Chapter 4: Assessment and Identification of Flood Mitigation Needs

Task 4A: Flood Mitigation Needs Analysis

This chapter describes the process adopted by the Trinity Regional Flood Planning Group (RFPG) to conduct a Flood Mitigation Needs Analysis (***Task 4A***) to identify the areas of greatest known flood risk and areas where the greatest flood risk knowledge gaps exist. The ***Task 4A*** process is a big picture assessment that helps guide the subsequent ***Task 4B*** effort of identifying Flood Management Evaluations (FMEs), Flood Mitigation Projects (FMPs), and Flood Management Strategies (FMSs). ***Table 4.1***~~***Table 4.1***~~ provides a summary of the Texas Water Development Board (TWDB) guidance and factors that were considered in the Flood Mitigation Needs Analysis.

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Process and Scoring Criteria

The ***Task 4A*** analysis is based on a geospatial process that combines information from multiple datasets representing several of the factors listed in ***Table 4.1*** and provides a basis for achieving the ***Task 4A*** objectives. The geospatial process was developed in a geographic information system (GIS) and was based on the data collected in ***Tasks 1*** through ***3***. A variety of data sources were used in this assessment, including GIS data collected directly from communities during outreach efforts. During the data collection phase, individuals participated in an online survey where they were able to respond geographically on a map. The entity responses, as of September 16, 2021, were directly applied to this assessment.

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A Hydrologic Unit Code (HUC) is a unique code assigned to watersheds in the United States. As the watersheds get smaller, the number of units used to identify them get longer. Therefore, the smallest unit of division used to identify a watershed is 12 digits, or a HUC-12. The geospatial assessment was prepared at a HUC-12 watershed level of detail, which is consistent with the minimum watershed size for ***Task 4B*** specified in the Technical Guidelines (at least one square mile). The Trinity Region has a total of 471 HUC-12 watersheds, with an average size of 40 square miles.

A total of 13 data categories (see ***Table 4.2***~~***Table 4.2***~~) were used in the geospatial assessment. A scoring range was determined for each data category based on the statistical distribution of the data. The scoring ranges vary for each category based on the HUC-12s with the smallest and largest quantity. A uniform scoring scale of zero to five was adopted and each HUC-12 was assigned an appropriate score for each category.

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Table 4.1: Texas Water Development Board Guidance and Factors to Consider

Guidance	Factors to Consider
1. Most prone to flooding that threatens life and property	• Buildings and critical facilities within 100-year floodplain • Low water crossings (LWCs) • Agricultural and ranching areas in 100-year floodplain
2. Locations, extent, and performance of current floodplain management and land use policies and infrastructure	• Communities not participating in National Flood Insurance Program (NFIP) • Disadvantaged/underserved communities • City/county design manuals • Land use policies • Floodplain ordinance(s)
3. Inadequate inundation mapping	• No mapping • Presence of Fathom/base level engineering (BLE)/Federal Emergency Management Agency (FEMA) Zone A flood risk data • Detailed FEMA models older than 10 years
4. Lack of hydrologic and hydraulic (H&H) models	• Communities with zero or limited models
5. Emergency need	• Damaged or failing infrastructure • Other emergency conditions
6. Existing modeling analyses and flood risk mitigation plans	• Exclude FMPs already in implementation • Leverage existing models, analyses, and flood risk mitigation plans
7. Previously identified and evaluated flood mitigation projects	• Exclude FMPs already in implementation • Leverage existing FMPs
8. Historic flooding events	• Disaster declarations • Flood insurance claim information • Areas with a history of flooding according to survey responses • Other significant local events
9. Previously implemented FMPs	• Exclude areas where FMPs have already been implemented unless significant residual risk remains
10. Additional other factors deemed relevant by the Trinity RFPG	• Alignment with Trinity RFPG goals • Alignment with TWDB guidance principles • Social Vulnerability Index (SVI)

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Table 4.2: Task 4A Scoring Ranges: Areas Most Prone to Flooding that Threatens Life and Property

Score (points)	0	1	2	3	4	5
Number of Buildings	0	1-50	51-250	251-500	501-750	751+
Number of LWCs	0	1-5	6-10	11-15	16-20	21+
Total Agricultural Area (square miles)	0	0.01-0.35	0.36-2.00	2.01-3.00	3.01-5.50	5.51+
Number of Critical Facilities	0	1-5	5-10	11-25	26-50	51+
Number of Locations where Roads Flood	0	1	2	3	4	5+

The scores for each HUC-12 under each category were then added to obtain a total score that was used to reveal the areas of greatest known flood risk. The Inadequate Inundation Mapping category (which is discussed further later in this chapter) was selected as the basis for determining the areas where the greatest flood risk knowledge gaps exist.

The following sections provide a brief description of the data categories included and how each HUC-12 watershed was scored. Note that the objective of the ***Task 4A*** process is to determine the factors that are present within a given HUC-12, and to what degree; not necessarily to determine the relative importance of each factor in determining flood risk. Therefore, no weight has been applied to emphasize one factor over another at this time.

Areas Most Prone to Flooding that Threatens Life and Property

Buildings in the 100-year Floodplain

The building footprints dataset was provided by the TWDB on the Data Hub. This dataset was divided into point values based on the total number of buildings in the 100-year floodplain within each HUC-12. The count ranged widely throughout the region, with rural HUC-12s only having one to two buildings in the floodplain, while major urban centers may have over 1,000 buildings in the floodplain. The points breakdown for this metric is shown in ***Table 4.2******~~Table 4.2~~***.

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Low Water Crossings

LWCs were identified in ***Tasks 1*** (***Chapter 1***) and ***2*** (***Chapter 2***) and were downloaded from the TWDB Data Hub. LWC data was also provided by communities through the data collection portal developed for the Trinity Region. ***Task 2*** also identified a few more based on bridge deck elevation from LiDAR data and flood depths. This category is scored based on the quantity of

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LWCs occurring in a HUC-12. The points breakdown for this metric is shown in ***Table 4.2***~~***Table 4.2***~~.

Agricultural Areas at Risk of Flooding

Agricultural areas have been defined for this task as a land use of either farming or ranching. Impacted agricultural areas are those intersecting the 100-year floodplain as determined in the flood exposure analysis (See ***Chapter 2***). This layer will emphasize rural HUC-12s where agricultural impacts due to flooding are most prominent. The total impacted agricultural area in each HUC-12 was the criteria considered to assign points. The points breakdown for this metric is shown in ***Table 4.2***~~***Table 4.2***~~.

Existing Critical Facilities

Critical facilities for this assessment include hospitals, schools, fire stations, shelters, as well as electric and gas lines. Critical facilities within the 100-year floodplain were identified as part of the flood exposure analysis (See ***Chapter 2***). The community representatives were able to update the existing critical facilities by adding or removing facilities in the web GIS survey from ***Task 2***. A total of 159 critical facilities were added by survey participants, and 26 were removed or corrected. This category is scored based on the total number of critical facilities identified within the 100-year floodplain. The points breakdown for this metric is shown in ***Table 4.2***~~***Table 4.2***~~.

Locations Where the Road Floods

This dataset is based on survey responses from ***Task 2***. Survey participants identified roads that are prone to flooding by drawing lines on the interactive map. A total of 49 locations were added by survey participants. Although this factor primarily addresses water over roadways, it also represents potential urban flooding scenarios. Each line entered was given one point. If the line was drawn across multiple HUC-12s, then both HUCs received a point. The point breakdown for this metric is shown in ***Table 4.2***~~***Table 4.2***~~.

Current Floodplain Management and Land Use Policies and Infrastructure

Communities Not Participating in the National Flood Insurance Program

Participation in the NFIP was considered as a proxy for having adequate floodplain management regulations in each community. The NFIP participation status for each community is presented in ***Chapter 3***. Non-participating communities are not eligible for flood insurance under the NFIP. Furthermore, if a presidentially-declared disaster occurs because of flooding, no federal financial assistance can be provided to non-participating communities for repairing or reconstructing insurable buildings in Special Flood Hazard Areas (SFHAs). Therefore, this analysis considered non-NFIP communities as being more vulnerable to flooding risks. If most of

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the HUC-12 (greater than 50 percent) intersected a non-NFIP community, it was assigned five points. Otherwise, no points were allocated. Non-NFIP communities are mostly clustered in the mid-basin area, with others dispersed throughout the region. The point breakdown for this metric is shown in ***Table 4.3*~~***Table 4.3***~~.

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Table 4.3: Task 4A Scoring Range: Current Floodplain Management and Land Use Policies and Infrastructure

Score (points)	0	1	2	3	4	5
Community	NFIP Participant					Non-NFIP Participant

Areas Without Adequate Inundation Maps

Inadequate Inundation Mapping

This analysis was completed using the ExFldHazard layer. This layer contains existing seamless floodplain quilt inundation boundaries gathered for the Trinity Region in ***Task 2***. The floodplain quilt attributes include the source of the floodplain data. Based on the definitions of the source data from TWDB (TWDB, 2021), the Trinity RFPG assumed that the sources that represented adequate inundation mapping data include:

- National Flood Hazard Layer (NFHL) Preliminary Data (Zones AE, AH, AO, VE, and X)
- NFHL Effective Data (Zones AE, AH, AO, VE, and X)

The following data sources were considered inadequate inundation mapping data in this assessment as they are not considered appropriate for regulatory purposes:

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

The total floodplain area (from all sources in the floodplain quilt) and the amount of inadequate floodplain data in each HUC-12 were calculated. The computation produced a percentage of the HUC-12 floodplain data that is considered inadequate for the purposes of this assessment. The HUC-12s with the highest percentages of inadequate data appear in the very far north region area and in the middle of the region. The points breakdown for this metric is shown in ***Table 4.4***~~***Table 4.4***~~.

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Table 4.4: Task 4A Scoring Range: Areas Without Adequate Inundation Maps

Score (points)	0	1	2	3	4	5
% Inadequate	0	0.01-20%	21-50%	51-75%	76-90%	90%+

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Areas Without Hydrologic and Hydraulic Models

The existing H&H models that were identified for the Trinity Region are presented in ***Chapter 2***. Separate scoring criteria was not developed for this category since the risk associated with lack of technical data is already being considered by the "Inadequate Inundation Mapping" category. Any areas with detailed mapping are presumed to have H&H modeling.

Areas with Emergency Needs

The Trinity RFPG has developed a definition for emergency needs based on regional needs and input from the planning committee. Areas with severe repetitive loss (SRL), critical facilities within the 1% annual chance storm event area, and locations associated with a high number of fatalities are the three metrics the Trinity Region has decided to use to attribute as emergency need. For a more detailed description, please see the ***Task 4B*** discussion later in this chapter.

Existing Modeling Analyses and Flood Risk Mitigation Plans

Hazard Mitigation Action Plans were identified for all 38 counties within the Trinity Region. Therefore, this category was not included in the assessment since it does not provide any differentiation regarding flood risk within the region.

Flood Mitigation Projects Previously Identified

Per the public survey responses, only two ongoing projects were identified with dedicated funding in place (see ***Chapter 2***). Due to the limited data available, this category was not included in this assessment.

Historic Flooding Events

Report Flood Concerns

This category was generated by the community responses to the survey in ***Task 2***. A total of 110 data point locations were provided by survey participants. This dataset primarily included flood concerns related to undersized storm drain systems and localized street flooding. The score for this factor was based on the number of flood concern locations identified by survey participants within each HUC-12. The points breakdown for this metric is shown in ***Table 4.5~~Table 4.5~~***.

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Table 4.5: Task 4A Scoring Ranges: Historic Flood Events

Score (points)	0	1	2	3	4	5
Number of Flood Concerns	0	1	2	3	4	5+
Number of FEMA Claims	0	1-5	6-10	11-30	31-50	51+
Number of Historic Storms Events	0	1-2	3-4	5-6	7-8	9+
Property Damages ($)*	0	1-10,000	10,001-30,000	30,001-100,000	100,001-500,000	500,000+
Number of Areas with History of Flooding or need Mitigation	0	1	2	3	4	5+

** One additional point was added if injuries were reported, and two additional points if deaths were reported.*

Federal Emergency Management Agency Claims

This dataset compiles all the FEMA flood claims within the Trinity Region as of July 31, 2021. The geospatial data assigned to the claims was highly redacted. Therefore, the Trinity RFPG opted for using the cities to which the flood claims were assigned. Each city was divided into the HUC-12s that intersected the city limits. The number of flood claims for each city was divided proportionately amongst the HUC-12s composing each city. Most of the claims recorded in this dataset occurred in the Dallas-Fort Worth (DFW) metropolitan area. The points breakdown for this metric is shown in ***Table 4.5***~~***Table 4.5***~~.

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Historic Storm Events

The occurrence of historic storm events was evaluated using the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information Storm Events Database (NCEI, 2022). This database compiles historic storm events from 1950 to 2021. This dataset is an official NOAA publication which documents the following:

- The occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce
- Rare, unusual, weather phenomena that generate media attention
- Other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occurs in connection with another event

Storm events are included in this database following the procedures established in the National Weather Service (NWS) Directive Number 10-1605 – Storm Data Preparation (NWS, 2021). Storm events are subdivided into 48 categories, which include flood related events as well as

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other natural hazards. Three primary event categories were selected for this assessment: floods, flash floods, and heavy rain. A total of 837 storm events were reported for the Trinity Region between 1996 and 2020, consisting of 158 floods, 660 flash floods, and 19 heavy rain events. Each event includes the source of data and a narrative describing the details of the event.

The number of ~~histor~~4-8istoryic storm events occurring within each HUC-12 was tabulated and scores were assigned according to the point breakdown shown in ***Table 4.5*** ~~***Table 4.5***~~.

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Damages from Historic Storms

In addition to the frequency of historic storm events, the severity of these events was also considered in the assessment. Event severity was represented by reported damages, injuries, and deaths associated with each event as recorded in the Historic Storm Events database. A score of zero to five points was first assigned based on reported property damages. (See scoring scale in ***Table 4.5*** ~~***Table 4.5***~~.) One additional point was added if injuries were reported, and two additional points were added if deaths were reported.

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Areas with a History of Flooding/Areas that need Mitigation

The data collection survey performed in ***Task 2*** also provided an opportunity for participants to identify areas in their communities that repetitively flood or may require mitigation. A total of 87 data points were provided by survey participants. Within each HUC-12 boundary, the number of areas marked were scored according to the scale shown in ***Table 4.5*** ~~***Table 4.5***~~. This dataset is limited to locations identified by individuals in the ***Task 2*** survey.

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Previously Implemented Flood Mitigation Projects

Per the data collection survey responses, no FMPs were identified as previously implemented (see ***Chapter 2***); therefore, this category was not included in this assessment.

Other Factors

Social Vulnerability Index

As discussed in ***Chapter 2***, 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. SVI values for the State of Texas were downloaded from the Centers for Disease Control and Prevention's (CDC) Agency for Toxic Substances and Disease Registry (ATSDR) website (United States CDC, 2018). The most recent SVI values published on the website (2018) were used in this assessment. SVI values are assigned per census tract, which needed to be converted to SVI per HUC-12. SVI values were assigned to each HUC-12 based on an area-weighted average. The percent of a census tract that intersects a HUC-12 was multiplied by the SVI. This procedure was followed for all census tracts intersecting a HUC-12

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boundary, and those weighted SVI values were added together to produce one SVI value for each HUC-12. The SVI ratings vary between zero and one and were scored according to ***Table 4.6***~~***Table 4.6***~~. The higher the SVI, the higher the vulnerability of a community; the lower the SVI, the higher the resilience. Overall, the HUC-12s in the middle and lower portions of the region resulted in the highest SVI values.

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Table 4.6: Task 4A Scoring Ranges: Social Vulnerability Index Ratings

Score (points)	1	2	3	4	5
SVI rating	0.01-0.16	0.17-0.33	0.34-0.50	0.51-0.67	0.67+

Scoring Example

Five HUC-12 basins were selected to demonstrate, in detail, the scoring process described earlier in this chapter. The selected basins are located in the Lower Trinity-Kickapoo and Lower Trinity Sub-Basins, south of Lake Livingston (see ***Figure 4.1***~~***Figure 4.1***~~). These five basins, labeled A through E for simplicity, had a wide variety of scores for each category and resulted in total scores that represent the entire range of known flood risk levels as defined in this assessment.

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Figure 4.1: Example Task 4A Hydrologic Unit Code-12 Scoring

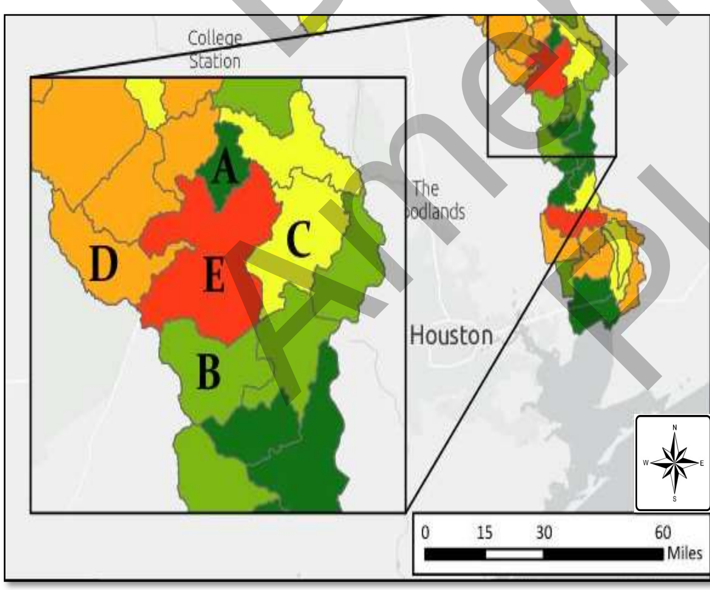

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Table 4.7***Table 4.7***shows the detailed scores for the selected HUC-12 basins. These results are presented graphically in ***Figure 4.2******Figure 4.2***. This data demonstrates how the combination of different factors can help determine if a given HUC-12 has a high level of known flood risk relative to others. In this example, Basin E scored high in several categories, which resulted in the highest total score. Conversely, Basin A only scored high in the SVI category, indicating a much lower level of known flood risk. However, the fact that a HUC-12 results in a low score does not necessarily mean that there is no flood risk in this area. The results for Basin B show a relatively low total score, but it scored high in the SVI and inadequate inundation mapping categories. In addition, some buildings, critical facilities, and LWCs would still be impacted by the 1% annual chance storm event. This clearly indicates that there is still a level of flood risk associated to this area, but not as significant as in Basin E.

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The inadequate inundation mapping category was selected as the basis for determining the areas where the greatest flood risk knowledge gaps exist. In this example, four of the selected HUC-12s scored high for this category, indicating that inundation maps in these areas are considered inadequate. This result indicates that there is significant uncertainty regarding floodplain boundaries in these areas and that studies (FMEs) would be needed to reduce uncertainty, and in turn, minimize flood risk.

Analysis Results

The process and scoring methodology described above was implemented across the entire Trinity Region. As previously discussed, this assessment was performed to address the two goals of ***Task 4A***. The first goal was to identify the areas where the greatest flood risk knowledge gaps exist. The inadequate inundation mapping category was selected as the basis for identifying these areas. Based on the data utilized in this preliminary assessment, approximately two-thirds of the Trinity Region is considered inadequately mapped (as indicated by the red HUC-12s in ***Figure 4.3******Figure 4.3***). Note that the red HUC-12s may contain studies that have been completed but are not yet regulatory products.

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The second goal was to determine the areas of greatest known flood risk and flood mitigation needs. For each HUC-12 in the Trinity Region, the scores from the 13 categories were added to obtain a total score. All categories have an equal representation in the total score. This analysis also included the inadequate inundation mapping category because uncertainty itself is a risk. Based on the distribution of the final scores in this preliminary assessment, the top 10 percent were colored red, and the top 30 percent were colored either red or orange to highlight the areas with the greatest known flood risks (***Figure 4.4******Figure 4.4***). It is important to note that a HUC-12 with a low score does not necessarily mean that there is no flood risk in this area, only that this risk is relatively low compared to the others.

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Table 4.7: Example Task 4A Hydrologic Unit Code-12 Scoring

Category / Score	HUC-12				
	A	B	C	D	E
Category 1 - # of Buildings	2	191	203	56	1018
Category 1 – Score	1	2	2	2	5
Category 2 - # of Crossings	0	0	0	0	0
Category 2 – Score	0	0	0	0	0
Category 3 – Agricultural Area Impacted (mi^2)	0.09	4.64	2.27	0.34	16.67
Category 3 – Score	1	4	3	1	5
Category 4 - # of Critical Facilities	0	0	0	0	0
Category 4 – Score	0	0	0	0	0
Category 5 - # of Locations where Road Floods	0	0	0	0	0
Category 5 – Score	0	0	0	0	0
Category 6 – NFIP Community	0	0	0	0	0
Category 6 – Score	0	0	0	0	0
Category 7 – Inadequate Inundation Mapping	100%	5%	96%	100%	84%
Category 7 – Score	5	1	5	5	4
Category 8 - # of Flood Concerns	0	0	0	0	0
Category 8 – Score	0	0	0	0	0
Category 9 - # of FEMA Claims	0	0	0	76	12
Category 9 – Score	0	0	0	5	3
Category 10 - # of Historic Storm Events	0	0	0	1	3
Category 10 – Score	0	0	0	1	2
Category 11 – Damages ($)	0	0	0	$10,000	$35,000
Category 11 – Score*	0	0	0	1	3
Category 12 - # of Areas with History of Flooding	0	0	0	0	0
Category 12 – Score	0	0	0	0	0
Category 13 – SVI Rating	0.23	0.57	0.59	0.60	0.61
Category 13 - Score	2	4	4	4	4
Total Score	**9**	**11**	**14**	**19**	**26**

**HUC-12 did not have any injuries or deaths associated with the historic storms; therefore, no additional points were given for this category.*

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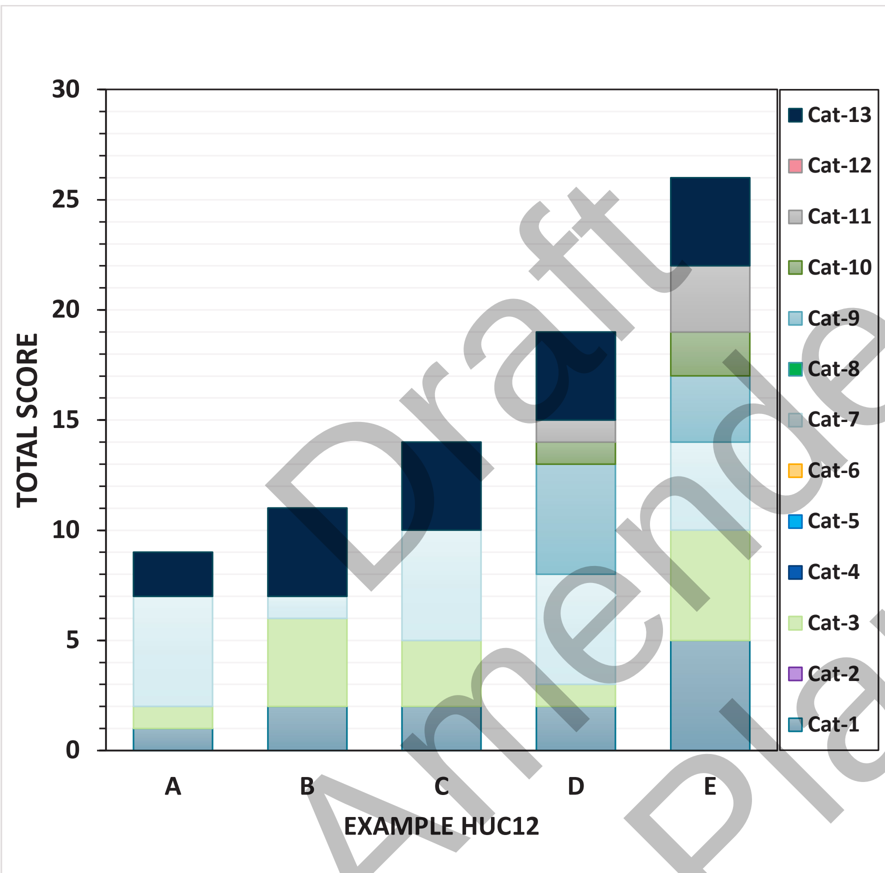
Figure 4.2: Distribution of Points and Total Score for Hydrologic Unit Code-12 Examples



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The maps resulting from the ***Task 4A*** assessment served as a guide to the Trinity RFPG's subsequent efforts in ***Task 4B***. The red and orange HUC-12s in ***Figure 4.3***~~***Figure 4.3***~~highlight the areas in the Trinity Region where potentially feasible flood risk studies (FMEs) should be considered as part of ***Task 4B***. The red and orange HUC-12s in ***Figure 4.4***~~***Figure 4.4***~~emphasize watersheds where the Trinity RFPG should strive to identify and implement FMSs and FMPs as part of ***Task 4B*** to reduce the known flood risks within those areas.

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Figure 4.3: Flood Risk Knowledge Gaps

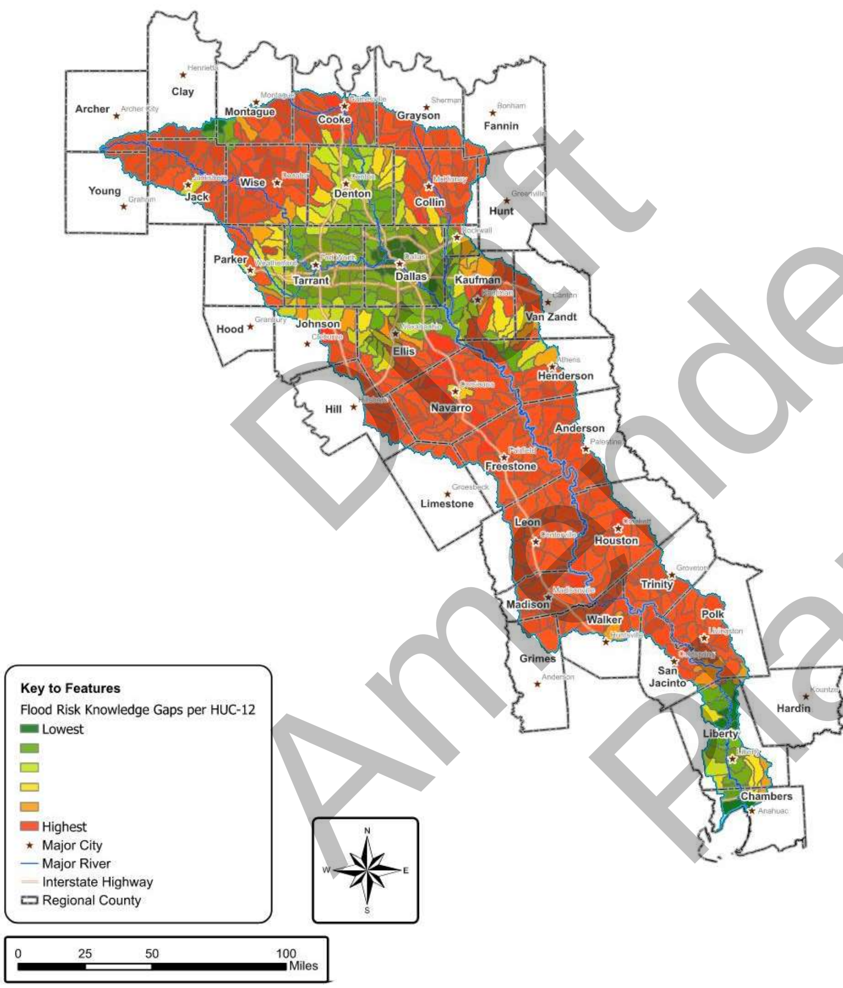

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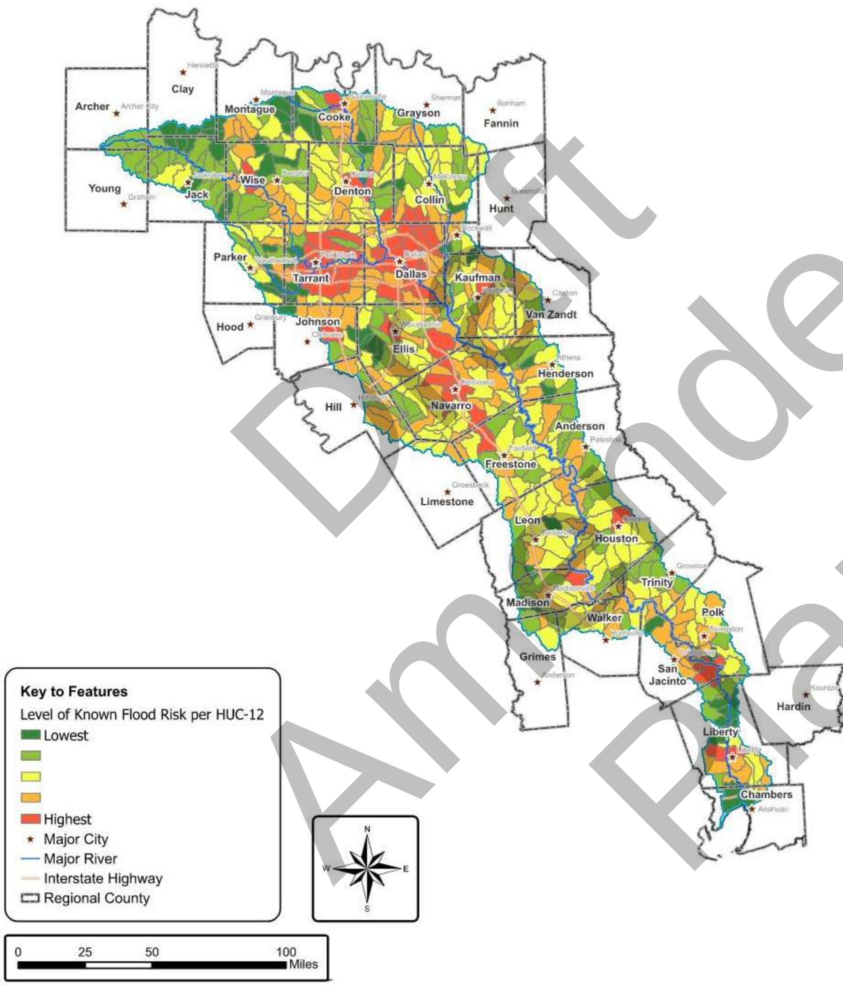
Figure 4.4: Areas of Greatest Known Flood Risk



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Task 4B: Identification and Evaluation of Potential Flood Management Evaluations, Potentially Feasible Flood Management Strategies, and Flood Mitigation Projects

Process to Identify Flood Management Evaluations, Strategies, and Flood Mitigation Projects

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The goal of ***Task 4B*** was to identify and evaluate a wide range of potential actions to define and mitigate flood risk across the basin. These actions were broadly categorized into three distinct types, as defined below:

- **FME**: a proposed flood 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
- **FMP**: a proposed project, either structural or non-structural, that has non-zero capital costs or other non-recurring cost, and when implemented will reduce flood risk or mitigate flood hazards to life or property
- **FMS**: a proposed plan to reduce flood risk or mitigate flood hazards to life or property

Identification of potential FMEs and potentially feasible FMPs and FMSs began with the execution of the Flood Mitigation Needs Analysis to identify the areas with the greatest gaps in flood risk knowledge and the areas of greatest known flood risk. This process and its outputs have been described previously in ***Task 4A***. Based on the results of this analysis, several sources of data were used to develop a list of potential flood risk reduction actions for addressing the basin's needs. The data includes information compiled under previous tasks, such as:

- Existing flood infrastructure, flood projects currently in progress, and known flood mitigation needs (***Task 1***)
- Existing and future flood risk exposure and vulnerability (***Tasks 2A*** and ***2B***)
- Floodplain management and flood protection goals and strategies developed by the Trinity RFPG (***Task 3A*** and ***3B***)
- Community input

Once these datasets were identified and evaluated through initial screening and data gathering under this task, the FMEs, FMSs, and FMPs were further evaluated to compile the necessary technical data for the Trinity RFPG to decide whether ~~or not~~ to recommend these actions, or a subset of these actions, as part of ***Task 5***.

This ~~first regional~~ flood plan~~ning cycle~~ relies primarily on compiling readily available information to determine appropriate flood mitigation actions to recommend for inclusion in the regional flood plan, rather than performing technical analyses to identify new actions.

The lists of potential FMEs and potentially feasible FMSs and FMPs were compiled based on contributions from the Trinity RFPG and other regional communities, using sources such as previous flood studies, drainage master plans, flood protection studies, and capital improvement studies. In addition, plans that were considered in the flood planning process include local and countywide Hazard Mitigation Plans (HMPs); various ordinances, planning, and zoning documents; and FEMA NFHL data. Each of these documents and datasets provides insight into the jurisdiction's capabilities, the guidelines of each location, and the potential challenges of implementing FMEs, FMSs, and FMPs within the flood planning area. A list of data sources relevant to the regional flood plan development for the Trinity RFPG are provided in ***Table 4.8***~~***Table 4.8***~~ through ***Table 4.10***~~***Table 4.10***~~.

In all, 38 counties and seven cities within the Trinity Region had HMPs ranging from 2013 to 2021. Several communities provided their zoning and land use documents. Drainage studies, flood prevention ordinances, regulations for floodplain managements, and flood control ordinances were also included in the planning process. All participating counties have data in the NFHL; however, Trinity County does not have countywide data available. Additionally, five~~seven~~ counties have preliminary flood studies in progress that will go effective in the near future.

Classification of Potential Flood Management Evaluations and Potentially Feasible Flood Management Strategies and Flood Mitigation Projects

Several different general action types provided by the TWDB considered are listed in ***Table 4.11***~~***Table 4.11***~~***.*** Once potential flood risk reduction actions were preliminarily identified using this list, a high-level screening process was used to confirm that potential actions had been sorted into their appropriate categorization. The screening process is shown in ***Figure 4.5***~~***Figure 4.5***~~.

Generally, an action was considered an FME if it was meant to study and quantify flood risk in an area, as well as define potential FMPs and FMSs to address the risk. Potential actions that could be considered FMPs were screened to determine if they were developed in enough detail and included sufficient data to meet the technical requirements for these action types. Actions that were initially considered for FMPs that did not meet these requirements were adapted and repurposed as FMEs. Potential solutions that did not easily meet the criteria of FMEs or FMPs could be included as FMSs. The specific requirements for each action type are described in subsequent sections.

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Table 4.8: Local Plans, Manuals, and Ordinances Submitted to the Trinity Regional Flood Planning Group through the Survey

Document	Year
Anderson County Floodplain Resolution	2010
Chambers County Drainage Criteria Manual	2020
Chambers County Floodplain Regulations	2015
City of Addison Code of Ordinances	2021
City of Aledo Subdivision Ordinance	2007
City of Allen Land Development Code	2020
City of Alma Planning and Zoning	n/a
City of Alvarado Code of Ordinances	2018
City of Ames Subdivisions	2021
City of Anahuac Code Compliance	2021
City of Anna Code of Ordinances	2021
City of Burleson Design Standards Manual	2008
City of Burleson Future Land Use Map	n/a
City of Burleson Subdivision Regulations	2021
City of Combine Code of Ordinances	2018
City of Crockett Zoning Map	2006
City of Dallas Floodplain and Escarpment Zone Regulations	n/a
City of Decatur Executed Flood Control Ordinance	2011
City of Decatur Future Land Use Map	n/a
City of Decatur Zoning	n/a
City of Keene Flood Hazard Reduction	2012
City of Mansfield Flood Damage Prevention Ordinance	2013
City of Mansfield Storm Water Management Design Manual	2010
City of McKinney Engineering Design Manual	2021
City of McKinney Stormwater Management	2018

Document	Year
City of Mesquite Engineering Design Manual	2020
City of Mesquite Stormwater and Flood Prevention Ordinance	2012
City of Mont Belvieu City Limits and ETJ Map	2021
City of Newark Floodplain Ordinance	2001
City of Retreat Code of Ordinances	1986
City of Sanger Comprehensive Land Use Plan	2007
City of Sanger Future Land Use Map	2007
City of Talty Flood Damage Prevention Ordinance	2009
City of Tioga Flood Damage Prevention Ordinance	1989
City of Tom Bean Comprehensive Zoning Ordinance and Zoning Manual	2008
City of Whitesboro Floodplain Ordinance	2005
Denton County Floodplain Regulations	2019
Denton County Subdivision Rules and Regulations	2009
Fannin County Flood Damage Prevention Ordinance	2011
Fannin County Lake Zoning Regulations	2018
Kaufman County Floodplain Management Court Order	2019
Kaufman County Subdivision and Land Development Regulations	2019
Madison County Flood Damage Prevention Order	2011
Polk County Flood Damage Prevention Order	2019
Polk County Subdivision Regulations	2021
Town of Annetta North Floodplain Ordinance	2018
Town of Dish Comprehensive Plan Zoning Map	n/a
Town of Dish Zoning Map	2018
Town of St Paul Flood Damage Prevention	2009
Walker County Regulations for Flood Plain Management	1987

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Table 4.9: Federal Emergency Management Agency Flood Insurance Studies

Entity Name	Flood Insurance Study Name	Effective Date
Anderson	Anderson County, Texas and Incorporated Areas	2010
Archer	Archer County, Texas and Incorporated Areas	2021
Chambers	Chambers County, Texas and Incorporated Areas	2018
Clay	Clay County, Texas and Incorporated Areas	1991
Collin	Collin County, Texas and Incorporated Areas	2017
Cooke	Cooke County, Texas and Incorporated Areas	2008
Dallas	Dallas County, Texas and Incorporated Areas	2019
Denton	Denton County, Texas and Incorporated Areas	2020
Ellis	Ellis County, Texas and Incorporated Areas	2013
Fannin	Fannin County, Texas and Incorporated Areas	2011
Freestone	-	N/A
Grayson	Grayson County, Texas and Incorporated Areas	2010
Grimes	Grimes County, Texas and Incorporated Areas	2012
Hardin	Hardin County, Texas and Incorporated Areas	2010
Henderson	Henderson County, Texas and Incorporated Areas	2010
Hill	Hill County, Texas and Incorporated Areas	2019
Hood	Hood County, Texas and Incorporated Areas	2019
Houston	Houston County, Texas and Incorporated Areas	2011
Hunt	Hunt County, Texas and Incorporated Areas	2012
Jack	Jack County, Texas and Incorporated Areas	2021
Johnson	Johnson County, Texas and Incorporated Areas	2019
Kaufman	Kaufman County, Texas and Incorporated Areas	2020
Leon	Leon County, Texas and Incorporated Areas	2013
Liberty	Liberty County, Texas and Incorporated Areas	2018
Limestone	Limestone County, Texas and Incorporated Areas	2019
Madison	Madison County, Texas and Incorporated Areas	1991
Montague	Montague County, Texas and Incorporated Areas	2011
Navarro	Navarro County, Texas and Incorporated Areas	2012
Parker	Parker County, Texas and Incorporated Areas	2020
Polk	Polk County, Texas and Incorporated Areas	2010
Rockwall	Rockwall County, Texas and Incorporated Areas	2020
San Jacinto	San Jacinto County, Texas and Incorporated Areas	2018
Tarrant	Tarrant County, Texas and Incorporated Areas	2020
Trinity	-	N/A
Van Zandt	Van Zandt County, Texas and Incorporated Areas	2010
Walker	Walker County, Texas and Incorporated Areas	2011
Wise	Wise County, Texas and Incorporated Areas	2020
Young	Young County, Texas and Incorporated Areas	2019

Note: Data as of March 2022

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Table 4.10: Hazard Mitigation Plans

Entity Name	Year of HMP
Anderson County	2018
Archer County	2020
Chambers	2017
City of Dallas	2018
City of Decatur	2016
City of Garland	2017
City of Grand Prairie	2017
City of McKinney	2015
City of Mesquite	2020
City of Plano	2013
Clay County	2020
Collin County	2016
Cooke County	2018
Dallas County	2020
Denton County	2016
Ellis County	2014
Fannin County	2015
Freestone County	2021
Grayson County	2012
Grimes County	2013
Hardin County	2017
Henderson County	2020
Hill County	2020

Entity Name	Year of HMP
Hood County	2021
Houston County	2020
Hunt County	2014
Jack County	2020
Johnson County	2019
Kaufman County	2015
Leon County	2019
Liberty County	2018
Limestone County	2019
Madison County	2013
Montague County	2020
Navarro County	2015
Parker County	2021
Polk County	2019
Rockwall County	2017
San Jacinto County	2018
Tarrant County	2020
Trinity County	2019
Van Zandt County	2020
Walker County	2017
Wise County	2014
Young County	2020

Note: Data as of March 2022

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Table 4.11: General Flood Risk Reduction Action Types

Flood Risk Reduction Action Category	Action Types
FME	a. Watershed Planning i. H&H Modeling ii. Flood Mapping Updates iii. Regional Watershed Studies b. Engineering Project Planning i. Feasibility Assessments c. Preliminary Engineering (alternative analysis and up to 30% design) d. Studies on Flood Preparedness
FMP	**Structural** a. LWCs or Bridge Improvements b. Infrastructure (channels, ditches, ponds, stormwater pipes, etc.) c. Regional Detention d. Regional Channel Improvements e. Storm Drain Improvements f. Reservoirs g. Dam Improvements, Maintenance, and Repair h. Flood Walls/Levees i. Coastal Protections j. Nature Based Projects – living levees, increasing storage, increasing channel roughness, increasing losses, de-synchronizing peak flows, dune management, river restoration, riparian restoration, run-off pathway management, wetland restoration, low impact development, green infrastructure k. Comprehensive Regional Project
	Non-Structural a. Property or Easement Acquisition b. Elevation of Individual Structures c. Flood Readiness and Resilience d. Flood Early Warning Systems, including stream gauges and monitoring stations e. Floodproofing f. Regulatory Requirements for Reduction of Flood Risk
FMS	None specified; RFPGs were instructed to include at a minimum any proposed action that the group wanted to consider for inclusion in the plan that did not qualify as either an FME or FMP.

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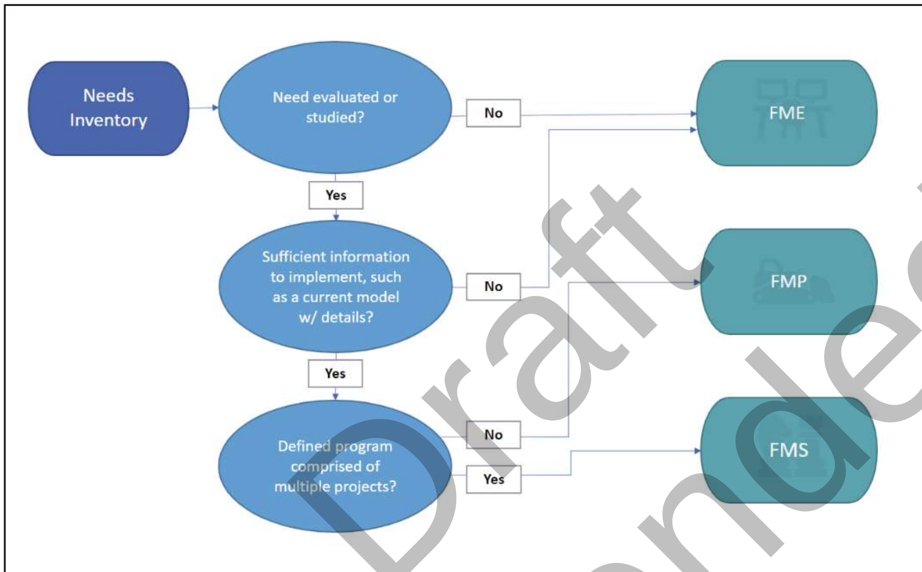
Figure 4.5: Potential Flood Risk Reduction Action Screening Process



FMSs were also identified for other strategies the RFPG wished to pursue. One example of a potential FMS was identifying repetitive loss properties and establishing a community-wide program of voluntary acquisitions to be implemented over several years. Another example included a program to enhance public education and awareness about flooding throughout the region, which does not require a construction cost.

Evaluation of Potential Flood Management Evaluations

Several actions were identified as potential FMEs to address gaps in available flood risk data associated with the first planning cycle. The following data sources were used to identify FMEs across the basin:

- Previous flood studies
- Capital Improvement Plans (CIPs)
- Drainage master plans
- FEMA Flood Insurance Studies (FISs)
- Hazard Mitigation Plans (HMPs)
- Flood Infrastructure Fund (FIF) applications ~~not chosen for funding~~
- Direct input from the Trinity RFPG
- Requests submitted by potential sponsors

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The evaluation of FMEs relied on the compilation of planning level data to gauge alignment with regional strategies, flood planning guidance, the potential flood risk in the area, and the funding need and availability. This data included:

- Type of study and location
- Availability of existing modeling and mapping data
- Regional flood mitigation and floodplain management goals addressed by the FME, and whether the FME meets an emergency need
- Flood risk information, including flood risk type, number and location of structures, population, roadways, and agricultural areas at risk
- Sponsor entity and other entities with oversight
- Cost information, including study cost and potential funding sources

Flood Mitigation Evaluation Types

The definition of an FME allows for a variety of study types to help assess flood risk and potentially define future FMPs and FMSs. A general list of study types is summarized in ***Table 4.12*** ~~***Table 4.12***~~. The following section describes these project types in more detail and provides a summary of the different potential FMEs identified in the Trinity Region.

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Watershed Planning

FMEs classified as watershed planning typically involved efforts associated with H&H modeling to help define flood risk or identify flood prone areas at a regional scale. The goal of watershed planning was to distribute resources equitably throughout a watershed to implement plans, programs, and projects that maintain watershed function and prevent adverse flood effects. A wide variety of project types fit under the umbrella of watershed planning, and the subcategories defined in the Trinity Region include:

- **Flood Mapping Updates:** Flood mapping data helps communities quantify and manage their flood risk. It also provides communities a pathway to access flood insurance administered through the NFIP. Flood mapping FMEs were identified for all counties within the Trinity Region except for Tarrant and Dallas counties. The FMEs included both the development of regulatory maps where none exist and updating existing maps to account for revised rainfall data, recent development conditions, and advances in floodplain modeling and mapping methodologies. Existing Base Level Engineering (BLE) studies will be leveraged, and the H&H analysis will be expanded as necessary to achieve a higher level of detail that will allow communities to adopt the mapping products as Zone AE. Areas currently classified as FEMA Zone AE based on recent H&H studies (less than 10 years) are considered adequate and will not be updated as part of the recommended flood mapping FMEs.

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Table 4.12: Flood Mitigation Evaluation Types and General Description

FME Type	FME Sub-Types	General Description	Number of FMEs Identified
Watershed Planning	Watershed Planning – Drainage Master Plans	Supports the development and analysis of H&H models to evaluate flood risk within a given jurisdiction, evaluate potential alternatives to mitigate flood risk, and develop capital improvement plans.	53 ~~51~~
	Watershed Planning – H&H Modeling, Regional Watershed Studies	Supports the development and analysis of H&H models to define flood risk or identify flood prone areas OR large-scale studies that are likely to benefit multiple jurisdictions.	23 ~~15~~
	Watershed Planning – Flood Mapping Updates	Promotes the development and/or refinement of detailed flood risk maps to address data gaps and inadequate mapping. Creates FEMA mapping in previously unmapped areas and updates existing FEMA maps as needed.	75 ~~37~~
	Watershed Planning – Flood Mapping for Dam and Levee Failure	Conducts studies to develop dam and levee failure inundation maps and models. Hydrologic studies to determine threat, risk, and potential impacts of flooding from dam and levee failure.	11
Project Planning	Engineering Project Planning	Evaluation of a proposed project to determine whether implementation would be feasible OR initial engineering assessment that includes conceptual design, alternative analysis, and up to 30 percent engineering design.	334 ~~236~~
Preparedness	Studies on Flood Preparedness	Encourages preemptive evaluations and strategies to better prepare an area in the event of flood.	5
Other	Other – Dam Studies	Other projects not classified above.	22 ~~1~~

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- **Drainage Master Plans:** Drainage master plans support the development and analysis of H&H models to evaluate flood risk within a given jurisdiction, evaluate potential alternatives to mitigate flood risk, and develop capital improvement plans.
- **H&H Modeling:** The objective of H&H modeling FMEs is to evaluate and define flood risk, identify flood prone areas, and evaluate alternatives for mitigating risk at a local level.
- **Regional Watershed Studies:** Regional watershed studies are large-scale H&H studies that will likely benefit multiple jurisdictions.
- **Flood Mapping for Dam Failure**: Studies are conducted to develop dam failure inundation maps and models. Per the Texas Commission on Environmental Quality (TCEQ) regulations, dams are required to be evaluated for hydrologic capacity for minimum design flood based on the Probable Maximum Flood (PMF) event. In addition to evaluating the design flood capacity, the hydrologic models are used to establish peak water surface elevations (WSEs) and reservoir inflow hydrographs, which are in turn utilized for performing the breach analysis and generating breach inundation mapping.
- **Flood Mapping for Levee Failure:** Studies are conducted to develop levee failure inundation maps and models. These hydrologic studies help to determine threat, risk, and potential impacts of flooding from levee failure.

Engineering Project Planning

FMEs classified as engineering project planning included studies to evaluate potential construction projects. These evaluations included feasibility assessments, preliminary alternatives analysis, and preliminary engineering design. The scope of the flood planning process defined a 30 percent design level as the cut-off between the study phase associated with an FME and the design and implementation phase associated with an FMP. The following engineering project planning subcategories were identified in the Trinity Region:

- Channelization
- Culvert improvements
- Erosion control
- LWC improvements
- Road/bridge improvements
- Storm drain improvements
- Stream stabilization
- Property Acquisition
- Ditch/Gully Improvements
- Other

Flood Preparedness Studies

FMEs classified as studies on flood preparedness included proactive evaluations of a community's readiness to respond to a flood event. These types of evaluations considered factors such as early warning systems, public awareness programs about flooding, capabilities of emergency operations personnel, and the development of emergency operations and evacuation plans.

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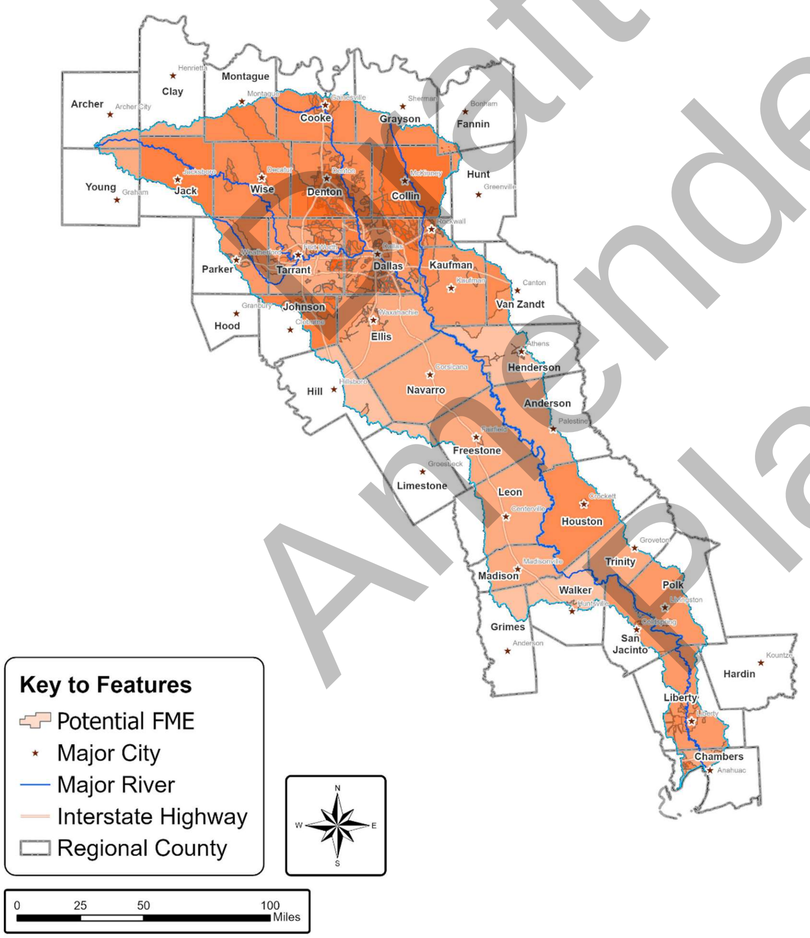
Flood Mitigation Evaluation Classification Summary

An overall summary of the identified FMEs was provided in ***Table 4.12***~~***Table 4.12***~~. All potential FMEs that were identified are listed with their supporting technical information in ***TWDB-Required Table 12*** (***Appendix A***). In total, 521~~356~~ potential FMEs were identified and evaluated. The geographical distribution of the identified FMEs is shown in ***Figure 4.6***~~***Figure 4.6***~~. Color gradations in ***Figure 4.6***~~***Figure 4.6***~~ reflect the number of FMEs that overlap for the same area, the darker the color, the greater the number of FMEs.

Figure 4.6: Geographical Distribution of Potential Flood Mitigation Evaluations



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Planning Level Cost Estimates

A planning level cost estimate was developed for each FME in accordance with the *Technical Guidelines*. The process to produce these cost estimates for each FME project type is outlined in the following sections. Cost estimates presented in this section are for planning purposes only and are not supported by detailed scopes of work or workhour estimates. The Trinity RFPG expects that the local sponsor will develop detailed scopes of work and associated cost estimates prior to submitting any future funding application through TWDB or other sources.

Watershed Planning – Flood Mapping Updates

A spreadsheet was generated to produce planning level cost estimates for Flood Insurance Studies (FIS) utilizing relevant line items from the FEMA guidance document, *Estimating the Value of Partner Contributions to Flood Mapping Projects* (FEMA Cooperating Technical Partners, 2017). Costs pertaining to management; discovery, alluvial, hydrologic, hydraulic, coastal, and floodplain mapping data capture; and final deliverables were included as part of the overall cost. The number of FIRM panels ~~that were~~ contained within each project boundary was also accounted for in the cost estimates.

The FME study area was defined as the portion of the county boundary that is within the Trinity Region. A range of unit costs was developed to generate estimates based on the square mileage of the study areas and the total length of stream miles for which hydraulic modeling would be performed. The Trinity RFPG estimated that the stream miles to be included would be 25 percent of the total stream miles classified as FEMA Zone A, Zone X, or unmapped within a given study area. This estimate was based on the adopted short-term goal of reducing gaps in flood mapping by 25 percent (see ***Chapter 3***).

Experience with previous mapping projects was used to estimate the level of detail associated with the H&H analyses that are required for these studies. The level of detail needed to perform a regulatory study reflects differences in the physical characteristics of the basins and their levels of urban development. In terms of hydrologic analysis, it was estimated that 80 percent of the total project area could be analyzed using low-detail methods, while 20 percent would require more in-depth rainfall-runoff analyses. For the hydraulic analysis, it was estimated that 70 percent of the included streams could be properly modeled with a low-detail hydraulic model, 20 percent with a medium-detail model, and only 10 percent would require highly detailed models. Unit costs were applied to reflect these different levels of detail.

Each cost estimate also included standard budget items based on the total project cost. These included a markup of two percent to account for quality assurance and quality control; 15 percent for project management, survey data capture, and technical reporting; and finally, a 30 percent contingency to account for uncertainties associated with planning level estimates.

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Watershed Planning – Drainage Master Plans

Separate planning level cost estimates were developed for drainage master plans depending on whether the sponsor was a county or city. Initially, the cost of each countywide drainage master plan was generated using a cost per square mile methodology, based on the cost of previous countywide drainage master plan studies. This quantity included basic services such as project management, coordination and collaboration work sessions, data collection, screening assessment, targeted H&H modeling and alternatives analysis, a technical report, and public outreach. A 30 percent contingency was applied to account for uncertainties associated with planning level estimates. After a comparative analysis of results, it was noted that a uniform cost estimate of $500,000 would be appropriate to complete each countywide plan. It is anticipated that this placeholder budget will provide sufficient funds for each county to broadly evaluate their jurisdiction and develop potential FMEs and FMPs that could be included in future regional flood plans.

The same scope and basic services were applied for citywide drainage master plans. However, the cost varied based on each city~~’s~~ or town’s population size, which was taken from 2020 United States Census data (United States Census Bureau, 2020). Three categories were identified for the population sizes and a corresponding cost estimate was assigned based on professional engineering experience (***Table 4.13***~~*Table 4.13*~~).

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Table 4.13: Citywide Drainage Master Plan Cost Estimate Ranges

Relative City Size	Population (2020 Census)	Cost Estimate
Small	< 25,000	$250,000
Medium	25,000 - 100,000	$500,000
Large	> 100,000	$1,000,000

Watershed Planning – Hydrologic and Hydraulic Modeling and Regional Watershed Studies

Planning level cost estimates were developed for FMEs assuming a typical scope of work that included project management, data collection, topographic survey, hydrologic analysis, hydraulic analysis, alternatives evaluation, and final deliverables. A range of unit costs was developed to generate estimates based on the square mileage of the study areas and the total length of stream miles for which hydraulic modeling would be performed. Experience from previous studies was used to scale the study effort and estimate the level of detail associated with the H&H analyses that are required for these studies. It was estimated that 20 percent of the total project area could be analyzed with low level of detail, 70 percent with medium level of detail, and 10 percent would require highly detailed H&H models. Unit costs were applied to

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reflect these different levels of detail, while also considering the differences in the physical characteristics of the basins and their levels of urban development.

Each cost estimate also included standard budget items based on the total project cost. These included a markup of 2 percent to account for quality assurance and quality control; 15 percent for project management, survey data capture, and technical reporting; and finally, a 30 percent contingency was applied for uncertainties associated with planning level estimates.

Watershed Planning – Flood Mapping for Dam and Levee Failure

Cost estimates for FMEs under this category reflect the following basic services: project management, discovery data capture, screening assessment, and detailed dam breach analysis. Each cost estimate also included standard budget items based on the total project cost and a 30 percent contingency to account for uncertainties associated with planning level estimates.

The discovery data capture effort involved dam data collection and a built-in cost to account for quality assurance and quality control. The screening assessment identified all public and private dams in each county by researching and gathering any historical information about the dams. The detailed dam breach analysis was the bulk of this overall evaluation cost since it required a complex H&H analysis. It was assumed that a maximum of 10 dams would be analyzed at this level for cost estimating purposes. In instances where there were less than 10 dams in a county, the value decreased, and the cost estimate was adjusted accordingly.

Engineering Project Planning

Engineering project planning considers two important components: (1) the evaluation of a proposed project to determine whether implementation would be feasible, and (2) an initial engineering assessment including conceptual design, alternative analysis, and up to 30 percent engineering design. Each evaluation area was project-specific and varied greatly due to the wide range of improvements in channels, culvert improvements, LWCs, roads and bridges, storm drain systems, and stream stabilization.

Costs for each evaluation were taken from Capital Improvement Projects (CIP) when available. It was assumed that the total cost represented in the report was the overall construction cost and that the evaluation effort would equate to five percent of the total construction cost or a minimum of $250,000. This methodology was applicable to the City of Grand Prairie and the City of Hurst – both of which, together, comprised 81 out of the 332~~236~~ engineering project planning FMEs.

The City of Garland had 3~~2~~2 FMEs that fell under this category, 22~~all~~ of which were updates to previous drainage studies. The year(s) these studies were initially performed range from April 2003 to September 2010. Thus, the project cost was taken for each of these, when available, and scaled accordingly to September 2020 United States dollars.

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The HMPs were used, when available, for determining planning level cost estimates. It was assumed that the costs provided for the HMPs were in 2020 United States dollars. In instances where neither HMPs nor CIPs were available, additional research and outreach were conducted to gather supplemental information from potential FME sponsors and previously conducted studies to develop a general scope of work and associated cost estimate.

Studies on Flood Preparedness

Studies on flood preparedness encourage preemptive evaluations and strategies to better prepare an area in the event of a flood. The identified FMEs in this category included studies to perform vulnerability assessments, develop emergency action plans, and perform dam compliance assessments. Placeholder costs were assigned to these FMEs based on professional engineering experience with similar projects.

Other

The twenty-two (22)~~The only~~ FMEs classified as “Other” were~~as a USDA~~ dam studies~~y~~ and evaluations ~~rehabilitation~~ for Denton County, City of Dallas, and several Soil and Water Conservation Districts (SWCD). The scope and scale of these~~is~~ dam studies~~y~~ could vary widely, and there is uncertainty in terms of the number of dams that could potentially be rehabilitated and further studied. Using a dam failure analysis as a basis of comparison, it is likely that this effort would cost ~~$2,000,000~~$9.26 million.

Process to Determine Flood Risk Indicators

Flood risk indicators were quantified to define the existing flood hazard, flood risk, and flood vulnerability within each FME project area. GIS operations were performed to combine and summarize this information by clipping the flood risk information generated for the basin as part of ***Task 2A*** to the individual project boundaries associated with each FME. The resulting flood risk indicator information was used to populate the associated fields in the FME feature class. These values are summarized in ***TWDB-Required Table 12***.

Comparison and Assessment of Flood Mitigation Evaluations

As previously stated, most of the counties within the Trinity Region have been submitted as a flood mapping update FME due to a lack of current, fully detailed, model-backed H&H floodplain analyses. Clay County contains no regulatory floodplain information. Apart from Dallas and Tarrant counties, the exposure analysis resulted in the highest exposed structure counts within Denton and Liberty counties, demonstrating the need for accurate floodplain information for future mitigation and resiliency planning. Navarro and Hill counties have the Trinity Region’s highest flood exposure SVI, equating to a possible disproportionate amount of potential loss due to inaccurate floodplain information. Current mapping within the lower portion of the Trinity Region did not reflect the increase in rainfall resulting from the NOAA

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Atlas 14 release, prompting a significant need for FME flood mapping updates in counties south of Leon County.

Over~~Nearly~~ 50~~,~~ drainage master plan FME projects were collected for inclusion in ***TWDB-Required Table 12***. Drainage master plan areas were based on either city or county boundaries. Of the counties listed, the Dallas County drainage master plan and vulnerability assessment project area had the highest floodplain exposure and most population at risk. The City of Denton and Haltom City had the highest floodplain exposure out of the cities listed. Drainage master planning FMEs for the City of Madisonville, Everman, Crockett, and Athens had the highest city-wide SVI scores of over 0.9.

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A majority of the FMEs collected were categorized as engineering project planning. These were either riverine or urban flood prone specific areas that were identified and collected by a community. These FMEs were identified either by observation and eyewitness flood reports or through a detailed study with conceptual improvement alternatives. The analysis obtained from these proposed projects did not meet the full requirements to be included as an FMP and were relegated to an FME for further refinement. Over 70~~60~~ percent of the FME engineering project planning projects collected were located in Dallas and Tarrant County. Three~~Four~~ FMEs ~~projects~~ listed a~~we~~re contained within Hill County, which has~~d~~ the second highest flood exposure SVI within the Trinity Region. The total engineering project planning project areas contained a combined 49,000 structures at risk, with over 65 percent of the structures being classified as residential.

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Every recommended FME would leverage existing studies and H&H models. The FMEs would expand the existing analysis as necessary and perform an accurate No Negative Impact Analysis in support of potential FMP candidates for future state flood plans.

Determination of Emergency Need

The term "emergency need" can be interpreted in multiple ways, and each region was tasked with defining the term for each individual flood planning region. The Trinity RFPG used several criteria to determine areas of emergency need.

Removing SRL properties through FMSs were deemed emergency needs. SRL properties are those that flood repeatedly, causing significant difficulties for property owners. The National Flood Insurance Reform Act of 2004 defined a SRL 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 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

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exceeding the reported value of the property". (FEMA, 2005) Property acquisition, demolition, or elevation can remove SRL structures from the floodplain through coordinating FMSs.

Other emergency needs that would remove critical facilities from the 1% annual chance storm event risk area through various types of FMEs, FMPS, and FMSs included acquisition, demolition, or elevation; floodproofing or retrofitting; and infrastructure projects. Designating these critical facility structures as emergency need enabled mitigation measures in the form of FMEs, FMPs and FMSs to be enacted to reduce future risk.

Loss of life due to a flood event is used to determine emergency need when corresponding data was available in determining the location of the fatality. Ultimately, emergency needs were designated as areas that would sustain negative impacts within the foreseeable future if no measures were taken.

Evaluation of Potentially Feasible Flood Mitigation Projects and Flood Management Strategies

Potentially feasible FMPs were identified based on responses to the survey, reviews of previous studies, FIF applications ~~(both those selected for funding and those not selected for funding)~~within the region~~not selected for funding~~, and direct coordination with communities. FMSs and FMPs are required to be developed with a sufficient level of detail to be included in the regional flood plan and recommended for state funding. In most cases, this included having recent H&H modeling data to assess the impacts of the project and an associated project cost to develop the project's benefit-cost ratio (BCR). The development and use of the technical information to evaluate potentially feasible actions are described in the subsections that follow.

Potentially Feasible Flood Mitigation Projects

The Trinity RFPG identified 73~~33~~ potentially feasible FMPs for the Trinity Region. The geographical distribution of each identified FMP is shown in ***Figure 4.7***~~***Figure 4.7***~~, with technical information for each FMP summarized in ***TWDB-Required Table 13*** (***Appendix A***). ~~Color gradations in ***Figure 4.7*** reflect the number of FMPs that overlap for the same area, and the darker the color is, the greater the number of FMPs.~~

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Each project is unique, and the specific FMPs recommended by the Trinity RFPG will be described in detail in ***Chapter 5***. A general description of the potentially feasible FMPs is presented in ***Table 4.14***~~***Table 4.14***~~.

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Figure 4.7: Geographical Distribution of Potential Flood Mitigation Projects

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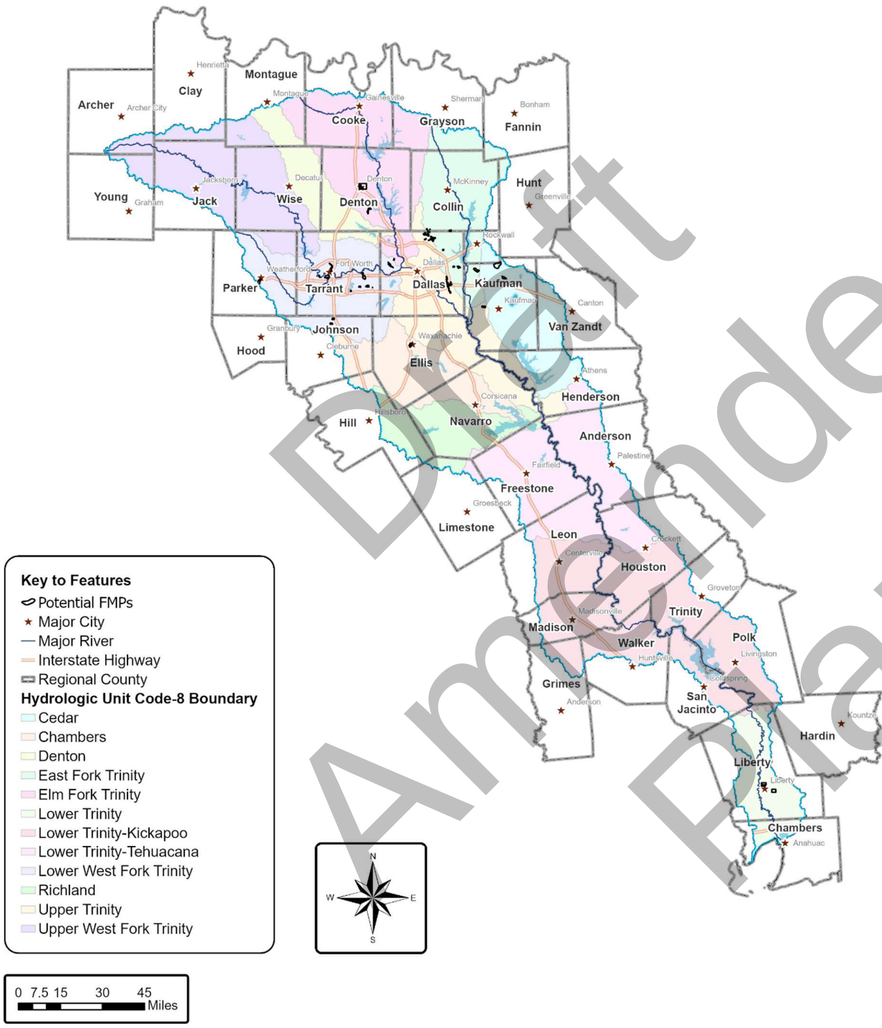

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Table 4.14: Summary of Flood Mitigation Project Types

FMP Type	General Description	Number of FMPs Identified
~~Stormwater~~ Infrastructure ~~Improvements~~	Improvements to stormwater infrastructure including channels, ditches, ponds, stormwater pipes, etc.	46 ~~31~~
Storm Drain Improvements	Improvements exclusively to underground urban stormwater infrastructure.	14
Regional Detention Facilities	Runoff control and management via detention facilities.	5
Property or Easement Acquisition	Acquisition of properties located in the floodplain	3
Dam Improvements, Maintenance and Repair	Dam upgrades to meet TCEQ dam safety requirements	2
Flood Early Warning Systems	Installation of safety improvements at hazardous stream crossings	2
~~Regional Detention Facilities~~	~~Runoff control and management via detention facilities.~~	~~2~~
Low Water Crossing or Bridge Improvement	Low water crossing replaced by a bridge crossing	1

The identified potentially feasible FMPs ~~for this first planning cycle~~ were primarily located within the Upper Basin area. These were the only actions for which a sponsor provided sufficient information to be considered as a potentially feasible FMP, or that an existing ~~funded or unfunded~~ FIF application was potentially available. The potential sponsors and their associated number of FMPs are listed below:

- City of Arlington (6~~1~~)
- City of Fort Worth (4~~3~~)
- City of Irving (2~~1~~)
- City of Richardson (29~~5~~)
- City of Sachse (1)
- Town of Sunnyvale (2)
- City of Burleson (4)
- Liberty County Water Control Improvement District #5 (3)
- City of Waxahachie (2)
- City of Weatherford (2)
- City of Dalworthington Gardens (1)
- City of Terrell (1)
- City of Denton (3)
- Kaufman County (5)
- City of Balch Springs (3)
- City of Westworth Village (3)
- City of Garland (1)
- Town of Copper Canyon (1)

Additional potentially feasible FMPs ~~may be~~were identified through continued outreach with regional entities under ***Task 11*** and were ~~through the execution of identified FMEs, either as~~

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~~FMEs are~~ approved by the Trinity RFPG to be performed and included under ***Task 12*** of the Amended Flood Plan.~~, or as other funding sources are acquired by entities.~~

Potentially Feasible Flood Management Strategies

The Trinity RFPG identified 145~~3~~ potentially feasible FMSs for the Trinity Region. The geographical distribution of each identified FMS is shown in ***Figure 4.8~~Figure 4.8~~***, with technical information for each FMS summarized in ***TWDB-Required Table 14*** (***Appendix A***). Color gradations in ***Figure 4.8~~Figure 4.8~~*** reflect the number of FMSs that overlap for the same area, and the darker the color is, the greater the number of FMSs.

A variety of FMS types were identified. Some FMSs proposed to establish and implement public awareness and educational programs to better inform communities of the risks associated with flood waters. Other FMSs proposed to improve preventative maintenance programs to maximize operational efficiency of existing stormwater management infrastructure, develop stormwater management manuals to encourage best management practices, or establish community-wide flood warning systems. A significant number of property acquisition programs were also identified. These programs included a variety of purposes such as acquiring floodplain and environmentally sensitive areas to convert them into open space land and acquisition of repetitive loss structures. A summary listing of FMS types is provided in ***Table 4.15~~Table 4.15~~***.

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Figure 4.8: Geographical Distribution of Potential Flood Management Strategies

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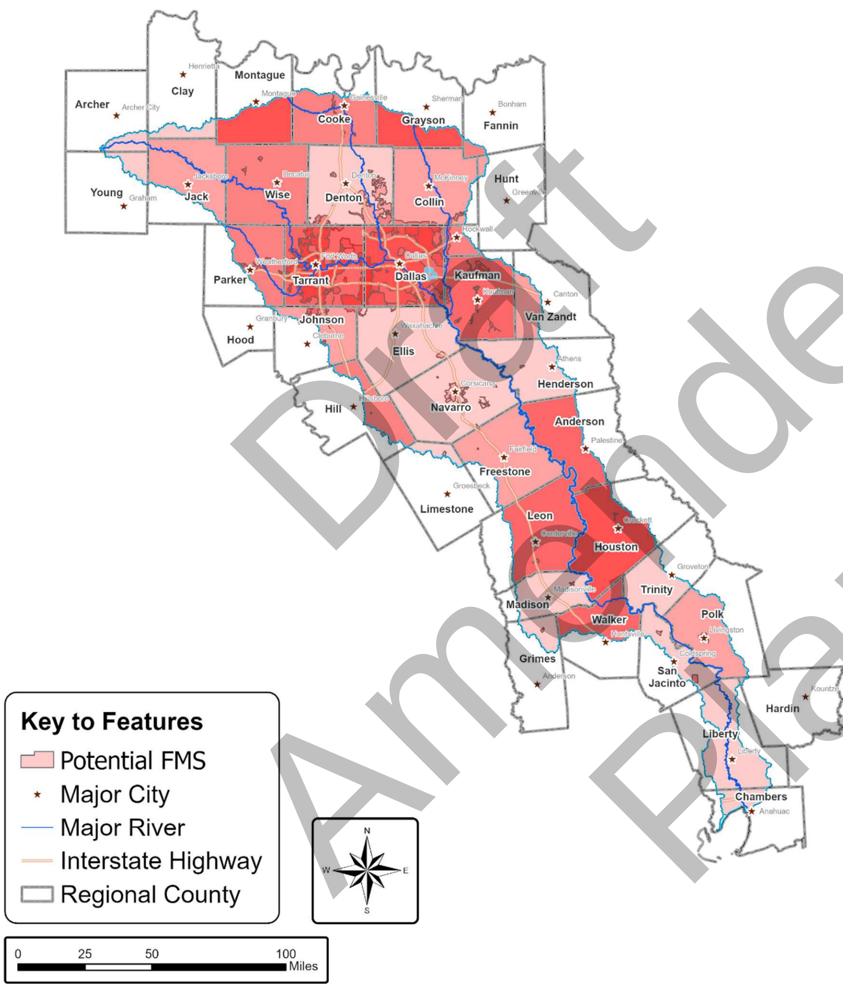

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Table 4.15: Summary of Flood Management Strategy Types

FMS Type	General Description	Number of FMSs Identified
Education and Outreach	Develop a coordinated education, outreach, and training program to inform and educate the public about the dangers of flooding and how to prevent flood damages to property.	22
Flood Measurement and Warning	Install gauges, sensors, and precipitation measuring sites to monitor streams and waterways for potential flooding.	20
Infrastructure Projects	City-wide improvement projects.	5
Property Acquisition and Structural Elevation	Acquire, relocate, and/or elevate flood-prone structures.	20 ~~298~~
	Acquire floodplain and protect environmentally sensitive areas by converting floodplain encroachments into open space land.	
Regulatory and Guidance	Develop and implement flood damage prevention ordinances.	62 ~~55~~
	Catalog, evaluate, and update floodplain regulations to comply with the latest FEMA minimum regulations or to adopt higher standards.	
	Incorporate regulatory standards to protect open space in flood prone areas.	
	Promote the inclusion of low impact development requirements in local and regional development ordinances.	
Floodproofing	Structural and nonstructural measures to reduce a structure's risk of flooding; weather hardening.	2
Other	Other items may include preventive maintenance programs, erosion control programs, funding mechanisms, nature-based solutions - implement the use of green infrastructure.	14 ~~3~~

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Comparison and Assessment of Flood Management Strategies and Flood Mitigation Projects

Potentially Feasible Flood Mitigation Project Comparison and Assessment

Over 70~~30~~ FMPs were collected and met the recommendation requirements to be considered for inclusion. Approximately 80~~90~~ percent of the FMPs recorded are categorized as infrastructure or storm drain improvements. These FMPs represented proposed design and construction projects that would improve a sponsor's storm drainage and channel infrastructure to reduce flooding in high flood risk areas. The City of Irving's West Irving Creek project had the potential to protect the highest population count from flooding compared to the other FMPs listed. This indicated that buildings located within the existing floodplain and within the project footprint have high occupancy. Drainage improvement projects located in Arlington and Garland were proposed to mitigate flood threat to the highest number of residential properties. FMPs located in Garland, Arlington, Irving, and Kennedale had the highest SVI, ranging from 0.7 to 0.9.

Commented [GS6]: Statements will be updated after geodatabase is finalized.

Potentially Feasible Flood Management Strategy Comparison and Assessment

Approximately 25 percent of the FMSs listed are categorized as floodplain management policy/regulatory guidance. Developing minimum NFIP or higher floodplain regulatory standards for new development near a regulatory or community effective floodplain preserves the natural capacity of the flooding source and limits upstream and downstream negative impacts. Minimum FEMA NFIP floodplain regulations can be found in Chapter 44 of the *Code of Federal Regulations* (FEMA, 2022). The Texas Floodplain Management Association (TFMA) has developed a *Guide for Higher Standards for Floodplain Management (2018)* (TFMA Higher Standards Committee, 2018), which can serve as an example for higher floodplain development standards for the referenced FMSs.

Twenty-two sponsors requested flood awareness and safety education support. These FMSs ranged from implementing the NWS's "Turn Around, Don't Drown" campaign to general education regarding the NFIP. Of the sponsors requesting education and outreach support, Houston County demonstrated the highest flood risk to habitable structures, road crossings, and agricultural land.

Nearly 20 sponsors expressed interest in flood measuring, monitoring, and warning systems. These systems may include local warning notifications, monitoring/measuring gages, highwater detection systems, sirens, warning lights, signage, and automated gates. Seven of these types of FMSs were requested in Dallas and Tarrant counties, which had the highest flood exposure in the Trinity Region. The proposed flood warning system in Leon County would service the most socially vulnerable among the list of flood warning FMSs.

Another FMS that sponsors requested related to property and land acquisition programs. These "buyout" program FMSs were provided on either a county or city-wide basis. Four of these programs, which span multiple jurisdictions, were planned to have multiple sponsorship. Of the county-wide buyout FMSs, the Leon County repetitive loss property acquisition had the highest SVI. Of the city-wide buyout FMSs, Chico and Terrell ranked as having the highest SVI, with values ranging from 0.75-0.95.

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Effects on Neighboring Areas of Flood Management Strategies or Flood Mitigation Projects

Each potentially feasible FMP and FMS must demonstrate that there would be no negative flood impacts on a neighboring area due to its implementation. No negative impact means that a project will not increase flood risk to surrounding properties. The analysis must be based on best available data and be sufficiently robust to demonstrate that the post-project flood hazard is no greater than the existing flood hazard.

Several communities in the Trinity Region have established no negative flood impact policies for proposed development. However, communities have different thresholds for defining what level of impact is considered adverse and require the analysis to be performed for different flood event scenarios. The *Technical Guidelines and Rules* governing state flood planning require the impacts analysis to be performed for the 1% annual chance storm event. Additionally, the *Technical Guidelines* require the following criteria to be met, as applicable, to establish no negative flood impact:

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

If negative impacts are identified, mitigation measures may be utilized to alleviate such impacts. Projects with design level mitigation measures already identified may be included in the regional flood plan and could be finalized at a later stage to conform to the "No Negative Impact" requirements prior to funding or execution of a project.

Furthermore, the Trinity RFPG has flexibility to consider and accept additional "negative impact" for the requirements listed based on professional engineering judgment and analysis, given any affected communities are informed and accept the impacts. This should be well-documented and consistent across the entire region. However, flexibility regarding negative impact remains subject to TWDB review.

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A comparative assessment of pre-project and post-project conditions for the 1% annual chance storm event (100-year flood) was performed for each potentially feasible FMP based on associated H&H models. The floodplain boundary extents, resulting WSEs, and peak discharge values were compared at pertinent locations to determine if the FMP conformed to the no negative impacts requirements. This comparative assessment was performed for the entire zone of influence of the FMP.

The comparative assessment to determine "no negative flood impact" on upstream or downstream areas or neighboring regions was performed based on currently available regional planning level data. The local sponsor will be ultimately responsible for proving the final project design has no negative flood impact prior to initiating construction.

Estimated Benefits of Flood Mitigation Projects or Flood Management Strategies

To be recommended, each FMP or FMS must align with a regional floodplain management goal established under ***Task 3*** and demonstrate a flood risk reduction benefit. To quantify the flood risk reduction benefit of each FMP or FMS, the anticipated impact after project implementation was evaluated as providing:

- Reduction in habitable, equivalent living units flood risk
- Reduction in residential population flood risk
- Reduction in critical facilities flood risk
- Reduction in road closure occurrences
- Reduction in acres of active farmland and ranchland flood risk
- Estimated reduction in fatalities, when available
- Estimated reduction in injuries, when available
- Reduction in expected annual damages from residential, commercial, and public property
- Other benefits as deemed relevant by the RFPG including environmental benefits and other public benefits

These estimated benefits were produced from geospatial data by analyzing the existing 1% and 0.2% annual chance storm event floodplain boundaries with the proposed post-project floodplain boundaries. The proposed flood risk conditions were compared to the existing conditions flood risk indicators for a given area to quantify the reduction of flood risk achieved by implementation of an FMP or FMS. The results of the analysis are shown for each FMP or FMS in ***TWDB-Required Table 13*** and ***Table 14***, respectively.

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Potential Impacts and Benefits from the Flood Management Strategies or Flood Mitigation Projects to Other Resources

Potential impacts and benefits from FMS or FMP were explored for the Trinity Region from the standpoint of environment, agriculture, recreation, navigation, water quality, erosion, and sedimentation. Factors unique to the Trinity Region were reviewed and an assessment of how these factors might interact with a potential FMS or FMP are discussed below.

Environmental

Senate Bill 3 (SB3) was designed to establish environmental flow standards for all major river basins and bay systems in Texas through a scientific, community-driven, and consensus-based process. The key questions addressed by the SB3 process as defined by TWDB include:

1. What is the quantity of water required by the state's rivers/estuaries to sustain a sound ecological environment?
2. How can this water be protected?
3. What is the appropriate balance between water needed to sustain a sound ecological environment and water needed for human or other uses?

FMSs or FMPs in the Trinity Region should consider potential impacts as they relate to the ecological flows established under the directive of SB3. Several studies have been completed for the Trinity Region with the purpose of studying environmental flow needs as part of the objectives of SB3 (Quigg & Steichen, 2015); (Mangham, Osting, & Flores, 2015); (Quigg & Steichen, Defining Bioindicators for Freshwater Inflow Needs Studies Phase 2: Defining a Sound Ecological Environment for Galveston Bay, 2018).

FMSs or FMPs should be able to maintain the established SB3 environmental flows in the Trinity River at the Grand Prairie, Dallas, Oakwood, and Romayor gauge locations. (Li, Passalacqua, & Hodges, 2018) identified anthropogenic factors affecting this study site and the stream segment. The study identified floodplain management as more impactful on riparian areas than high pulse flow management. The study also determined return flows at the base flow level as the main factor to satisfy subsistence and base flows. FMSs or FMPs at or upstream of these locations should focus on floodplain management and maintaining return flows. Similarly, at the Dallas location, FMSs or FMPs should be able to maintain return flows to satisfy SB3 subsistence and base flows. A study conducted under SB 2 by Texas Instream Flow Program (TIFP) suggests that base flows between 75 and 450 cubic feet per second at Oakwood could exhibit temperatures above the TIFP goals in select shallow areas. FMSs or FMPs that increase the base flows could ensure that the TIFP temperature goals are met at this location. Dissolved oxygen (DO) could also improve if FMSs or FMPs increase base flows. FMSs or FMPs should maintain return flows to satisfy SB3 subsistence and base flows. An FMS or FMP, in all

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likelihood, will increase base flows at Romayor above 575 cubic feet per second, which is required for continuous sand transport.

The high pulse flow SB3 values at the above locations primarily provide sediment, water table, and in-channel habitat functions. FMSs or FMPs are expected to reduce the extreme peak flows yet maintain the periodic high pulse flows required at these locations to sustain ecological and habitat functions.

Agricultural

According to the Texas A&M AgriLife Extension Service economists, Hurricane Harvey caused more than $200 million in crop and livestock losses in Texas. Flood waters have the potential to destroy standing crops, create water-logged conditions that delay planting or harvesting, wash away productive topsoil, and damage farm equipment and infrastructure. FMSs or FMPs potentially reduce extremely high flows in rivers and streams, thereby preventing flood waters from inundating areas outside of the floodway, including agricultural areas. Structural FMSs or FMPs, like small flood control ponds, also have the potential to assist in agricultural production by serving the dual purposes of flood mitigation and water supply. Non-structural FMSs or FMPs can have similar impacts on peak flow and flood reduction including agricultural conservation practices such as conservation tillage, residue management, cover crops, and furrow dikes. These practices not only reduce downstream flooding by reducing surface runoff and increasing infiltration on agricultural lands, but also decrease sediment and nutrient losses, thereby improving downstream water quality.

Recreational Resources

There are 34 major lakes and reservoirs in the Trinity Region. Recreational opportunities associated with these lakes and reservoirs have the potential to be impacted when the water bodies are being operated to mitigate flood risk. Flood control reservoirs hold water in their flood pools during peak runoff periods until the impounded water can be safely released downstream. During these periods, recreational use of adjacent parks and playgrounds may be vastly reduced. Flood risk management through FMSs or FMPs may consist of creating additional flood control reservoirs with the intent of impounding water to mitigate flood risk. The impoundment of water at flood pool elevations (which are considerably higher than the normal pool elevations) can potentially impact recreational functions of parks, campgrounds, boat ramps, etc.

Recreational use in flood control reservoirs may also be impacted by the water quality in the waterbodies. TCEQ assesses waterbodies in Texas every two years for five designated use categories including recreational use. The biennial recreational use assessment by TCEQ consists of evaluating waterbodies for E. coli (fresh water) or Enterococcus (tidal waters) from a standpoint of human health protection from recreational contact in the waterbodies. The 2020

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Texas Integrated Report classifies a significant number of segments in the Trinity Region as "Non-Supporting" for recreational use (TCEQ, 2020). FMSs or FMPs that focus on reducing runoff and therefore reducing export of bacteria to waterbodies have the potential to improve the recreational use condition of segments currently assessed as "Non-Supporting".

Navigation

The Trinity River is not used for commercial navigation. In 1963, the United States Army Corps of Engineers (USACE) approved making the Trinity River navigable by barges. In 1965, Congress and then-President Lyndon B. Johnson approved a package of flood control and navigation projects, including a barge canal connecting the DFW metroplex with the Gulf of Mexico. The barge canal was estimated to cost approximately $1 billion. In 1973, voters rejected to finance the barge canal and USACE subsequently abandoned the project. Navigation on the Trinity River is generally limited to recreational canoeing and kayaking in the rivers and creeks and boating in the lakes and reservoirs. These activities are impacted when flows in the Trinity River and water levels in the reservoirs are being actively managed for flood control. FMSs or FMPs are expected to have similar impacts on recreational navigation in the Trinity Region.

Water Quality

Many of the reservoirs in the Trinity Region are saturated with nutrients, and stormwater runoff is the primary source of nutrient loading. Despite the high levels of nutrients, reservoirs in the Trinity Region are classified as mesotrophic or eutrophic. The Trinity River Authority (TRA) hypothesizes that light penetration in the turbid waters rather than nutrient availability is the limiting factor for algal growth in these reservoirs (TRA, 2020). The TRA 2020 basin summary report explains that zebra mussels increase water clarity thereby allowing light penetration deeper in the water, resulting in increased nuisance plant growth. TRA therefore recommends proactive watershed protection programs and extensive use of best management practices to reduce nutrient loading and risk of harmful algal blooms. Structural FMSs or FMPs such as small flood control ponds are designed to capture stormwater runoff and pollutants thereby improving the water quality reaching the water supply reservoirs. However, the algal blooms might occur in these small reservoirs due to excessive availability of nutrients. Non-structural FMSs or FMPs that reduce stormwater runoff production have the potential to reduce nutrient loading to water supply reservoirs and other structural FMSs or FMPs.

Based on sampling for bacteria throughout the Trinity Region, TCEQ found that 69 of the 162 assessment units have concerns or do not support contact recreational use. Many of these findings are intermittent urban streams in the DFW metroplex. Intermittent streams can have high bacteria levels because they are not washed out frequently or assimilated. A total maximum daily loads (TMDLs) Implementation Plan, covering much of the metroplex, outlines activities to potentially reduce bacteria loading to these streams. Non-structural FMSs or FMPs that focus on runoff reduction from sources are expected to reduce bacteria loads. Depending

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on their location and operation, structural FMSs or FMPs, such as small flood control ponds, may maintain small levels of flows in downstream intermittent streams to flush out the streams and improve assimilation.

Erosion

The Trinity River Environmental Restoration Initiative 2010, funded by the TWDB, studied the rates and sources of sediment (and nutrient) loading to 12 major water supply reservoirs in 10 watersheds of the Upper Trinity Region (Wang, et al., 2010). The study reported a wide range of annual overland erosion rates, varying from 0.07 tons per acre per year in the Bridgeport Basin to 0.7 tons per acre per year in the Lewisville Basin. The study found that in most watersheds, the total sediment loading to the reservoirs was larger than the overland erosion amounts, suggesting bank and bed erosion as important sources.

The study also concluded that small flood control reservoirs (PL-556 structures) generally had a positive impact on reduction of total sediment load delivered to the flood control reservoirs. The efficiency of these small flood control structures in trapping sediment varied greatly from approximately four percent in the Ray Hubbard watershed to 48 percent in the Lewisville watershed. The effectiveness of these flood control structures in reducing delivery of sediment loads to water supply reservoirs are directly influenced by the percentage of watershed area draining to the ponds, their locations and the watershed's erosion characteristics. Structural FMSs or FMPs are expected to have similar impacts as the small flood control reservoirs identified in the TWDB study. Sediment attenuation will be largely influenced by the location and drainage area of the structural FMSs or FMPs, and watershed characteristics.

Non-structural FMSs or FMPs that limit sediment production and transport may be viable options for reducing erosion and transport of sediment in the Trinity Region. The TWDB study found that conservation practices, such as no rangeland grazing, resulted in reduced source sediment loads and delivered loads. Non-structural and structural FMSs or FMPs have the potential to reduce sediment production in the watersheds and delivery to the waterbodies in the Trinity Region.

Sedimentation

Sedimentation is a natural process by which runoff water, often rivers, transport small particles from upstream to downstream. As the water slows down, the particles settle to the bottom of the river or lake. A volumetric and sedimentation survey of Lake Livingston by the TWDB (Leber, et al., 2022) measured 129,149 acre-feet of sedimentation. The survey concluded that the lake had lost capacity at an average of 2,583 acre-feet per year due to sedimentation since impoundment in 1971. Sedimentation has been reported for most major reservoirs in the Trinity Region based on periodic volumetric and sedimentation surveys conducted by the TWDB.

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Structural FMSs or FMPs, such as small flood control reservoirs, receive and impound water (and sediment) from the respective drainage areas. Long residence time in a flood control pond results in settling of large proportions of the incoming sediment. Periodic discharges from small flood control projects are generally expected to carry smaller sediment loads than the influent runoff. Therefore, structural FMSs or FMPs are expected to reduce sedimentation in downstream water supply reservoirs by trapping sediment in their pools. While sedimentation in the large downstream reservoirs potentially reduce, sedimentation is expected to occur in the individual flood control projects.

Non-structural FMSs or FMPs, such as conservation practices that potentially reduce sediment production at the source, are expected to reduce sedimentation in structural FMSs or FMPs, as well as large downstream reservoirs.

Estimated Capital Cost of Flood Mitigation Projects and Flood Management Strategies

Cost estimates for each FMP were acquired from the engineering report that was used to generate the FMP. Cost estimates were adjusted as needed to account for inflation and other changes in price of labor and commodities that had taken place since the publication date of the original reports. In addition, cost estimates were adjusted as needed to include any applicable non-recurring and recurring project costs as listed on ***Table 22*** of the *Technical Guidance*. The cost estimates listed in ***TWDB-Required Table 13*** and ***Table 14*** are expressed in September 2020 dollars (see ***Appendix A***).

Cost estimates for each FMS were acquired from the HMPs that were used to generate the FMS, if available. Cost assumptions from ***Table 4.16~~Table 4.16Table 4.16~~*** were used if the HMPs did not have associated costs or if the reported costs were lower than the cost assumptions. The cost assumptions are expressed in 2020 dollars and were developed based on engineering experience and other similar projects.

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FMS cost estimates presented in this section are for planning purposes only and are not supported by detailed scopes of work or workhour estimates. The Trinity RFPG expects that the local sponsor will develop detailed scopes of work and associated cost estimates prior to submitting any future funding application through TWDB or other sources.

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Table 4.16: Flood Mitigation Strategy Cost Estimates Assumptions

FMS Type	Cost Estimate Range	Scope and Assumptions
Education and Outreach	$50K	"Turn Around Don't Drown" Campaign: Assume $50,000 based on other similar educational programs.
		NFIP Public Education: Assume $50,000 based on other similar educational programs.
Flood Measurement and Warning	$250K to $500K	Early/Local Flood Warning System: Assume $250,000 based on similar projects that have received TWDB FIF grants.
		Rain/Stream Gauge and Weather Station Installation: Assume $250,000 based on similar projects that have received TWDB FIF grants.
		LWC Warning Devices: Assume $250,000 based on similar projects that have received TWDB FIF grants.
Infrastructure Projects	$500K to $35M	Hazardous Roadway Crossings: There is one strategy identified within the region that consists of strategically improving hazardous road crossings within a community. This program cost is estimated at $35,000,000 for a single community.
		Capital Improvement Plan (CIP): Community planning tool including a compilation of drainage infrastructure projects. Costs are included in the CIP and aggregated for the assigned FMS.
Other	$50K to $5M	Debris Clearing Maintenance Program: Assume $100,000 based on a similar project in the region.
		Channel Maintenance and Erosion Control: Assume $250,000 based on high level engineering consultant estimate.
		Dam Inspection Program: Assume $100,000 per dam, per year based on high level engineering consultant estimate.
		Levee Inspection Program: Assume $50,000 per levee system, per year based on high level engineering consultant estimate.
		Establish City Parks: Assume $1,000,000 based on high level engineering consultant estimate.
		Implement Green Infrastructure: Assume $500,000 based on high level engineering consultant estimate.
Property Acquisition and Structural Elevation	$5M to $50M	Acquire High Risk and Repetitive Loss Properties: Assume $5,000,000 to acquire as many properties as possible with this cost. This assumption is based on other similar projects in the region.
		Acquire and Preserve Open Space: Assume $5,000,000 based on other similar projects in the region.
Regulatory and Guidance	$100K to $1M	City Floodplain Ordinance Creation/Update: Assume $100,000 to cover engineering consultant fees.
		Zoning Regulations and Land Use Programs: Assume $100,000 to cover engineering consultant fees.
		Stormwater Management Plan: Assume $300,000 to cover engineering consultant fees.
		Levy Stormwater Fee: Assume $200,000 based on another similar project.

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Benefit Cost Ratio for Flood Mitigation Projects

Benefit-Cost Analysis (BCA) is the method by which the future benefits of a hazard mitigation project were determined and compared to its costs. The end result is a BCR, which is calculated by dividing the project's total benefits, quantified as a dollar amount, by the total costs. The BCR is a numerical expression of the relative "cost-effectiveness" of a project. A project is generally considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs (URS Group, Inc., 2009). However, a BCR greater than 1.0 is not a requirement for inclusion in the regional flood plan. The Trinity RFPG can recommend a project with a lower BCR with appropriate justification.

When a BCR had been previously calculated in an engineering report or study that was used to create an FMP, the previously calculated BCR value was utilized for the FMP analysis. For any FMP that did not already have a calculated BCR value, the TWDB BCA Input Spreadsheet was utilized, in conjunction with the FEMA BCA Toolkit 6.0, to generate BCR values.

Residual, Post-Project, and Future-Risks of Flood Mitigation Projects

While it is not possible to protect against all potential flood risks, the evaluation of FMPs should consider the associated residual, post-project and future risks, including the risk of potential catastrophic failure and the potential for future increases to these risks due to lack of maintenance. For more details of the approach and TWDB's proposed scoring guidelines, please see TWDB's *Exhibit C: Technical Guidelines for Regional Flood Planning* (TWDB, 2021).

Residual Risk

Residual risk describes the risks after structural or non-structural FMPs have been implemented (United Nations Office for Disaster Risk Reduction, 2020). Even after meeting the FMP goals, residual flood risk will remain (TWDB, 2021). The RFPG must consider and identify residual risk for each goal identified. As an example, if the goal is to protect all life and property from the 1% annual chance storm event (100-year flood), the residual risk to life and property remains for flood events that exceed a one percent likelihood.

Transformed risk is defined by the USACE as the change in nature of flood risk for an area associated with the presence of flood hazard reduction infrastructure. Flood risk is often reduced by the construction of flood mitigation structures but, as a result, may also be 'transformed' into a different type of risk; for example, in the form of risk from structural failure of that mitigation infrastructure (e.g., a dam or levee).

Residual risks by nature have a low probability of occurrence. Keeping residual risks low requires continued maintenance of FMPs and effective emergency services for preparedness, response, and recovery as a holistic approach.

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Post-Project Risk

Post-project risk analysis is typically utilized to gather information for evaluating the final risk impacts at the completion of a project. A report of the post-project risk analysis informs individuals and decision-makers with a general idea of what worked well and what did not in the Project Management Plan, so future projects can benefit from the lessons learned. The post-project information can be used to prioritize a list of recommended FMPs with a set of criteria, including:

- Post-project 100-year flood risk reduction
- Post-project 100-year critical facilities damage reduction
- Post-project 100-year flood damage reduction
- Post-project improvement of mobility

Post-Project 100-year Flood Risk Reduction

After a project is constructed, the analysis indicates the reduced flood risk by percentage of structures removed from a 100-year floodplain in the post-project condition, using the data of

- 100-year floodplain shapefiles with elevations in the pre- and post-project conditions
- Structures within the 100-year floodplains in the pre- and post-project conditions
- Land elevations and structure shapefiles
- Other available data

Post-Project 100-year Flood Damage Reduction

After construction, the analysis indicates flood damage reduction (property protection) by a percentage of 100-year damage reduction calculation using:

- Data of average depth of a 100-year flood in the pre-project condition
- Shapefiles, elevations, or average depth/reduction of the 100-year flood in the post-project condition
- Shapefiles, land elevations, and structure shapefiles
- Other available data

Post-Project 100-year Critical Facilities Damage Reduction

Following construction, the analysis indicates reduced flood risk by percentage of critical facilities removed from a 100-year floodplain in the post-project condition using the data of:

- Average depth of the 100-year flood in the pre-project condition
- Floodplain shapefile, elevations, or average depth/reduction of the 100-year flood in the post-project condition

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- Critical facilities in the 100-year floodplains in the pre- and post-project conditions

Mobility

This criterion indicates project improvement and protection of mobility during flood events, with particular emphasis on emergency service access and other major access routes, using the data of:

- 100-year floodplain shapefile with elevations in the pre- and post-project conditions
- TxDOT Functional Classification Shapefile
- Project shapefiles and other available data

Future Risks

Future flood risks shall be determined considering three components:

- Flood hazards in future condition
- Additional exposure and vulnerability
- Operations and maintenance (O&M) and design standards

Flood Hazards in Future Condition

Future risk analyses of FMPs should consider the changes in flood risks in future conditions. The factors that may result in altered flood hazards include increase of impervious surface cover, change in sea level and/or land subsidence, anticipated erosion, and sedimentation in flood control structures. In particular, any future flood risk analysis should consider potential effects of climate change on future rainfall patterns, flood frequency, and magnitude, which will possibly lead to substantial increases in future flood risks over areas with greater population.

Information from existing resources like H&H model results and maps should be summarized with details in terms of the source of flood hazard data, associated dates, timeframe of future conditions (fully developed land use conditions, 30-year, 50-year, etc.), and a brief description of each existing dataset compiled for flood hazard analysis.

Additional Exposure and Vulnerability

Exposure and vulnerability analyses identifies the existing and future flood hazard areas if the current development practices continue in the region of FMPs. According to ***Chapter 2*** of this plan, a rapid increase of structures and population is projected in the Trinity Region over the next 30 years. This implies that potential exposure and vulnerabilities of the population, structures, critical facilities, and public infrastructure to the flood hazards may increase. While future condition floodplain maps cannot be used for emergency operation and insurance rating purposes, they can be used to enhance public awareness of future flood risks, exposure, and

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vulnerability. The detailed information of flood exposure and vulnerability analyses for the future conditions are included in ***Chapter 2*** of this plan.

Operations and Maintenance and Design Standards

O&M, as well as the standards of public infrastructure design can greatly distress future flood risks. FMPs can fail to function as designed due to improper operations and poor maintenance. Examples of the catastrophic dam failures include the Oroville Dam in California in 2017 and Edenville Dam in Michigan in 2020, which both resulted in massive floods from the combination of intense rainfall events and lack of maintenance.

Future risks of structural failures can increase if the FMPs are not properly managed and maintained. Thus, re-evaluation of the design standards and requirements of O&M of FMPs should be considered to reduce future risks. Minimum and most stringent specifications of the design standards of FMPs should be followed to prepare for flood hazard in the future.

Implementation Issues of Flood Mitigation Projects

Project implementation issues include conflicts pertaining to right of way, permitting, acquisitions, utility, or transportation relocations, amongst other issues that might be encountered before an FMP is able to be fully implemented. Such issues are an inherent part of FMPs.

Because a right of way is a public path across private land, it can create issues when securing access to projects for construction and maintenance. The acquisition of right of way or utility relocation located near or on property impacted by a project requires close coordination between the state, cities, counties, and other forms of local government, as well as private entities and landowners. Coordination with the appropriate entities is key to facilitating projects. The Right of Way Division of Texas Department of Transportation (TxDOT) coordinates the acquisition of land to build, widen, or enhance highways, and provides relocation assistance when needed.

Most FMPs will require a variety of permits so that they are following best practices, meeting code requirements, following regulations, and adhering to the laws and regulations. During the implementation of any project, the goal is to obtain and acquire all necessary and required permits and approvals as efficiently as possible. Although acquiring permits can also be a lengthy process, it is an essential step in any FMP.

The terms "buyout" and "acquisition" are often utilized interchangeably, but in the context of flood protection, both refer generally to the purchase of private property by the government for public use. After properties are purchased through a buyout program, the land is converted to open space. In the case of flood acquisitions, the process involves the purchase of a property

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in a floodplain to reduce the damage of future flooding on the site and/or for properties adjacent to the one being acquired.

Voluntary property acquisition is not a simple process and requires agreement by the property owner and local jurisdiction. If state or federal funding is involved, then the property acquisition could also include other governmental officials, the state, and federal agencies. Voluntary buyout programs are a specific subset of property acquisitions in which private lands are purchased, existing structures are demolished, and the land is returned to its natural undeveloped state for public use in perpetuity. Buyouts are voluntary and no one is required to sell their property which provides no guarantee of acquisition. The process can also be financially burdensome and lengthy.

Additional issues can arise with utility relocation. Utilities may include water lines, wastewater lines, storm drain systems, telecommunications, power lines, and other similar infrastructure. Utilities may be buried below the surface, attached to the side of bridges, or suspended aerially. Utilities located in a road or highway right of way may need to be relocated to allow for construction of a mitigation project. The local government is usually responsible for utility relocations; however, TxDOT may assume responsibility, particularly for projects along the state highway system. Developers may also assume responsibility for utility relocations depending on the project. Utility relocation means the adjustment of a utility facility required for the construction of a project. It includes removing and reinstalling the facility, including necessary, temporary facilities; acquiring necessary right of way on new location; moving, rearranging, or changing the type of existing facilities; and taking any necessary safety and protective measures. Such measures can be time consuming as well as costly.

Potential Funding Sources

A wide variety of funding opportunities could be utilized to fund the identified actions. Traditionally, stormwater funding sources have been locally sourced (user fees or general taxes) or state or federal grants. While low-interest loan programs do provide for additional funding, few local entities choose this option due to the lack of a dedicated funding source sufficient to cover debt service. Therefore, many communities adopt a “pay-as-you-go” method of funding stormwater projects or, in the event of a disaster, apply for state and federal disaster recovery grants. Today, communities have a broader range of funding sources and programs that include the mentioned options plus recently created mitigation grant and loan programs, such as the FEMA Building Resilient Infrastructure and Communities (BRIC) and the TWDB FIF. The potential funding sources for the identified FMEs, FMPs, and FMSs are listed in ***TWDB-Required Tables 12**, **13,*** and ***14***, respectively (see ***Appendix A***). Further details on funding opportunities and the anticipated funding sources for the recommended actions are included in ***Chapter 9***.

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Bibliography

FEMA. (2005, October). *National Flood Insurance Program: Frequently Asked Questions*. Retrieved from FEMA: https://www.fema.gov/txt/rebuild/repetitive_loss_faqs.txt

FEMA. (2022). Title 44 - Emergency Management and Assistance. In F. E. Agency, *Code of Federal Regulations* (pp. 50-149). Washington, D.C.: National Archives and Records Administration.

FEMA Cooperating Technical Partners. (2017). *Estimating the Value of Partner Contributions to Flood Mapping Projects.* Federal Emergency Management Agency, Cooperating Technical Partners. Atlanta: Federal Emergency Management Agency. Retrieved from https://www.fema.gov/sites/default/files/documents/fema_risk-map_blue-book_2017.pdf

Leber, N., Holmquist, H., Iqbal, K., Duty, J., Pruitt, E., & Crouse, L. (2022). *Volumetric and Sedimentation Survey of Lake Livingston.* Arlington: Trinity River Authority.

Li, Z., Passalacqua, P., & Hodges, B. R. (2018). *Hydrodynamic Model Development for the Trinity River Delta.* Austin : Texas Water Development Board.

Mangham, W., Osting, T., & Flores, D. (2015). *LiDAR Acquisition and Flow Assessment fo rthe Middle Trinity River.* Arlington: Trinity River Authority.

NCEI. (2022). Storm Events Database. Washington, D.C., District of Columbia, United States of America.

NWS. (2021). *Storm Data Preparation.* National Oceanic and Atmospheric Administration.

Quigg, A., & Steichen, J. (2015). *Defining Bioindicators for Freshwater Inflow Needs Studies.* Galveston: Texas Water Development Board.

Quigg, A., & Steichen, J. (2018). *Defining Bioindicators for Freshwater Inflow Needs Studies Phase 2: Defining a Sound Ecological Environment for Galveston Bay.* Galveston: Texas Water Development Board.

TCEQ. (2020). *2020 Texas Integrated Report - Assessment Results for Basin 8 - Trinity River Basin.* Austin: Texas Commission on Environmental Quality.

TFMA Higher Standards Committee. (2018). *A Guide for Higher Standards in Floodplain Management.* Texas Flooplain Management Association.

TRA. (2020). *2020 Basin Summary Report.* Arlington: Texas Commission on Environmental Quality.

Draft Amended Plan

TWDB. (2021, July 27). *Flood Planning Data*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/data.asp

TWDB. (2021, July 22). *TWDB Flood Planning Frequently Asked Questions*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/faq.asp

United Nations Office for Disaster Risk Reduction. (2020). *2020 Annual Report.* Geneva: United Nations.

United States CDC. (2018). CDC/ATSDR Social Vulnerability Index. Washington, D.C., District of Columbia, United States of America.

United States Census Bureau. (2020, March 3). 2020 United States Census Results. Washington, D.C., District of Columbia, United States of America.

URS Group, Inc. (2009). *BCA Reference Guide.* Washington, D.C.: Federal Emergency Management Agency.

Wang, X., White, M., Lee, T., Tuppad, P., Srinivasan, R., Jones, A., & Narasimhan, B. (2010). *Trinity River Basin Environmental Restoration Initiative 2010.* Arlington: Texas Water Development Board.

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