and priority levels regarding this flooding could then be indicated, as seen in *Figure 10.2*.

Figure 10.2: Interactive Web Map



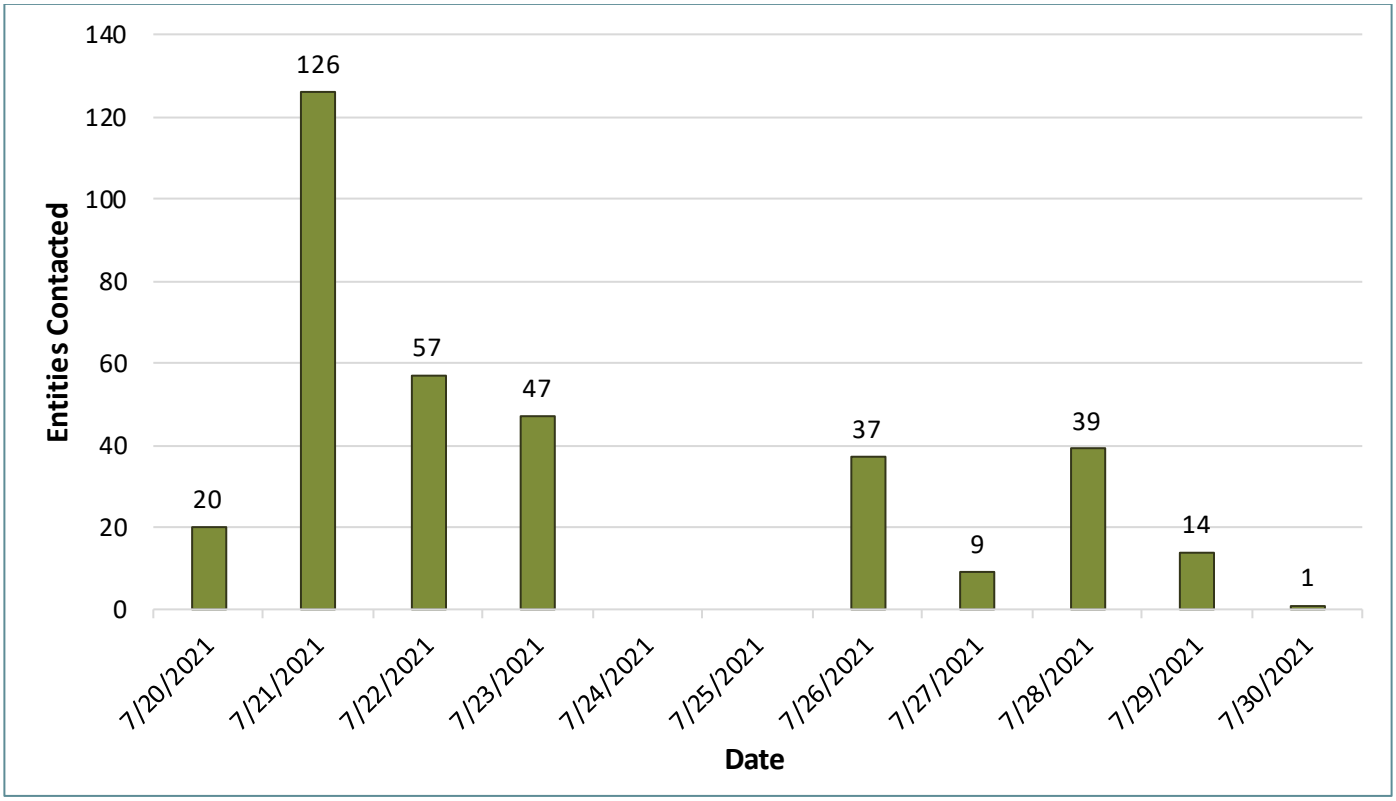
The survey was initially sent out by the BRA to the identified interest groups through email on June 30, 2021, with a due date extension from August 13 to August 31, 2021. However, the survey was still accessible throughout the regional flood planning process. Information was continually collected, but only submittals provided by the due date were ensured to be incorporated into the Lower Brazos Regional Flood Plan. Records were kept of submittals received past August 31, 2022 to be considered during the amendment period or future planning cycles as applicable.

10.2.1.c. Follow-Up Communications

Several forms of follow-up communication were utilized to boost response rates and ensure all interest groups had the opportunity to provide their feedback. The initial notification was provided through an email blast, and several email reminders were sent in the following weeks. Posts to the website and social media accounts were also used to promote the survey.

However, the greatest follow-up effort was achieved through phone calls. From July 20th to July 30th, the first round of over 350 calls was made to the identified interest groups. Every identified contact that had not yet opened the survey or responded to the survey request in some manner was identified. Individuals that had previously established relationships with members of the Halff Associates Team were contacted on a case-by-case basis. All other identified contacts were given a phone call to ensure the interest group received the email containing the survey, understood the importance and purpose of the survey, and was provided with any help needed to navigate or respond to the questionnaire. The distribution of the dates of when the calls were performed can be seen in *Figure 10.3*.

Figure 10.3: First Round of Outreach Phone Calls



After this initial outreach to all interest groups that received the survey, a more targeted approach was taken. Contacts representing counties or entities with populations greater than 20,000 were targeted for another round of phone calls. These targeted entities were determined to be more likely to have the information requested by the survey easily accessible and likely have a larger impact on the characterization of the region as a whole. One hundred twenty-eight interest groups were contacted during this round. Ongoing outreach was performed throughout August and September to follow up with contacts who had previously shown interest in the regional flood planning efforts or were otherwise deemed as "promising" candidates to fill out the questionnaire or provide the team with pertinent information. A list of the representatives contacted can be found in *Appendix 10.2*.

10.2.1.d. Responses

The extensive outreach efforts performed gleaned 64 responses to the survey. *Figure 10.4* shows the outreach extents, *Figure 10.5* and shows the distribution of responses throughout the Lower Brazos Region. Although this only amounted to a 14 percent response rate, the region could be characterized by the coverage. Additionally, the density of responses in the southern portion of the basin indicated to the RFPG the higher interest and needs associated with the geographical location. *Figure 10.6* and *Figure 10.7* provide context on the number of counties and municipalities represented in the responses. Other respondents to the survey include representatives of management districts, river authorities, and councils of governments.

Figure 10.4: Outreach Calls

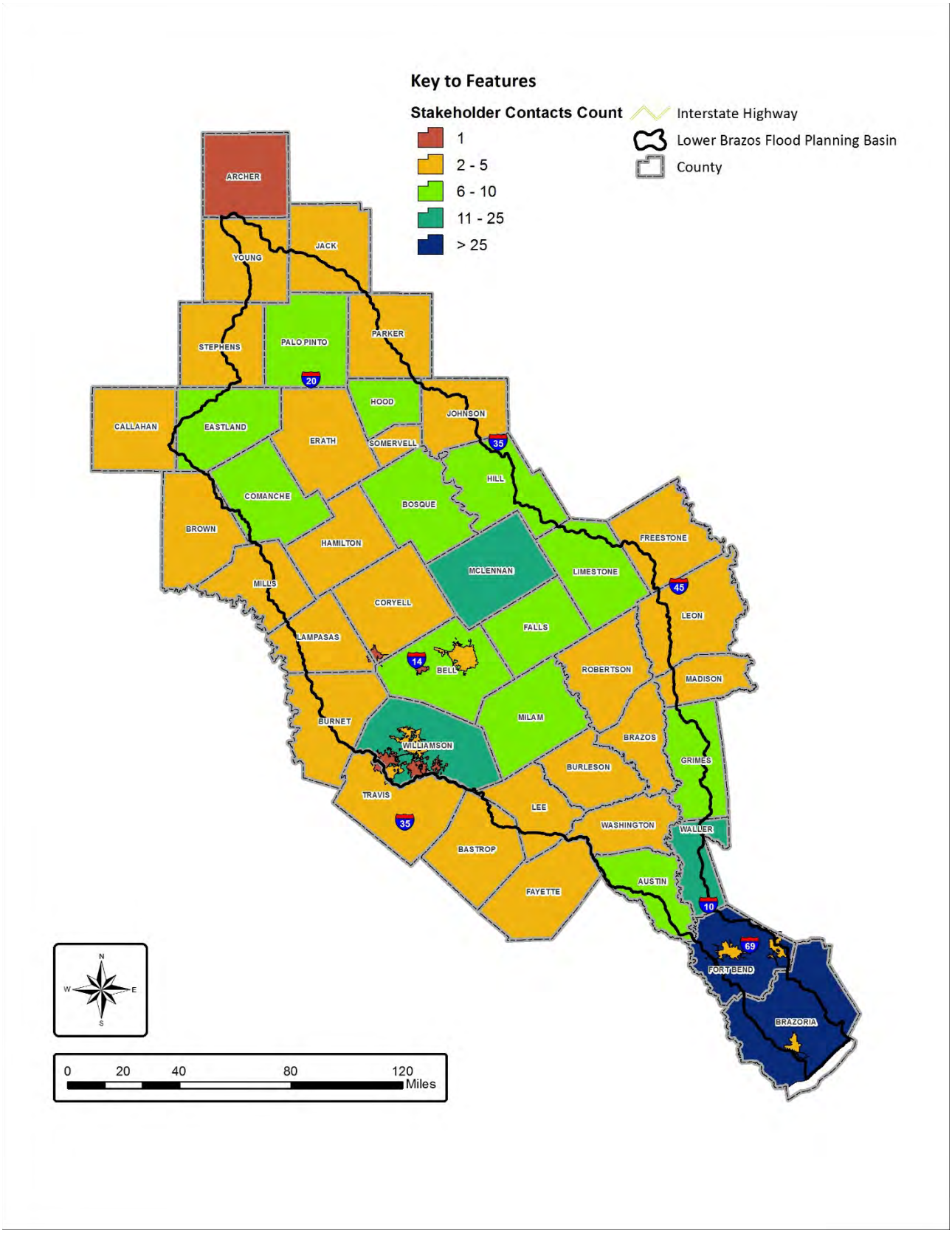


Figure 10.5: Survey Response Distribution

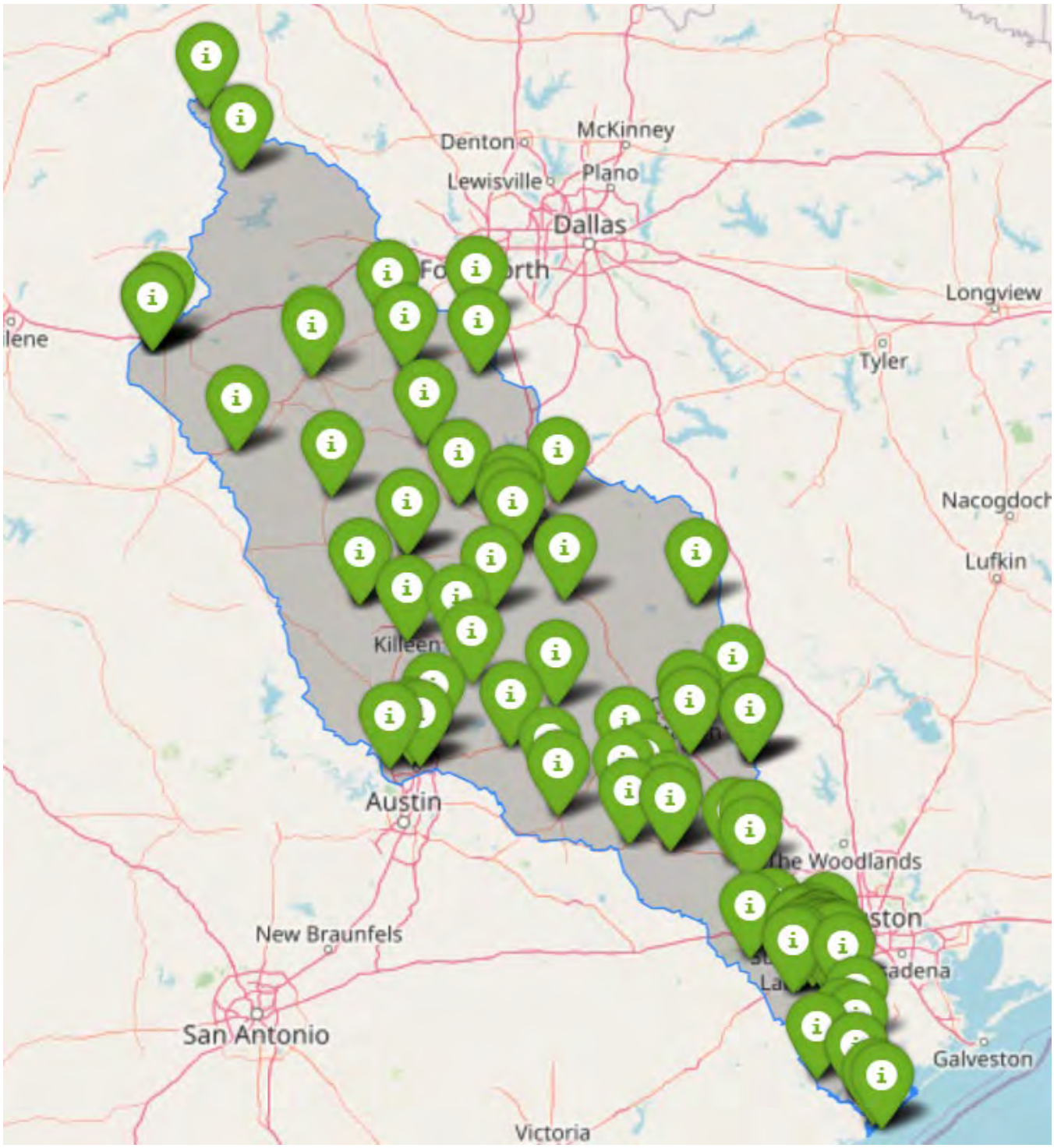


Figure 10.6: County Response Rate to Outreach

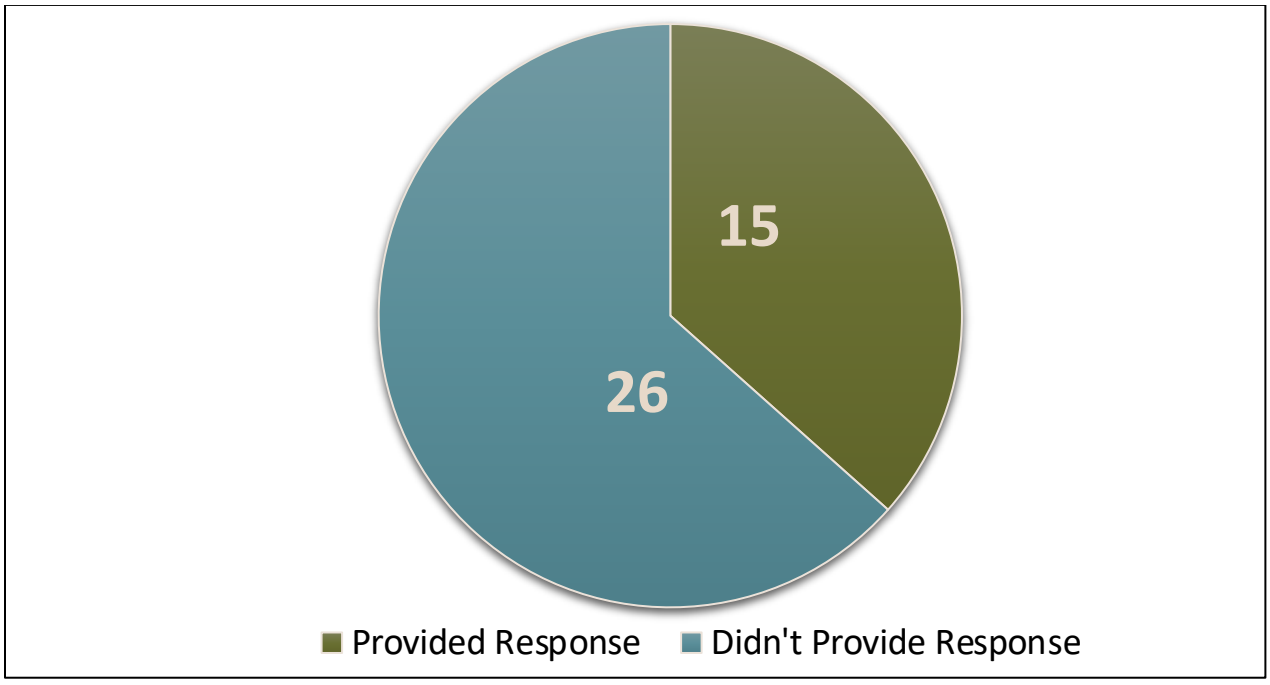
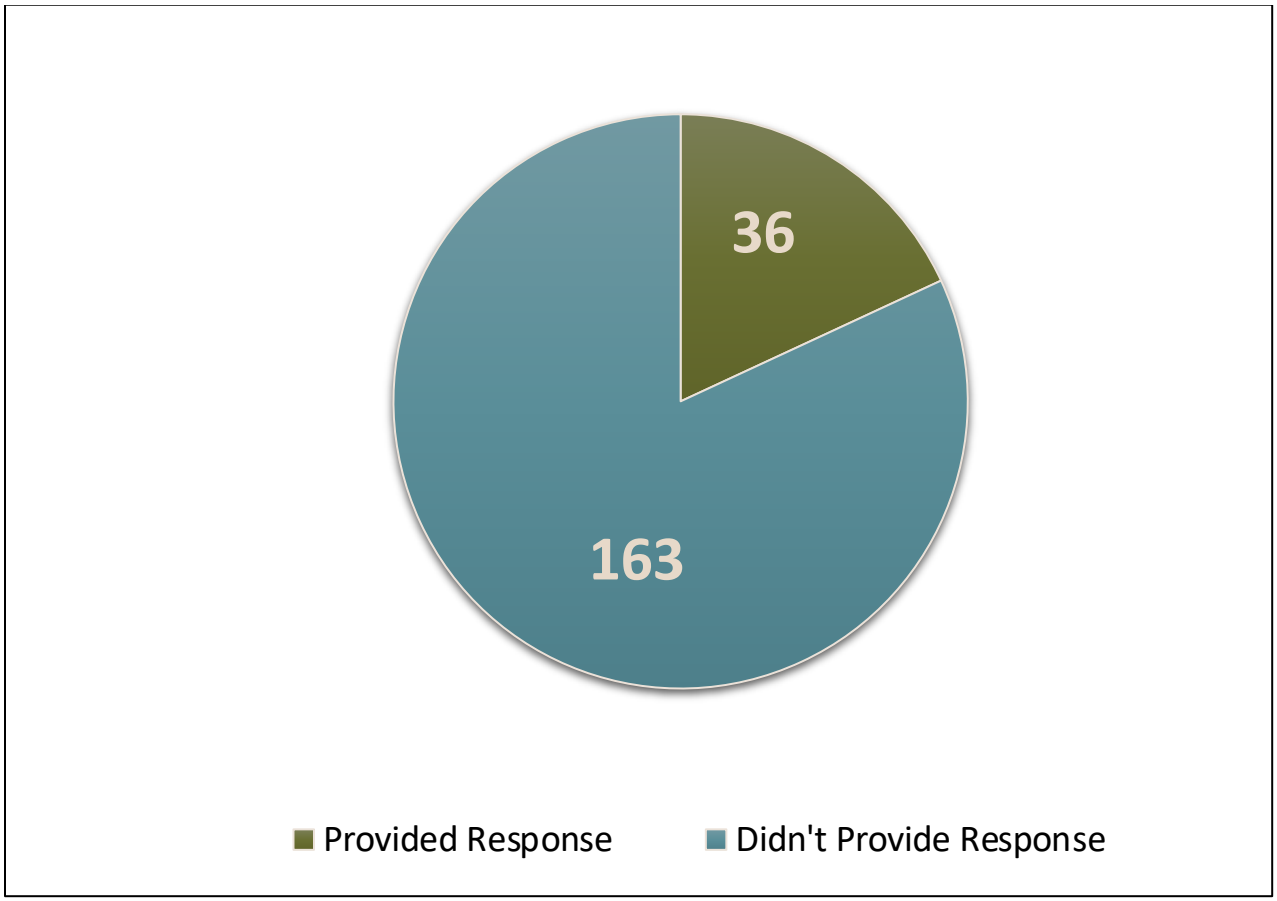


Figure 10.7: City Response Rate to Outreach



10.2.2 Additional Data Collection Efforts

Although the interest group survey generated some feedback, additional data needs were identified throughout the flood planning process, and targeted outreach was performed to fill these gaps. Specifically, when developing the list of flood mitigation and management projects, strategies, and evaluations, extensive data was needed to perform the required evaluations. In particular, FMPs needed associated models to adequately examine them. Due to many of the FMPs being collected through publicly available documentation found during research, the associated models were not previously provided by most of the entities. A targeted outreach effort was performed to try and obtain hydrologic and hydraulic models for potentially feasible FMPs.

Emails were sent to the associated interest groups for the identified sponsors of the collected FMPs. Nine entities were contacted in November 2021 and again in February 2022 to request modeling associated with the potentially feasible FMPs collected for their community. Out of these, three entities provided the additional information requested to develop their flood mitigation and management needs and ensure they were included within the Lower Brazos Regional Flood Plan.

10.3 – Lower Brazos RFPG Meetings

10.3.1 Pre-Planning RFPG Meetings

Pre-planning meetings were held on June 2, 2021, and June 24, 2021, to provide background on forming the RFPG and planning process. During the meetings, the RFPG also gathered suggestions and recommendations regarding issues, provisions, projects, and strategies that should be considered in developing the Regional Flood Plan. The roles and responsibilities of the RFPG and the Technical Consultant Team were conveyed to the public and are listed in *Table 10.1.*

Table 10.1: Responsibilities

RFPG Responsibilities	Technical Consultant Responsibilities
Support public and stakeholder engagement	Ensure compliance with the TWDB requirements and schedule
Identify key communities and entities	Guide and facilitate the planning process
Prepare for and participate in meetings and workshops	Facilitate public and entity engagement
Review and provide feedback on consultant deliverables	Gather data/information
Approve submittal of Chapters, Technical Memo, and Draft Regional Plan	Conduct planning and technical analysis
Adopt and submit the Regional Flood Plan	Prepare Chapters, Technical Memo, Draft Report, and Final Report based on RFPG input

During the pre-planning meetings, the Halff Associates Team provided an overview of the regional flood planning expectations. The plan is not expected to solve flooding but lead to future flooding reduction.

The planning effort depends on the data and information provided by communities and entities, and no new floodplain modeling is expected. For the effort to be successful, regional participation was critical. The need for further studies or flood management evaluations to determine true flood risk throughout the Lower Brazos Planning Region was discussed by the Technical Consultant Team. Additionally, preliminary plans for stakeholder engagement through a survey were proposed and discussed.

10.3.2 Monthly RFPG Meetings

The Lower Brazos RFPG held monthly meetings to obtain updates from the Technical Consultant Team, led by Halff Associates, discuss potential processes and methodologies, and provide approval of components of the Draft Lower Brazos Regional Flood Plan. These meetings were open to the public and complied with TWDB Rules and the Texas Open Meetings Act. The meetings were held at the Brazos River Authority's Central Office in Waco, Texas, and simultaneously hosted through Microsoft Teams for a videoconferencing option. The Lower Brazos RFPG decided to hold meetings on the fourth Thursday of every month at 10:00 am unless they conflicted with members' schedules or holidays. *Table 10.2* summarizes the RFPG meeting date and key discussions or approvals at each monthly meeting. Meeting minutes, documents, and recordings can be accessed under the 'Meeting Archive' tab on the Lower Brazos RFPG website. The RFPG posted meeting notices and meeting materials in accordance with the Texas Open Meetings Act. The RFPG met all the requirements of under the Texas Open Meetings Act and the Public Information Act.

Table 10.2: Summary of Lower Brazos RFPG Meetings

Meeting Date	Key Discussion Items	Voting Items
June 24, 2021	Timeline and tasks planned for public outreach and data collection. Discussion of flooding concerns with each interest category.	N/A
July 22, 2021	Introduction and overview of Tasks 1, 2, and 3. Update on public outreach and data collection efforts.	N/A
August 26, 2021	Updates on the development of Tasks 1 and 2A. Discussion on Task 2B approach as it relates to developing future conditions. Discussion of potential public meeting locations and dates. Discussion of draft goals and standards as related to Task 3.	N/A
September 23, 2021	Discussion of adoption vs. recommendation in the development of Task 3A standards. Discussion of draft Task 3B goals. Update on Task 2B as related to the previous discussion. Introduction to Task 4B.	N/A
October 28, 2021	Discussion of the evaluation process, sources, and benefit areas related to Task 4B. Updates on Tasks 1, 2, and 10.	Approval of Task 3A Standards and 3B Goals.

Meeting Date	Key Discussion Items	Voting Items
November 16, 2021	Updates on Tasks 1, 2, 3, 4A, and 4C.	Approval of Task 4B Identification and Evaluation Process.
December 14, 2021	Discussion on public outreach meeting locations and dates. Discussion on existing conditions analyses as related to Task 2A. Agreement with Task 2B approach provided.	Approval of Technical Memorandum for submittal.
January 27, 2022	Introduction and overview of Task 5. Discussion of meeting materials, dates, attendees, and locations for public meetings. Updates on Task 2A and emergency need definition as related to Task 4B. Discussion of Water Supply and Flood Control interactions as related to Task 6.	N/A
February 24, 2022	Discussion of Technical Memorandum Addendum and related Task 2. Discussion of emergency needs definition as related to Task 4B. Updates and introductions of Tasks 1, 6, 7, 8, and 10.	Approval of Technical Memorandum Addendum for submittal.
March 24, 2022	Discussion of Task 3 report. Discussion of Task 5 evaluation and recommendation process. Updates on Tasks 6, 7, 8, and 10.	N/A
April 28, 2022	Public Roadshow Meetings recap and review of Task 2 report. Discussion of Task 5 evaluation and recommendation process. Presentation and discussion of preliminary Task 4A results.	N/A
May 26, 2022	Update on Tasks 4A, 8, and 9. Discussion of Flood Control and Water Supply interaction as related to Task 6.	Approval of Task 5 Flood Management Evaluation (FME), Flood Management Strategy (FMS), and Flood Mitigation Project (FMP) Recommendations.
June 23, 2022	Comments on chapters 1 through 10 of the Regional Flood Plan. Discussion on Task 8 recommendations.	N/A
July 21, 2022	Draft Regional Flood Plan.	Approval of the Draft Regional Flood Plan.
September 22, 2022	Opportunity for public to provide comments on the Draft Plan. Discussion of potential uses of Amendment Tasks (12 and 13).	N/A

Meeting Date	Key Discussion Items	Voting Items
October 28, 2022	Discussion of comments received on Draft Regional Flood Plan. Discussion of potential uses of Amendment Tasks (12 and 13).	Approval of Task 4 and 5 FME, FMS, and FMP lists to include changes due to public comment. Approval of FMEs to be carried out under Task 12.
December 13, 2022	Discussion of comments received on Draft Regional Flood Plan and major resulting changes. Update on Tasks 12 and 13 progress.	Approval of Task 4 and 5 FME, FMS, and FMP lists to include changes due to public and TWDB comments. Approval of budget adjustments. Adoption of Lower Brazos Regional Flood Plan.
January 26, 2023	Discussion of submittal of Final Lower Brazos Regional Flood Plan to TWDB. Update on Tasks 12 and 13 progress.	Approval of Carl Burch as voting member of RFPG representing Electric Generating Utilities. Nominations and approvals of RFPG member positions.
March 23, 2023	Updates on Tasks 12 and 13 progress. Discussion of 1 square mile FMP restriction.	N/A
April 27, 2023	Discussion of comments received from TWDB on Final Lower Brazos Regional Flood Plan. Discussion of formation of a Technical Committee.	N/A
May 4, 2023	Discussion on additional criteria to evaluate and recommend FMPs with drainage areas less than 1 square mile.	N/A
May 25, 2023	Discussion and acceptance of Technical Committee recommendations. Discussion of Task 12 and 13 preliminary results.	Approval of FMS, FME, and FMP lists to include additional entries based on Task 12 efforts and submittals received from public.
June 22, 2023	Discussion of Amended Lower Brazos Regional Flood Plan.	Adoption of Amended Lower Brazos Regional Flood Plan.

10.4 – Coordination with Other Planning Regions

10.4.1 Summary of Coordination Efforts

10.4.1.a. TWDB Regional Team Calls

Throughout the regional flood planning process, TWDB held regional calls on a quarterly basis with the RFPG Chairs, Technical Consultants and RFPG Sponsors. These virtual meetings were facilitated by TWDB's Director of Flood Planning and Manager of Regional Flood Planning, on a quarterly basis to provide additional guidance and allow time for questions and discussion between the regions and TWDB. In addition, TWDB held regional calls prior to the submittal deadlines for the RFPG Technical

Memorandum, RFPG Technical Memorandum Addendum and Draft Regional Flood Plans to address questions and facilitate discussion between the regions. There was also significant coordination between the regions on utilized approaches and datasets that helped identify solutions to problems encountered throughout the state.

10.4.1.b. Meeting Agenda

The Lower Brazos RFPG selected by nomination voting members to serve as liaisons with adjacent regions and a coastal liaison. During the monthly Lower Brazos RFPG meetings, liaisons provided updates on the progress of those regions. These updates helped facilitate discussions concerning timelines and different approaches across the regions. In addition, it allowed the Lower Brazos RFPG members to express concerns over inequities experienced between different areas within the region, allowing for Technical Consultant Team to consider different methodologies.

10.4.2.c. Other Coordination

In addition to the previously mentioned official avenues of coordination, many regions had ongoing communication to facilitate the flood planning process. With the regional flood planning effort in its inaugural cycle, there was the prevailing discussion over how to best execute the scope of work provided by the TWDB. Coordination was key to ensuring the Regional Flood Plans could be combined into a cohesive State Flood Plan.

One particular cause for communication was the overlap between neighboring regions. Some entities, strategies, and evaluations spanned more than one region. Coordination was required to ensure they were treated equitably between the regions, and the information provided was considered appropriate. Several flood mitigation and management need initially identified for potential inclusion in the Lower Brazos Regional Flood Plan were determined to have a greater impact on neighboring regions. As discussed in Chapter 4, these were provided to the applicable neighboring regions.

10.5 – Public Roadshow

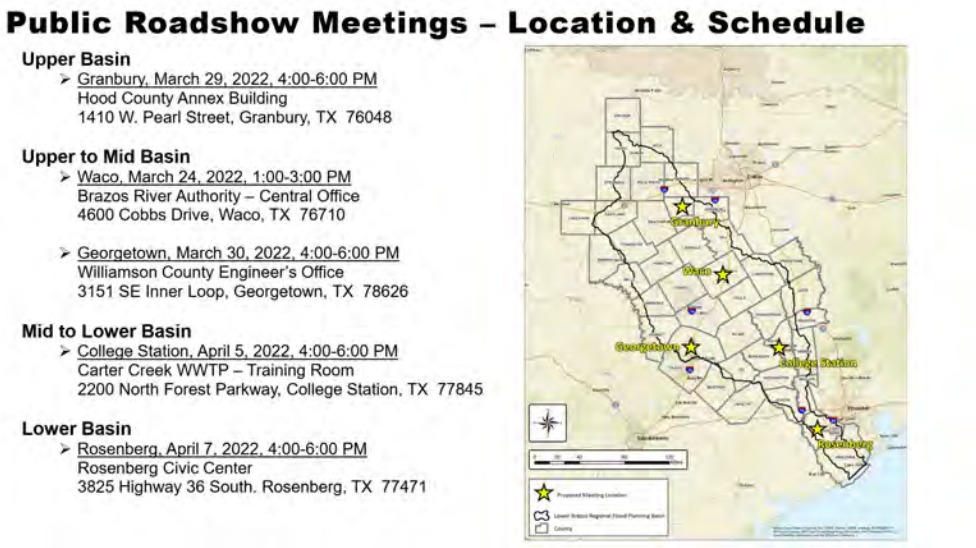
The Lower Brazos RFPG held five public roadshow meetings throughout the basin during late March 2022 and early April 2022. The purpose of these meetings was to inform the public on the current progress of regional flood planning for the Lower Brazos Planning Region and to gather feedback on the information included in the Draft Lower Brazos Regional Flood Plan.

10.5.1 Meeting Locations and Format

The Lower Brazos Basin was divided into four subregions for the public roadshow: (1) Upper Basin, (2) Upper to Mid Basin, (3) Mid to Lower Basin, and (4) Lower Basin. One public meeting was held within each subregion except for the Upper to Mid Basin area. Two public meetings were scheduled in this subregion, with the initial one being held following the March RFPG meeting at the Brazos River Authority's Central Office in Waco (reference *Figure 10.8*). Also, the criteria for selecting the meeting sites included not overlapping with the outreach efforts of the Texas General Land Office combined River Base Flood Study for the Western Region, being available for use without a fee, and having a space

large enough to accommodate approximately 50 attendees along with having the necessary presentation equipment.

Figure 10.8: Public Roadshow Meetings



The public roadshow meetings were designed to have an open house format, allowing the public to 'come and go' depending on their schedule. Each of the five meetings had the same information presented at the beginning of the meeting, including a welcome provided by the RFPG Chair, Vice-Chair, or RFPG Voting Member. The presentation included an overview of the Lower Brazos RFPG, the TWDB planning process, and the timeline for completing the First State Flood Plan. An interactive workshop was held following the initial presentation to allow the meeting attendees an opportunity to visit with the Halff Associates Team and the TWDB staff and provide feedback at each of the following meeting stations:

- **Station 1:** The TWDB State and Regional Flood Planning Process
- **Station 2:** Lower Brazos Regional Flood Plan Goals and Practices
- **Station 3:** Draft Flood Risk Maps for the Lower Brazos Region (laptop computer provided at this station)
- **Station 4:** Draft FMEs, FMPs, and FMSs identified for the Lower Brazos Region

Questions and answers from the initial presentation were addressed at the four meeting stations. Also, a half-page handout that listed the Lower Brazos RFPG website and email address was provided to the attendees at the sign-in table at each meeting location (reference copy of meeting handout in *Appendix 10.4*). Copies of the presentation slides were posted on the Lower Brazos RFPG website in advance of each public meeting. In addition, phone calls were made before each meeting to key interest groups to encourage their attendance. *Appendix 10.5* provides a copy of the roadshow presentation. *Appendix 10.6* provides the attendance lists for each meeting location.

10.5.2 Meeting Recap

10.5.2.a. Waco Meeting

The roadshow was kicked off with the first open house meeting following the Lower Brazos RFPG meeting from 1:00 to 3:00 pm on March 24, 2022, at the Brazos River Authority's Central Office in Waco. Eleven members of the public attended the open house, representing Bell, Coryell, Falls, and McLennan Counties, as well as the Cities of Harker Heights, Hillsboro, and Robinson. The TWDB Project Manager, Lower Brazos RFPG Chair, other RFPG Voting Members, Brazos River Authority, and the Halff Associates Team attended the meeting. The primary feedback from the attendees focused on the availability of future flood infrastructure funding and specific FMPs listed in the draft plan.

10.5.2.b. Granbury Meeting

The second open house meeting was held in the Upper Basin in the City of Granbury at the Hood County Annex Building on March 29, 2022, from 4:00 to 6:00 pm. This meeting had 11 members of the public in attendance, representing Hood County and the City of Granbury. The TWDB Project Manager, Lower Brazos RFPG Chair, Brazos River Authority, and the Technical Consultant Team led by Halff Associates also attended the meeting. The primary feedback included adding a freeboard recommendation to the Lower Brazos RFPG goals and standards as guidance for engineering designers.

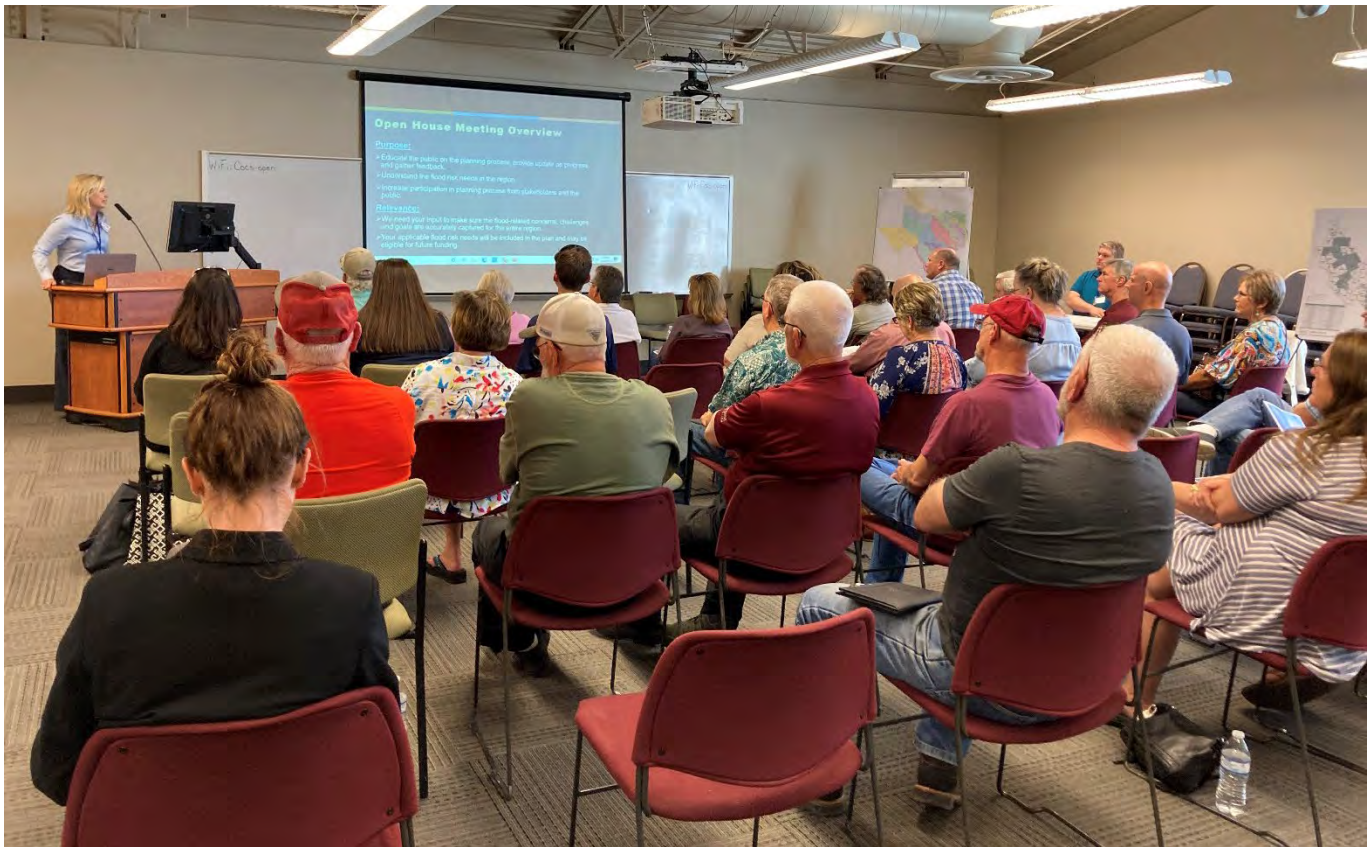
10.5.2.c. Georgetown Meeting

The third open house meeting was held in the Upper to Mid Basin area in the City of Georgetown at the Williamson County Engineer's Office on March 30, 2022, from 4:00 to 6:00 pm. Only two members of the public attended the meeting, both from Williamson County. The TWDB Project Manager, Regional Flood Planning Manager, Lower Brazos RFPG Chair, other RFPG Voting Members, Brazos River Authority, and the Technical Consultant Team led by Halff Associates also attended the meeting. The primary feedback from Williamson County was the interest in consistent regional floodplain regulations.

10.5.2.d. College Station Meeting

The fourth open house meeting was held in the Mid to Lower Basin in the City of College Station at the Carter Creek Wastewater Facility Training Room on April 5, 2022, from 4:00 to 6:00 pm. A picture of the meeting attendees can be seen in *Figure 10.9*. This meeting had our largest turnout of 40 members of the public in attendance, representing the Lake Limestone Property Association, Navasota River residents, SLC Water Supply Corporation, Fort Bend County Drainage District, Texas A&M University, and the Cities of Bryan and College Station. The TWDB Project Manager and Director of Flood Planning, Lower Brazos RFPG Vice-Chair, Brazos River Authority, and the Technical Consultant Team led by Halff Associates also attended the meeting. The primary feedback from the attendees focused on the concern of future projects impacting releases from Lake Limestone. The attendees also recommended including an FMS to fund drainage maintenance throughout the basin to address localized flooding issues.

Figure 10.9: College Station Roadshow Meeting



10.5.2.e. Rosenberg Meeting

The final open house meeting was held in the Lower Basin in the City of Rosenberg at the Rosenberg Civic Center on April 7, 2022, from 4:00 to 6:00 pm. This meeting had a large turnout of 30 members of the public in attendance, representing Fort Bend County, Fort Bend County Drainage District, Angleton Drainage District, Velasco Drainage District, Fort Bend EDC, Fort Bend County MUD No. 25, Fort Bend County Levee Improvement Districts (#2, 6, 10, 11, 14, 19), Bayou Park, and the City of Sugar Land. The TWDB Project Manager, Lower Brazos Voting Members, Brazos River Authority, and the Technical Consultant Team led by Halff Associates also attended the meeting. The common theme of the feedback received from the attendees focused on extensive erosion issues along the banks of the Brazos River.

10.6 – Public Hearing and Responses to Public Comments on the Draft Regional Flood Plan and Amended Plan

The Lower Brazos RFPG held a public hearing on September 22, 2022, to receive comments from the public on the Draft 2023 Lower Brazos Regional Flood Plan. The public comment process included 60 days centered around the public hearing date to allow the public to review and comment on the Draft Lower Brazos Regional Flood Plan. During the 60-day comment period, the draft Regional Flood Plan was available for the public to view on the Lower Brazos RFPG website. Hard copies of the draft plan were

also available for the public to review in person at three publicly accessible locations, Hood County Library, Sugar Land Branch Library, and Taylor Public Library. The hard copies were available within the region for 30 days before and also 30 days after the public hearing date.

A copy of the sign-in sheets, verbal/written comments received during the public hearing and public comment process, and the corresponding responses from the Lower Brazos RFPG are provided in *Appendix 10.7* for reference. Comments from the public on the Draft Regional Flood Plan were closed out during the Lower Brazos RFPG meeting on October 27, 2022. Afterward, the public comments were addressed, incorporated into the Final Regional Flood Plan, and adopted by the Lower Brazos RFPG.

After the submittal of the Final Regional Flood Plan, several communities provided the Lower Brazos RFPG with additional FMXs for consideration. These comments were addressed, incorporated into the Amended Regional Flood Plan, and adopted by the Lower Brazos RFPG. The comments received from the public are included in *Appendix 10.8* for reference.

10.7 – Responses to the TWDB Comments on Regional Flood Plan

The Lower Brazos RFPG submitted the Draft Regional Flood Plan to the TWDB by August 1, 2022, to initiate the TWDB staff review. Following the public hearing on September 22, 2022, the TWDB provided review comments to be addressed by the Lower Brazos RFPG and Technical Consultant Team on October 21, 2022. A copy of the review comments received from the TWDB staff is provided in *Appendix 10.7* for reference; these comments were addressed, incorporated into the Final Regional Flood Plan, and adopted by the Lower Brazos RFPG.

The Lower Brazos RFPG submitted the Final Regional Flood Plan to the TWDB by January 10, 2023. The TWDB provided review comments to be addressed by the Lower Brazos RFPG and Technical Consultant Team on March 29, 2023. A copy of the comments received from the TWDB staff is provided in *Appendix 10.8* for reference; these comments were addressed, incorporated into the Amended Regional Flood Plan, and adopted by the Lower Brazos RFPG.

The Lower Brazos RFPG submitted the Amended Regional Flood Plan to the TWDB by July 14, 2023. The TWDB provided review comments to be addressed by the Lower Brazos RFPG and Technical Consultant Team on November 7, 2023. A copy of the comments received from the TWDB staff is provided in *Appendix 10.10* for reference; these comments were addressed, incorporated into the Amended Regional Flood Plan, and returned to the TWDB on November 27, 2023.

10.8 – Plan Adoption

The Lower Brazos RFPG formally adopted the Final 2023 Lower Brazos Regional Flood Plan on December 13, 2022, and directed the Brazos River Authority and Technical Consultant Team to submit the Final Regional Plan to the TWDB on or before January 10, 2023.

The Lower Brazos RFPG adopted the Amended Lower Brazos Regional Flood Plan on June 22, 2023, and directed the Brazos River Authority and Technical Consultant Team to submit the Amended Regional Plan to the TWDB on or before July 14, 2023. An index of the changes made during the amendment process is provided in *Appendix 10.9* for reference.

10.9 – Conformance with Title 31 TAC §362.3 Guidance Principles

In accordance with Title 31 TAC §361.20, the Lower Brazos Regional Flood Plan conformed with the guidance principles established in Title 31 TAC §362.3. The Lower Brazos RFPG performed a No Negative Impact assessment for each potentially feasible FMP and FMS. Those that had, or appeared to have, a potential negative impact was removed from further consideration and was not included as recommended FMPs or FMSs in the draft or final regional flood plan. Implementation of the regional flood plan would not negatively impact a neighboring area and would adequately provide for the preservation of life and property. *Table 10.3* includes a list of the 39 regional flood planning principles and where they are addressed in this plan.

Table 10.3: Conformance with Title 31 TAC §362.3

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
1	shall be a guide to state, regional, and local flood risk management policy	Incorporated throughout the regional flood planning process
2	shall be based on the best available science, data, models, and flood risk mapping	Included in ***Chapters 2, 4, 5, 6***, and ***9***
3	shall focus on identifying both current and future flood risks, including hazard, exposure, vulnerability and residual risks; selecting achievable flood mitigation goals, as determined by each RFPG for their region; and incorporating strategies and projects to reduce the identified risks accordingly	Included in ***Chapters 2, 3, 4,*** and ***5***
4	shall, at a minimum, evaluate flood hazard exposure to life and property associated with 0.2 percent annual chance flood event (the 500-year flood) and, in these efforts, shall not be limited to consideration of historic flood events	Included in ***Chapter 2***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
5	shall, when possible and at a minimum, evaluate flood risk to life and property associated with 1.0 percent annual chance flood event (the 100-year flood) and address, through recommended strategies and projects, the flood mitigation goals of the RFPG (per item 2 above) to address flood events associated with a 1.0 percent annual chance flood event (the 100-year flood); and, in these efforts, shall not be limited to consideration of historic flood events	Included in ***Chapters 2, 3,*** and ***5***; ***TWDB-Required Tables 15, 16,*** and ***17***
6	shall consider the extent to which current floodplain management, land use regulations, and economic development practices increase future flood risks to life and property and consider recommending adoption of floodplain management, land use regulations, and economic development practices to reduce future flood risk	Included in ***Chapter 3***
7	shall consider future development within the planning region and its potential to impact the benefits of flood management strategies (and associated projects) recommended in the plan	Included in ***Chapters 2, 3, 4,*** and ***5***
8	shall consider various types of flooding risks that pose a threat to life and property, including, but not limited to, riverine flooding, urban flooding, engineered structure failures, slow rise flooding, ponding, flash flooding, and coastal flooding, including relative sea level change and storm surge	Included in ***Chapters 2, 4, 5,*** and ***7***
9	shall focus primarily on flood management strategies and projects with a contributing drainage area greater than or equal to 1.0 (one) square miles except in instances of flooding of critical facilities or transportation routes or for other reasons, including levels of risk or project size, determined by the RFPG	Included in ***Chapter 5*** and ***TWDB-Required Tables 15, 16,*** and ***17***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
10	shall consider the potential upstream and downstream effects, including environmental, of potential flood management strategies (and associated projects) on neighboring areas. In recommending strategies, RFPGs shall ensure that no neighboring area is negatively affected by the regional flood plan	Included in ***Chapters 4, 5,*** and ***6***
11	shall include an assessment of existing, major flood mitigation infrastructure and will recommend both new strategies and projects that will further reduce risk, beyond what existing flood strategies and projects were designed to provide, and make recommendations regarding required expenditures to address deferred maintenance on or repairs to existing flood infrastructure	Included in ***Chapters 2*** and ***5*** and ***TWDB-Required Tables 1, 16,*** and ***17***
12	shall include the estimate of costs and benefits at a level of detail sufficient for RFPGs and sponsors of flood mitigation projects to understand project benefits and, when applicable, compare the relative benefits and costs, including environmental and social benefits and costs, between feasible options	Included in ***Chapters 4*** and ***5*** and ***TWDB-Required Tables 12, 13, 14, 15, 16,*** and ***17***
13	shall provide for the orderly preparation for and response to flood conditions to protect against the loss of life and property and reduce injuries and other flood-related human suffering	Included in ***Chapter 7***
14	shall provide for an achievable reduction in flood risk at a reasonable cost to protect against the loss of life and property from flooding	Included in ***Chapters 5*** and ***9*** and ***TWDB-Required Tables 15, 16, 17,*** and ***19***
15	shall be supported by state agencies, including the TWDB, General Land Office, Texas Commission on Environmental Quality, Texas State Soil and Water Conservation Board, Texas Parks, and Wildlife Department, and the Texas Department of Agriculture, working cooperatively to avoid duplication of effort and to make the best and most efficient use of state and federal resources	Held conference calls as appropriate and shared data and files with these agencies and others upon request.

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
16	shall include recommended strategies and projects that minimize residual flood risk and provide effective and economical management of flood risk to people, properties, and communities, and associated environmental benefits	Included in ***Chapters 5*** and ***6***
17	shall include strategies and projects that provide for a balance of structural and nonstructural flood mitigation measures, including projects that use nature-based features, that lead to long-term mitigation of flood risk	Included in ***Chapters 4*** and ***5*** and ***TWDB-Required Tables 13, 14, 16,*** and ***17***
18	shall contribute to water supply development where possible	Discussed in ***Chapter 6***
19	shall also follow all regional and state water planning guidance principles (31 TAC 358.3) in instances where recommended flood projects also include a water supply component	Discussed in ***Chapter 6***
20	shall be based on decision-making that is open to, understandable for, and accountable to the public with full dissemination of planning results except for those matters made confidential by law	Included in ***Chapter 10***
21	shall be based on established terms of participation that shall be equitable and shall not unduly hinder participation	Included in ***Chapter 10***; bylaws are available on the RFPG website
22	shall include flood management strategies and projects recommended by the RFPGs that are based upon identification, analysis, and comparison of all flood management strategies the RFPGs determine to be potentially feasible to meet flood mitigation and floodplain management goals	Included in ***Chapter 5*** and ***TWDB-Required Tables 16*** and ***17***
23	shall consider land-use and floodplain management policies and approaches that support short- and long-term flood mitigation and floodplain management goals	Included in ***Chapter 3*** and ***TWDB-Required Tables 6*** and ***10***
24	shall consider natural systems and beneficial functions of floodplains, including flood peak attenuation and ecosystem services	Included in ***Chapters 1, 3, 4,*** and ***5***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
25	shall be consistent with the National Flood Insurance Program (NFIP) and shall not undermine participation in nor the incentives or benefits associated with the NFIP	Included in ***Chapter 3*** and ***TWDB-Required Table 6***
26	shall emphasize the fundamental importance of floodplain management policies that reduce flood risk	Included in ***Chapter 3*** and ***TWDB-Required Table 6***
27	shall encourage flood mitigation design approaches that work with, rather than against, natural patterns and conditions of floodplains	Included in ***Chapter 5*** and ***TWDB-Required Table 16***
28	shall not cause long-term impairment to the designated water quality as shown in the state water quality management plan as a result of a recommended flood management strategy or project	Included in ***Chapter 6***
29	shall be based on identifying common needs, issues, and challenges; achieving efficiencies; fostering cooperative planning with local, state, and federal partners; and resolving conflicts in a fair, equitable, and efficient manner	Included in ***Chapters 3, 8,*** and ***10***
30	shall include recommended strategies and projects that are described in sufficient detail to allow a state agency making a financial or regulatory decision to determine if a proposed action before the state agency is consistent with an approved regional flood plan	Included in ***Chapters 5*** and ***9*** and ***TWDB-Required Tables 15, 16, 17,*** and ***19***
31	shall include ongoing flood projects that are in the planning stage, have been permitted, or are under construction	Included in ***Chapter 1*** and ***TWDB-Required Table 2***
32	shall include legislative recommendations that are considered necessary and desirable to facilitate flood management planning and implementation to protect life and property	Included in ***Chapter 8***
33	shall be based on coordination of flood management planning, strategies, and mitigation projects with local, regional, state, and federal agencies projects and goals	Included in ***Chapters 1, 3, 5, 9,*** and ***10*** and ***TWDB-Required Tables 16*** and ***17***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
34	shall be in accordance with all existing water rights laws, including but not limited to Texas statutes and rules, federal statutes and rules, interstate compacts, and international treaties	Included in ***Chapter 6***
35	shall consider protection of vulnerable populations	Included in ***Chapters 1*** and ***5*** and ***TWDB-Required Tables 3, 13,*** and ***16***
36	shall consider benefits of flood management strategies to water quality, fish and wildlife, ecosystem function, and recreation as appropriate	Included in ***Chapter 6***
37	shall minimize adverse environmental impacts and be in accordance with adopted environmental flow standards	Discussed in ***Chapter 6***
38	shall consider how long-term maintenance and operation of flood strategies will be conducted and funded	Discussed in ***Chapters 4*** and ***6***
39	shall consider multi-use opportunities such as green space, parks, water quality, or recreation, portions of which could be funded, constructed, and or maintained by additional third-party project participants	Included in ***Chapters 5, 6, 8,*** and ***9***