Final Report: Caldwell County Flood Protection Planning Study

(Source: MySanAntonio.com)

Prepared For:

Caldwell County, Texas

Prepared By:

Doucet, A Kleinfelder Company

Langford Community Management Services

In Association With:

Texas Water Development Board

GBRA Guadalupe-Blanco River Authority

April 15, 2024

Texas Water Development Board Contract 40012

Final Report: Caldwell County Flood Protection Planning Study

Texas Water Development Board Contract 40012

Prepared For:

Caldwell County, Texas
110 South Main
Lockhart, Texas 78644

Prepared By:

Colin Slagle, P.E., CFM
Jonathan Carey, P.E., CFM
Doucet, A Kleinfelder Company
7401B Hwy 71 West, Suite 160
Austin, Texas 78735
Phone: (512) 583-2600
www.doucetengineers.com
TBPELS Engineering Firm No. F-3937
TBPELS Surveying Firm No. 10194551

Langford Community Management Services
9017 W. State Hwy 29, Suite 206
Liberty Hill, Texas 78642
Phone: (512) 452-0432
Fax: (512) 452-5380
www.lcmsinc.com

April 15, 2024

Acknowledgements

Doucet, A Kleinfelder Company would like to thank the following individuals for their key contributions to the Caldwell County Flood Protection Planning Study:

- Texas Water Development Board
    - Malcolm Hamilton, P.E., CFM – Project Manager
- Caldwell County
    - Honorable Hoppy Haden – County Judge
    - Amber Quinley – Grants Administrator
    - Dennis Engelke – Grants Administrator (Retired November 2023)
- Langford Community Management Services, LLC
    - Judy Langford – Grant Administration
    - Paula Rodriguez – Grant Administration
    - Melisa Durham – Environmental Assessment
- Region 10 Lower Colorado-Lavaca Regional Flood Planning Group
    - Mike Personett – Halff Associates, Inc. – Technical Consultant
- Region 11 Guadalupe Regional Flood Planning Group
    - Jay Scanlon, P.E., CFM – Freese & Nichols, Inc. – Technical Consultant

Table of contents

List of appendices

List of tables

List of figures

Executive Summary

The Caldwell County Flood Protection Planning Study (FPPS) provides flood hazard mitigation assessment and stormwater planning for high-priority watersheds affecting the County, including Plum Creek, Walnut Creek-Cedar Creek, Upper San Marcos River, and Lower San Marcos River. Funding is provided, in part, through a grant from the Texas Water Development Board (TWDB) Flood Infrastructure Fund (FIF) Commitment No. G1001276 with local funding from Caldwell County. The key stakeholders and the percentage of funding provided are summarized below:

- Texas Water Development Board – 75%
- Caldwell County – 25%

Through this FPPS, Caldwell County sought to complete a detailed analysis of the study area to identify existing and future flood prone areas and develop a flood protection plan to mitigate flood problems. The study scope of work included the following items:

- Project management
- Collection and review of baseline information
- Assessment of environmental constraints
- Initial identification of flood problem areas
- Field survey and measurements
- Hydrologic modeling
- Hydraulic modeling
- Final identification of flood problem areas, establishment of flood protection criteria, and evaluation of flood mitigation alternatives
- Hydrologic and hydraulic analyses of flood mitigation alternatives
- Benefit-cost analysis of flood mitigation alternatives
- Flood early warning system and response planning
- Implementation and phasing plan
- Final report

To assess existing flood hazards within the County, new and updated hydrologic and hydraulic models were developed reflecting Atlas 14 rainfall data for approximately 519 square miles of drainage area and approximately 357 stream miles, as detailed in **Table ES-1** and shown in **Figure ES-1**. Detailed hydrologic models were developed using HEC-HMS version 4.3 for the Plum Creek watershed and version 4.9 for the Walnut Creek-Cedar Creek, Upper San Marcos, and Lower San Marcos watersheds. Detailed hydraulic models were developed for all study streams using HEC-RAS version 6.3. The 20-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance exceedance (5-, 10-, 25-, 50-, 100- and 500-year return period) storm events were analyzed.

Table ES-1. Study area summary by HUC-10.

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	---	Plum Creek	PLC	42.7	37
Plum Creek (PLC)	389.3	Brushy Creek (BRU)	Brushy Creek	BRU	4.7	3
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Rabbit Branch	RAB	1.9	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek	ELC	9.1	9
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 1	ELC_T01	1.6	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 2	ELC_T02	2.1	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek	COW	7.6	4
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek Trib 1	COW_T01	2.5	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Plum Creek Trib 4	PLC_T04	1.7	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Cottonwood Creek	COT	2.9	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Jerry Creek	JER	4.6	3
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Dry Creek	DRY	13.9	6
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Plum Creek Trib 3	PLC_T03	1.7	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek	CLFP	23.8	21
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek Trib 1	CLFP_T01	2.8	1
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Brushy Branch	BRB	3.5	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Dry Branch	DRB	9.3	6
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Boggy Creek	BOC	6.3	6
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Little West Fork Plum Creek	LWF	1.9	1
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	West Fork Plum Creek	WFP	21.3	8
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Pin Oak Creek	PIN	8.1	3
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Daniels Creek	DAN	6.2	2
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek	TEN	11.9	5
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek Trib 1	TEN_T01	4.2	1
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Copperas Creek	COP	5.1	3
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Hines Branch	HIN	6.7	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2	DR2	10.2	2
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 1	DR2_T01	1.8	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 2	DR2_T02	1.9	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Linscome Creek	LIN	5.0	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Spanish Oak Creek	SPA	3.3	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Pecan Branch	PCB	4.7	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 1	PLC_T01	2.3	3
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 2	PLC_T02	1.9	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	McNeil Creek	MCN	8.0	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch	SLT	7.6	13
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Trib 1 to Salt Branch Trib 1	SLT_T01_01	1.5	1

Table ES-1. Study area summary by HUC-10 (continued).

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch Trib 1	SLT_T01	4.5	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek	CED	7.2	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek Trib 1	CED_T01	3.2	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Lytton Springs Creek	LSC	4.1	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek	LYT	4.0	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek Trib 1	LYT_T01	4.1	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Walnut Creek	WAL	10.8	4
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Haggai Creek	HAG	4.7	3
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Bee Creek	BEE	4.2	1
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Cat Branch	CAT	4.0	2
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Morrison Creek	MOR	10.1	8
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Hemphill Creek	HEM	7.0	4
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Callihan Creek	CAL	7.0	3
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Dickerson Creek	DIC	7.9	3
Lower San Marcos River (LSM)	20.8	Seals Creek (SEA)	Seals Creek	SEA	13.9	7
TOTAL	**519.0**	---	---	**---**	**356.8**	**208**

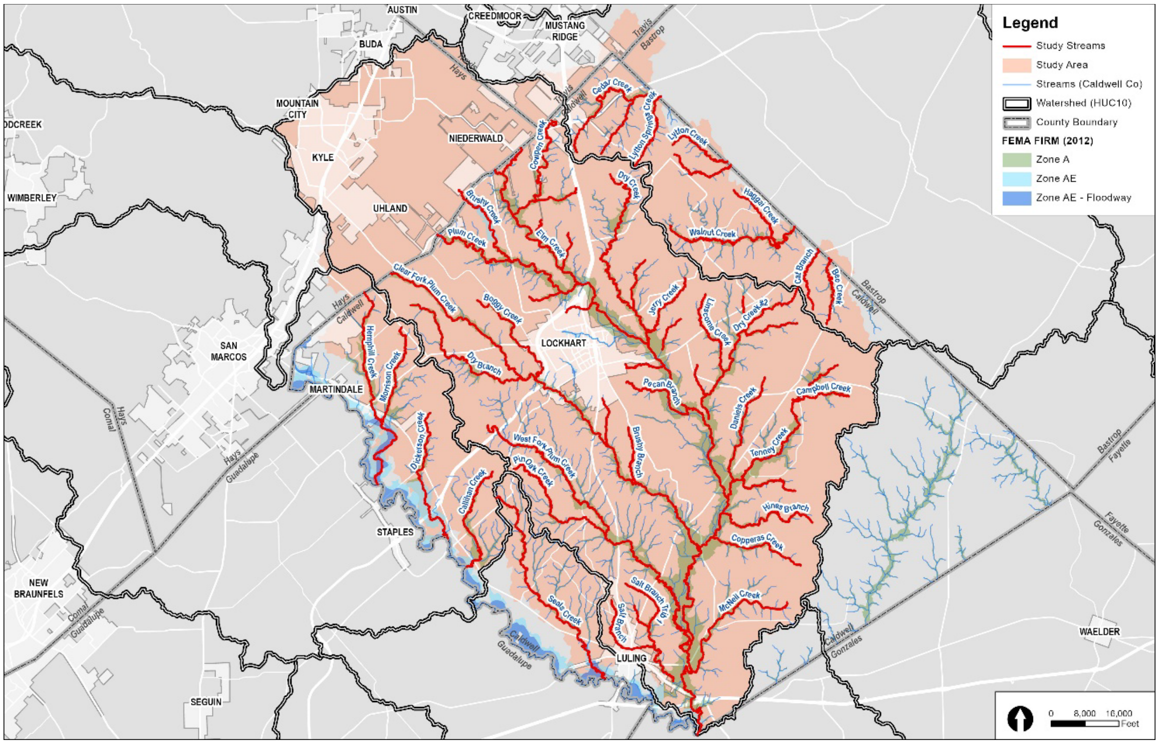

Figure ES-1. Project study area map.

Updated floodplain mapping for the 1% and 0.2% storm events was developed for the study reaches, which included a total of 53 streams and tributaries. While these updated models and floodplain boundaries will not supersede the effective FEMA data, communities within Caldwell County will be able to use them as “best available data” for regulatory and planning purposes.

In addition to the modeling efforts, public outreach was an essential component of this study and was the primary source of information for identifying high-priority flood problem areas in Caldwell County. This input was obtained through coordination with community officials, as well as three public meetings attended by residents with knowledge on flood prone areas.

The FPPS identified 14 recommended Flood Mitigation Project (FMPs) throughout the study area with a total of $129,907,256 in estimated construction costs. These recommended FMPs include upgrades to existing low-water crossings to improve their levels-of-service, as well as channel improvements to mitigate flooding of commercial and residential structures. Using criteria developed for the TWDB Regional Flood Planning efforts, an effort was made to prioritize the FMPs based on the severity of the flood hazards being addressed and the level of benefit they provide. In addition to the 14 FMPs, 20 other areas were recommended as Flood Management Evaluations (FMEs) for additional study and evaluation. This identification of projects and associated prioritization is intended to aid the stakeholders and communities in the selection of future flood hazard mitigation projects. A summary of the proposed flood mitigation projects and recommended evaluations is provided in **Table ES-2**.

Table ES-2. Summary of recommended Flood Mitigation Projects and Flood Management Evaluations.

Flood Problem Area Priority	Flood Problem Area Name	Flood Mitigation Action Type	Estimated Cost
1	SH 80 Low Water Crossing Improvements @ Morrison Creek	Project	$20,224,000
2	Hemphill Creek Drainage Improvements Near FM 1984	Project	$19,790,000
3	CR 233 and FM 2001 @ Plum Creek	Project	$7,934,000
4	US 183 @ Clear Fork Plum Creek	Project	$16,501,000
5	Brushy Creek Channel Improvements Near Las Estancias II	Project	$9,622,000
6	Plum Creek Channel Improvements Near CR 227	Project	$5,587,000
7	CR 227 @ Brushy Creek	Project	$3,504,000
8	CR 141 @ Hines Branch	Project	$2,893,000
9	Salt Branch Drainage Improvements in Luling	Project	$5,798,000
10	Cedar Creek Channel Improvements Near Christian Drive	Project	$14,654,000
11	CR 218 @ Boggy Creek and Clear Fork Plum Creek	Project	$7,836,256
12	CR 170 Low Water Crossing Improvements @ Lytton Creek	Project	$4,877,000
13	CR 172 Low Water Crossing Improvements @ Lytton Creek	Project	$4,574,000
14	Boggy Creek Channel Improvements Near SH 142	Project	$6,113,000
15	CR 175 @ Cedar Creek Tributary 1	Evaluation	$40,000
16	Lytton Springs Creek Near CR 174	Evaluation	$40,000
17	Plum Creek Near US 183 and I-10 Intersection	Evaluation	$50,000
18	FM 1322 @ Plum Creek	Evaluation	$50,000
19	CR 146 @ Plum Creek	Evaluation	$50,000
20	CR 230 @ Clear Fork Plum Creek	Evaluation	$60,000
21	CR 159 @ Spanish Oak Creek	Evaluation	$50,000
22	Cowpen Creek Near Dove Hill Drive	Evaluation	$50,000
23	CR 221 and CR 233 @ Elm Creek	Evaluation	$50,000
24	McMahan VFD @ Tenney Creek	Evaluation	$50,000
25	Rolling Oaks @ Ebbon Road	Evaluation	$50,000
26	Hemphill Creek Between SH 142 and SH 80	Evaluation	$50,000
27	Dickerson Creek Near CR 111	Evaluation	$50,000
28	CR 103 @ Morrison Creek	Evaluation	$50,000
29	CR 208 @ Plum Creek	Evaluation	$50,000
30	Mebane Creek Channel Improvements	Evaluation	$50,000
31	Mebane Creek Floodwall	Evaluation	$50,000
32	Town Branch Detention	Evaluation	$60,000
33	Caldwell County Flood Early Warning System	Evaluation	$50,000
34	Assessment of Property Buyout Alternatives	Evaluation	$40,000

1 Introduction

The Caldwell County Flood Protection Planning Study (FPPS) provides flood hazard mitigation assessment and stormwater planning for high-priority watersheds affecting the County, including Plum Creek, Walnut Creek-Cedar Creek, Upper San Marcos River, and Lower San Marcos River.

1.1 Key stakeholders

Funding is provided, in part, through a grant from the Texas Water Development Board (TWDB) Flood Infrastructure Fund (FIF) Commitment No. G1001276 with local funding from Caldwell County. The key stakeholders and the percentage of funding provided are summarized below:

- Texas Water Development Board – 75%
- Caldwell County – 25%

1.2 Description of project area

Covering a total project area of 519 square miles, this FPPS included the development of new hydrologic and hydraulic models for streams within the following HUC-10 basins:

- Plum Creek
- Walnut Creek-Cedar Creek
- Upper San Marcos River
- Lower San Marcos River

The study area primarily lies within Caldwell County and Hays County with some coverage extending into Bastrop County, Gonzales County, and Travis County. Existing land uses largely consist of rural, undeveloped land with urbanized areas in the cities of San Marcos, Lockhart, and Luling. New hydraulic models were developed for a total of 356.8 stream miles on 53 streams and tributaries within Caldwell County. Please see **Figure 1-1** and **Table 1-1** for a summary of the study areas by HUC-10.

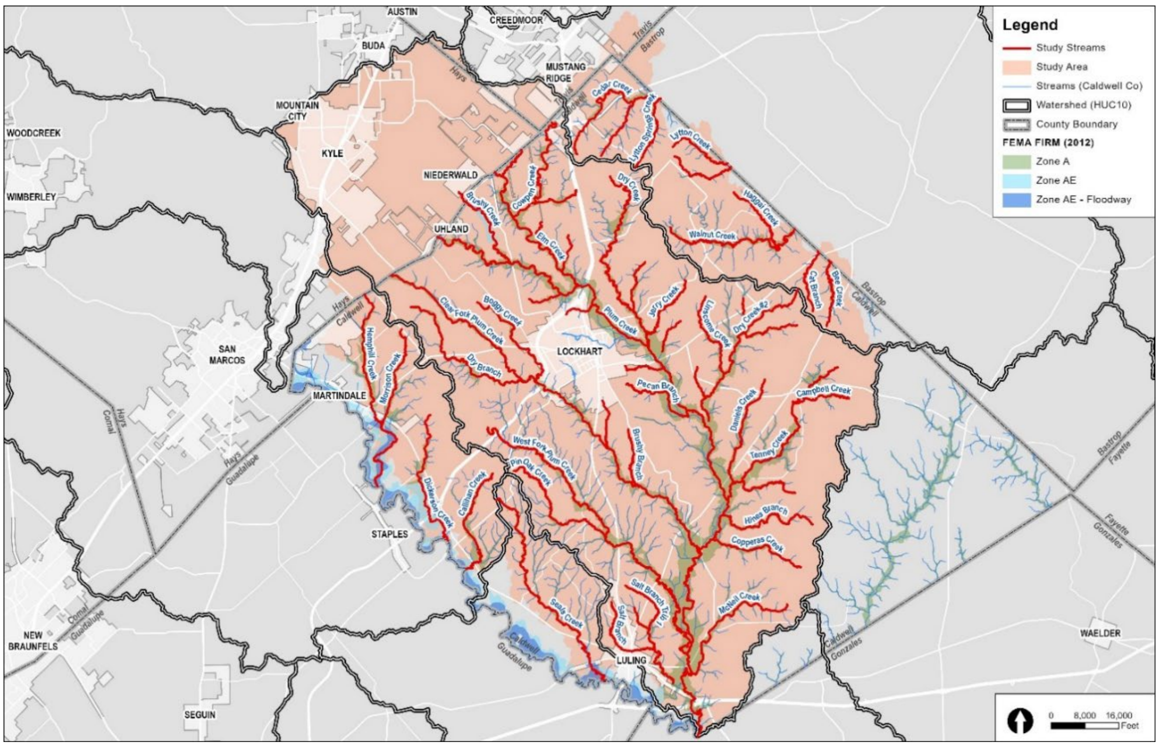

Figure 1-1. Project study area map.

Table 1-1. Study area summary by HUC-10.

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	---	Plum Creek	PLC	42.7	37
Plum Creek (PLC)	389.3	Brushy Creek (BRU)	Brushy Creek	BRU	4.7	3
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Rabbit Branch	RAB	1.9	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek	ELC	9.1	9
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 1	ELC_T01	1.6	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 2	ELC_T02	2.1	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek	COW	7.6	4
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek Trib 1	COW_T01	2.5	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Plum Creek Trib 4	PLC_T04	1.7	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Cottonwood Creek	COT	2.9	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Jerry Creek	JER	4.6	3
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Dry Creek	DRY	13.9	6
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Plum Creek Trib 3	PLC_T03	1.7	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek	CLFP	23.8	21
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek Trib 1	CLFP_T01	2.8	1
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Brushy Branch	BRB	3.5	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Dry Branch	DRB	9.3	6
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Boggy Creek	BOC	6.3	6
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Little West Fork Plum Creek	LWF	1.9	1
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	West Fork Plum Creek	WFP	21.3	8
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Pin Oak Creek	PIN	8.1	3
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Daniels Creek	DAN	6.2	2
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek	TEN	11.9	5
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek Trib 1	TEN_T01	4.2	1
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Copperas Creek	COP	5.1	3
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Hines Branch	HIN	6.7	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2	DR2	10.2	2
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 1	DR2_T01	1.8	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 2	DR2_T02	1.9	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Linscome Creek	LIN	5.0	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Spanish Oak Creek	SPA	3.3	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Pecan Branch	PCB	4.7	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 1	PLC_T01	2.3	3
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 2	PLC_T02	1.9	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	McNeil Creek	MCN	8.0	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch	SLT	7.6	13
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Trib 1 to Salt Branch Trib 1	SLT_T01_01	1.5	1

Table 1-1. Study area summary by HUC-10 (continued).

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch Trib 1	SLT_T01	4.5	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek	CED	7.2	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek Trib 1	CED_T01	3.2	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Lytton Springs Creek	LSC	4.1	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek	LYT	4.0	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek Trib 1	LYT_T01	4.1	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Walnut Creek	WAL	10.8	4
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Haggai Creek	HAG	4.7	3
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Bee Creek	BEE	4.2	1
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Cat Branch	CAT	4.0	2
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Morrison Creek	MOR	10.1	8
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Hemphill Creek	HEM	7.0	4
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Callihan Creek	CAL	7.0	3
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Dickerson Creek	DIC	7.9	3
Lower San Marcos River (LSM)	20.8	Seals Creek (SEA)	Seals Creek	SEA	13.9	7
TOTAL	**519.0**	---	---	**---**	**356.8**	**208**

1.3 Description of project scope

Through this FPPS, Caldwell County sought to complete a detailed analysis of the study area to identify existing and future flood prone areas and develop a flood protection plan to mitigate flood problems. The objective of the planning effort was to provide the participating communities with the following:

- An accurate assessment of the hydrologic and hydraulic conditions of the subject watersheds and streams
- A practical storm water management plan to address the critical flooding problems
- An important tool to manage growth and development.

A detailed description of the planning study scope of work is presented in the following sections.

1.3.1 Project management

A kick-off meeting with Caldwell County, the TWDB project manager, and the representatives from the participating entities was held on July 23, 2021 to cover the following topics:

- Project communication & reporting responsibilities to establish the frequency and method of interfacing with the TWDB project manager, Caldwell County project manager, and the representatives from the participating entities;
- Project milestones and schedule; and
- Project deliverables at each milestone.

During the course of the study, project progress reports were submitted to TWDB at a minimum interval of quarterly (once every 3 months). Project progress meetings were also conducted on a monthly basis. Meeting agendas included the following:

- Tasks accomplished since last meeting
- Discussion of issues discovered, if any
- Tasks to be performed
- Project schedule status
- Budget status

Three (3) public meetings were also conducted by the project team: one to solicit input on initial flood problem area identification, one following development of flood mitigation alternatives, and one upon development of the final report.

1.3.2 Collection and review of baseline information

The project team collected and reviewed previous drainage studies, FEMA Flood Insurance Study (FIS) and maps, FEMA LOMRs, master plans, drainage studies and reports, citizen drainage complaint reports, storm damage reports, field survey data, as-built information, and other relevant data within the planning area.

A base map was developed using the following information:

- Current FEMA FIS and Flood Insurance Rate Map (FIRM)
- Digital GIS data of parcels, zoning maps, current land use maps, and soils maps;
- As-builts drawings for channel and bridge/culvert improvements;
- Most current LiDAR topography; and

- Approved LOMRs since the 2012 FIRM update

1.3.3 Assessment of environmental constraints

This project included a record review and data research of Critical Environmental Features (CEF) within the study area. These features are generally defined as springs, bluffs, canyon rimrocks, caves, sinkholes & recharge features and wetlands.

This task did not include detailed field survey, investigation, and determination of CEFs, but rather established the framework for the requirements of environmental assessment during the implementation and final design phase of the flood mitigation measures.

1.3.4 Initial identification of flood problem areas

Based on the previous drainage studies, reports, and other baseline data, known flood problem areas were identified. Caldwell County and the participating communities conducted a public meeting to solicit input on the drainage problem areas including the specifics and nature of the flooding.

1.3.5 Field survey and measurements

Caldwell County utilized best available LiDAR data including 2017 Central Texas StratMap and 2019 USGS Hurricane datasets. In addition, this study included budget to obtain field survey and measurement data for critical regional detention facilities, bridge/culvert crossings, cross sections and finished floor elevations, as needed to support future Zone AE FIRM updates. Use of existing field survey data available from participating communities were incorporated where applicable.

1.3.6 Hydrologic modeling

Doucet developed GIS geo-referenced hydrologic models using the USACE HEC-HMS computer program, including the program's built-in geospatial tools. Hydrologic rainfall-runoff models were developed based on existing watershed conditions. The following information was incorporated into the HEC-HMS models:

- SCS flood control reservoirs and regional detention facilities;
- FEMA LOMR hydrologic models; and
- Other large scale storm water impoundment facilities (more than 20 acres in surface area).

The hydrologic model input parameters were developed based on the following approach.

- Terrain Processing – Caldwell County utilized best available LiDAR data including 2017 and 2019 USGS Hurricane datasets, ESRI ArcGIS Pro, and HEC-HMS tools to develop a digital terrain model (DTM) to support hydrologic model development.
- Rainfall data – NOAA Atlas 14, Volume 11, Version 2 precipitation frequency estimates were applied using a frequency storm distribution in HEC-HMS. The 5-, 10-, 25-, 50-, 100- and 500-year frequency storm events were modeled. For drainage subareas greater than 10 square miles, a depth areal reduction was applied based on TP-40 methodology.
- Drainage Area – Hydrologic subbasins were delineated using the DTM, ESRI ArcGIS Pro, and HEC-HMS tools.

- Runoff Loss Method – The Initial and Constant Rate (Block and Uniform) loss method was used to compute runoff losses within each subbasin. These loss rates were assigned to each subbasin using area weighted percent sand and percent clay values. The default loss rates for sand and clay varied for each design frequency storm events based on the 1986 USACE NUDALLAS methodology, consistent with other studies in the region (e.g., 2015 USACE Plum Creek Study).
- Unit Hydrograph Method – The Snyder Unit Hydrograph method was used to develop runoff hydrographs within HEC-HMS. The Snyder Unit Hydrograph method is the primary method utilized by the Corps of Engineers Fort Worth District for the majority of hydrologic studies in the region. The Snyder method requires two parameters, the Snyder standard lag and the Snyder peaking coefficient (Cp). Snyder's lag values were developed using the USACE Fort Worth District Urbanization Curve methodology with HEC-HMS and ESRI ArcGIS Pro tools. Snyder peaking coefficients were developed based on previous studies within the region (e.g., 2015 USACE Plum Creek Study).
- Hydrograph Routing – For the study reaches and other reaches where existing hydraulic models were available, the Modified Puls routing method was used to account for peak flow and timing attenuation along the stream. For reaches without existing hydraulic models, the Muskingum-Cunge was applied for hydrograph routing.
- Model Calibration – The hydrologic models were calibrated to peak discharges recorded during historic storm events at USGS gauges or other data sources.

1.3.7 Hydraulic modeling

Doucet developed GIS geo-referenced hydraulic models using the USACE HEC-RAS computer program, including the geospatial tools available in the HEC-RAS Mapper module. The HEC-RAS hydraulic models covered all the stream miles identified in **Table 1-1**. The hydraulic model input parameters and modeling procedures are presented as follows:

- Peak discharges from the HEC-HMS junctions were specified at the appropriate cross sections.
- Manning's roughness coefficients ("n") were established based on field reconnaissance, aerial photos and standard engineering reference tables or publications.
- Field survey and/or measurements were performed for major detention facilities and roadway crossings where no as-built information was available.
- Other HEC-RAS parameters, such as "ineffective flow areas", "expansion/contraction coefficients" and "bridge/culvert energy loss coefficients" were used as appropriate.

1.3.8 Final identification of flood problem areas, establishment of flood protection criteria, and evaluation of flood mitigation alternatives

Based on the collected baseline information and results of the hydraulic models, flood problem areas were identified and evaluated. Regional Flood Planning criteria from TWDB were used to assist in the evaluation and prioritization of flood problem areas. These factors included, but were not limited to:

- Number of affected structures with consideration of flood depth and frequency;
- Roadway overtopping with consideration of flood depth and frequency;
- Risk to life and safety;

- Availability of alternative evacuation routes; and
- Potential environmental constraints

For the flood problem areas identified, the structural flood mitigations measures like the following were evaluated for feasibility at each location:

- Detention/Retention Facilities;
- Channel Improvements using the Natural Channel Method;
- Roadway Bridge/Culvert Improvements;
- Levees/Berms/Floodwalls; and
- Combination of any of two or more of the above.

Non-structural solutions, such as the following, were also considered:

- Updates to the Caldwell County and participating community's drainage criteria (if applicable) and existing land development ordinance if necessary;
- Buy-outs of the flooded properties;
- Installation of Early Flood Warning systems;
- Installation of flood warning signs and barricades at frequent inundated roadway crossings; and
- Develop public information publications describing flood risks and flood insurance.

1.3.9 Hydrologic and hydraulic analyses of flood mitigation alternatives

The flood mitigation alternatives were modeled using 2D HEC-RAS models for various hypothetical flood events following TWDB Regional Flood Planning guidelines. Existing and proposed conditions for low-water crossings were generally assessed for the 2-, 10-, and 100-year storm events. In cases where there were no existing damages in the 2-year storm, the 10-, 25-, and 100-year storm events were used for the analyses. Conceptual flood control measures were developed and added to the hydraulic models as appropriate to evaluate the flood mitigation potential.

Flood mitigation alternatives were evaluated not only at the problem area (to reduce the levels of flooding) but also upstream and downstream of the problem area to ensure no adverse hydrologic/hydraulic impacts at other locations in the watershed.

1.3.10 Benefit-cost analysis of flood mitigation alternatives

The flood mitigation alternatives identified by the study were evaluated and selected based on their cost-effectiveness and overall feasibility. Caldwell County performed a benefit/cost analysis for each flood mitigation alternative following the TWDB Regional Flood Planning guidelines.

A public meeting was conducted to obtain citizen and stakeholder input on the proposed flood mitigation alternatives and the results of the benefit/cost analysis. To the extent possible, citizen and stakeholder concerns were incorporated.

1.3.11 Flood early warning system and response planning

The goal of the Flood Early Warning effort was to review existing gage and flood early warning equipment in-place, evaluate software and hardware required to develop and/or improve flood early warning system effectiveness, develop long term funding strategies for the overall system, coordinate with local participating entities on desired end products associated with Flood Early Warning, and discuss budget implications to implement a successful long term flood early warning system for this area. This effort included coordination with other outside entities involved in recent extreme floods to develop a list of "lessons learned" that can be applied to this watershed area.

1.3.12 Implementation and phasing plan

Based on input from the public meeting, a project implementation and phasing plan was developed. The implementation and phasing plan considered items such as funding sources, project location, project timing, community priorities, and benefit-cost ratio.

1.3.13 Final report

A draft final report summarizing the results of the hydrologic/hydraulic investigations, flood mitigation alternatives, benefit/cost analysis and stakeholder input was developed. The draft report included technical descriptions of hydrologic/hydraulic analyses, methodologies, assumptions, and modeling notes, as well as improvement alternative costs, easement requirements (if applicable), phasing and implementation plan, floodplain maps and other applicable exhibits.

A final public meeting was conducted to present the draft final report. Following the public meeting and incorporation of public input, the draft final report was submitted to TWDB for review. Upon addressing TWDB review comments, the final report was submitted to TWDB.

2 Project background

Damages sustained during significant flood events in recent decades, as well as the need for updated flood hazard data, led Caldwell County to undertake this flood protection planning study. To create the framework for the study, relevant historical and technical data were acquired from various sources and reviewed. Some of these data, such as existing hydrologic and hydraulic models, were leveraged in this study where appropriate.

2.1 Need for project

Caldwell County has been subject to extreme flooding including catastrophic events in October 1998, November 2011, October 2013, May 2014, multiple events in 2015 & 2016 and August 2017 (Hurricane Harvey). From 1996 to 2019 alone, floods in Caldwell County have resulted in 11 lives lost and more than $170M in damages. Following Hurricane Harvey in 2017, thousands of families were impacted when stream crossings became unpassable for up to two weeks. Inadequate roadway drainage infrastructure at many stream crossings across the County result in roadway overtopping during frequent, light rainfall events, resulting in regular disturbances in emergency services availability (i.e., fire, medical, and law enforcement), school bus routes, and public access to homes and businesses.

Based on recorded historical flood occurrences within Caldwell County and immediately surrounding areas, the 2020 HMAP estimates a probability of occurrence of at least three (3) to four (4) events per year (i.e., highly likely) in the future with an average annual loss estimate of $7.4M. During these events, Caldwell County could anticipate "minor" impacts including shut down of critical facilities for more than one week and damage or destruction to more than 10 percent of property within the floodplain. However, the historical number of fatalities and injuries indicates a "substantial" impact, with multiple fatalities possible depending on the size of the event.

As shown in **Figure 2-1**, the proximity of Caldwell County to the Texas Coast makes this area vulnerable to flooding from hurricanes and hurricane-force winds that cause damage across large areas. This exposes all building, facilities, and populations within the County to the impact of a hurricane or tropical storm. Damage to towers, trees, and underground utility lines from uprooted trees and fallen poles can cause damage to utility infrastructure and cause considerable disruption. Debris such as small items left outside, signs, roofing materials, and trees can become extremely hazardous in hurricanes and tropical storms and strong winds can easily destroy poorly constructed buildings, barns and mobile homes. Hurricanes and tropical storms also produce large amounts of rain increasing the risk of flooding. This rain can overwhelm drainage systems as hurricanes or tropical storms that have weakened after making landfall can continue to drop significant quantities of water. The impacts to communities from a Category 5 storm can result in complete destruction of houses, commercial property, cropland resulting in large-scale economic impacts and population displacement.

Based on ACS 2016 data, housing within Caldwell County includes 24% manufactured homes, which are more vulnerable to extreme flood events than site-built structures, and 39% of homes constructed prior to 1980. These structures are likely to have been built to lower or less stringent construction standards than newer construction and typically more susceptible to damages during significant events. In addition, manufactured and temporary housing is located sporadically throughout rural portions of the County, which are more prone to being isolated from essential needs and emergency services in the event of a disaster.

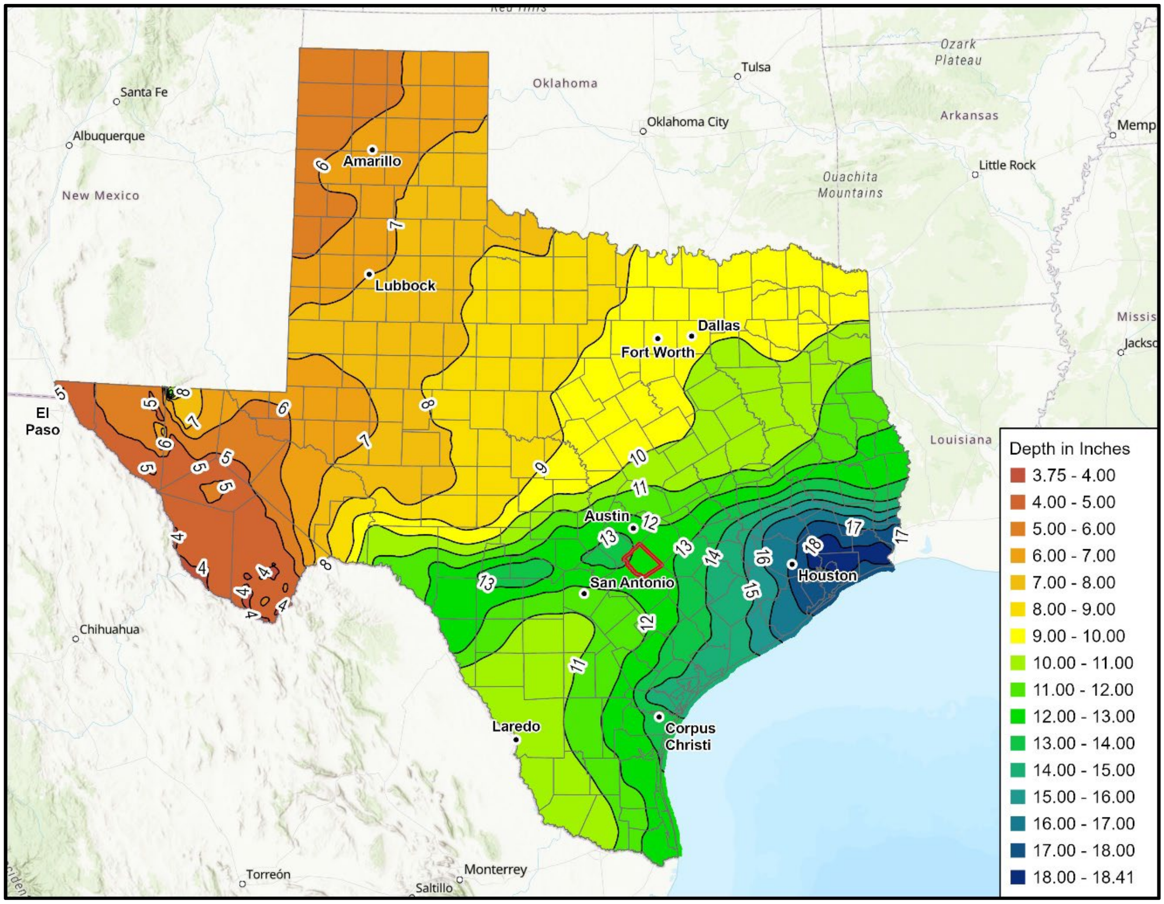

Figure 2-1. Atlas 14 100-year 24-hour precipitation depths in inches – Caldwell County shown in red.

The current Flood Insurance Rate Map (FIRM) for the watersheds within the planning area is over 8 years old and contains outdated and inaccurate peak discharges and base flood information. Approximately 83% of the County's FIRM floodplains are Zone A floodplains developed by approximate (limited detail) methods, and 86% of the County's FIRM floodplains are based on modeling performed prior to 1989. Although the FIRM was updated in June 2012, new hydrologic/hydraulic analyses were not performed for most of the FPPS study area. In order to have an effective tool to manage quality and sustainable growth, it is important to prepare an updated and comprehensive drainage plan in the planning area.

2.2 Data collection

Relevant sources of information, such as previous drainage studies, topographic data, as-built plans, and citizen drainage complaint reports were collected and reviewed to develop a historical and technical understanding of the planning area. This section describes the baseline data collected during this FPPS.

2.2.1 Public meetings

Public input from residents and community officials was an important source of information for this flood protection planning study. To solicit this input, three public meetings were held during the course of the project. The intention of the first public meeting, which was held on March 22, 2022, was to ask for the public's knowledge and experience to identify and discuss known flood problem areas within Caldwell County. The second public meeting was held on July 17, 2023 to present 1) revised floodplain mapping for the streams included in the study and 2) conceptual flood mitigation alternatives for high-priority flood problem areas. The third and final public meeting was held on March 6, 2024 to present and discuss final recommendations for flood mitigation solutions and community initiatives. Documents from the public meetings are included in **Appendix B**.

2.2.2 Topographic data

Preparation of the hydrologic and hydraulic analyses necessitated the acquisition of up-to-date topographic data. This information was needed to ensure the models accurately reflected existing terrain and hydraulic structures, such as bridge and culvert crossings.

LiDAR data

The following publicly available LiDAR datasets were obtained from the Texas Natural Resources Information System (TNRIS) to represent the topography throughout the study area:

- 2017 Central Texas LiDAR
    - Collected by Fugro between January 28, 2017 and March 22, 2017
    - Spatial Reference: NAD83(2011) / UTM zone 14N
- 2019 USGS Hurricane LiDAR
    - Collected by Fugro between January 4, 2019 and February 20, 2019
    - Spatial Reference: NAD83(2011) / UTM zone 14N

Field survey and measurements

In order to accurately represent existing bridge and culvert structures in the hydraulic models, field survey and measurement of the hydraulic structures on each study stream was conducted between April 11, 2022 and February 16, 2023. In addition to the field measurements, photographs of the upstream and downstream channels, the upstream and downstream faces, and the roadway centerline were taken for each hydraulic structure. These photographs, as well as detailed field measurement reports, are provided in **Appendix C**. Where possible, field data from previous studies were utilized in the hydraulic models and new field measurements were not taken.

2.2.3 Previous and ongoing drainage studies

Multiple previous and ongoing studies were utilized to obtain hydrologic and hydraulic modeling data, as well as historical flooding information. Where possible, drainage basin boundaries, hydrologic parameters, HEC-RAS cross-sections, and hydraulic structure data were leveraged from these other studies. **Table 2-1** provides a summary of the studies utilized in this flood protection plan.

Table 2-1. Previous and ongoing drainage studies in Caldwell County.

Caldwell County
Caldwell County Hazard Mitigation Action Plan - April 2, 2020
CDBG-MIT Grant Application and Potential Project Locations - September 2020
Texas Water Development Board (TWDB)
Cooperating Technical Partners Flood Risk Project Mapping Activity Statement No. 23 - Plum Creek Watershed - June 30, 2022
Region 10 Lower Colorado-Lavaca Regional Flood Planning Study – Amended July 2023
Region 11 Guadalupe Regional Flood Planning Study – Amended July 2023
Base Level Engineering
Lower Colorado-Cummins Watershed, TX Base Level Engineering (BLE) Results - June 2018 (Compass)
San Marcos HUC-8 Subshed, TX Base Level Engineering (BLE) Results - November 2016 (Compass)
Guadalupe-Blanco River Authority (GBRA)
Hazard Mitigation Action Plan (HMAP) - September 19, 2018
USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study - Phase 1
Technical Report Notebook (TRN) - Appendix B.2 - Engineering Analysis - Hydrology - September 2013
Technical Report Notebook (TRN) - Appendix D.2 - Engineering Analysis - Hydraulics - March 2014
USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study - Phase 2
Technical Report Notebook (TRN) - Engineering Analysis - Hydrology and Hydraulics - September 2015
Interagency Flood Risk Management (InFRM)
Interagency Flood Risk Management Hydrology Report for the San Marcos River Basin - Sept. 15, 2016
Texas General Land Office (GLO)
Ongoing GLO Combined River Basin Flood Study - Western Region - Estimated completion Summer 2024
Federal Emergency Management Agency (FEMA)
Cooperating Technical Partners Flood Risk Project Mapping Activity Statement No. 14 - Lower Colorado-Cummins Watershed - April 17, 2020

2.2.4 City of San Marcos

Recent aerial imagery was reviewed to identify any new developments that had been constructed since the creation of the LiDAR data used in the study. During this review, it was discovered that the Whisper Subdivision and Amazon SAT6 Distribution Facility were developed near San Marcos within the Hemphill Creek watershed after the creation of the LiDAR data. The following files were obtained from the City of San Marcos in order to adjust watershed boundaries and lag time parameters to reflect these developments:

- Whisper P.I.D. Subdivision Public Improvements Construction Plans – November 2, 2017
- Whisper Mixed Use Subdivision Watershed Protection Plan (Phase 2) – October 26, 2018
- SAT6 Civil Construction Plans – January 15, 2021

The City of San Marcos also provided construction plans, drainage information, and geospatial files associated with the underground storm drain system at the San Marcos Regional Airport. This information was utilized during the development of drainage area boundaries and lag time parameters in the Hemphill Creek watershed. The following is a list of the data provided by the City of San Marcos:

- San Marcos Regional Airport Drainage Improvement Plans – October 21, 2013 and November 9, 2015
- San Marcos Regional Airport Drainage Analysis and Planning Technical Memorandum – June 12, 2012
- San Marcos Regional Airport Stormwater GIS Files
    - Inlets
    - Junctions
    - Outfalls
    - Storm sewer pipes
    - Retrofit sites
    - Water quality storage and devices

2.2.5 As-built plans

Where available, as-built plans for existing hydraulic structures on state and federal highways, farm-to-market roads, and county roads were obtained from TxDOT and used to develop hydraulic models for the study streams. These plans were dated as early as 1921 and as recent as 2014. A table summarizing the TxDOT as-builts utilized in this study is provided in **Appendix D**.

As-built documents for existing NRCS dams within the study area were obtained from the Plum Creek Conservation District (PCCD) and the supporting documentation for TWDB CTP Flood Risk Project MAS 23. A table summarizing the inventory of as-builts for NRCS dams is provided in **Appendix D**.

3 Hydrologic analysis

Detailed, geo-referenced hydrologic rainfall-runoff models were prepared for each of the 4 study watersheds discussed in Section 3.1 using USACE HEC-HMS v. 4.3 for Plum Creek and v.4.9 for Walnut Creek-Cedar Creek, Upper San Marcos River, and Lower San Marcos River. The following sections discuss the methodology and assumptions used to develop the models and input parameters.

3.1 Overview of watershed study areas

The hydrologic analysis for this FPPS included the development of new HEC-HMS hydrologic models for streams within the following HUC-10 basins:

- Plum Creek
- Walnut Creek-Cedar Creek
- Upper San Marcos River
- Lower San Marcos River

The 519-square-mile study area, shown in **Figure 3-1**, was divided into the 4 HUC-10 basins listed above. For simplicity and consistency, each of the 4 basins was assigned a 3-character code for file naming and labeling purposes. **Table 3-1** below lists the 4 basins, their associated basin codes, and drainage areas. Additional information on each of the basins is discussed in Section 3.1.1 through 3.1.4.

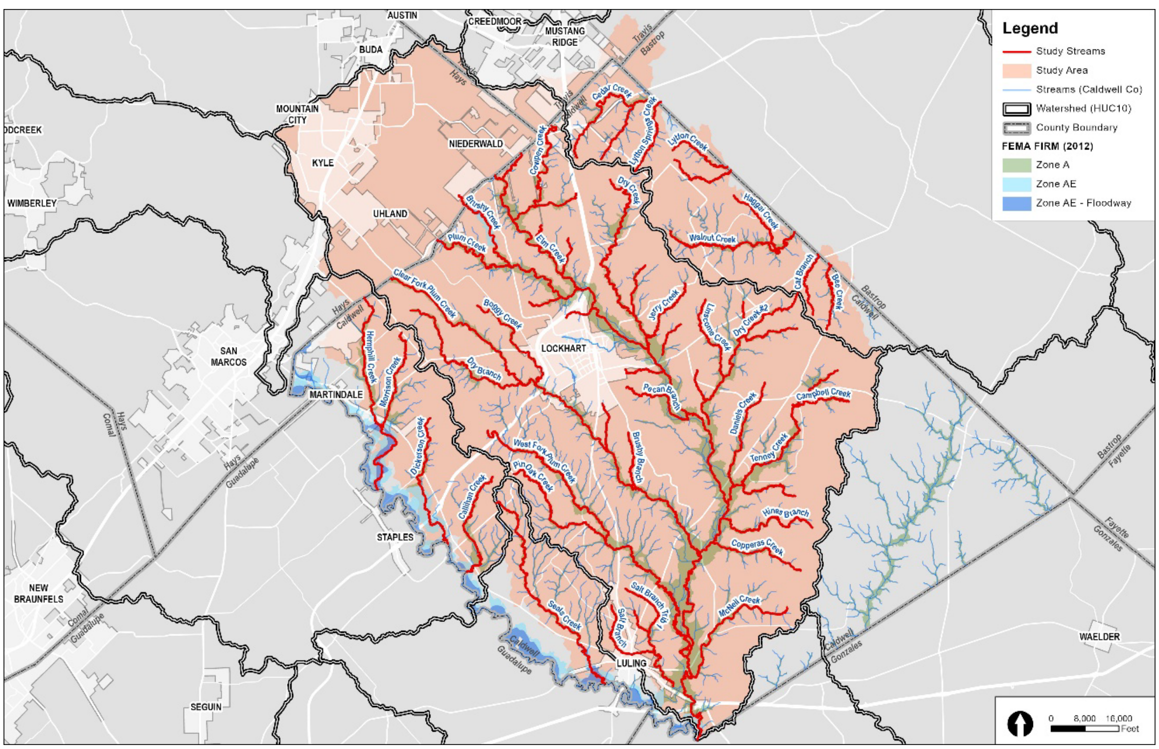

Figure 3-1. **Project study area map.**

Table 3-1. Hydrologic study HUC-10 basins and basin codes.

HUC-10	Basin Code	Drainage Area (sq mi)
Plum Creek	PLC	389.3
Walnut Creek-Cedar Creek	WCC	62.6
Upper San Marcos River	USM	46.4
Lower San Marcos River	LSM	20.8
	TOTAL	**519.0**

3.1.1 Plum Creek HUC-10

Covering 389.3 square miles, the Plum Creek Watershed is the largest of the 4 basins analyzed in this FPPS. The upstream limits of the watershed lie within southeastern Hays County and southern Travis County. The basin extends south through Caldwell County to the confluence with the San Marcos River in southern Caldwell County near Luling. The land use within the watershed largely comprises undeveloped pasture, shrub/scrub, deciduous forest, and cropland, with urban areas in Lockhart and Luling. The most recent detailed hydrologic study of this watershed was the TWDB CTP Plum Creek Flood Risk Project MAS 23. The hydrologic parameters for the basins and routing reaches were largely leveraged from that study except where minor revisions were required to match basin boundaries in the adjoining Walnut Creek-Cedar Creek, Lower San Marcos River, and Upper San Marcos River HUC-10 basins. Additional discussion of these minor revisions is provided in Section 3.2.

3.1.2 Walnut Creek-Cedar Creek HUC-10

The Walnut Creek-Cedar Creek HUC-10 covers a total of 351.7 square miles extending from southern Travis County and northeastern Caldwell County to the east through Bastrop County, where it terminates at the confluence of Cedar Creek and the Colorado River. This FPPS analyzed the portion of the drainage basin lying upstream of and within Caldwell County, which totaled 62.6 square miles. The land use within the study area largely comprises undeveloped pasture, shrub/scrub, deciduous forest, and cropland, with some urban development in Dale and Mustang Ridge. The most recent detailed hydrologic study of this watershed was the TWDB CTP Lower Colorado-Cummins Flood Risk Project MAS 14, and portions of the hydrologic model parameters were leveraged from that study.

3.1.3 Upper San Marcos River HUC-10

Covering a total of 320.2 square miles, the Upper San Marcos River HUC-10 lies within eastern Comal County, southern Hays County, western Caldwell County, and northern Guadalupe County. This FPPS analyzed the portion affecting tributaries to the San Marcos River within Caldwell County, totaling 46.4 square miles. Urban land uses associated with the City of San Marcos exist within the drainage basin. Other major existing land uses are undeveloped pasture, shrub/scrub, and cropland. No detailed hydrologic models of this study area were available, so a new hydrologic analysis was prepared.

3.1.4 Lower San Marcos River HUC-10

Lying in southern Caldwell County, eastern Guadalupe County, and northern Gonzales County, the Lower San Marcos River HUC-10 covers at total of 213.8 square miles. This FPPS analyzed the portion of the HUC-10 representing the drainage area for Seals Creek within Caldwell

County, which totaled 20.8 square miles. There are no major urban areas within the drainage basin, and the primary land uses are undeveloped pasture, shrub/scrub, and deciduous forest. No detailed hydrologic models of the Seals Creek watershed were available, so a new hydrologic analysis was prepared.

3.2 Hydrologic methodology and assumptions

The following sections discuss the methodology and assumptions used to develop the hydrologic parameters and detailed HEC-HMS models for the 4 study watersheds. Hydrologic methodologies were largely chosen for consistency with previous studies in the project area, such as the 2015 USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I and II and TWDB CTP Plum Creek Flood Risk Project MAS 23.

3.2.1 Data leveraged from previous studies

Where appropriate, drainage area boundaries and hydrologic model parameters were leveraged from the following previous studies:

- TWDB CTP Plum Creek Flood Risk Project MAS 23
- TWDB CTP Lower Colorado-Cummins Flood Risk Project MAS 14

3.2.2 Terrain processing

Best available LiDAR data, including 2017 Central Texas and 2019 USGS Hurricane LiDAR, were processed using ESRI ArcGIS Pro and HEC-HMS tools to develop a digital terrain model (DTM) to support hydrologic model development.

3.2.3 Drainage area delineation

Drainage area boundaries in the Plum Creek HUC-10 were leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23. Basin edge-matching was reviewed where the Plum Creek basins adjoined the Upper and Lower San Marcos River basins, as well as the Walnut Creek-Cedar Creek basins. In general, the MAS 23 boundaries were maintained. Where adjustments were needed, the basin boundaries were revised to reflect the project DTM.

Similarly, boundaries for the Walnut Creek-Cedar Creek subbasins were leveraged from the TWDB CTP Lower Colorado-Cummins Flood Risk Project MAS 14 study. Basin edge-matching was reviewed where the Walnut Creek-Cedar Creek basins adjoined the Plum Creek basins. In general, the MAS 14 boundaries were maintained. Where adjustments were needed, the basin boundaries were revised to reflect the project DTM.

Hydrologic subbasins for the Lower San Marcos River and Upper San Marcos River HUC-10s were delineated using the DTM, ESRI ArcGIS Pro, and HEC-HMS GIS tools. Basin edge-matching was reviewed where the Lower and Upper San Marcos River basins adjoined the Plum Creek basins. In most cases, the Lower and Upper San Marcos River basins were adjusted to match the Plum Creek boundaries from MAS 23. Where adjustments to the MAS 23 Plum Creek basins were needed, the basin boundaries were revised to reflect the project DTM.

The drainage area boundaries for Hemphill Creek in the Upper San Marcos River HUC-10 were adjusted to account for the Whisper Subdivision, SAT6 facility, and Hymeadow Subdivision developments, which were not reflected in the 2017 Central Texas LiDAR. Plans for the

Whisper and SAT6 developments were obtained from the City of San Marcos. Hymeadow was accounted for in the MAS 23 study, and the drainage area boundaries were maintained for this FPPS. Drainage area boundaries on Hemphill Creek were also adjusted to reflect the existing storm sewer system at the San Marcos Regional Airport. Plans and GIS shapefiles for this storm sewer system were obtained from the City of San Marcos.

Subbasins were merged and refined where stream confluences were located less than 1,000 feet apart, and intervening hydrologic routing was considered negligible. These confluences were modeled as a single hydrologic junction in HEC-HMS.

Where study crossings and/or confluences were located within 1,500 feet of one another, the contributing subbasins were delineated to the most downstream study point to avoid creating small intermediate basins. To be conservative, the most downstream discharges were used to analyze the study points within 1,500 feet of one another.

Table 3-2 provides a summary of the maximum, minimum, and average sub-basin sizes in each of the 4 HUC-10s analyzed in this FPPS. To ensure consistency in the peak time computations within the HEC-HMS models, sub-basins were delineated to be relatively uniform in size.

Table 3-2. Summary of sub-basin sizes by HUC-10.

HUC-10	Minimum (sq. mi.)	Maximum (sq. mi.)	Average (sq. mi.)
Plum Creek	0.02	5.39	0.96
Walnut Creek-Cedar Creek	0.12	6.23	1.44
Upper San Marcos River	0.07	3.62	1.29
Lower San Marcos River	0.14	3.39	1.15

3.2.4 Precipitation

One of the primary intentions of this FPPS was to prepare detailed hydrologic models for the study watersheds to reflect updated NOAA Atlas 14 precipitation data. Since the Atlas 14 precipitation updates for the Plum Creek watershed were completed with the MAS 23 study, the precipitation values used in the MAS 23 study were maintained for this FPPS. According to the MAS 23 report, the precipitation depths for basins within Hays County were obtained from the Hays County Drainage Criteria Manual. Those depth values were developed using a point at the centroid of Hays County. For drainage basins within Caldwell County, precipitation depths were developed at a point representing the centroid of Caldwell County. **Table 3-3** and **Table 3-4** summarize the Atlas 14 precipitation depth values for both counties. For the new hydrologic models developed in this FPPS for the Upper San Marcos River, Lower San Marcos River, and Walnut Creek-Cedar Creek watersheds, the Caldwell County Atlas 14 precipitation depths utilized in the MAS 23 study were used. The only exception to this approach was on Hemphill Creek in the Upper San Marcos River HUC-10. Since the headwater basin for that stream (basin HEM_010) lies primarily in Hays County, the Hays County Atlas 14 precipitation depths utilized in the MAS 23 study were used for that basin. For hydrologic elements with drainage areas greater than 10 square miles, a depth-area analysis was carried out in HEC-HMS to account for the decrease in peak storm intensity for those elements.

Table 3-3. NOAA Atlas 14 precipitation depths in inches for Caldwell County.

Duration	50%	20%	10%	4%	2%	1%	0.2%
5 min	0.53	0.67	0.78	0.94	1.07	1.20	1.54
15 min	1.06	1.33	1.56	1.88	2.13	2.39	3.05
1 hr	1.98	2.48	2.91	3.51	3.98	4.48	5.85
2 hr	2.44	3.12	3.73	4.61	5.31	6.09	8.28
3 hr	2.71	3.51	4.25	5.32	6.22	7.22	10.00
6 hr	3.18	4.18	5.13	6.55	7.76	9.14	13.10
12 hr	3.64	4.82	5.96	7.69	9.19	10.90	16.10
24 hr	4.13	5.49	6.82	8.87	10.60	12.70	19.00

Table 3-4. NOAA Atlas 14 precipitation depths in inches for Hays County.

Duration	50%	20%	10%	4%	2%	1%	0.2%
5 min	0.53	0.67	0.80	0.98	1.12	1.28	1.67
15 min	1.06	1.34	1.59	1.95	2.24	2.54	3.30
1 hr	1.96	2.50	2.97	3.65	4.19	4.78	6.42
2 hr	2.44	3.14	3.81	4.81	5.67	6.66	9.44
3 hr	2.73	3.53	4.33	5.58	6.69	7.98	11.70
6 hr	3.22	4.21	5.23	6.85	8.33	10.10	15.10
12 hr	3.69	4.87	6.08	7.99	9.72	11.80	17.70
24 hr	4.18	5.56	6.95	9.10	11.00	13.30	19.90

3.2.5 Stream centerlines and longest flow paths

HEC-HMS 4.9 terrain processing tools were used to generate “raw” stream centerlines for each study stream, as well as longest flow paths for each sub-basin in the Upper San Marcos River, Lower San Marcos River, and Walnut Creek-Cedar Creek HUC-10 basins. These datasets were then refined in ESRI ArcGIS Pro based on review of recent aerial imagery, leveraged data, and terrain processing interim products (e.g., sinklocs.tif). Longest flow paths for basins in the Plum Creek HUC-10 were maintained from the MAS 23 study.

In some cases, longest flow paths were adjusted to begin at the most “hydraulically distant point” since the longest travel time may not always be represented by the longest horizontal path delineated during terrain processing. Longest flow paths within select HUC-12s were smoothed/generalized and matched to refined stream centerlines.

The longest flow path for basin HEM_040 was adjusted to reflect the existing storm sewer system on the north side of the tarmac at the San Marcos Regional Airport. Based on coordination with the City of San Marcos and the San Marcos Regional Airport, detailed information on the storm sewer invert elevations and slopes were not available. Anecdotal knowledge of the site indicates the storm sewer slopes are very flat. For the purpose of lag time calculations, the slope of the storm sewer was assumed to be 0.3% based on review of available data.

3.2.6 Infiltration losses

For consistency with the 2015 USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I and II and TWDB CTP Plum Creek Flood Risk Project MAS 23, the Initial and Constant Rate (Block and Uniform) loss method was used to compute runoff losses within each sub-basin. These loss rates were assigned to each sub-basin using area weighted percent sand and percent clay values. The default loss rates for sand and clay varied for each design frequency storm events based on the 1986 USACE NUDALLAS methodology, consistent with other studies in the region (e.g., 2015 USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I and II). Percent sand values were determined using a grid file provided by USACE. Percent impervious values for each sub-basin were determined using the 2019 National Land Cover Database.

3.2.7 Unit hydrograph method

For consistency with previous studies in the region, the Snyder Unit Hydrograph method was used to develop runoff hydrographs within HEC-HMS. The Snyder method requires two parameters, the Snyder standard lag and the Snyder peaking coefficient (Cp). Snyder's lag values were developed using the USACE Fort Worth District Urbanization Curve methodology with ESRI ArcGIS Pro and HEC-HMS GIS tools. The following equation was used to calculate the Snyder lag values:

$$\log(T_p) = 0.3833\log\left(\frac{L \times L_{ca}}{\sqrt{S_{st}}}\right) + [Sd \times (\log(Ip_s) - \log(Ip_c)) + \log(Ip_c)] - (BW \times Urb)$$

Where:

Tp	=	Lag time in hours
L	=	Longest flow path in miles from the basin outlet to the upstream limit of the basin
L_{ca}	=	Distance in miles along the longest flow path from the basin outlet to a point nearest the basin centroid
S_{st}	=	Weighted slope in ft/mi along the longest flow path from 85% of the distance upstream of the outlet to 10% of the distance upstream of the outlet
Sd	=	Percent sand of the drainage basin expressed as a decimal
Ip_s	=	Calibration point for sand (1.81 according to the Fort Worth District Urbanization Curves)
Ip_c	=	Calibration point for clay (0.92 according to the Fort Worth District Urbanization Curves)
BW	=	Bandwidth (0.266 according to the Fort Worth District Urbanization Curves)
Urb	=	Percent urbanization of the drainage basin expressed as a decimal

Snyder peaking coefficients were maintained from previous studies within the region (e.g., 2015 USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I and II and TWDB CTP Plum Creek Flood Risk Project MAS 23). The average percent sand values for each sub-basin were developed using a raster dataset for Texas obtained from the USACE. The percent urbanization values for each sub-basin were developed based on the 2019 NLCD land use designations and Table 1.15 in the *NCTOG iSWM Technical Manual - Hydrology*.

For sub-basins within the Plum Creek HUC-10, Snyder lag values were maintained from the MAS 23 study, including where sub-basin boundaries were modified for this FPPS. This approach was taken under the assumption that the minor sub-basin boundary revisions would not substantially impact the Snyder lag values.

3.2.8 Hydrograph routing

For reaches where existing or new hydraulic models were available, the Modified Puls routing method was used to account for peak flow and timing attenuation along the streams. For reaches without available hydraulic models, the Muskingum-Cunge 8-point cross-section method was applied for hydrograph routing. There were several FPP study streams within the Plum Creek HUC-10 that were previously modeled in the MAS 23 hydrology model using Muskingum-Cunge methodology. Since new hydraulic models were prepared for those streams as part of this FPPS, the reach routing parameters were upgraded to Modified Puls. The following is a list of the streams within the Plum Creek HUC-10 that were upgraded from Muskingum-Cunge to Modified Puls:

- Clear Fork Plum Creek
- Copperas Creek
- Daniels Creek
- Dry Creek
- Elm Creek
- McNeil Creek
- Pecan Branch
- West Fork Plum Creek

3.2.9 NRCS reservoirs

Within the study area, there are 31 existing storage reservoirs, 28 of which are NRCS dam facilities. These reservoirs are all located within the Plum Creek HUC-10. The HEC-HMS model parameters for these facilities, including elevation-area functions, initial elevations, and outflow structure settings, were maintained from the MAS 23 study.

3.3 Hydrologic model validation

The hydrologic model for Plum Creek was calibrated during the MAS 23 study by adjusting peaking coefficients to better align with the 2019 Interagency Flood Risk Management (InFRM) study for the Guadalupe River Basin, as well as the GBRA Interim Feasibility Study. Since only minor modifications were made on the Plum Creek hydrology as part of this FPPS, no additional parameter adjustments were made.

No USGS gages are located on study streams within the Walnut Creek-Cedar Creek, Upper San Marcos River, or Lower San Marcos River watersheds. Considering this lack of available gage data and the fact that modeling methodologies from the GBRA Interim Feasibility Study were maintained for this study, the hydrologic model parameters were not adjusted for calibration purposes.

4 Hydraulic analysis

Detailed, geo-referenced 1D steady-state hydraulic models were developed for each study stream using USACE HEC-RAS v.6.3. These sections describe the methodology and assumptions used to develop the models based on existing watershed conditions.

4.1 Overview of study streams

Within the 4 HUC-10 study regions discussed in Section 3, this FPPS included the development of new HEC-RAS hydraulic models for 53 study streams for a total of 356.8 stream miles (see **Figure 4-1**). These new hydraulic models also included a total of 208 bridge and culvert structures. For simplicity and consistency, each study stream was assigned a stream code for file naming and labeling purposes. **Table 4-1** lists the streams included in the study and provides a summary of the stream codes, stream miles, and number of bridge and culvert structures on each stream.

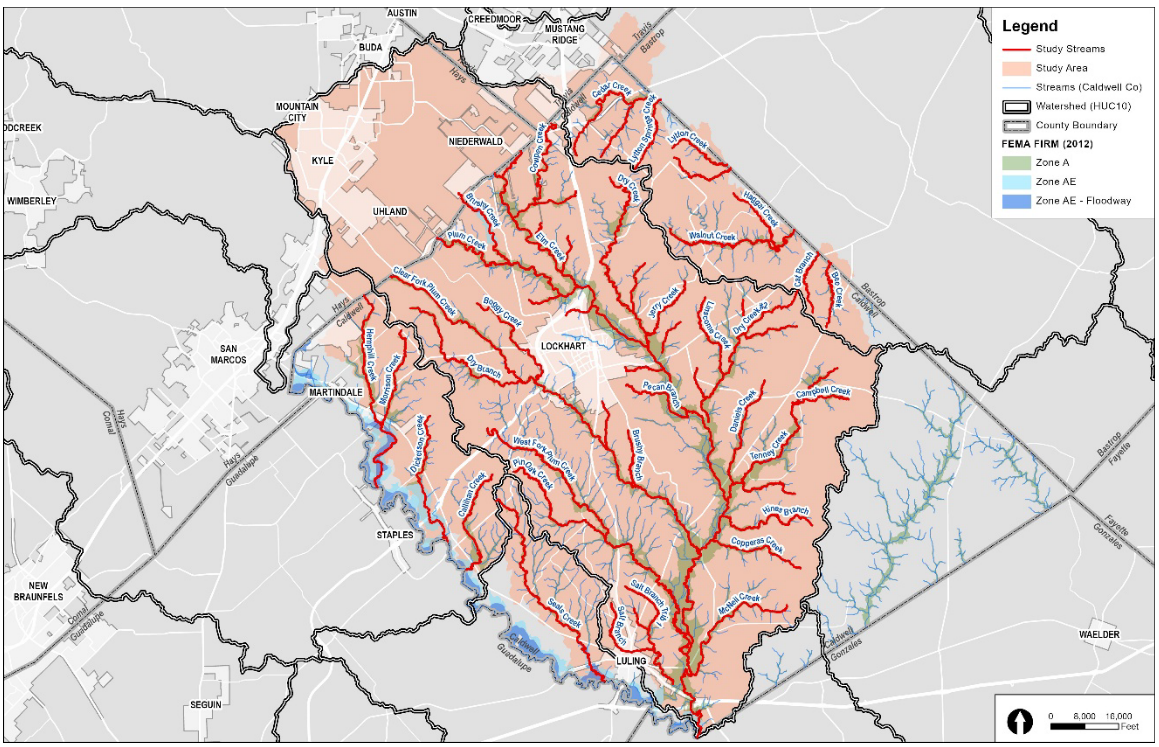

Figure 4-1. **Project study area map.**

Table 4-1. Summary of study streams.

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	---	Plum Creek	PLC	42.7	37
Plum Creek (PLC)	389.3	Brushy Creek (BRU)	Brushy Creek	BRU	4.7	3
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Rabbit Branch	RAB	1.9	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek	ELC	9.1	9
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 1	ELC_T01	1.6	0
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Elm Creek Trib 2	ELC_T02	2.1	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek	COW	7.6	4
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Cowpen Creek Trib 1	COW_T01	2.5	1
Plum Creek (PLC)	389.3	Elm Creek (ELC)	Plum Creek Trib 4	PLC_T04	1.7	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Cottonwood Creek	COT	2.9	0
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Jerry Creek	JER	4.6	3
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Dry Creek	DRY	13.9	6
Plum Creek (PLC)	389.3	Dry Creek (DRY)	Plum Creek Trib 3	PLC_T03	1.7	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek	CLFP	23.8	21
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Clear Fork Plum Creek Trib 1	CLFP_T01	2.8	1
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Brushy Branch	BRB	3.5	2
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Dry Branch	DRB	9.3	6
Plum Creek (PLC)	389.3	Clear Fork Plum Creek (CLFP)	Boggy Creek	BOC	6.3	6
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Little West Fork Plum Creek	LWF	1.9	1
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	West Fork Plum Creek	WFP	21.3	8
Plum Creek (PLC)	389.3	West Fork Plum Creek (WFP)	Pin Oak Creek	PIN	8.1	3
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Daniels Creek	DAN	6.2	2
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek	TEN	11.9	5
Plum Creek (PLC)	389.3	Daniels Creek (DAN)	Tenney Creek Trib 1	TEN_T01	4.2	1
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Copperas Creek	COP	5.1	3
Plum Creek (PLC)	389.3	Copperas Creek (COP)	Hines Branch	HIN	6.7	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2	DR2	10.2	2
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 1	DR2_T01	1.8	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Dry Creek #2 Trib 2	DR2_T02	1.9	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Linscome Creek	LIN	5.0	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Spanish Oak Creek	SPA	3.3	1
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Pecan Branch	PCB	4.7	0
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 1	PLC_T01	2.3	3
Plum Creek (PLC)	389.3	Pecan Branch (PCB)	Plum Creek Trib 2	PLC_T02	1.9	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	McNeil Creek	MCN	8.0	2
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch	SLT	7.6	13
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Trib 1 to Salt Branch Trib 1	SLT_T01_01	1.5	1

Table 4-1. Summary of study streams (continued).

HUC-10	HUC-10 Drainage Area (sq mi)	HUC-12	Stream Name	Stream Code	Stream Miles	Bridges/ Culverts
Plum Creek (PLC)	389.3	McNeil Creek (MCN)	Salt Branch Trib 1	SLT_T01	4.5	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek	CED	7.2	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Cedar Creek Trib 1	CED_T01	3.2	2
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Springs Creek (LSC)	Lytton Springs Creek	LSC	4.1	7
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek	LYT	4.0	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Lytton Creek Trib 1	LYT_T01	4.1	1
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Walnut Creek	WAL	10.8	4
Walnut Creek-Cedar Creek (WCC)	62.6	Lytton Creek (LYT)	Haggai Creek	HAG	4.7	3
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Bee Creek	BEE	4.2	1
Walnut Creek-Cedar Creek (WCC)	62.6	Bee Creek (BEE)	Cat Branch	CAT	4.0	2
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Morrison Creek	MOR	10.1	8
Upper San Marcos River (USM)	46.4	Morrison Creek (MOR)	Hemphill Creek	HEM	7.0	4
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Callihan Creek	CAL	7.0	3
Upper San Marcos River (USM)	46.4	Callihan Creek (CAL)	Dickerson Creek	DIC	7.9	3
Lower San Marcos River (LSM)	20.8	Seals Creek (SEA)	Seals Creek	SEA	13.9	7
TOTAL	**519.0**	---	---	**---**	**356.8**	**208**

4.2 Hydraulic methodology and assumptions

These sections describe the methodology and assumptions used to develop the detailed 1D steady-state HEC-RAS v.6.3 models based on existing watershed conditions. The models were developed in accordance with the HEC-RAS guidance documents, standard modeling practices, and engineering judgment. Additional details on special modeling conditions are described in the following sections.

4.2.1 Data leveraged from previous studies

Where appropriate, existing hydraulic models, stream centerlines, cross-sections, and hydraulic structure data were leveraged from the following previous studies:

- TWDB CTP Plum Creek Flood Risk Project MAS 23
- TWDB CTP Lower Colorado-Cummins Flood Risk Project MAS 14
- FEMA Region VI Lower Colorado-Cummins HUC-8 Subshed Base Level Engineering
- FEMA Region VI San Marcos HUC-8 Subshed Base Level Engineering
- USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I & II

4.2.2 Stream centerlines and cross-sections

Centerlines for each study stream were aligned with the natural channel bottom based on the project DTM with guidance from data leveraged from previous studies. Similarly, cross-sections were aligned along the stream centerline to be perpendicular to the direction of flow with guidance from data leveraged from previous studies. Cross-sections bounding hydraulic structures, such as bridges, culverts, and inline structures, were placed as directed in the HEC-RAS guidance manuals. Cross-sections were generally spaced no more than 500 feet apart in urban areas and no more than 1,000 feet apart in rural areas to capture adequate detail in the models. In some cases involving the confluence of two study streams, where the water surface elevation is controlled by the receiving stream, cross-sections in the receiving stream model were extended across both streams.

4.2.3 Manning's roughness value estimation

Manning's roughness values were defined using the 2019 NLCD land cover classifications. The land use classifications were assigned the roughness values shown in **Table 4-2**, which were selected to comply with Table 2.1 in the HEC-RAS 2D Modeling User Manual. Channel roughness values were refined to have a single value between the bank stations at each cross-section and generally ranged from 0.04 for grass-lined channels to 0.08 for dense vegetation. Overbank roughness values were simplified and refined where appropriate to minimize the total number of roughness values assigned to each cross-section.

Table 4-2. Manning's roughness values utilized in HEC-RAS models.

2019 NLCD Land Use Classification	2019 NLCD Gridcode	Manning's Roughness Value
Open Water	11	0.038
Developed, Open Space	21	0.040
Developed, Low Intensity	22	0.090
Developed, Medium Intensity	23	0.120
Developed, High Intensity	24	0.160
Barren Land Rock-Sand-Clay	31	0.025
Deciduous Forest	41	0.150
Evergreen Forest	42	0.120
Mixed Forest	43	0.140
Shrub-Scrub	52	0.115
Grassland-Herbaceous	71	0.038
Pasture-Hay	81	0.038
Cultivated Crops	82	0.035
Woody Wetlands	90	0.098
Emergent Herbaceous Wetlands	95	0.068

4.2.4 Hydraulic structures

To model existing bridge and culvert structures on each study stream, available as-built plans were obtained from TxDOT for use in model development. Where as-built plans were not available, field measurements were collected and were used to develop the structure models. Shallow structures with less than 4 feet of depth between the roadway surface and channel bottom were considered to have little impact on the limits of flooding during the 1% and 0.2% storm events. For such structures, no field measurements were collected, and nominal pipe sizes were assumed during model development.

At bridge and culvert structures, 4 cross sections were used to model the contraction and expansion areas in the vicinity of the openings. The roadway deck geometry was based on the project DTM and adjusted as needed based on field measurements collected for the project. Contraction and expansion coefficients of 0.3 and 0.5, respectively, were applied at the 2 nearest cross-sections upstream of each structure and 1 cross-section downstream. Where railing was present, 100% blockage was conservatively assumed, and the full height and length of railing was incorporated into the roadway deck geometry.

The same approach to cross-section placement and contraction and expansion coefficients was also utilized for existing inline dams and berms with a vertical height of 4 feet or greater. In those instances, the dams were modeled as inline structures. Where the models included large NRCS dams, rating curves from the HEC-HMS model were used to define the discharge through the structure.

4.2.5 Peak discharge application locations

Peak discharges for points of interest along each study stream were derived from the HEC-HMS models for each study watershed. For points of interest with drainage areas greater than 10 square miles, the peak discharges were taken from the depth-area analysis simulations in the HEC-HMS models. These peak discharges were applied in the HEC-RAS models using the following approach:

- For headwater basins and at the downstream end of reach segments, flow changes were placed 1/3 to 1/2 the stream distance upstream of the basin outfall.
- At stream confluences, the flow changes were generally set one cross-section downstream of the junction. Please refer to Section 4.3 for exceptions to this approach.
- In instances where flows from HEC-HMS nodes were found to decrease in the downstream direction, the more conservative upstream flows were maintained in the HEC-RAS model. This step was taken to ensure that flows increased in the downstream direction. The only exceptions to this approach were flow changes representing peak discharge reduction at NRCS dam structures.

4.3 Detailed hydraulic modeling considerations

In addition to the methodology described in Section 4.2, this section discusses stream-specific details, assumptions, and considerations where special conditions or challenges were encountered in the development of the hydraulic models.

4.3.1 Boggy Creek

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data.

4.3.2 Brushy Creek

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of this FPPS, the model was truncated to set the upstream limit at the Caldwell County boundary (RS 25040).

4.3.3 Clear Fork Plum Creek

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of FPPS, the model was truncated to set the upstream limit at the Caldwell County boundary (RS 125739).

In some instances, the Clear Fork Plum Creek water surface elevation controlled the inundation limits at confluences with tributaries. In those cases, the tributary models were extended far enough downstream to tie into the Clear Fork Plum Creek inundation limits. To represent the downstream portions of the tributaries that lay within the Clear Fork Plum Creek inundation limits, the cross-sections in the Clear Fork Plum Creek model were extended to intersect the centerline of the tributary, as well. This modeling approach was used at the confluence with the following streams:

- Boggy Creek
- Clear Fork Plum Creek Tributary 1
- Brushy Branch
- Dry Branch

4.3.4 Elm Creek

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of this FPPS, the model was truncated to set the upstream limit at the Caldwell County boundary (RS 47812).

In some instances, the Elm Creek water surface elevation controlled the inundation limits at confluences with tributaries. In those cases, the tributary models were extended far enough downstream to tie into the Elm Creek inundation limits. To represent the downstream portions of the tributaries that lay within the Elm Creek inundation limits, the cross-sections in the Elm Creek model were extended to intersect the centerline of the tributary, as well. This modeling approach was used at the confluence with the following streams:

- Elm Creek Tributary 1
- Cowpen Creek

4.3.5 Plum Creek

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of this FPPS, the model was truncated to set the upstream limit at the Caldwell County boundary (RS 225259).

In many instances, the Plum Creek water surface elevation controlled the inundation limits at confluences with tributaries. In those cases, the tributary models were extended far enough downstream to tie into the Plum Creek inundation limits. To represent the downstream portions of the tributaries that lay within the Plum Creek inundation limits, the cross-sections in the Plum Creek model were extended to intersect the centerline of the tributary, as well. This modeling approach was used at the confluence with the following streams:

- Pecan Branch
- Dry Creek #2
- Daniels Creek
- Tenney Creek
- Hines Branch
- Copperas Creek
- Clear Fork Plum Creek
- West Fork Plum Creek
- McNeil Creek
- Salt Branch

4.3.6 Plum Creek Tributary 3

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of this FPPS, the model was extended upstream to RS 8956 and downstream to RS 842 toward the confluence with Plum Creek.

4.3.7 Plum Creek Tributary 4

This HEC-RAS model was leveraged from TWDB CTP Plum Creek Flood Risk Project MAS 23, and minor adjustments were made to structures to reflect more recent field measurement/survey data. To align with the scope of this FPPS, the model was extended upstream to RS 9000.

4.3.8 Salt Branch

This HEC-RAS model was leveraged from USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phase 1. Minor adjustments were made to structures to reflect more recent field measurement/survey data. Updated Atlas 14 flows were applied from the Plum Creek HEC-HMS model for this FPPS (which was leveraged, with minor modifications, from TWDB CTP Plum Creek Flood Risk Project MAS 23).

4.3.9 Cowpen Creek and Cowpen Creek Tributary 1

These two streams were modeled in a single geometry file due to the existence of a spill from COW into COW_T01 near the confluence of the two streams. This spill was modeled using a lateral structure in the left overbank of COW between RS 10519 and 9719. The discharge over this lateral structure was applied in the right overbank of COW_T01 between RS 2030 and 1510. A junction (J_COW) was created on COW at the confluence with COW_T01 to reapply the combined flow into COW at RS 6691. Based on guidance from the HEC, a lower weir coefficient of 1.4 was applied to the lateral structure in the model to avoid overestimating the amount of flow leaving COW.

4.3.10 Tenney Creek and Campbell Creek

A spill was evident near the confluence of Tenney Creek and Campbell Creek. To represent these conditions, the Campbell Creek model was extended to RS 2820, allowing for a tie-in between the Tenney Creek and Campbell Creek inundation limits. Downstream of that point, beginning with RS 45953, the cross-sections in the Tenney Creek model were extended to span both streams. A multiple opening analysis was used at RS 45907 in the Tenney Creek model to represent the culvert structures at FM 3158.

4.3.11 Dry Creek #2 and Dry Creek #2 Tributary 2

Near the confluence of Dry Creek #2 and Dry Creek #2 Tributary 2, a spill caused the inundation limits to span both streams. To model these conditions, duplicate cross-sections spanning both streams were created in each model. Cross-sections 1491 – 305 in the DR2_T02 model were duplicates of cross-sections 32199 – 31525 in the DR2 model.

4.3.12 Walnut Creek and Haggai Creek

At the confluence of Walnut Creek and Haggai Creek, the floodplain is continuous across both streams. To model these conditions, duplicate cross-sections spanning both streams were created in each model. Cross-sections 3860 – 928 in the HAG model were duplicates of cross-sections 16384 – 14319 in the WAL model. As a conservative measure, the combined peak discharge at the confluence, represented by HMS Node J-WAL_060, was applied at the most upstream duplicate cross-section in both models (RS 16384 in the WAL model and RS 3860 in the HAG model).

4.4 Model calibration

Calibration data, such as high-water marks or historical flooding data, were not available for the study streams. Due to this lack of available information, the hydraulic model parameters were not adjusted for calibration purposes.

4.5 Floodplain mapping

Using the results of the 1D HEC-RAS models, updated floodplain boundaries reflecting Atlas 14 precipitation data were developed for the 1% and 0.2% storm events. The raw inundation boundaries were exported from RAS Mapper into ArcGIS Pro and processed to produce cleaner datasets for use in the creation of floodplain maps. The processing tasks included the elimination of inundation areas and holes less than one acre in size. In addition, the inundation boundaries were simplified by removing vertices with a maximum horizontal offset of 3 feet. Updated floodplain maps for each study stream are provided in **Appendix A**.

5 Flood mitigation alternatives

Based on the collected baseline information and results of the hydraulic models, flood problem areas were identified and evaluated. These sections describe the selection and assessment of flood mitigation alternatives for high-priority flood hazard areas in the County.

5.1 Flood problem area identification

Flood problem areas were identified throughout Caldwell County during the course of this FPPS. A complete list of these flood problem areas is provided in **Appendix J**. Many of these areas were identified as high-priority flood hazards by Caldwell County officials and residents, as well as previous flood hazard studies, such as the USACE Lower Guadalupe River Basin GBRA Interim Feasibility Study Phases I and II. Other flood problem areas were identified based on the results of the 1D hydraulic analyses discussed in Section 4. Fourteen (14) high-priority flood problem areas located throughout Caldwell County were selected to develop flood mitigation alternatives and are listed in **Table 5-1**.

Table 5-1. Caldwell County Flood Mitigation Projects.

Project Identifier	Flood Mitigation Project Title
CC-1	Cedar Creek Channel Improvements Near Christian Drive
CC-2	CR 170 Low Water Crossing Improvements at Lytton Creek
CC-3	CR 172 Low Water Crossing Improvements at Lytton Creek
CC-4	CR 141 at Hines Branch
CC-5	SH 80 Low Water Crossing Improvements at Morrison Creek
CC-6	Salt Branch Drainage Improvements in Luling*
CC-7	CR 233 and FM 2001 at Plum Creek
CC-8	Plum Creek Channel Improvements Near CR 227
CC-9	Hemphill Creek Drainage Improvements Near FM 1984
CC-10	US 183 at Clear Fork Plum Creek
CC-11	Brushy Creek Channel Improvements Near Las Estancias II
CC-12	Boggy Creek Channel Improvements Near SH 142
CC-13	CR 218 at Boggy Creek and Clear Fork Plum Creek
CC-14	CR 227 at Brushy Creek

*Identified as a Damage Center in the Guadalupe River Basin GBRA Interim Feasibility Study Phase I

Alternatives analyses included conceptual design, hydrologic and hydraulic modeling, construction cost estimation, and benefit-cost analyses. Conceptual design and modeling of alternatives were performed using new, two-dimensional (2D) HEC-RAS version 6.3 hydraulic models for each flood problem area.

The primary objectives of the proposed mitigation alternatives were to remove existing structures from the 100-year floodplain and to improve the level-of-service of existing low water crossings. Conceptual designs were adjusted to ensure no negative impacts were created beyond the public right-of-way (ROW), project property, or easement, in accordance with TWDB Technical Guidelines for Regional Flood Planning. Three (3) of the 14 proposed Flood Mitigation Projects (FMPs) discussed in this report were incorporated into the July 14, 2023 Amendment of the 2023 Lower Colorado-Lavaca Regional Flood Plan for Flood Planning Region 10, and the remaining 11 were incorporated into the Amended 2023 Guadalupe Regional Flood Plan for Flood Planning Region 11.

In addition to the 14 FMPs listed in **Table 5-1**, 20 additional flood problem areas were identified as Flood Management Evaluations (FMEs), where further analysis will be needed to define existing flood hazards and develop mitigation solutions. Many of these FMEs were previously identified as damage centers in the Guadalupe River Basin GBRA Interim Feasibility Study. These flood problem areas are listed in **Table 5-2** along with a brief description of the needed evaluations. As with the FMPs listed above, these FMEs were incorporated into the July 14, 2023 Amendments of the Regional Flood Plans for Flood Planning Regions 10 and 11. For more detailed summaries of the proposed FMEs and FMPs in accordance with Section 2.5 of *TWDB Technical Guidelines for Regional Flood Planning*, please see **Tables 5-3** and **5-4**. These tables have also been provided in **Appendix L**.

Table 5-2. Caldwell County Flood Management Evaluations.

Flood Management Evaluation Name	Description of Evaluation Needed
CR 175 at Cedar Creek Tributary 1	Evaluate upgrades to existing low water crossing at CR 175
Lytton Springs Creek Near CR 174	Evaluate channel improvements and/or buyouts to mitigate residential flooding near CR 174
Hemphill Creek Between SH 142 and SH 80	Evaluate projects to mitigate residential flooding on Hemphill Creek with consideration of influence from San Marcos River
Dickerson Creek Near CR 111	Evaluate projects to mitigate residential flooding on Dickerson Creek with consideration of influence from San Marcos River
CR 103 at Morrison Creek	Evaluate upgrades to low water crossing on Morrison Creek with consideration of influence from San Marcos River
Plum Creek Near US 183 and I-10 Intersection	Evaluate projects to mitigate residential and commercial flooding on Plum Creek with consideration of influence from San Marcos River
Rolling Oaks at Ebbon Road	Assess local drainage conditions on Rolling Oaks Drive and evaluate projects to address nuisance flooding
FM 1322 at Plum Creek	Evaluate bridge and roadway upgrades on FM 1322 to improve level-of-service
CR 146 at Plum Creek	Evaluate bridge, low-water crossing, and roadway upgrades on CR 146 to improve level-of-service
CR 230 at Clear Fork Plum Creek	Evaluate low-water crossing and roadway upgrades on CR 230 to improve level-of-service
CR 159 at Spanish Oak Creek	Assess local drainage conditions at CR 230 and evaluate low-water crossing upgrades with consideration of backwater from NRCS Site 24
Cowpen Creek Near Dove Hill Drive	Evaluate projects to mitigate residential flooding on Cowpen Creek near Dove Hill Drive
CR 221 and CR 233 at Elm Creek	Evaluate low-water crossing and roadway upgrades at intersection of CR 221 and CR 233 to improve level-of-service
McMahan VFD at Tenney Creek	Evaluate projects to mitigate flooding at critical facility
CR 208 at Plum Creek	Evaluate low-water crossing and roadway upgrades on CR 208 to improve level-of-service
Mebane Creek Channel Improvements	Evaluate channel improvements discussed in GBRA Interim Feasibility Study Phase II to mitigate residential flooding upstream of Clear Fork St.
Mebane Creek Floodwall	Evaluate floodwall alternative discussed in GBRA Interim Feasibility Study Phase II to mitigate residential flooding along Blue Stem Dr.
Town Branch Detention	Evaluate regional detention basin alternative discussed in GBRA Interim Feasibility Study Phase II to mitigate structural flooding within Lockhart.
Caldwell County FEWS	Evaluate upgrades to Flood Early Warning Systems
Assessment of Property Buyout Alternatives	Evaluate buyout alternatives for flood problem areas identified within Caldwell County

Table 5-3. Caldwell County Flood Management Evaluations recommended by RFPG.

FME ID	RFPG No.	RFPG Name	FME Name	Description	Associated Goals	Counties	HUC8s	HUC12s	Watershed Name	FME Area (sqmi)	Flood Risk Type	Sponsor	Entities with Oversight	Emergency Need	Estimated Study Cost	RFPG Recomm. (Y/N)	Reason for Recomm.
101000224	10	Lower Colorado-Lavaca	Lytton Springs Creek Near CR 174	Preliminary engineering study to evaluate potential mitigation actions at low water crossing	10000025	Caldwell	12090301	-	Lytton Springs Creek	0.11	Riverine	Caldwell County	Multiple	No	$40,000	Y	Meets minimum TWDB requirements
101000225	10	Lower Colorado-Lavaca	CR175 @ Cedar Creek Trib 1	Preliminary engineering study to evaluate potential mitigation actions at low water crossing	10000025	Caldwell	12090301	-	Cedar Creek	0.14	Riverine	Caldwell County	Multiple	No	$40,000	Y	Meets minimum TWDB requirements
111000152	11	Guadalupe	Caldwell County Plum Creek Near US 183 and I-10 Intersection	Evaluate projects to mitigate residential and commercial flooding on Plum Creek with consideration of influence from San Marcos River	11000009	Gonzales Guadalupe Caldwell	12100203	-	Plum Creek	0.5	Riverine	Caldwell County	Multiple	No	$60,000	Y	Meets minimum TWDB requirements
111000153	11	Guadalupe	Caldwell County FM 1322 @ Plum Creek	Evaluate bridge and roadway upgrades on FM 1322 to improve level-of-service	11000001 11000002	Caldwell	12100203	-	Plum Creek	5.1	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000154	11	Guadalupe	Caldwell County CR 146 @ Plum Creek	Evaluate bridge, low-water crossing, and roadway upgrades on CR 146 to improve level-of-service	11000001 11000002	Caldwell	12100203	-	Plum Creek	9.6	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000155	11	Guadalupe	Caldwell County CR 230 @ Clear Fork Plum Creek	Evaluate low-water crossing and roadway upgrades on CR 230 to improve level-of-service	11000001 11000002	Caldwell Hays	12100203	-	Clear Fork Plum Creek	15.7	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000156	11	Guadalupe	Caldwell County CR 159 @ Spanish Oak Creek	Assess local drainage conditions at CR 230 and evaluate low-water crossing upgrades with consideration of backwater from NRCS Site 24	11000001 11000002	Caldwell	12100203	-	Spanish Oak Creek	2.8	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements

Table 5-3. Caldwell County Flood Management Evaluations recommended by RFPG (continued).

FME ID	RFPG No.	RFPG Name	FME Name	Description	Associated Goals	Counties	HUC8s	HUC12s	Watershed Name	FME Area (sqmi)	Flood Risk Type	Sponsor	Entities with Oversight	Emergency Need	Estimated Study Cost	RFPG Recomm. (Y/N)	Reason for Recomm.
111000157	11	Guadalupe	Caldwell County Cowpen Creek Near Dove Hill Drive	Evaluate projects to mitigate residential flooding on Cowpen Creek near Dove Hill Drive	11000009	Caldwell Hays Travis	12100203	-	Cowpen Creek	10.2	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000158	11	Guadalupe	Caldwell County CR 221 and CR 233 @ Elm Creek	Evaluate low-water crossing and roadway upgrades at intersection of CR 221 and CR 233 to improve level-of-service	11000001	Caldwell	12100203	-	Elm Creek	7.6	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000159	11	Guadalupe	Caldwell County McMahan VFD @ Tenney Creek	Evaluate projects to mitigate flooding at critical facility	11000009	Caldwell	12100203	-	Tenney Creek	1.0	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000160	11	Guadalupe	Caldwell County Rolling Oaks @ Ebbon Road	Assess local drainage conditions on Rolling Oaks Drive and evaluate projects to address nuisance flooding	11000009	Caldwell	12100203	-	Plum Creek	1.4	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000161	11	Guadalupe	Caldwell County Hemphill Creek Between SH 142 and SH 80	Evaluate projects to mitigate residential flooding on Hemphill Creek with consideration of influence from San Marcos River	11000009	Guadalupe Caldwell Hays	12100203	-	Hemphill Creek	23.2	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000162	11	Guadalupe	Caldwell County Dickerson Creek Near CR 111	Evaluate projects to mitigate residential flooding on Dickerson Creek with consideration of influence from San Marcos River	11000009	Caldwell	12100203	-	Dickerson Creek	11.8	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000163	11	Guadalupe	Caldwell County CR 103 @ Morrison Creek	Evaluate upgrades to low water crossing on Morrison Creek with consideration of influence from San Marcos River	11000001	Caldwell	12100203	-	Morrison Creek	2.3	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements

Table 5-3. Caldwell County Flood Management Evaluations recommended by RFPG (continued).

FME ID	RFPG No.	RFPG Name	FME Name	Description	Associated Goals	Counties	HUC8s	HUC12s	Watershed Name	FME Area (sqmi)	Flood Risk Type	Sponsor	Entities with Oversight	Emergency Need	Estimated Study Cost	RFPG Recomm. (Y/N)	Reason for Recomm.
111000164	11	Guadalupe	Caldwell County FEWS	Study of Flood Early Warning System	11000009	Caldwell	12100202 12100203	-	Multiple	544.7	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000165	11	Guadalupe	Caldwell County CR 208 @ Plum Creek	Evaluate low-water crossing and roadway upgrades on CR 208 to improve level-of-service	11000001	Caldwell	12100203	-	Plum Creek	12.2	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000166	11	Guadalupe	Caldwell County Mebane Creek Channel Improvements	Evaluate channel improvements discussed in GBRA Interim Feasibility Study Phase II to mitigate residential flooding upstream of Clear Fork St.	11000009	Caldwell	12100203	-	Mebane Creek	13.0	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000167	11	Guadalupe	Caldwell County Mebane Creek Floodwall	Evaluate floodwall alternative discussed in GBRA Interim Feasibility Study Phase II to mitigate residential flooding along Blue Stem Dr.	11000009	Caldwell	12100203	-	Mebane Creek	13.0	Riverine	Caldwell County	Multiple	No	$50,000	Y	Meets minimum TWDB requirements
111000168	11	Guadalupe	Caldwell County Town Branch Detention	Evaluate regional detention basin alternative discussed in GBRA Interim Feasibility Study Phase II to mitigate structural flooding within Lockhart.	11000009	Caldwell	12100203	-	Town Branch	6.8	Riverine	Caldwell County	Multiple	No	$60,000	Y	Meets minimum TWDB requirements
111000181	11	Guadalupe	Caldwell County Assessment of Property Buyout Alternatives	Evaluate buyout alternatives for flood problem areas identified within Caldwell County	11000009	Caldwell	12100202 12100203	-	Multiple	544.7	Riverine	Caldwell County	Multiple	No	$40,000	Y	Meets minimum TWDB requirements

Table 5-4. Caldwell County Flood Mitigation Projects recommended by RFPG.

FMP ID	RFPG No.	RFPG Name	FMP Name	Description	Associated Goals (ID)	Counties	HUC8s	HUC12s	Watershed Name	Project Type	Project Area (sqmi)
103000062	10	Lower Colorado-Lavaca	Cedar Creek Channel Improvements Near Christian Drive	Channel improvements to reduce residential flooding near Christian Drive	10000025, 10000027	Caldwell	12090301	-	Cedar Creek	Channel	0.330
103000063	10	Lower Colorado-Lavaca	CR 170 Low Water Crossing Improvements @ Lytton Creek	Upgrade 2 existing low water crossings to include box culverts and channel improvements	10000025, 10000027	Caldwell	12090301	-	Lytton Creek	LWC upgrade	0.120
103000064	10	Lower Colorado-Lavaca	CR 172 Low Water Crossing Improvements @ Lytton Creek	Upgrade existing low water crossing to include box culverts and channel improvements	10000025, 10000027	Caldwell	12100203	-	Lytton Creek	LWC upgrade	0.040
113000074	11	Guadalupe	Caldwell County CR 141 @ Hines Branch	Upgrade existing low water crossing to include box culverts and channel improvements	11000001, 11000002	Caldwell	12100203	-	Hines Branch	LWC upgrade	0.221
113000075	11	Guadalupe	Caldwell County SH 80 Low Water Crossing Improvements @ Morrison Creek	Upgrade existing low water crossing to include culverts, channel improvements, and detention	11000009, 11000010, 11000001, 11000002	Caldwell	12100203	-	Morrison Creek	Comprehensive	1.849
113000076	11	Guadalupe	Caldwell County Salt Branch Drainage Improvements in Luling	Expand existing US 183 bridge and upgrade existing LWCs at Walnut and Laurel with box culverts and channel improvements	11000009, 11000010, 11000001, 11000002	Caldwell	12100203	-	Salt Branch	Comprehensive	0.281
113000077	11	Guadalupe	Caldwell County CR 233 and FM 2001 @ Plum Creek	Upgrade existing low water crossing on Polonia Road to include new bridge; channel improvements at FM 2001 and Polonia Road	11000009, 11000010, 11000001, 11000002	Caldwell	12100203	-	Plum Creek	Comprehensive	0.797
113000078	11	Guadalupe	Caldwell County Plum Creek Channel Improvements Near CR 227	Channel Improvements to mitigate residential and commercial flooding near CR 227	11000009, 11000010	Caldwell Hays	12100203	-	Plum Creek	Channel	0.390
113000079	11	Guadalupe	Caldwell County Hemphill Creek Drainage Improvements Near FM 1984	Channel improvements; Bridge Extension; Bridge conversion; and detention to reduce residential flooding near FM 1984	11000009, 11000010, 11000001, 11000002	Caldwell	12100203	-	Hemphill Creek	Comprehensive	0.615
113000080	11	Guadalupe	Caldwell County US 183 @ Clear Fork Plum Creek	Expand existing US 183 and Robin Ranch Rd bridge openings; channel improvements	11000009, 11000010	Caldwell	12100203	-	Clear Fork Plum Creek	Comprehensive	0.840
113000081	11	Guadalupe	Caldwell County Brushy Creek Channel Improvements Near Las Estancias II	Channel improvements to reduce residential flooding within Las Estancias II subdivision	11000009, 11000010	Caldwell Hays	12100203	-	Brushy Creek	Channel	0.378
113000082	11	Guadalupe	Caldwell County Boggy Creek Channel Improvements Near SH 142	Channel improvements to reduce residential/commercial flooding near SH142	11000009, 11000010	Caldwell	12100203	-	Boggy Creek	Channel	0.471
113000083	11	Guadalupe	Caldwell County CR 218 @ Boggy Creek and Clear Fork Plum Creek	Upgrade existing low water crossings to include box culverts and channel improvements	11000009, 11000010, 11000001, 11000002	Caldwell	12100203	-	Boggy Creek Clear Fork Plum Creek	LWC upgrade	0.423
113000084	11	Guadalupe	Caldwell County CR 227 @ Brushy Creek	Upgrade existing low water crossing to include box culverts and channel improvements	11000001, 11000002	Caldwell	12100203	-	Brushy Creek	LWC upgrade	0.771

Table 5-4. Caldwell County Flood Mitigation Projects recommended by RFPG (continued).

FMP ID	Flood Risk Type (Riverine, Coastal, Urban, Playa, Other)	Sponsor	Entities with Oversight	Emergency Need (Y/N)	Estimated Project Cost ($)	Potential Funding Sources and Amount	Cost/ Structure Removed	Percent Nature-Based Solution (by cost)	Negative Impact (Y/N)	Negative Impact Mitigation (Y/N)	Water Supply Benefit (Y/N)	Benefit-Cost Ratio	Social Vulnerability Index (SVI)	RFPG Recomm. (Y/N)	Reason for Recomm.
103000062	Riverine	Caldwell County	Multiple	No	$14,654,000	-	$1,628,222	5.00	No	N/A	No	0.0	0.606	Yes	Meets minimum TWDB requirements
103000063	Riverine	Caldwell County	Multiple	No	$4,877,000	-		5.00	No	N/A	No	0.1	0.606	Yes	Meets minimum TWDB requirements
103000064	Riverine	Caldwell County	Multiple	No	$4,574,000	-		5.00	No	N/A	No	0.5	0.606	Yes	Meets minimum TWDB requirements
113000074	Riverine	Caldwell County	Multiple	No	$2,893,000	-	-	5.00	No	-	No	0.2	0.170	Yes	Meets minimum TWDB requirements
113000075	Riverine	Caldwell County	Multiple	No	$20,224,000	-	$2,022,400	5.00	Yes	Yes	No	0.5	0.620	Yes	Meets minimum TWDB requirements
113000076	Riverine	Caldwell County	Multiple	No	$5,798,000	-	-	5.00	No	-	No	0.7	0.700	Yes	Meets minimum TWDB requirements
113000077	Riverine	Caldwell County	Multiple	No	$7,934,000	-	$7,934,000	5.00	No	-	No	0.5	0.610	Yes	Meets minimum TWDB requirements
113000078	Riverine	Caldwell County	Multiple	No	$5,587,000	-	$1,396,750	5.00	No	-	No	0.1	0.610	Yes	Meets minimum TWDB requirements
113000079	Riverine	Caldwell County	Multiple	No	$19,790,000	-	$1,979,000	5.00	Yes	Yes	No	0.4	0.620	Yes	Meets minimum TWDB requirements
113000080	Riverine	Caldwell County	Multiple	No	$16,501,000	-	$970,647	5.00	No	-	No	0.1	0.660	Yes	Meets minimum TWDB requirements
113000081	Riverine	Caldwell County	Multiple	No	$9,622,000	-	$874,727	5.00	No	-	No	0.1	0.610	Yes	Meets minimum TWDB requirements
113000082	Riverine	Caldwell County	Multiple	No	$6,113,000	-	$3,056,500	5.00	No	-	No	0.1	0.360	Yes	Meets minimum TWDB requirements
113000083	Riverine	Caldwell County	Multiple	No	$7,836,000	-	-	5.00	No	-	No	0.0	0.370	Yes	Meets minimum TWDB requirements
113000084	Riverine	Caldwell County	Multiple	No	$3,504,000	-	-	5.00	No	-	No	2.3	0.610	Yes	Meets minimum TWDB requirements

5.2 Modeling analysis and methodology

To analyze potential mitigation solutions for the 15 FMPs, 2D unsteady-state models were prepared in HEC-RAS version 6.3. This approach was taken to streamline the modeling process by eliminating intermediate steps requiring reach routing updates in the hydrologic (HEC-HMS) models to account for proposed channel modifications. In general, the 2D mesh for each study area was defined using a 50 ft x 50 ft grid with some modifications made as necessary around breaklines representing high points and 2D connections representing culvert or bridge structures.

The upstream and internal boundary conditions for the models were defined using flow hydrographs extracted from the HEC-HMS models. To define the downstream boundary conditions, normal depth slopes were estimated using the digital elevation model (DEM) developed for the FPPS from publicly available LiDAR data. The only exception to this downstream boundary condition approach was for the CR 227 at Brushy Creek project, where NRCS Dam Site 14R is located downstream of the crossing. For that model, the rating curve for the dam structure was obtained from the HEC-HMS model and used to define the downstream boundary condition for the 2D HEC-RAS model.

Land cover classifications were assigned using the 2019 National Land Cover Database, and Manning's roughness values for each classification were obtained from Table 2.1 in the HEC-RAS 2D Modeling User's Manual. The terrain modification tools within RAS Mapper were utilized to represent proposed channel improvements within the project area. In areas representing proposed excavation, a Manning's roughness value of 0.04 was generally used.

The flood mitigation alternatives were modeled for various hypothetical flood events following TWDB Regional Flood Planning guidelines. Existing and proposed conditions for low-water crossings were generally assessed for the 2-, 10-, and 100-year storm events. In cases where there were no existing damages in the 2-year storm, the 10-, 25-, and 100-year storm events were used for the analyses.

In general, the mitigation improvements proposed for each project were designed to remove existing structures from the 100-year floodplain and to improve the level-of-service of existing low-water crossings. Where channel improvements are proposed, channel benching was preliminarily designed to preserve the existing natural channel in an effort to minimize impacts to jurisdictional Waters of the US. A Manning's roughness value of 0.04 was generally assigned within areas of proposed excavation under the assumption that they would not be regularly maintained. Channel improvement projects will include nature-based solution (NBS) elements including riparian habitat restoration to enhance bank stability and water quality. Specific details for each improvement project are provided in Section 5.3.

5.3 Proposed Flood Mitigation Projects

This section provides details on the following items for each of the 14 proposed FMPs:

- The existing conditions flood risk
- The proposed improvements
- The flood mitigation benefits of the project

5.3.1 Project CC-1 – Cedar Creek Channel Improvements Near Christian Drive

The results of 1D hydraulic modeling on Cedar Creek showed flooding affecting multiple residential and agricultural structures in the vicinity of Christian Drive. Based on preliminary 2D modeling results, under existing conditions, a total of 16 structures lie within the 100-year floodplain, 9 of which are residential. The 100-year depth of flooding ranges from 4 inches to 48 inches at these 9 residential structures. During the 25-year event, 3 residential structures are flooded with depths ranging from 3 inches to 31 inches. During the 10-year event, 2 residential structures are flooded by 5 inches and 19 inches. Please see **Figure 5-1A** for a view of the study area.

To increase the storage capacity of the channel and reduce the extents of the floodplain, the proposed improvements include the construction of approximately 5,600 linear feet of trapezoidal benching with a 250-foot bottom width and 4:1 side slopes. No improvements to the existing low water crossing at Christian Drive or any other roadways are proposed. Please see **Figure 5-1B** for a depiction of the proposed improvements.

Based on the preliminary modeling results, the proposed channel improvements allow for the removal of 8 of the 9 residential structures from the 100-year floodplain. The 100-year depth of flooding is reduced from 48 inches to 1 inch at the ninth residential structure. During the 25-year event, 2 of the 3 flooded residential structures are removed from the floodplain, and the depth of flooding is reduced from 31 inches to 1 inch at the third structure. During the 10-year event, all residential structures were removed from the floodplain. Please see **Figure 5-1C** for a depiction of the 100-year flood risk reduction.

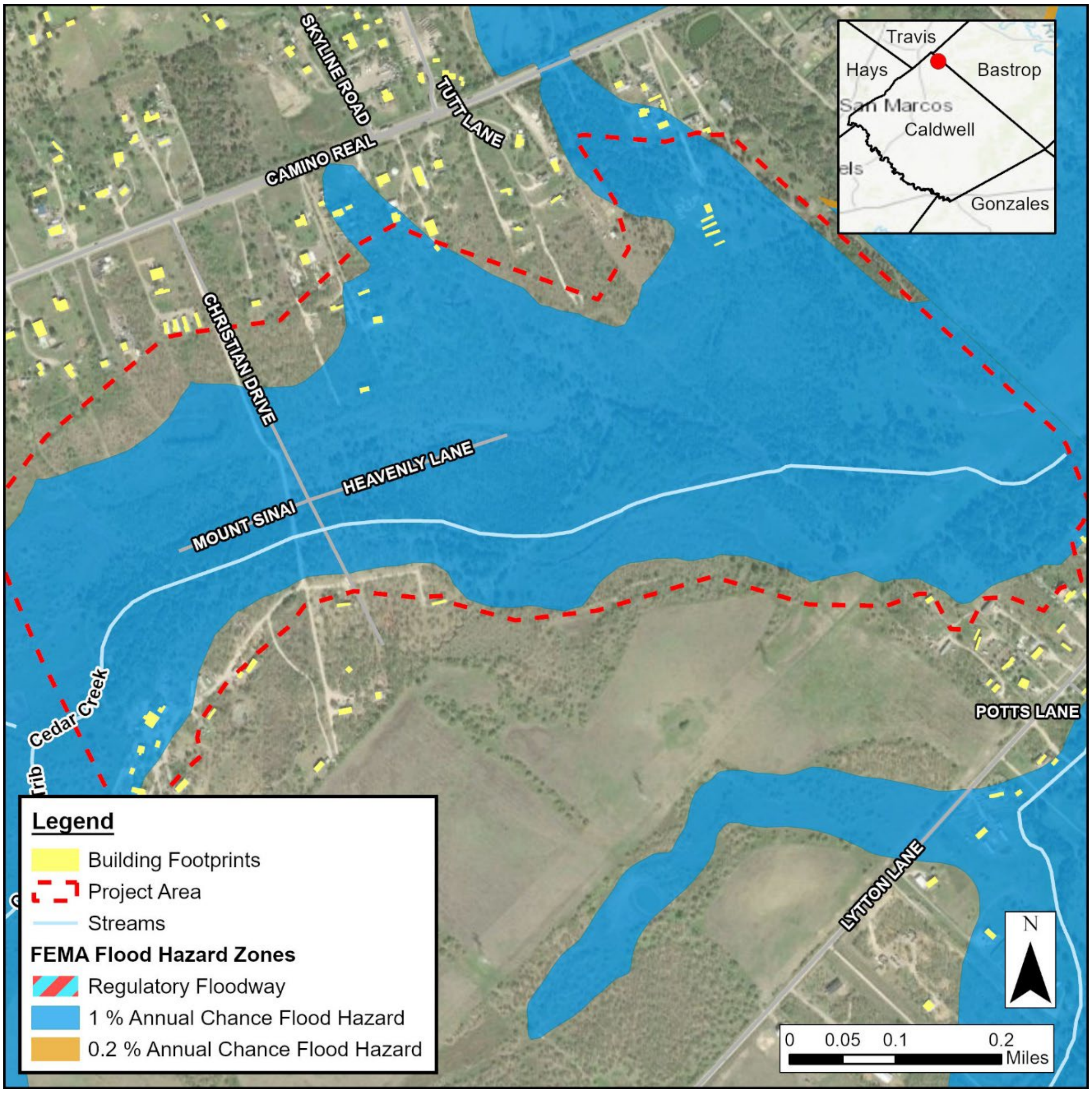

Figure 5-1A. Project CC-1 study area location.

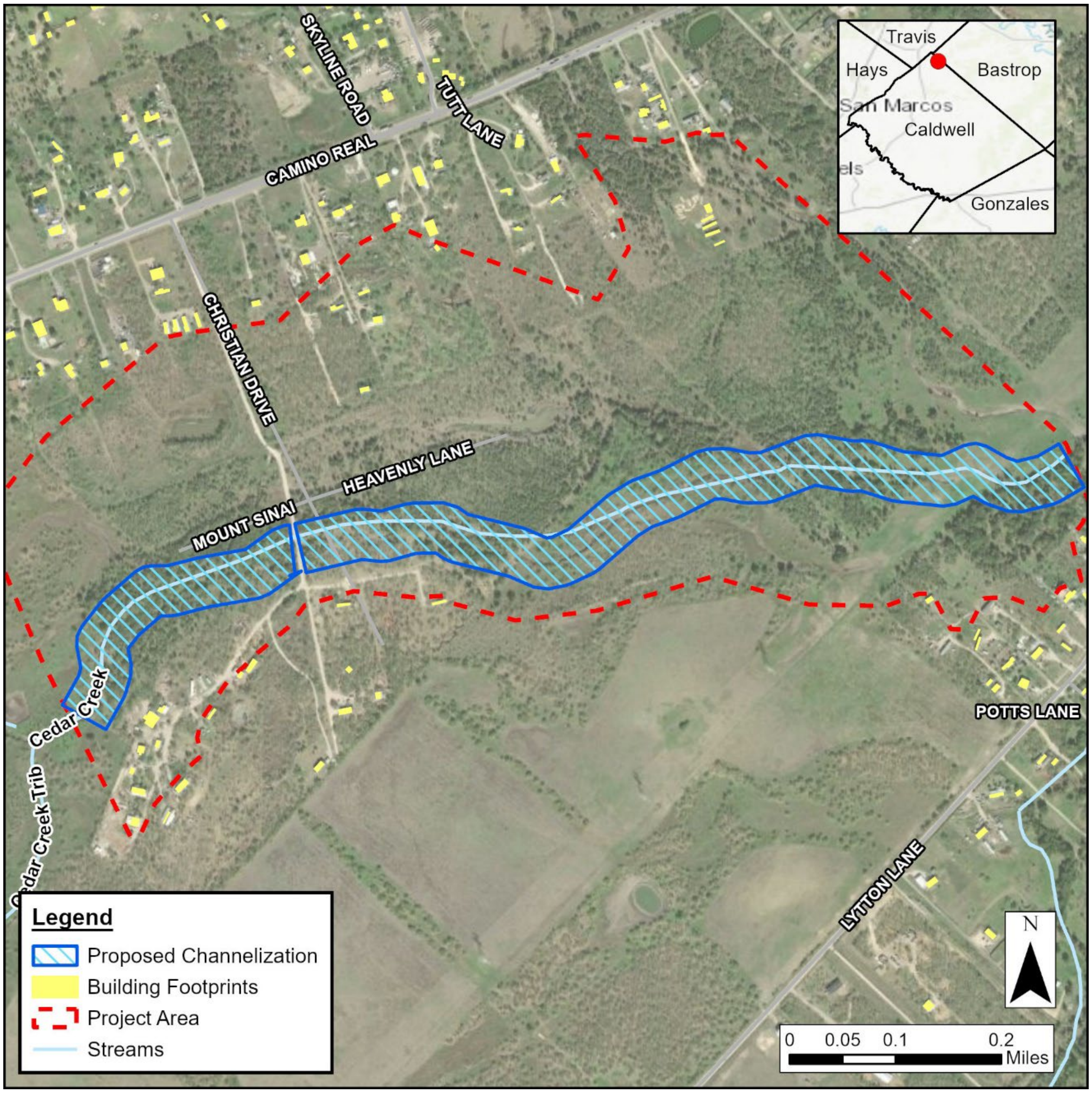

Figure 5-1B. Project CC-1 proposed improvements.

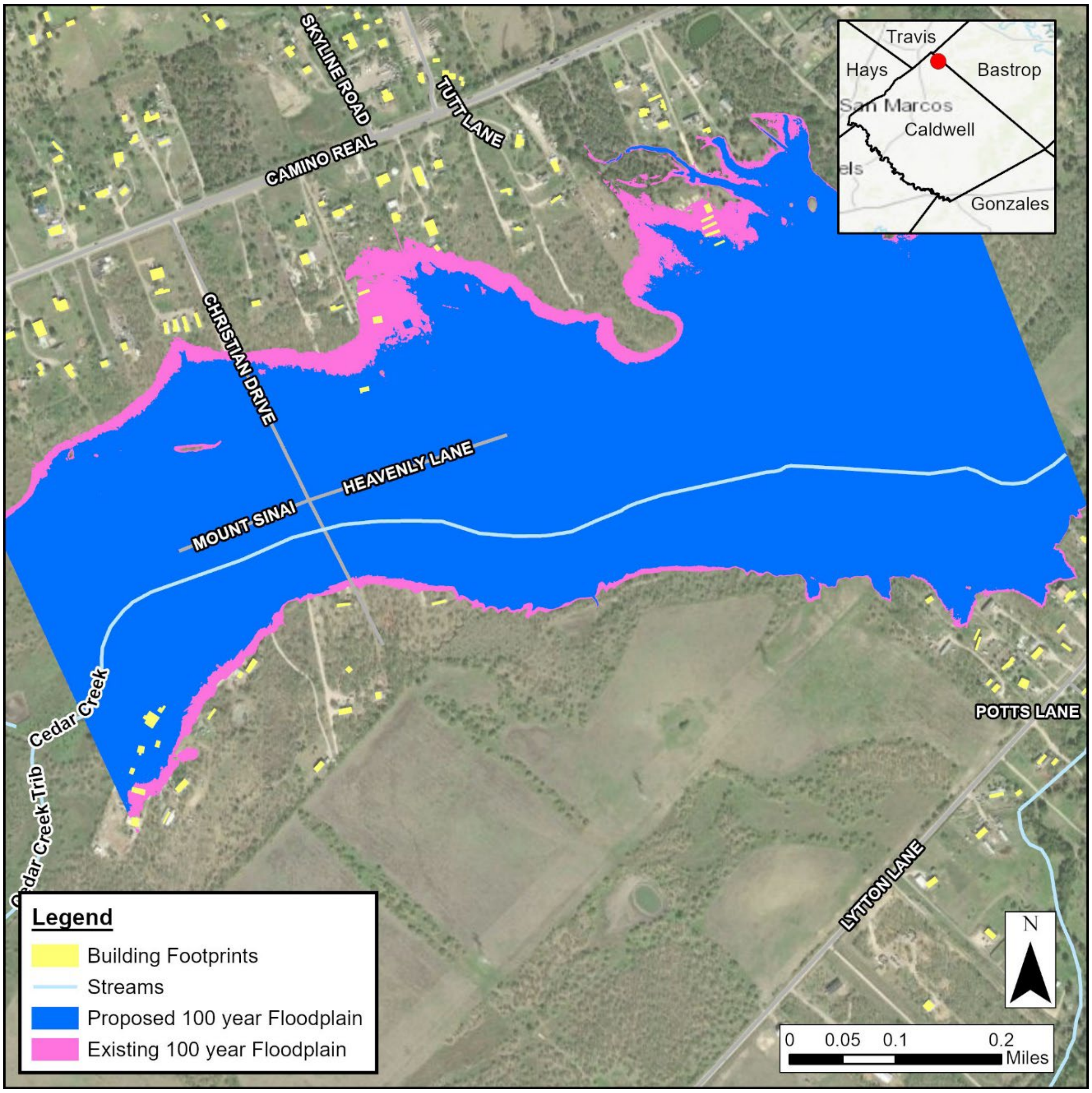

Figure 5-1C. Project CC-1 flood risk reduction for the 100-year event.

5.3.2 Project CC-2 – CR 170 Low Water Crossing Improvements at Lytton Creek

The CR 170 (Crooked Road) low water crossing at Lytton Creek was identified by Caldwell County as a high priority flood problem area. During Hurricane Harvey in 2017, the roadway was closed for 3 days. There are two existing low water crossings at the project site located approximately 0.2 miles apart. The western crossing lies on the Lytton Creek mainstem, and the eastern crossing lies on an unnamed tributary to Lytton Creek. Based on preliminary modeling results, under existing conditions, the 2-year depths of flooding at the western and eastern low water crossings are 47 inches and 36 inches, respectively, and the roadway is impassable for over 5 hours. During the 100-year event, those depths increase to 71 inches and 52 inches, making the roadway impassable for 19 hours. Please see **Figure 5-2A** for a view of the study area.

The proposed project at CR 170 was developed to improve the level-of-service of the roadway for daily traffic and emergency services. The proposed improvements at the western crossing include elevating the roadway approximately 5.5 feet, installing 5 – 10 ft x 6 ft box culverts, and approximately 2,100 linear feet of trapezoidal channel improvements with a bottom width of 100 feet and side slopes of 4:1. At the eastern crossing, the proposed improvements include elevating the roadway approximately 5 feet, installing 4 – 10 ft x 4 ft box culverts, and approximately 660 linear feet of trapezoidal channel improvements with a bottom width of 100 feet and side slopes of 4:1. Please see **Figure 5-2B** for a depiction of the proposed improvements.

Based on the preliminary modeling results, the proposed improvements result in a 2-year level of service for the roadway by reducing the depth and duration of roadway flooding to zero. During the 10-year event, the depth and duration of flooding at the eastern crossing is zero, while the depth at the western crossing is reduced from 60 inches to 11 inches. The length of time the road is impassable during the 10-year event is reduced from 6.5 hours to under 1.8 hours. In the 100-year event, the maximum flooding depths are reduced from 71 inches to 16 inches at the western crossing and from 52 inches to 5 inches at the eastern crossing. The length of time the road is impassable during the 100-year event is reduced from 19 hours to 3.2 hours. Please see **Figure 5-2C** for a depiction of the 100-year flood risk reduction.

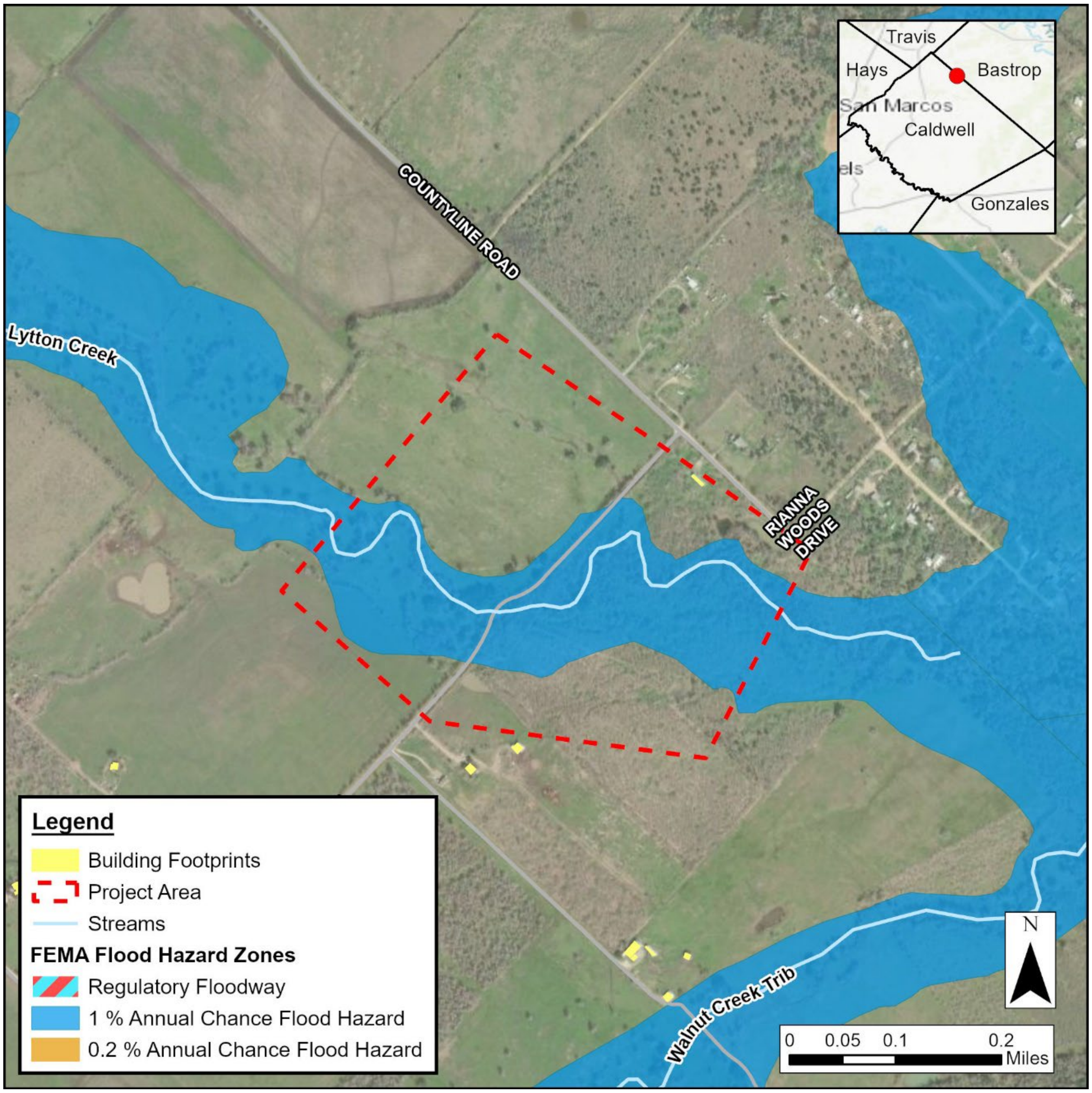

Figure 5-2A. Project CC-2 study area location.

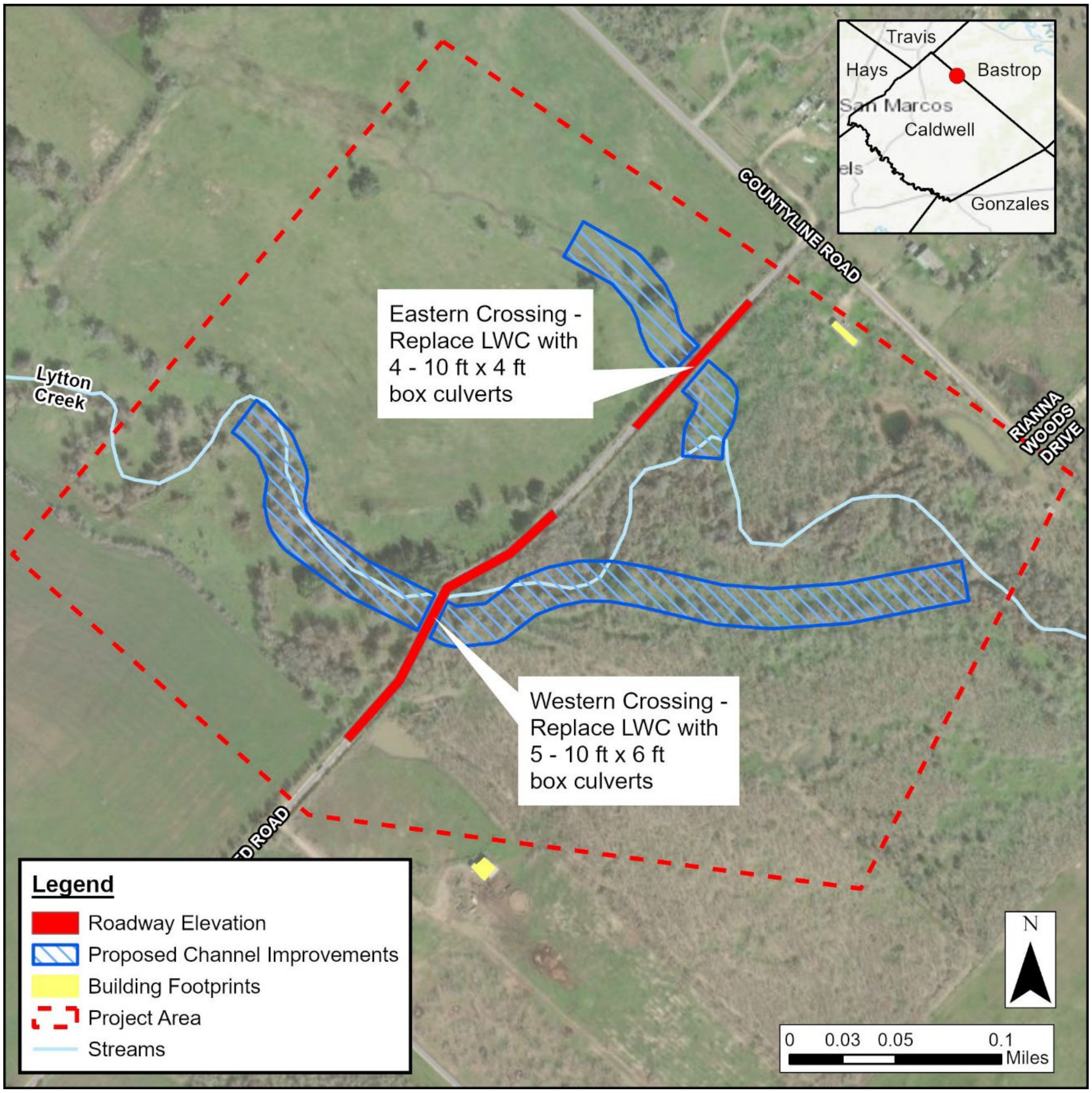

Figure 5-2B. Project CC-2 proposed improvements.

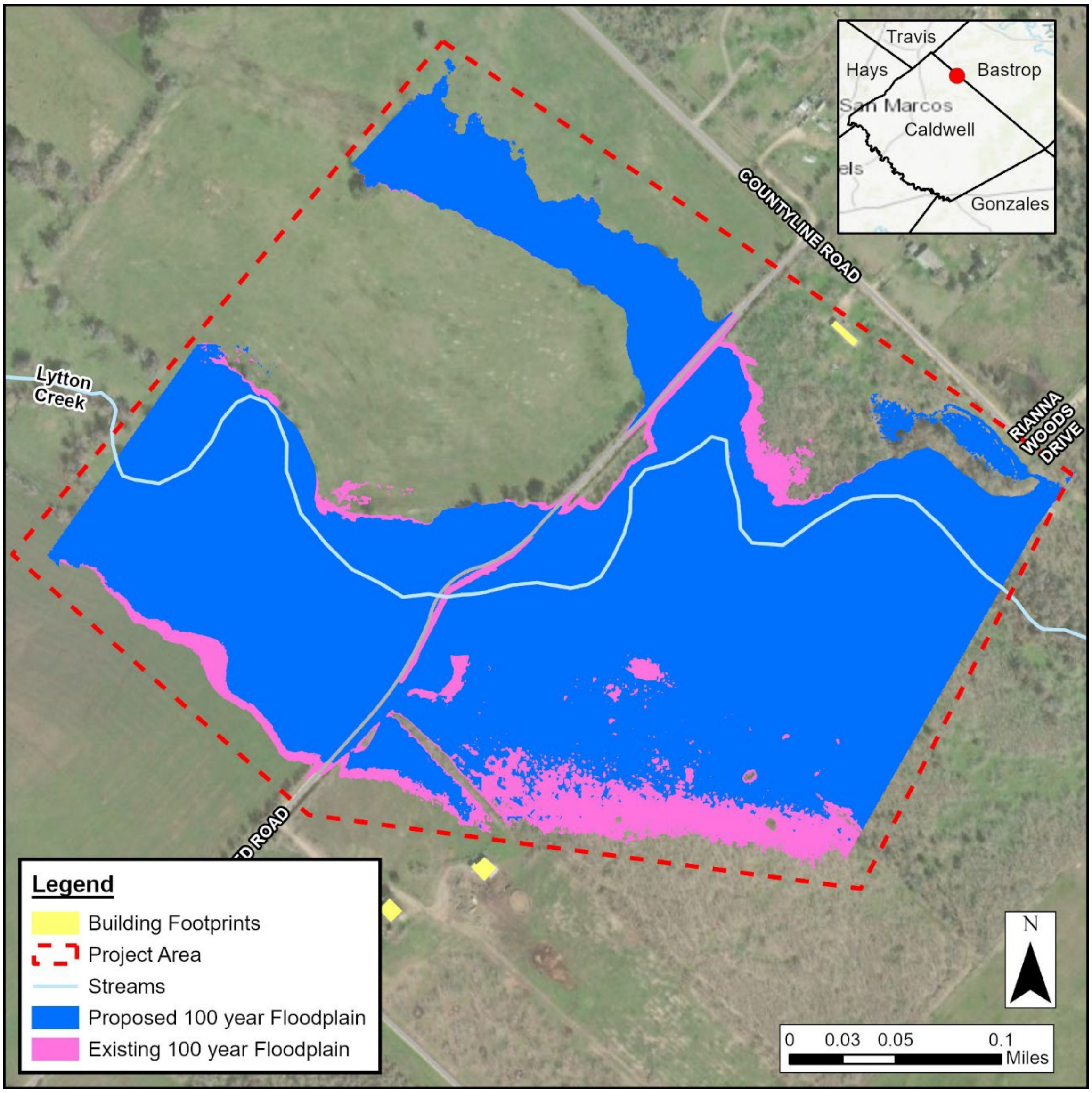

Figure 5-2C. Project CC-2 flood risk reduction for the 100-year event.

5.3.3 Project CC-3 – CR 172 Low Water Crossing Improvements at Lytton Creek

The existing low water crossing on CR 172 (County Line Road) at Lytton Creek was identified by Caldwell County as a high-priority flood problem area. During Hurricane Harvey in 2017, the roadway was closed for 2 days. Under existing conditions, the drainage structure has no opening under the roadway and acts solely as a weir to convey flow downstream. Preliminary 2D modeling results show the existing 2-year depth of flooding at the low water crossing is 46 inches, and the roadway is impassable for nearly 3 hours. During the 100-year event, the depth increases to 64 inches, making the roadway impassable for nearly 18 hours. Please see **Figure 5-3A** for a view of the study area.

The proposed project for CR 172 was developed to improve the level-of-service of the roadway for daily traffic and emergency services. The proposed improvements include elevating the roadway approximately 5 feet, installing 4 – 10 ft x 6 ft box culverts, and approximately 1,600 linear feet of trapezoidal channel improvements with a bottom width of 200 feet and side slopes of 4:1. Please see **Figure 5-3B** for a depiction of the proposed improvements.

Based on the preliminary modeling results, the proposed improvements result in a 100-year level of service for the roadway by reducing the maximum depth of flooding to less than 6 inches. This reduction in depth makes the roadway passable during the 100-year event, whereas the roadway is impassable for nearly 18 hours under existing conditions. With the proposed improvements, flood waters do not overtop the roadway during the 2- or 10-year event. Please see **Figure 5-3C** for a depiction of the 100-year flood risk reduction.

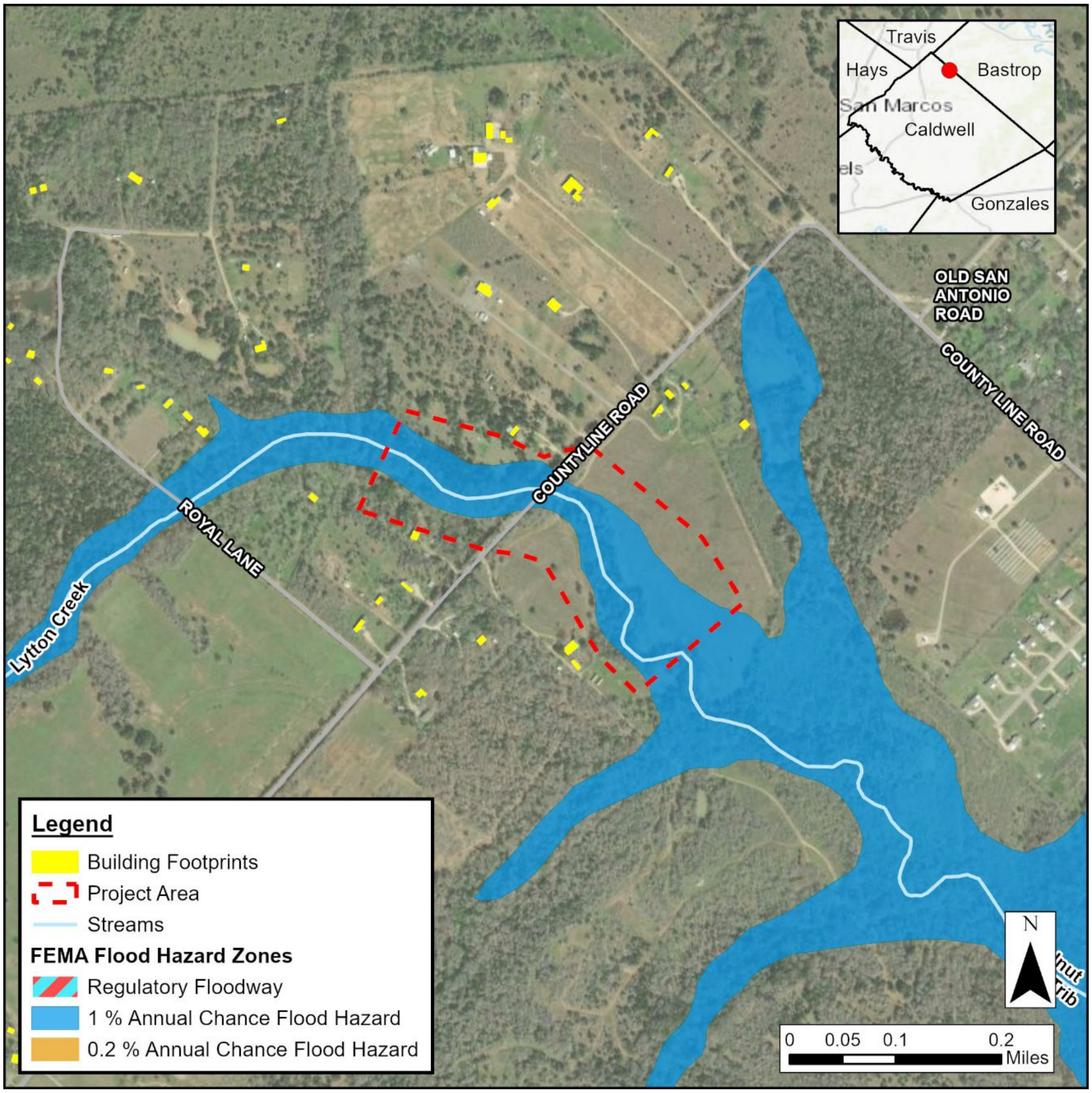

Figure 5-3A. Project CC-3 study area location.

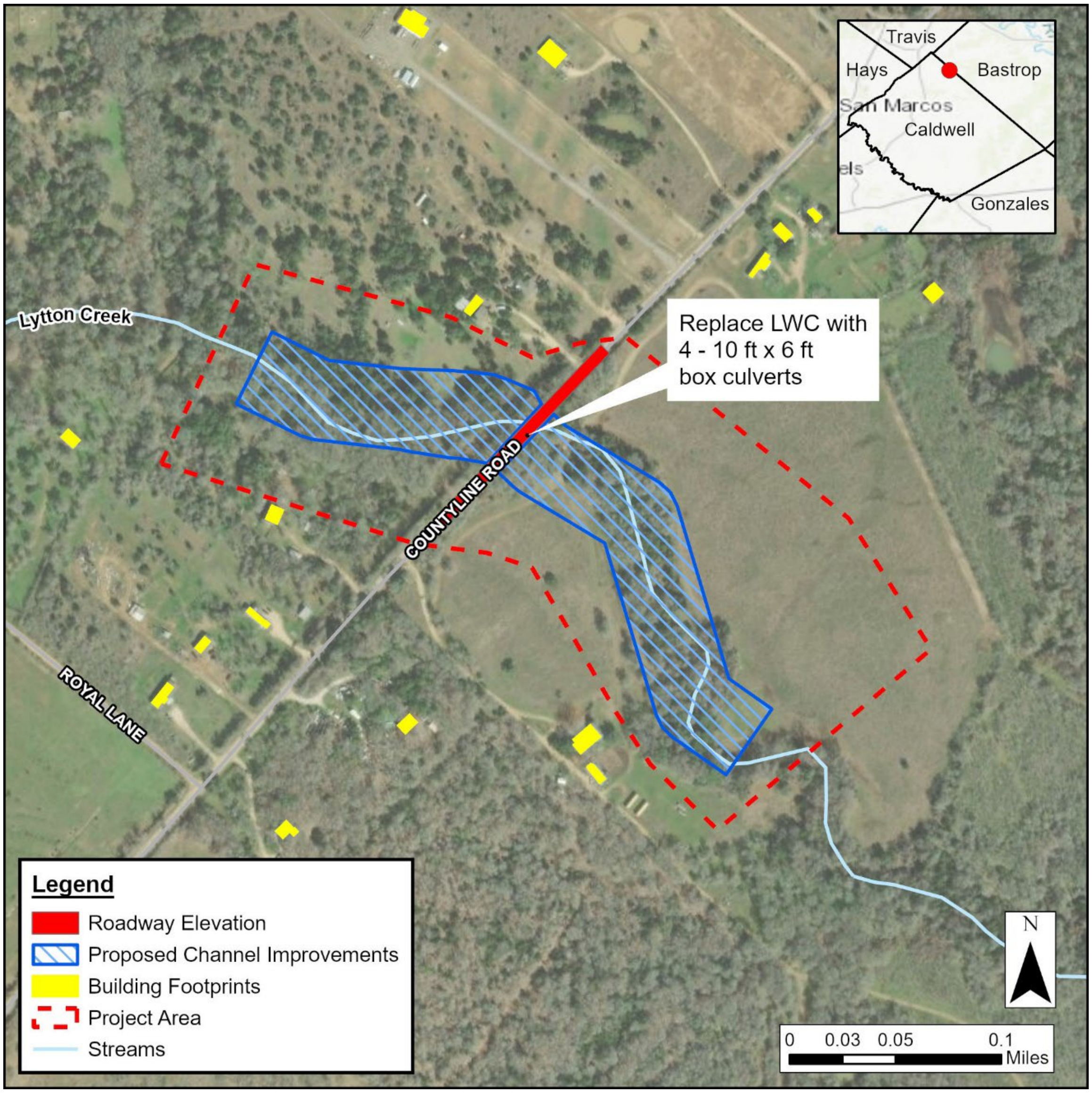

Figure 5-3B. Project CC-3 proposed improvements.

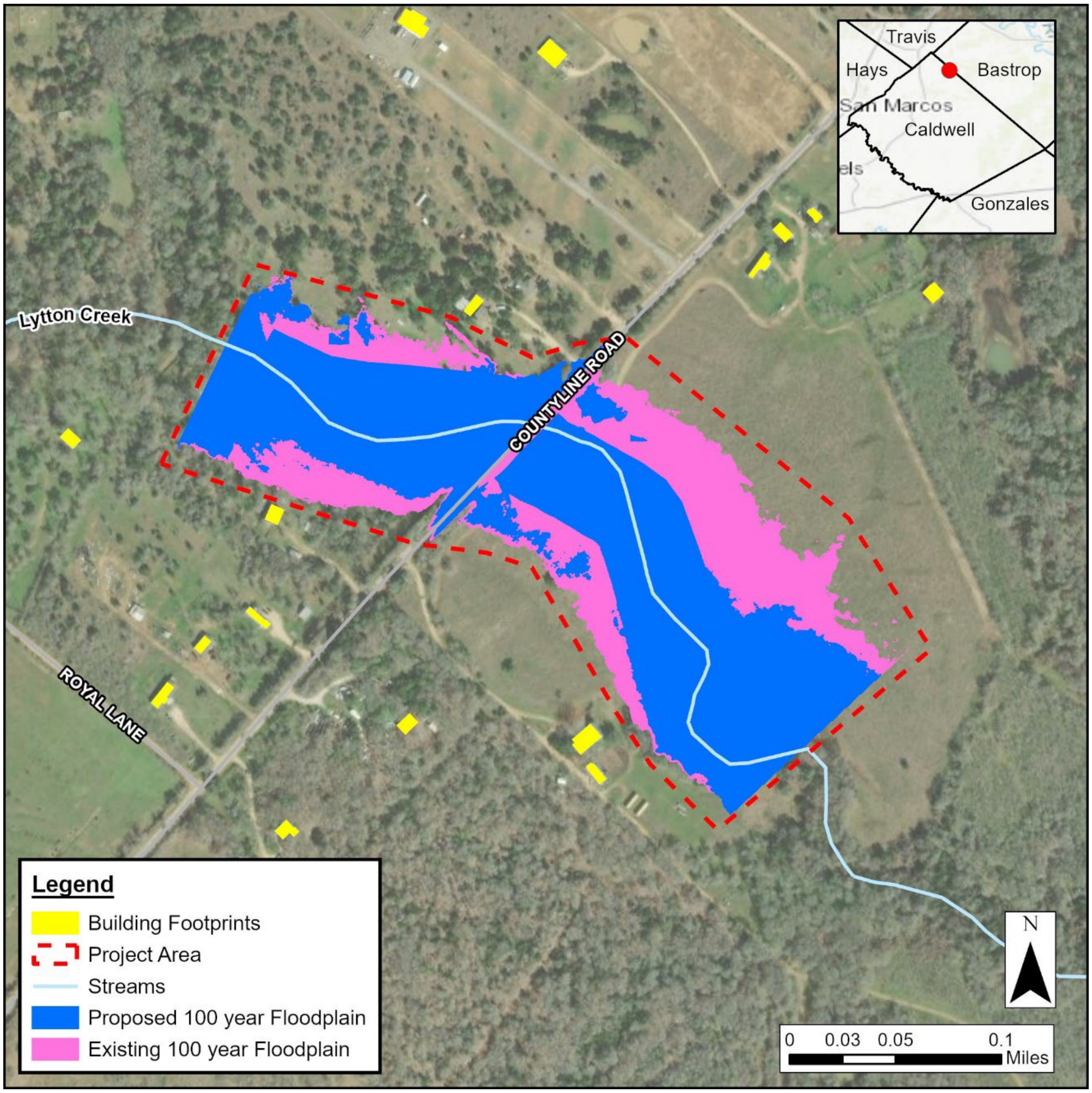

Figure 5-3C. **Project CC-3 flood risk reduction for the 100-year event.**

5.3.4 Project CC-4 – CR 141 at Hines Branch

The CR 141 (Tenney Creek Road) low water crossing at Hines Branch was identified by Caldwell County as a high-priority flood problem area. During Hurricane Harvey in 2017, the crossing was closed for 4 days. Based on preliminary modeling results, the 2-year depth of flooding at the crossing is 13 inches under existing conditions, and the roadway is impassable for nearly 5 hours. During the 100-year event, the flooding depth increases to 32 inches, making the roadway impassable for 15 hours. Please see **Figure 5-4A** for a view of the study area.

The proposed improvements at CR 141 (Tenney Creek Road) on Hines Branch are intended to improve the level-of-service for the roadway to accommodate daily traffic and emergency services. The project includes upgrading the existing low water crossing from 3 – 48 inch CMPs to 5 – 10 ft x 3 ft concrete box culverts, as well as approximately 1,800 linear feet of channel improvements with a 100 foot bottom width and 4:1 side slopes. To prevent additional damming of water upstream of the crossing, this project does not include elevation of the roadway deck. Please see **Figure 5-4B** for a depiction of the proposed improvements.

Based on preliminary modeling, the proposed improvements reduce the 2-year maximum roadway flooding depth from 13 inches to 8 inches, which also reduces the amount of time the roadway is impassable from 4.7 hours to 0.8 hours. During the 100-year event, the maximum depth of roadway flooding is reduced from 32 inches to 25 inches, reducing the amount of time the roadway is impassable from 15 hours to less than 8 hours. Please see **Figure 5-4C** for a depiction of the 100-year flood risk reduction.

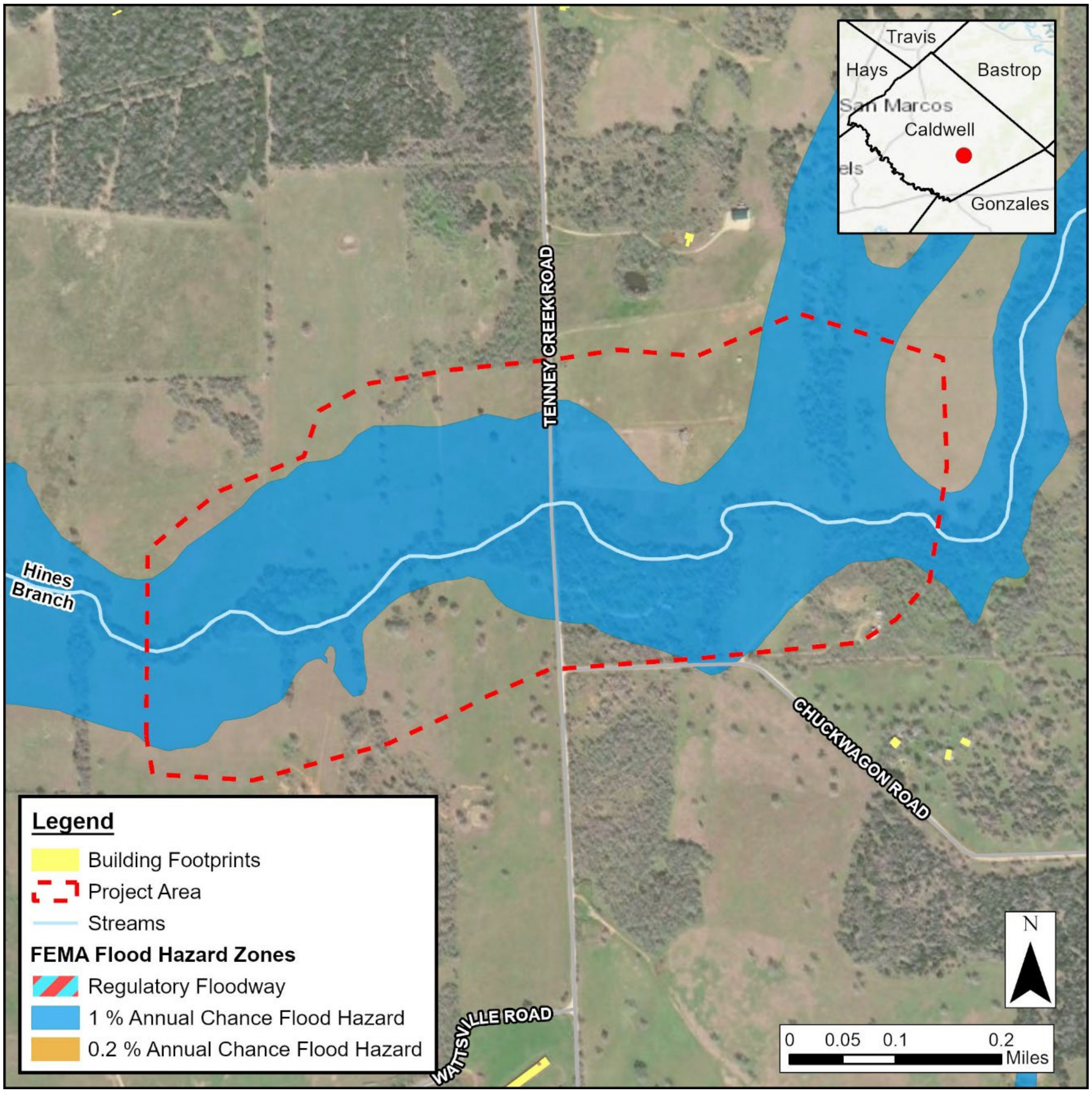

Figure 5-4A. Project CC-4 study area location.

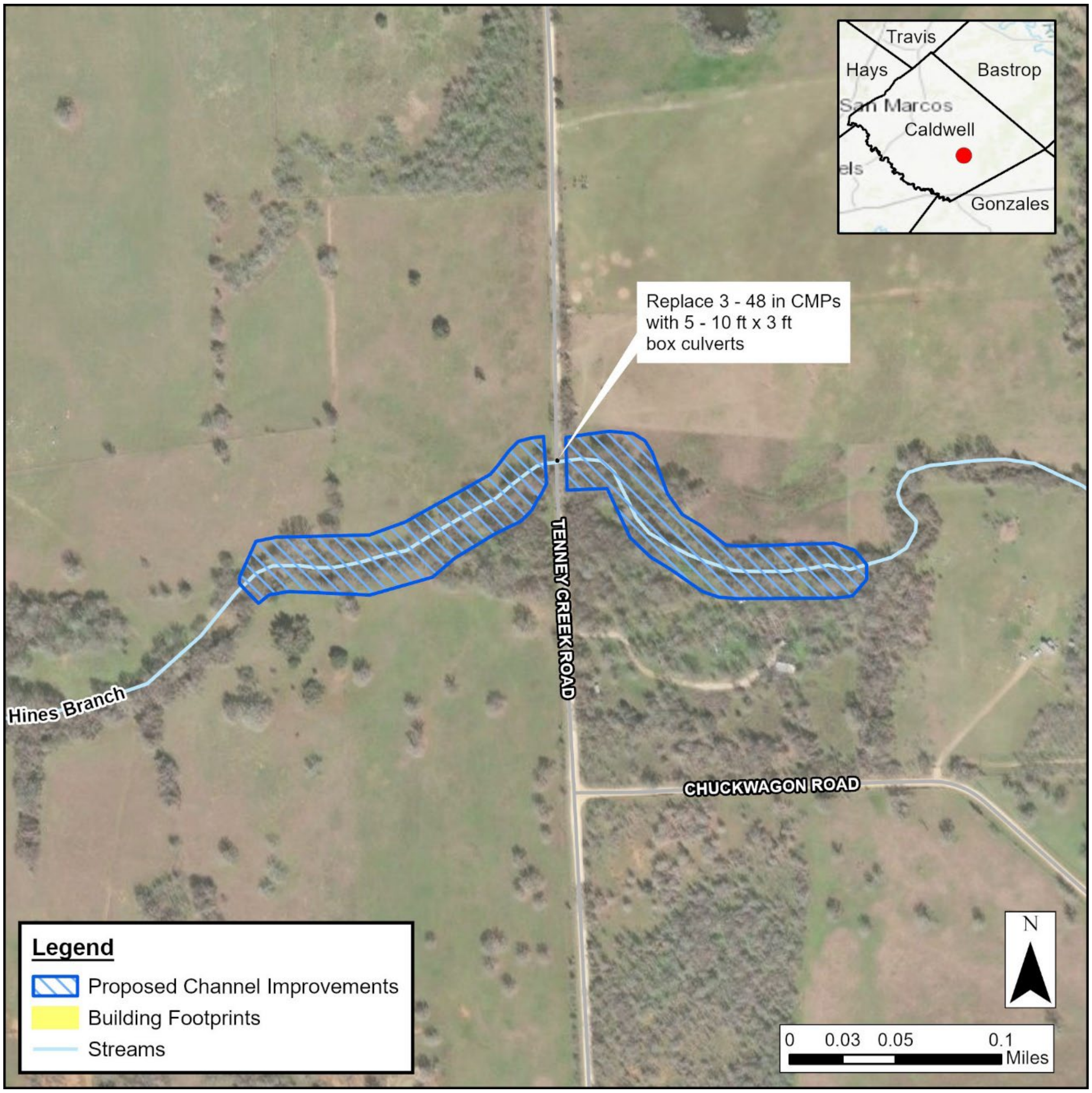

Figure 5-4B. Project CC-4 proposed improvements.

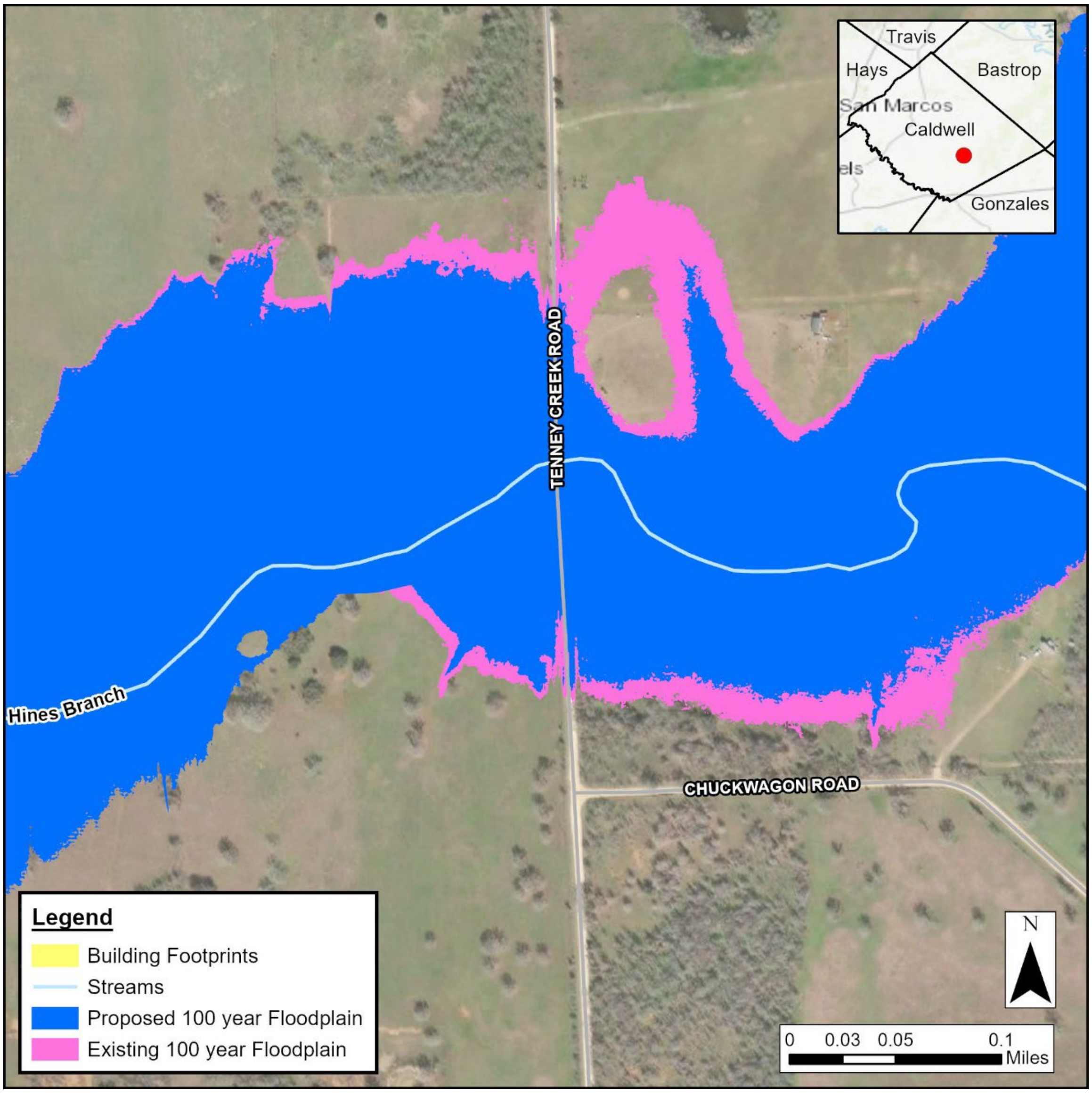

Figure 5-4C. Project CC-4 flood risk reduction for the 100-year event.

5.3.5 Project CC-5 – SH 80 Low Water Crossing Improvements at Morrison Creek

The flood problem area at SH 80 on Morrison Creek was identified based on the results of the 1D hydraulic analysis. Under existing conditions, 11 residential structures are located within the 100-year floodplain, with flooding depths ranging from 2 inches to 55 inches. In addition, the maximum depth of flooding on SH 80 is 9 inches, making the roadway impassable for 1.2 hours. Please see **Figure 5-5A** for a view of the study area.

The Morrison Creek project at SH 80 was developed to improve the level-of-service for the low water crossing and remove homes from the 100-year floodplain. The proposed mitigation alternative involves adding a total of 3 box culverts to the existing culverts, widening the channel to provide more capacity, adding a berm and a 100 acre-ft offline detention pond upstream of flooding homes. The study area includes 3 existing culvert structures on SH 80 located within a span of approximately 1,570 feet. Two 8 ft x 8 ft barrels for a total of 6 – 8 ft x 8 ft barrels were added to the most northwest crossing, and 1 – 10 ft x 8 ft barrel for a total of 2 – 10 ft x 8 ft barrels was added to the middle crossing. The proposed channel improvements extend 5,500 linear feet and have a bottom width of 250 feet with 4:1 side slopes. The berm is approximately 3,250 LF and set at an elevation of 522 feet. Please see **Figure 5-5B** for a depiction of the proposed improvements.

During the 100-year storm event, the proposed drainage improvements remove 10 residential structures from the floodplain. Furthermore, the maximum depth of flooding at SH 80 is reduced from 9 inches to 0 inches, providing a 100-year level-of-service for the crossing. Please see **Figure 5-5C** for a depiction of the 100-year flood risk reduction.

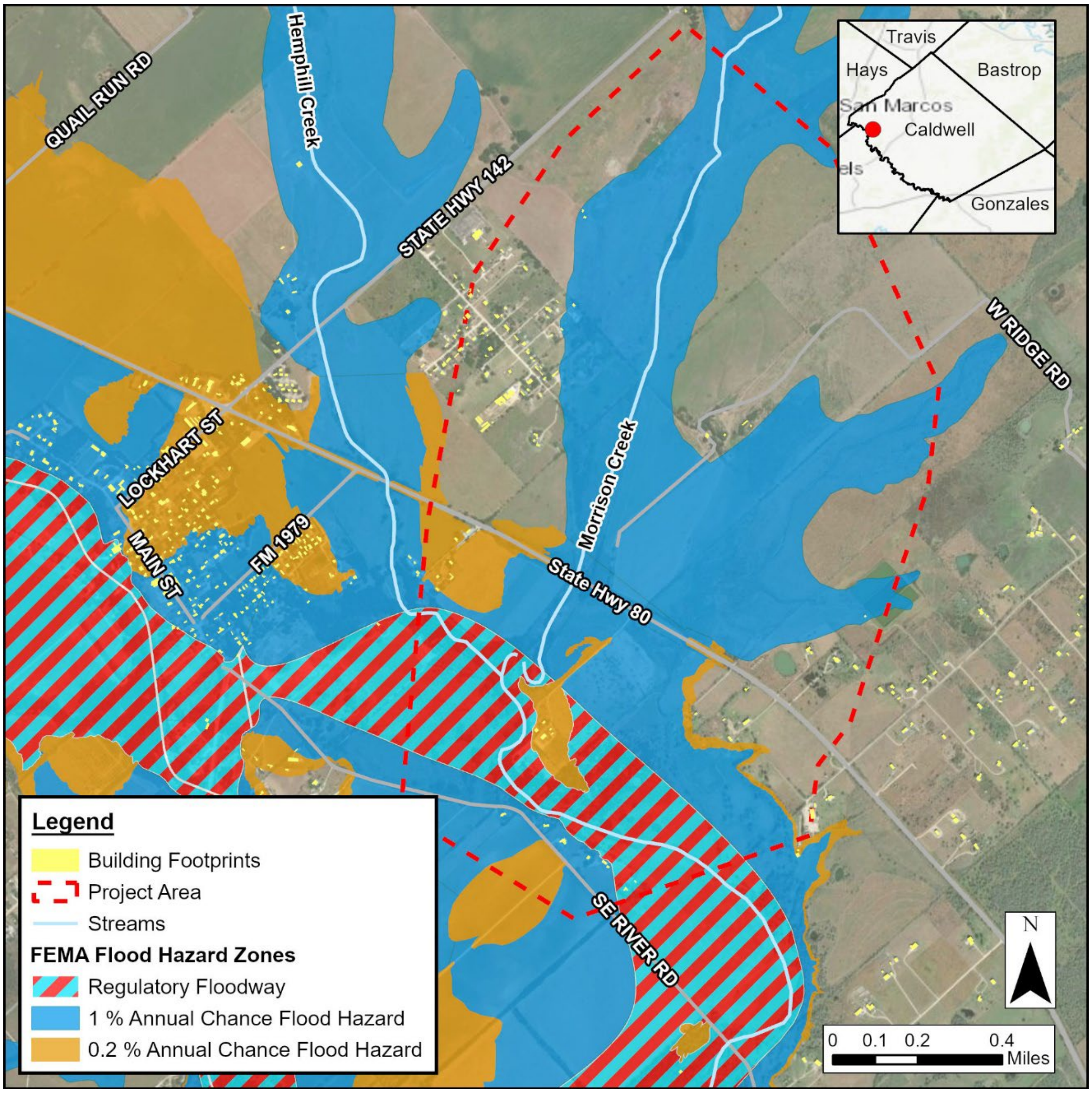

Figure 5-5A. Project CC-5 study area location.

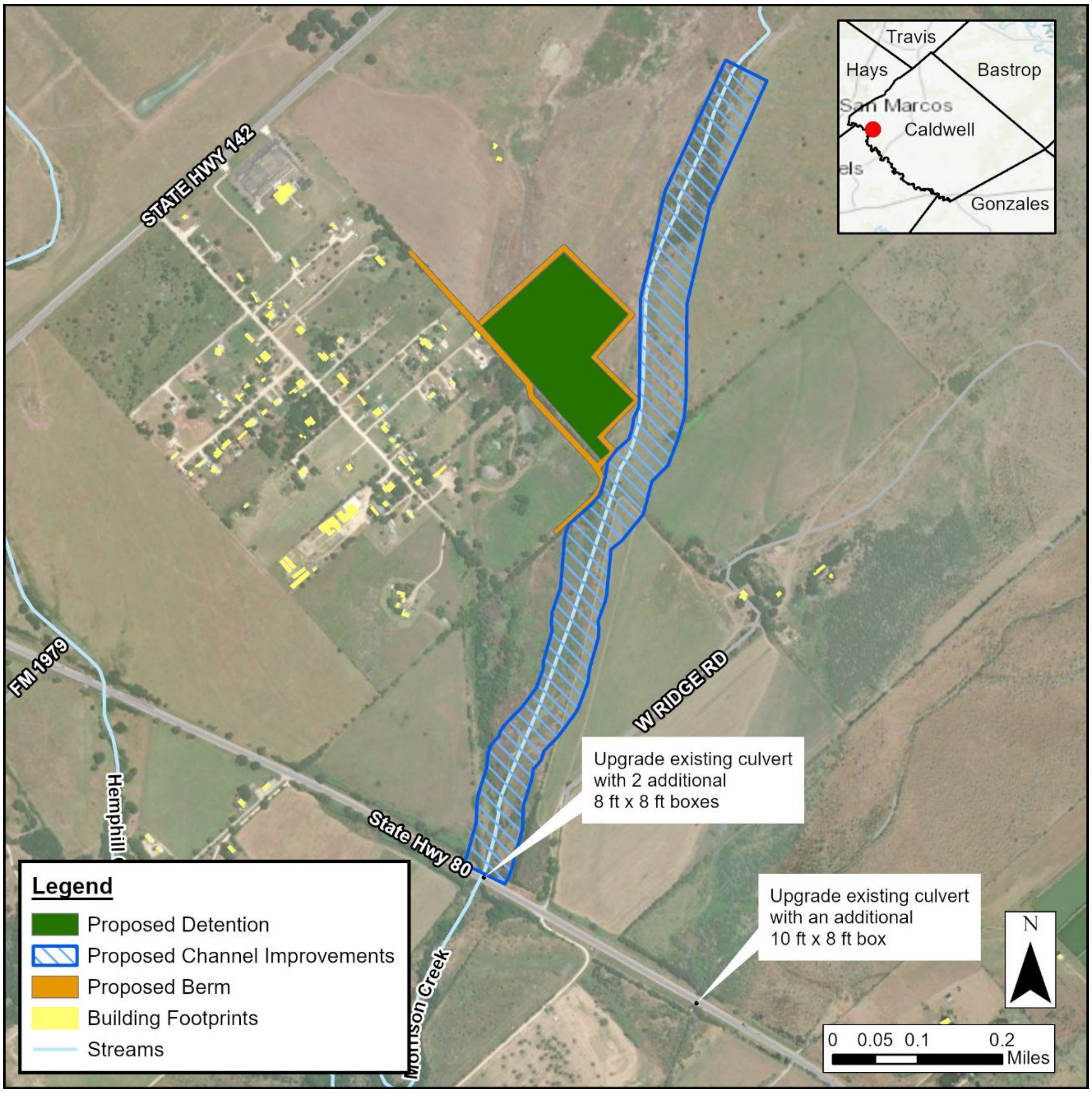

Figure 5-5B. Project CC-5 proposed improvements.

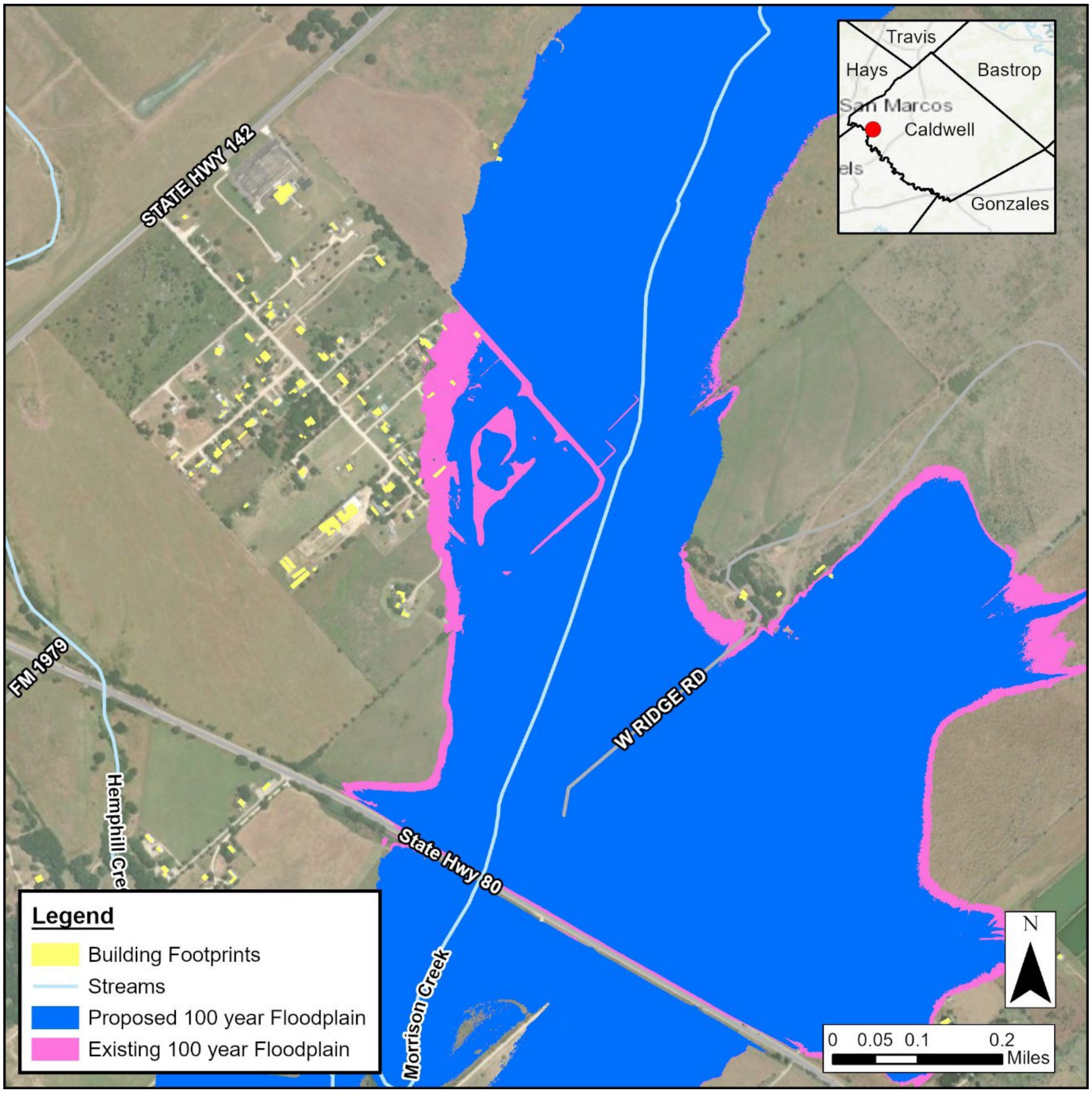

Figure 5-5C. Project CC-5 flood risk reduction for the 100-year event.

5.3.6 Project CC-6 – Salt Branch Drainage Improvements in Luling

The flood problem area on Salt Branch in the City of Luling was previously identified as a damage center in the GBRA Interim Feasibility Study Phase I. Based on preliminary modeling, 9 residential structures are located in the existing 100-year floodplain, with depths ranging from 3 inches to 39 inches. In addition, both Walnut Avenue and Laurel Avenue have less than a 2-year level-of-service, with maximum flooding depths of 7 inches and 15 inches, respectively, during the 2-year storm event. During the 100-year storm event, the depth of flooding increases to 31 inches for both crossings, making Walnut Avenue impassable for nearly 7 hours, and Laurel Avenue is impassable for over 13 hours. Please see **Figure 5-6A** for a view of the study area.

Drainage improvements along Salt Branch in Luling were designed to improve the level-of-service of Walnut Avenue and Laurel Avenue while also reducing the flood risk to residential structures adjacent to the stream. The proposed improvements include expanding the US 183 bridge opening by 50 feet, upgrading the Laurel Avenue culvert structure from 2 – 48-inch RCPs to 5 – 10 ft x 6 ft concrete box culverts, and upgrading the Walnut Avenue culvert structure with 2 additional 10 ft x 6 ft boxes for a total of 5. Approximately 2,060 linear feet of channel improvements are proposed between US 183 and Hackberry Avenue. These channel improvements have a bottom width of 50 feet with 3:1 side slopes. Please see **Figure 5-6B** for a depiction of the proposed improvements.

Preliminary modeling shows that the proposed improvements provide a 100-year level-of-service to the crossings on both Walnut Avenue and Laurel Avenue. The maximum 100-year depth of flooding at Walnut Avenue is reduced from 31 inches to 0 inches, and the maximum depth of flooding at Laurel Avenue is reduced from 31 inches to 3 inches. While none of the residential structures are entirely removed from the 100-year floodplain due to their proximity to the stream, the depth of flooding is reduced by as much as 8 inches at 7 structures. Please see **Figure 5-6C** for a depiction of the 100-year flood risk reduction.

Figure 5-6A. Project CC-6 study area location.

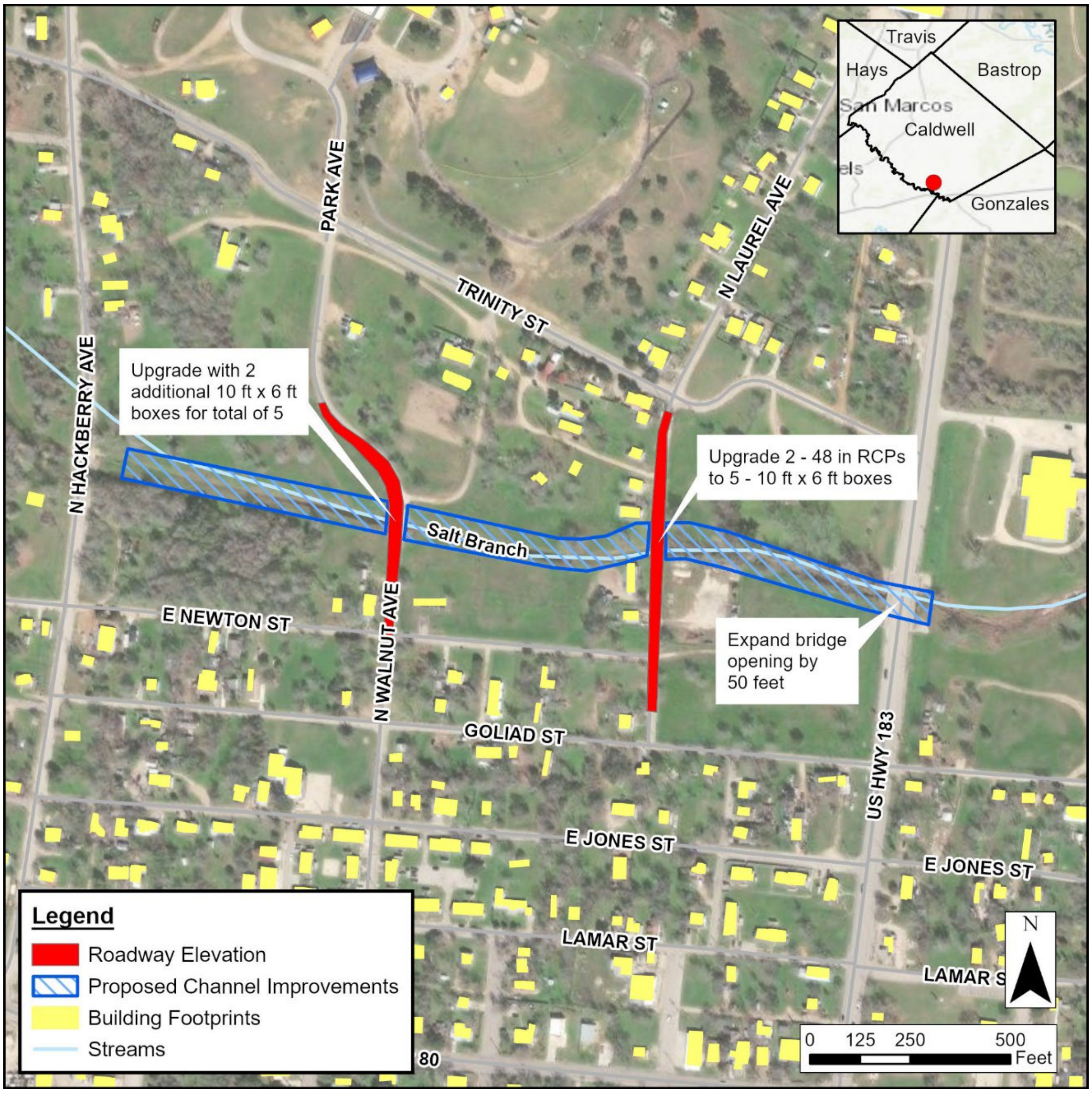

Figure 5-6B. **Project CC-6 proposed improvements.**

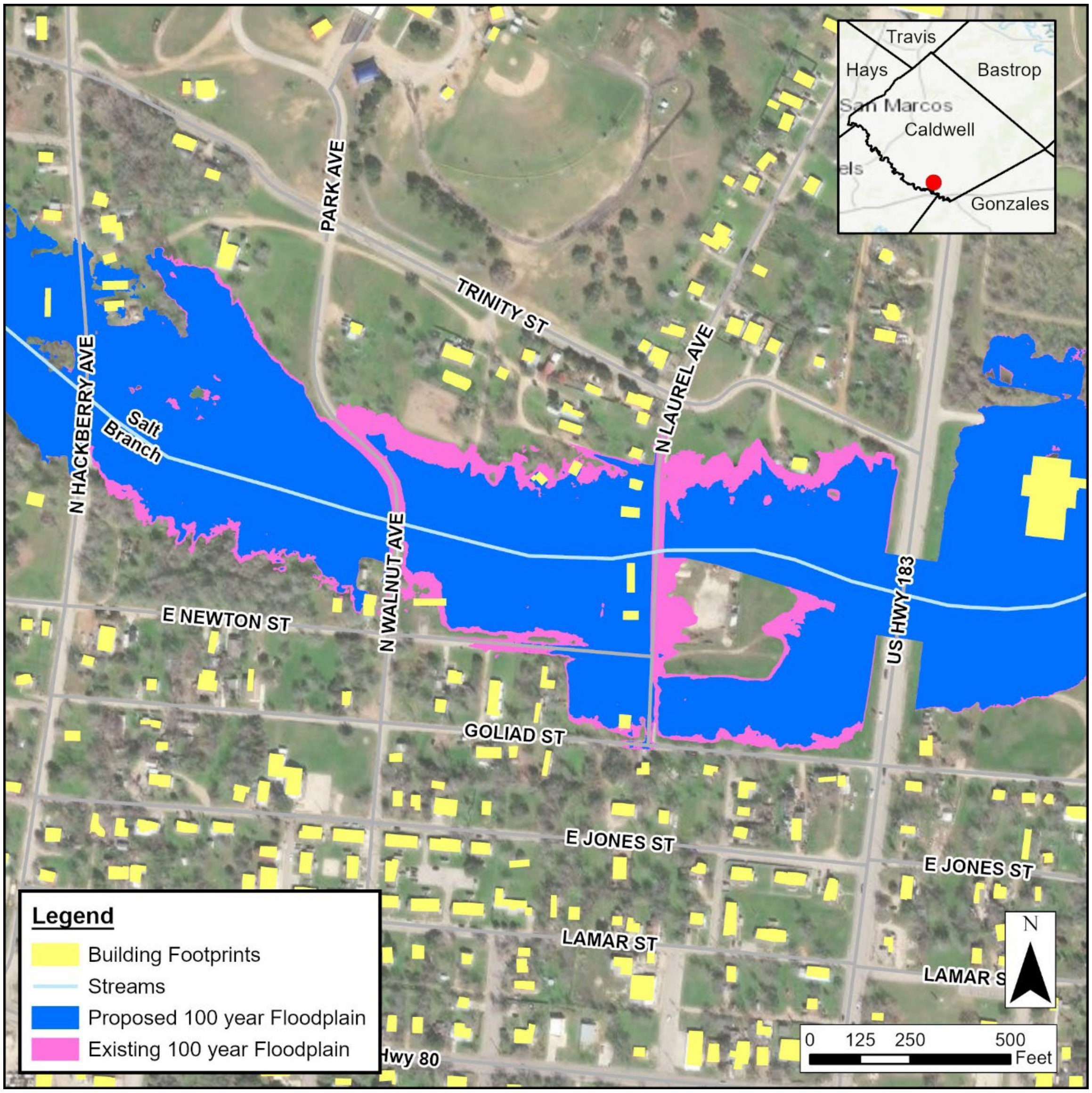

Figure 5-6C. Project CC-6 flood risk reduction for the 100-year event.

5.3.7 Project CC-7 – CR 233 and FM 2001 at Plum Creek

The low water crossing at CR 233 (Polonia Road) on Plum Creek was identified as a high-priority flood problem area. A drowning occurred at the location in 2013, and the roadway was closed for 16 days during Hurricane Harvey in 2017. Based on preliminary modeling, the depth of flooding under existing conditions is nearly 9 feet during the 2-year storm event and is over 14 feet during the 100-year event. For both storms, the roadway is impassable for multiple days. In addition, 4 residences are located within the existing conditions floodplain, with flooding depths ranging from 1 inch to 39 inches. Please see **Figure 5-7A** for a view of the study area and affected structures.

The primary objective of this improvement project is to improve the level-of-service and safety of the Plum Creek crossing at CR 233 (Polonia Road). The proposed improvements include elevating the roadway approximately 10 feet and upgrading the low water crossing from 2 – 24-inch CMPs to a 180-foot-long bridge. In addition, approximately 2,250 linear feet of channel improvements are proposed through the CR 233 crossing with a bottom width of 150 feet and 4:1 side slopes. Please see **Figure 5-7B** for a depiction of the proposed improvements.

Based on preliminary modeling results, the proposed improvements at CR 233 on Plum Creek provide a 2-year level-of-service for the crossing. The maximum depth of flooding during the 2-year event is reduced from 106 inches (8.8 feet) to 0 inches. The roadway becomes passable for the duration of the 2-year storm event, whereas it is impassable for several days under existing conditions. For the 100-year storm event, the maximum depth of flooding is reduced from 169 inches (14 feet) to 43 inches (3.6 feet), and the length of time the roadway is impassable is reduced from several days to 8 hours. In addition to the flood mitigation benefits at the CR 233 crossing, the proposed improvements remove one residential structure from the 100-year floodplain and reduce the flooding depths at 3 others by as much as 7 inches. Please see **Figure 5-7C** for a depiction of the 100-year flood risk reduction.

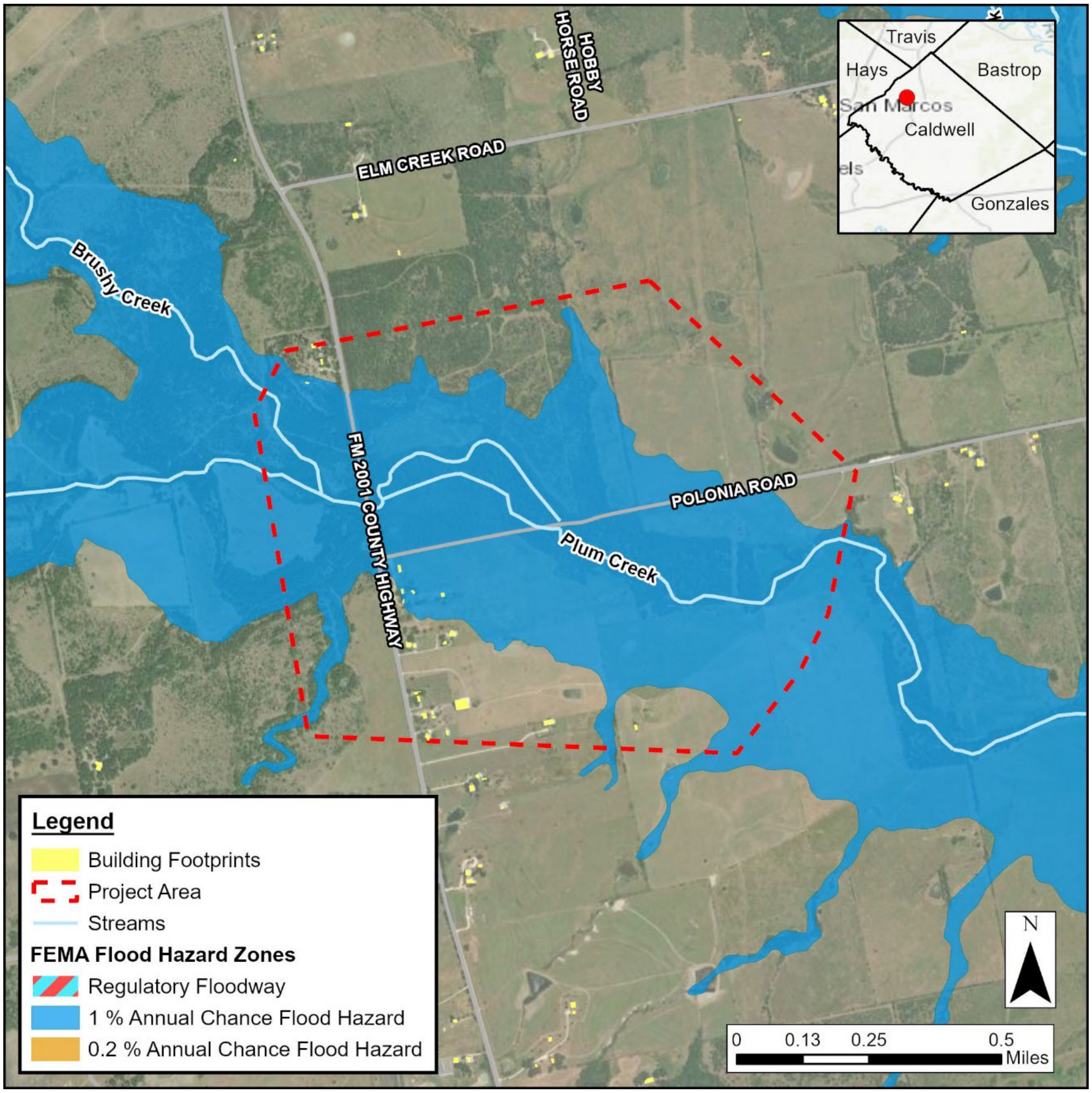

Figure 5-7A. Project CC-7 study area location.

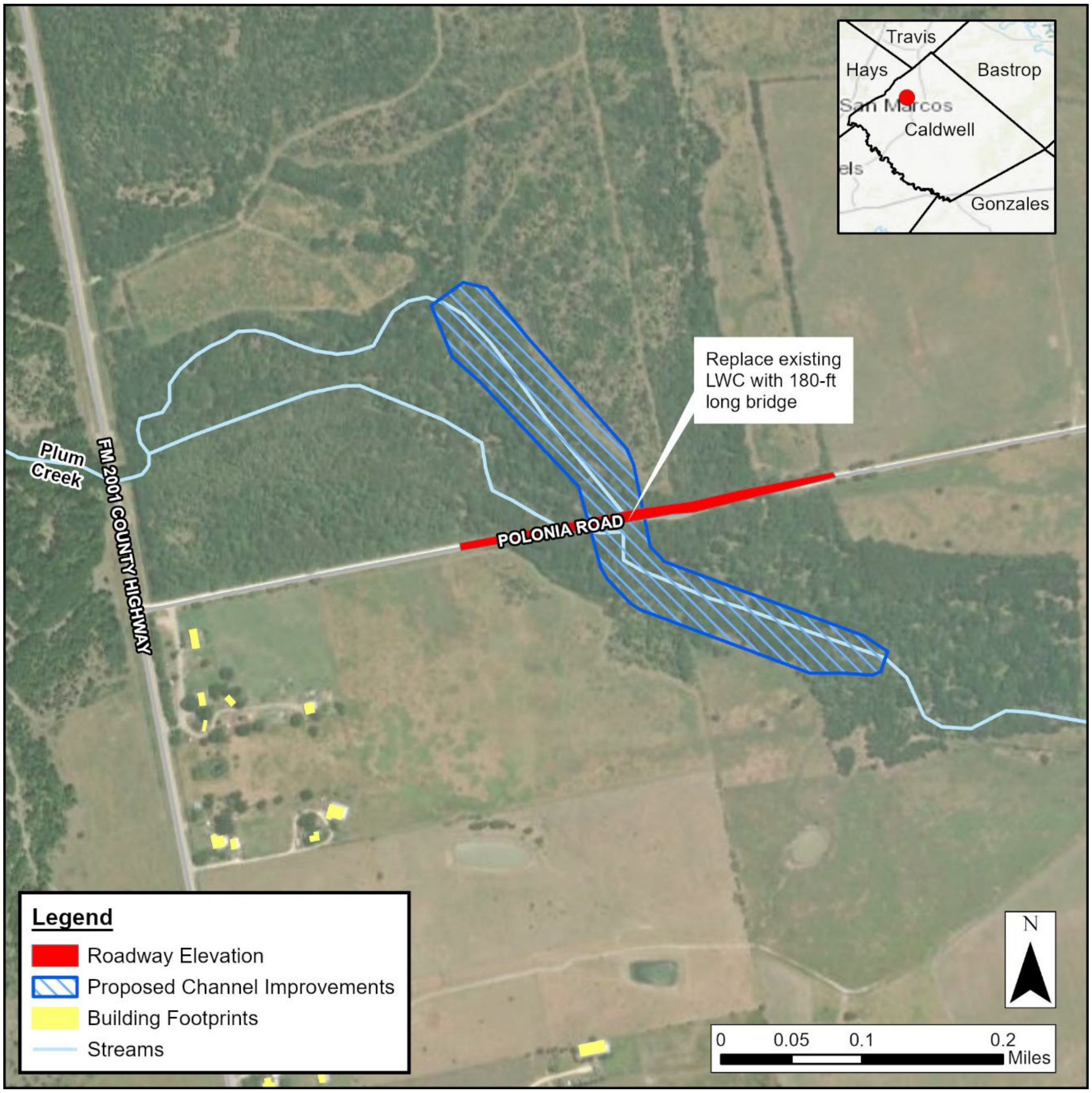

Figure 5-7B. Project CC-7 proposed improvements.

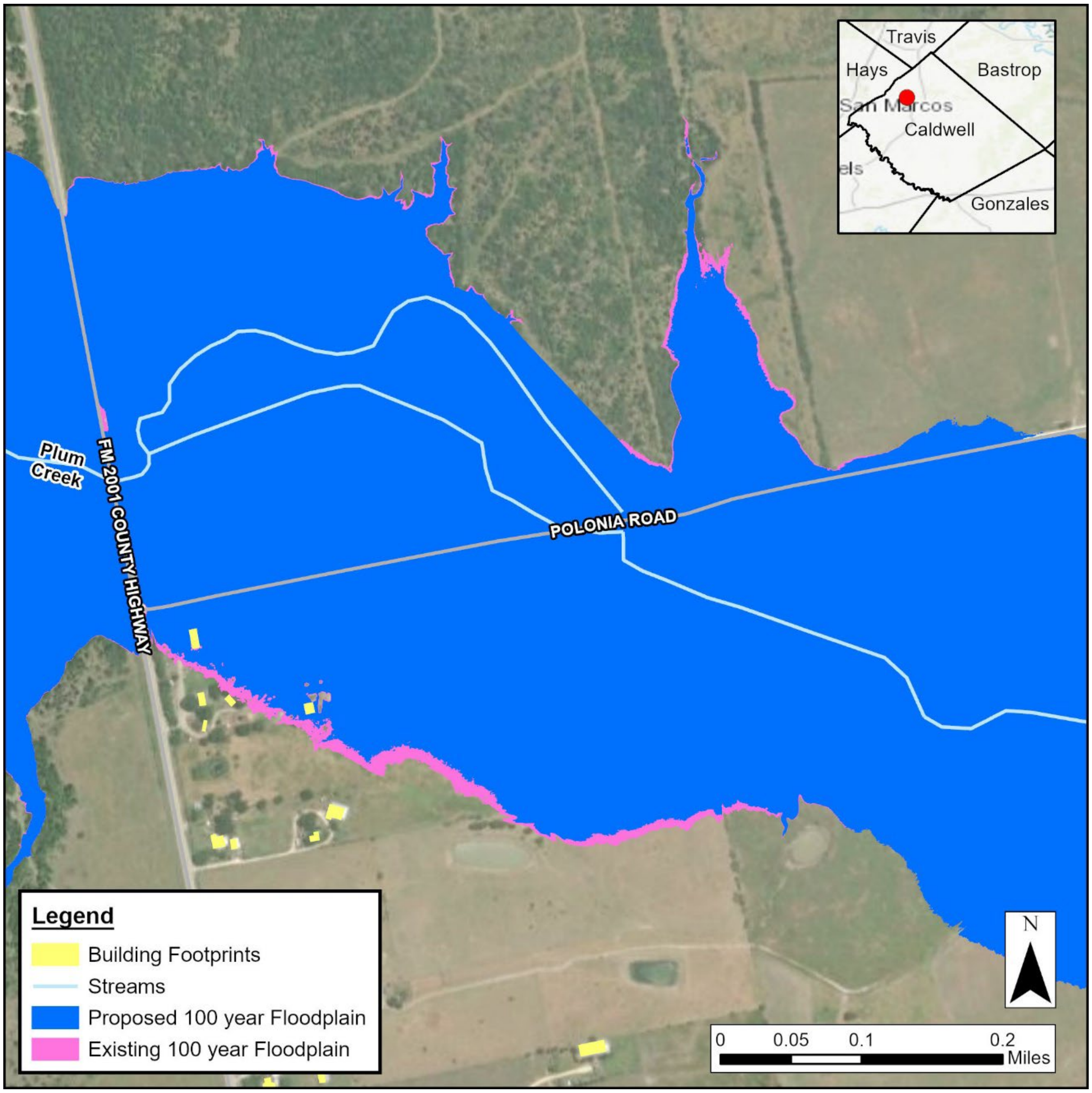

Figure 5-7C. **Project CC-7 flood risk reduction for the 100-year event.**

5.3.8 Project CC-8 – Plum Creek Channel Improvements Near CR 227

The flood problem area on Plum Creek downstream of CR 227 (Old Spanish Trail) was identified based on the results of the 1D hydraulic analysis associated with the FIF study. Under existing conditions, 4 residential structures are located within the 100-year floodplain, with depths ranging from 3 inches to 49 inches. In addition, 2 commercial structures are located within the 100-year floodplain, both flooded by 2 inches. Please see **Figure 5-8A** for a view of the study area.

The purpose of this channel improvement project is to mitigate flooding of residential and commercial structures south of the intersection of CR 227 (Old Spanish Trail) and Seeliger Drive in Uhland, TX. The primary section of channel improvements begins on the downstream side of CR 227 and extends approximately 1,600 linear feet downstream with a bottom width of 200 feet and 4:1 side slopes. Channel improvements are also proposed within a small, unnamed tributary that discharges into Plum Creek from the north near the affected structures. These improvements are approximately 350 feet in length with a bottom width of 50 feet and 4:1 side slopes. Please see **Figure 5-8B** for a depiction of the proposed improvements.

The proposed channel improvements on Plum Creek remove 2 residential structures and 2 commercial structures from the 100-year floodplain. Flooding depths at 2 additional residential structures are reduced by 16 inches and 15 inches. Under proposed conditions, no residential structures are located within the 2-year floodplain. Please see **Figure 5-8C** for a depiction of the 100-year flood risk reduction.

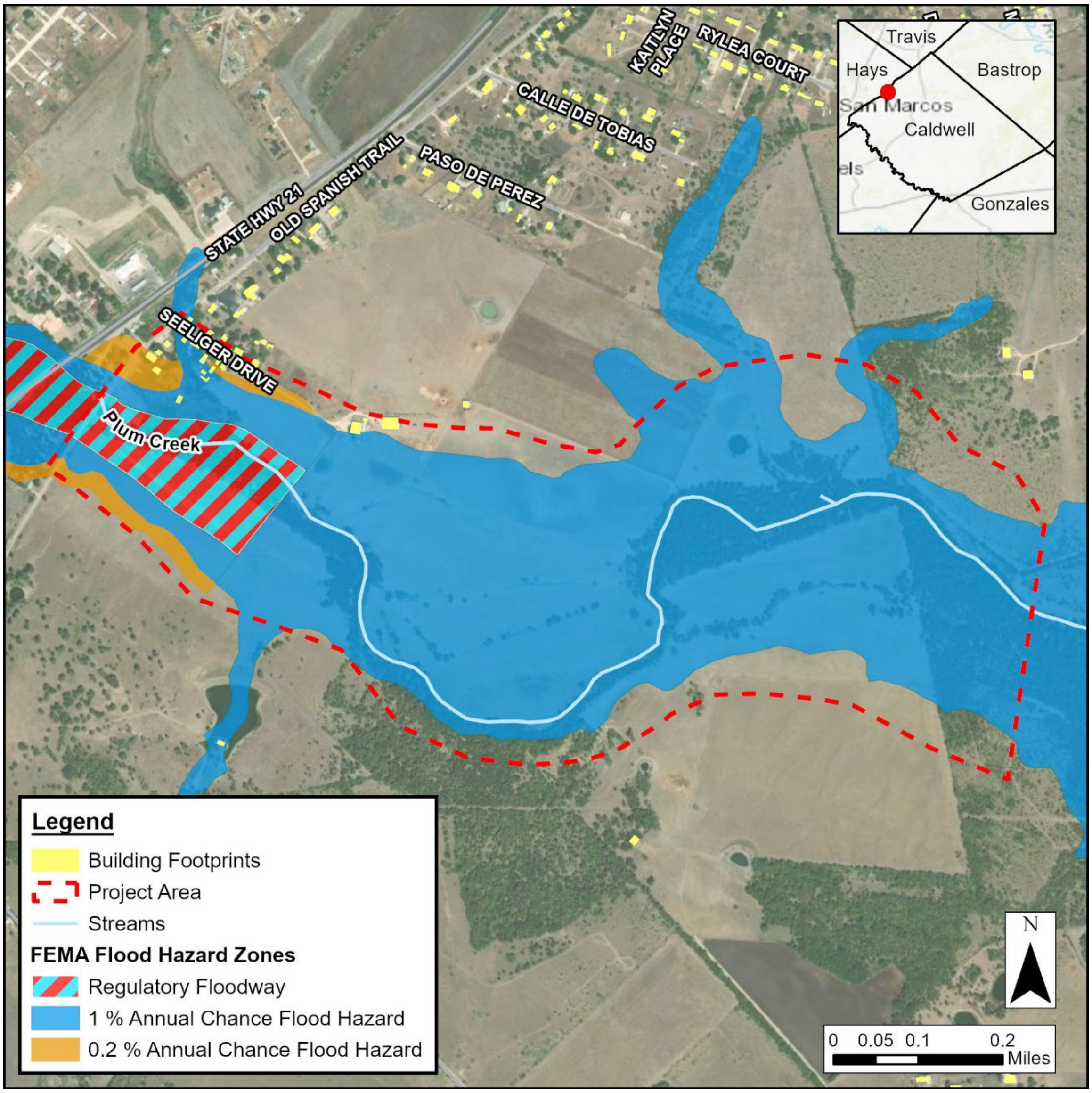

Figure 5-8A. Project CC-8 study area location.

Figure 5-8B. Project CC-8 proposed improvements.

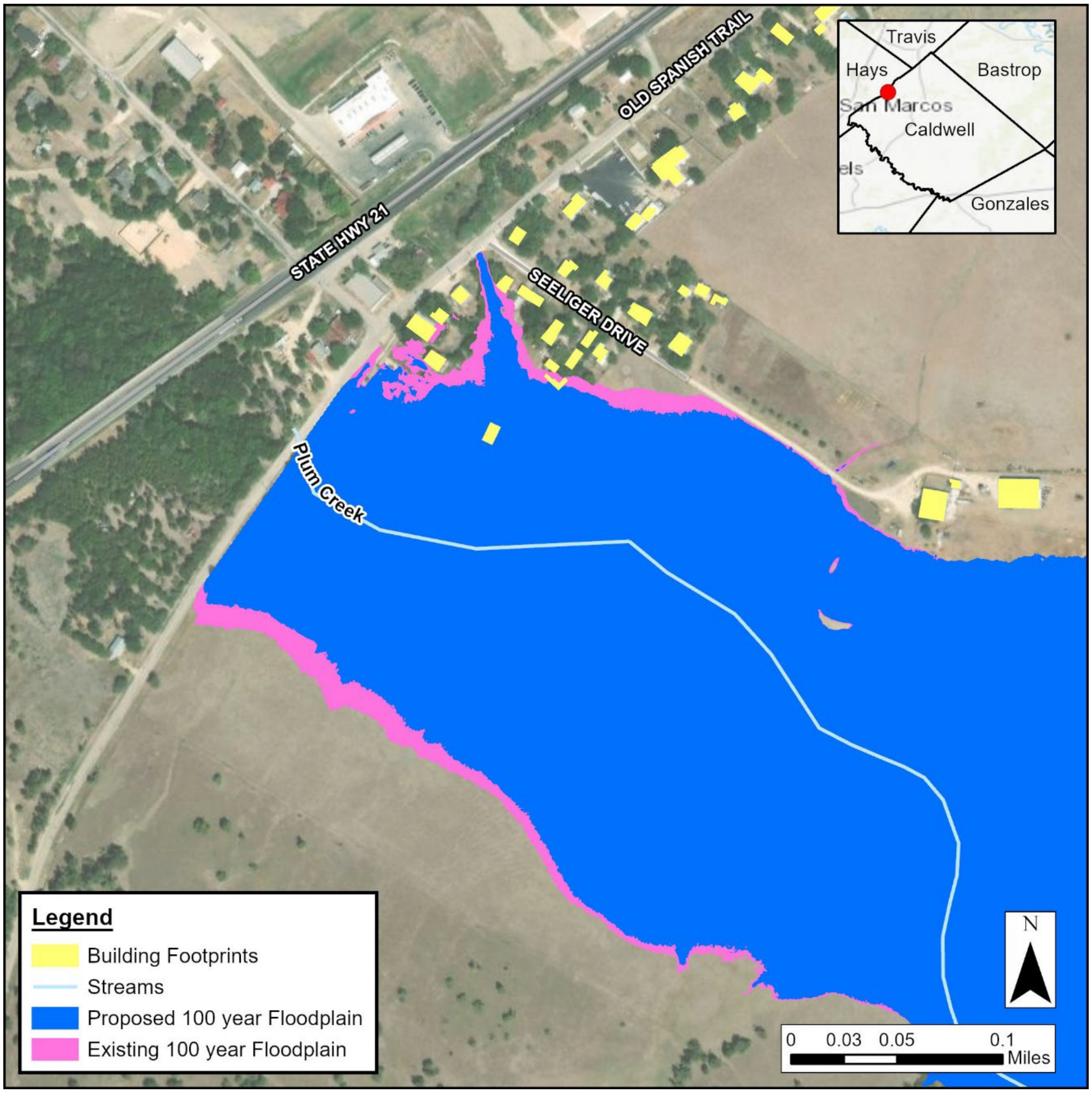

Figure 5-8C. **Project CC-8 flood risk reduction for the 100-year event.**

5.3.9 Project CC-9 – Hemphill Creek Drainage Improvements Near FM 1984

The flood problem area at FM 1984 on Hemphill Creek was identified based on the results of the 1D hydraulic analysis. Under existing conditions, 16 residential structures are located within the 100-year floodplain, with flooding depths ranging from 5 inches to 71 inches. In addition, the maximum depth of flooding on FM 1984 is 33 inches, making the roadway impassable for over 4 hours. It appears the flooding risk for this area is largely due to the constriction caused by the existing Union Pacific rail bridge downstream of FM 1984. Please see **Figure 5-9A** for a view of the study area.

The Hemphill Creek project near FM 1984 was developed to improve the level-of-service at the low water crossing and remove homes from the 100-year floodplain. The proposed mitigation alternative involves expanding the Union Pacific rail bridge opening to a total of 150 feet (25 feet on either side) and adding 2 piers, raising the FM 1984 deck approximately 2.5 feet, replacing the existing FM 1984 culverts with a 100 ft wide bridge, widening the channel to provide more capacity, and adding a 67 acre-ft detention pond. The proposed channel improvements extend approximately 6,000 linear feet and have a bottom width of 200 feet with 4:1 side slopes. Please see **Figure 5-9B** for a depiction of the proposed improvements.

Preliminary modeling results show that the proposed improvements provide a 100-year level of service on FM 1984. The maximum 100-year depth of flooding on the roadway is reduced from 33 inches (2.8 feet) to 0 inches, and the length of time the roadway is impassable is reduced from 4.2 hours to 0. In addition, 10 residential structures are removed from the 100-year floodplain, while the depth of flooding is reduced by 30-35 inches at 6 additional structures. Please see **Figure 5-9C** for a depiction of the 100-year flood risk reduction.

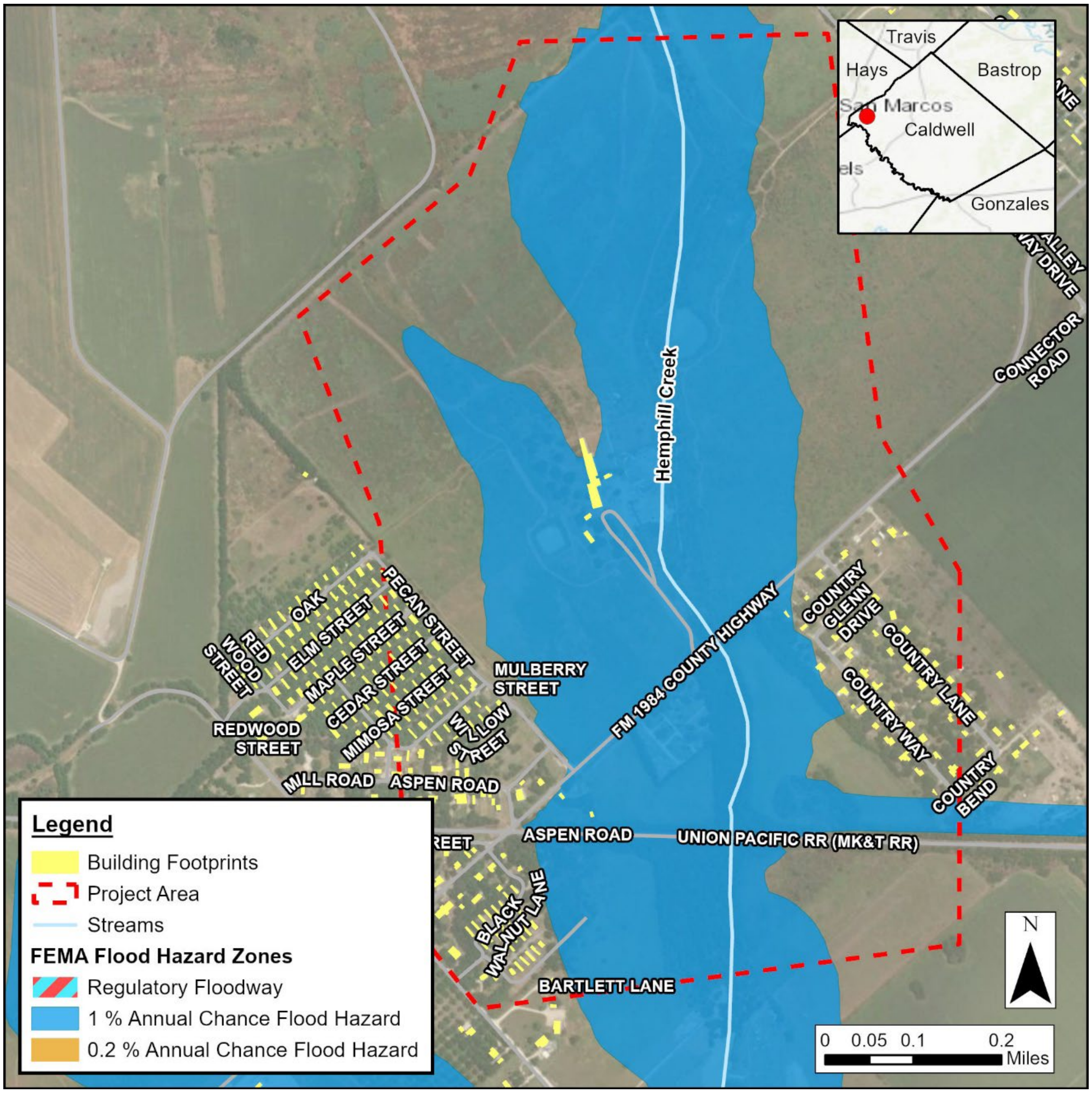

Figure 5-9A. **Project CC-9 study area location.**

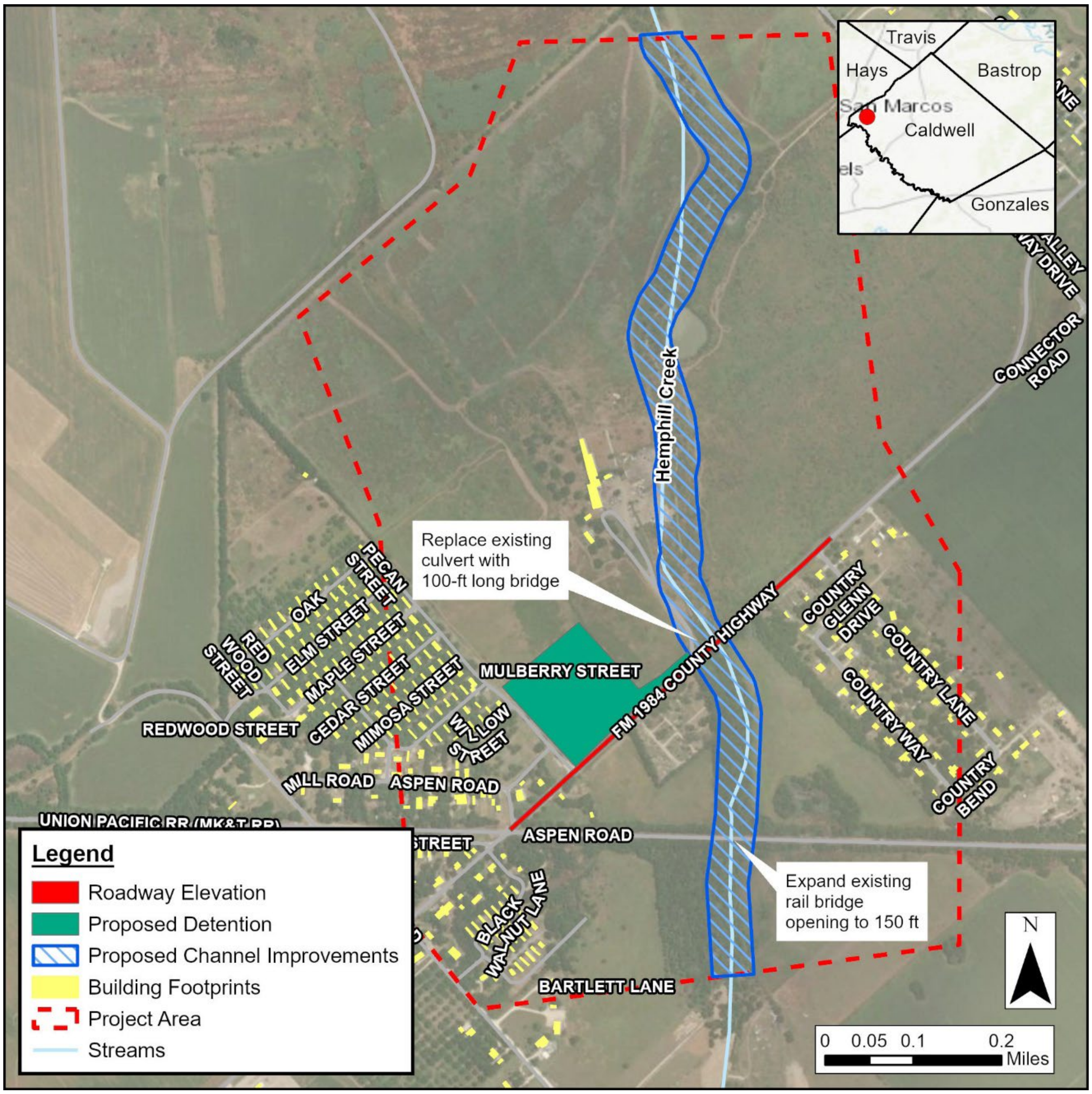

Figure 5-9B. Project CC-9 proposed improvements.

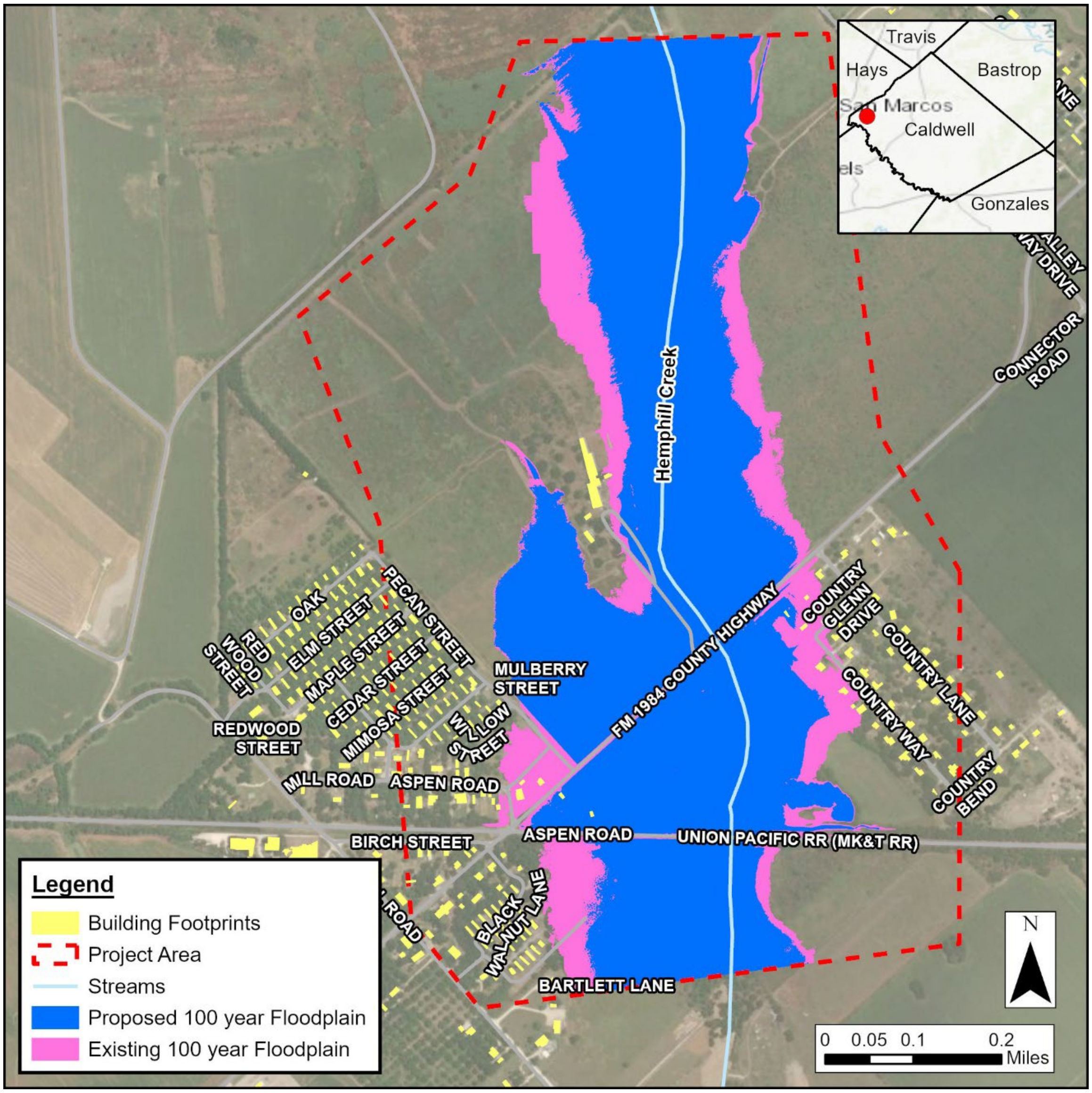

Figure 5-9C. Project CC-9 flood risk reduction for the 100-year event.

5.3.10 Project CC-10 – US 183 at Clear Fork Plum Creek

The flood problem area on Clear Fork Plum Creek upstream of US 183 was identified based on the results of the 1D hydraulic analysis. Under existing conditions, 1 residential structure is located within the 100-year floodplain, with a flooding depth of 10 inches. In addition, 19 commercial structures associated with Pegasus School, Premier Structures, and El Mercado Flea Market are located in the 100-year floodplain, with depths ranging from 1 inch to 73 inches. Please see **Figure 5-10A** for a view of the study area.

The primary goal of this drainage improvement project is to mitigate residential and commercial structure flooding upstream of US 183 on Clear Fork Plum Creek. This project involves drainage improvements at US 183, including expanding the bridge opening by 67 feet, construction of approximately 2,100 linear feet of channel improvements with a 200-foot bottom width and 4:1 side slopes, and construction of a berm to protect commercial structures located northeast of the stream and west of the roadway. Two outlet structures with backflow prevention will need to be installed through the berm to convey local runoff from the commercial structures to the creek. In addition, the project will involve drainage improvements at CR 213 (Robin Ranch Road) to provide flood protection to structures at the Pegasus School campus. The proposed improvements include expanding the bridge opening by 62 feet and construction of approximately 3,100 linear feet of channel improvements with a 200-foot bottom width and 4:1 side slopes. Please see **Figure 5-10B** for a depiction of the proposed improvements.

During the 100-year storm event, the proposed channel improvements on Clear Fork Plum Creek remove 17 commercial structures from the floodplain. Five of those structures are associated with Premier Structures, 3 are part of El Mercado Flea Market, and 9 are within the Pegasus School Campus. In addition, the depth of flooding is reduced by 3 inches at one residential structure, while flooding depths at two additional buildings on the Pegasus School campus are reduced by 34 inches and 24 inches. Please see **Figure 5-10C** for a depiction of the 100-year flood risk reduction.

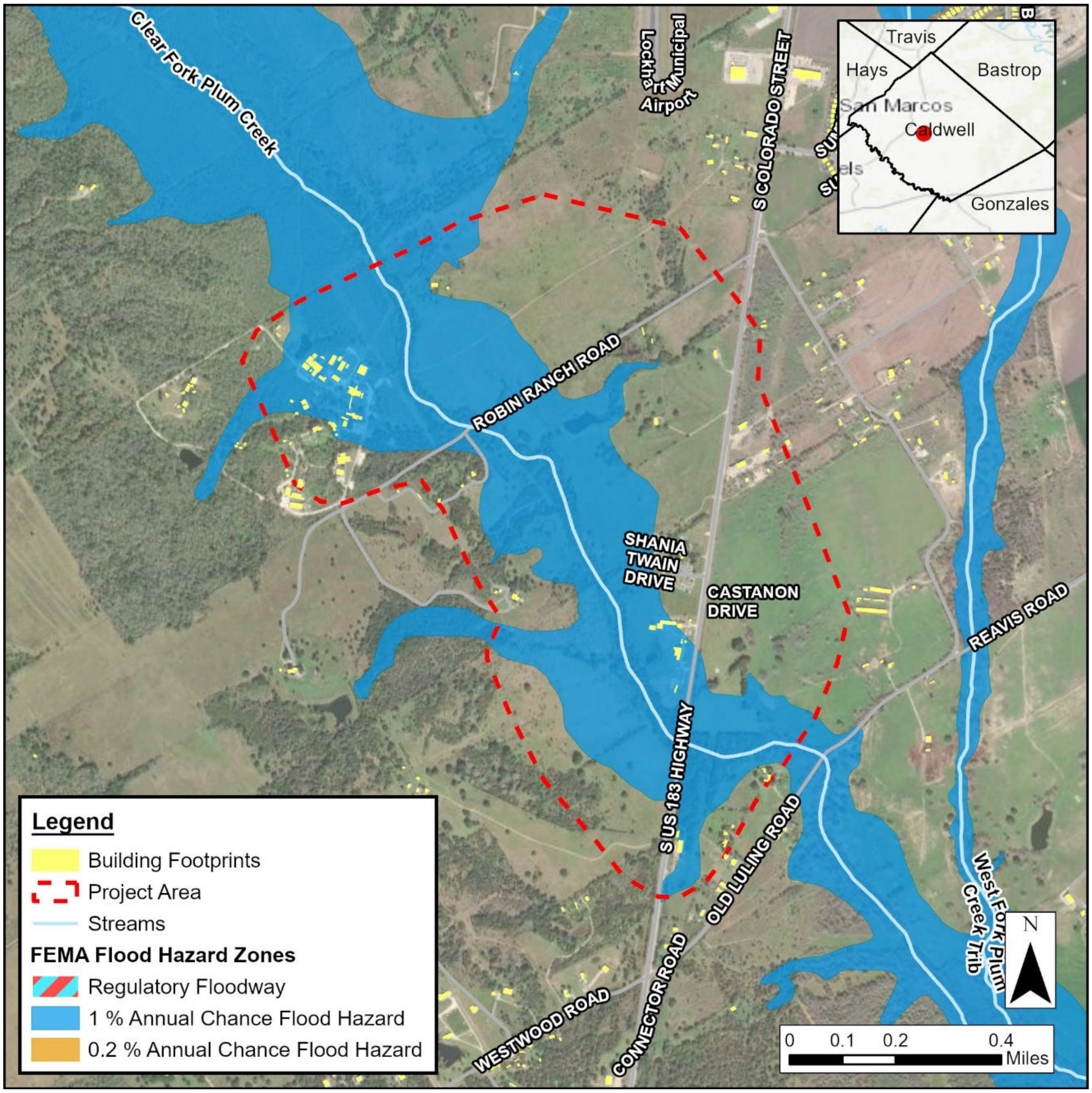

Figure 5-10A. Project CC-10 study area location.

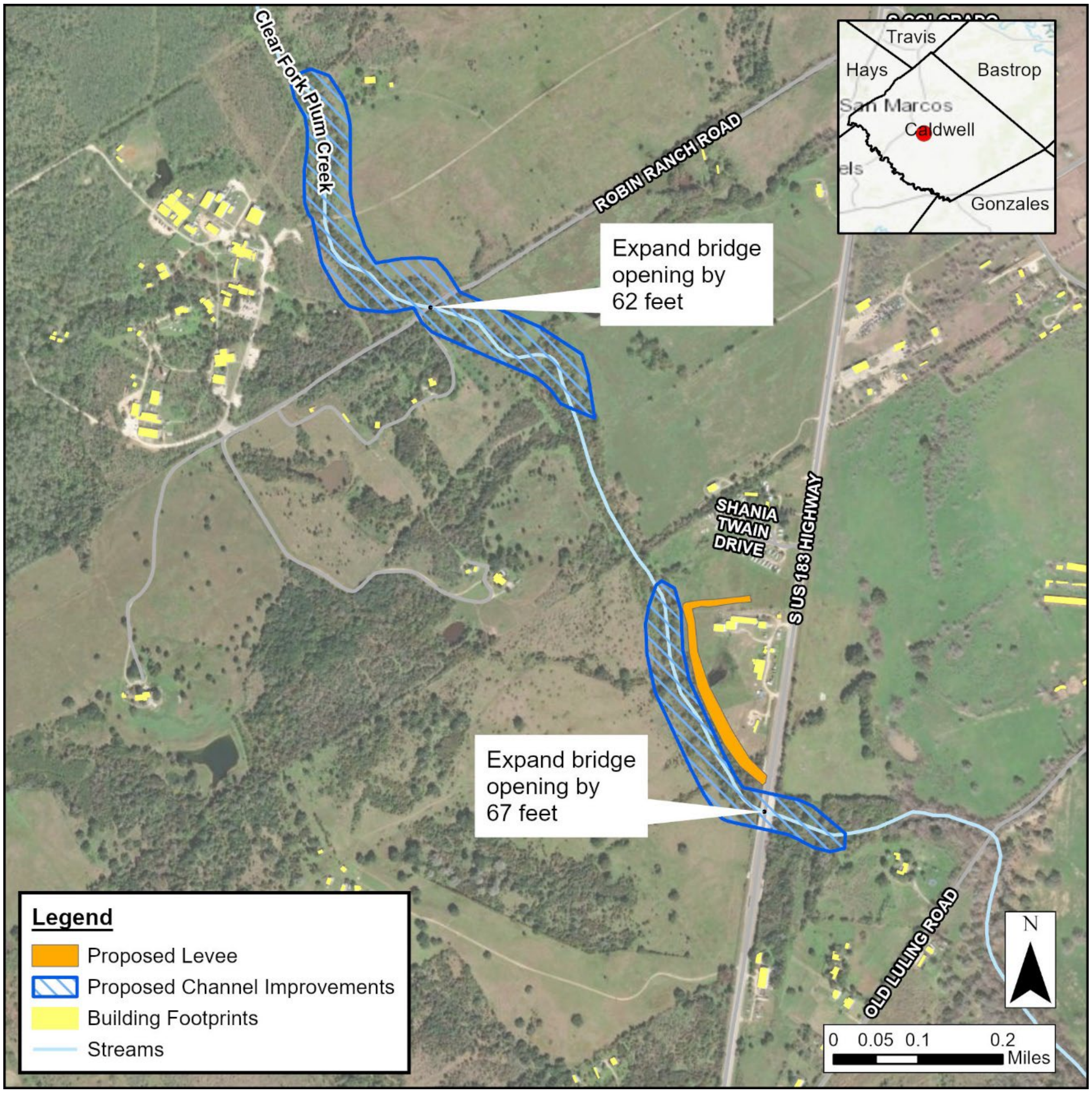

Figure 5-10B. Project CC-10 proposed improvements.

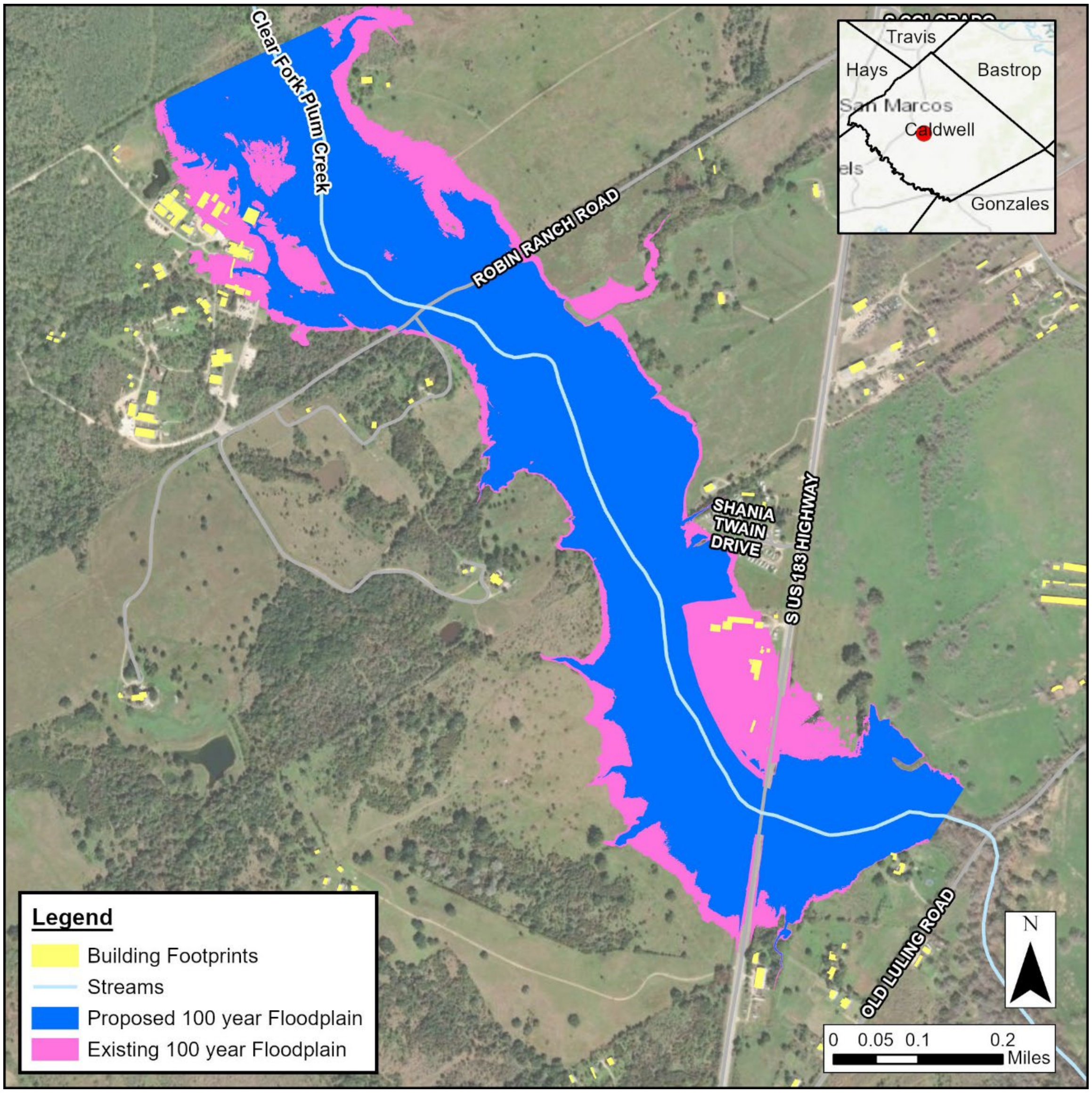

Figure 5-10C. Project CC-10 flood risk reduction for the 100-year event.

5.3.11 Project CC-11 – Brushy Creek Channel Improvements Near Las Estancias II

This flood problem area on Brushy Creek was identified based on the results of the 1D hydraulic analysis. The existing conditions 100-year floodplain affects 12 residential structures within the Las Estancias II subdivision, with flooding depths ranging from 3 inches to 24 inches. Please see **Figure 5-11A** for a view of the study area.

The purpose of this channel improvement project on Brushy Creek is to increase channel capacity and flood protection for 11 residential structures located in the nearby Las Estancias II subdivision. To accomplish these goals, approximately 148,000 cubic yards of excavation along 3,200 linear feet of Brushy Creek is proposed. The proposed benching has a bottom width of 300 feet with 4:1 side slopes. Please see **Figure 5-11B** for a depiction of the proposed improvements.

Based on preliminary modeling results, the proposed channel improvements on Brushy Creek successfully remove all 11 residential structures in the Las Estancias II subdivision from the 100-year floodplain. Please see **Figure 5-11C** for a depiction of the 100-year flood risk reduction.

Figure 5-11A. Project CC-11 study area location.

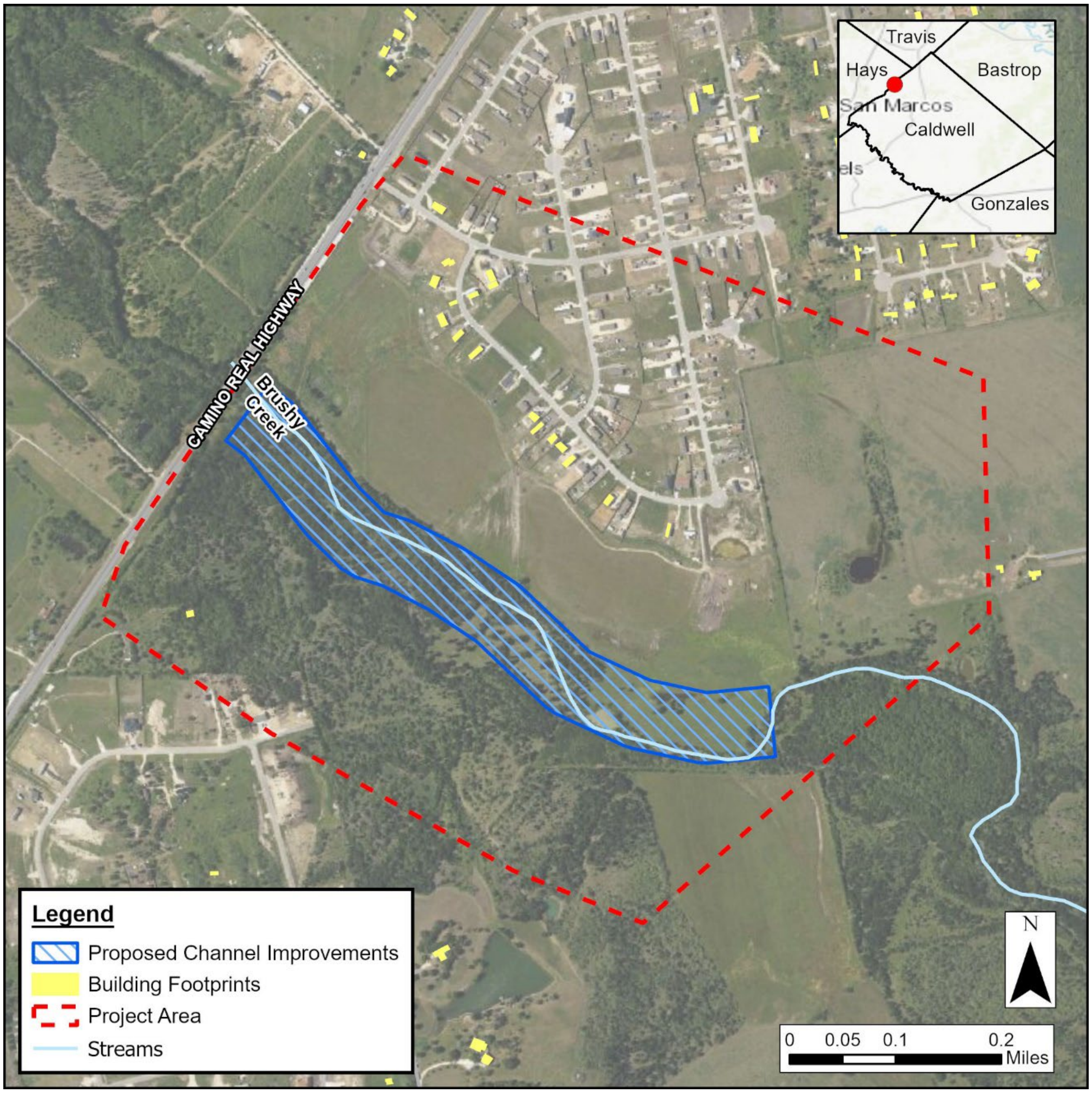

Figure 5-11B. Project CC-11 proposed improvements.

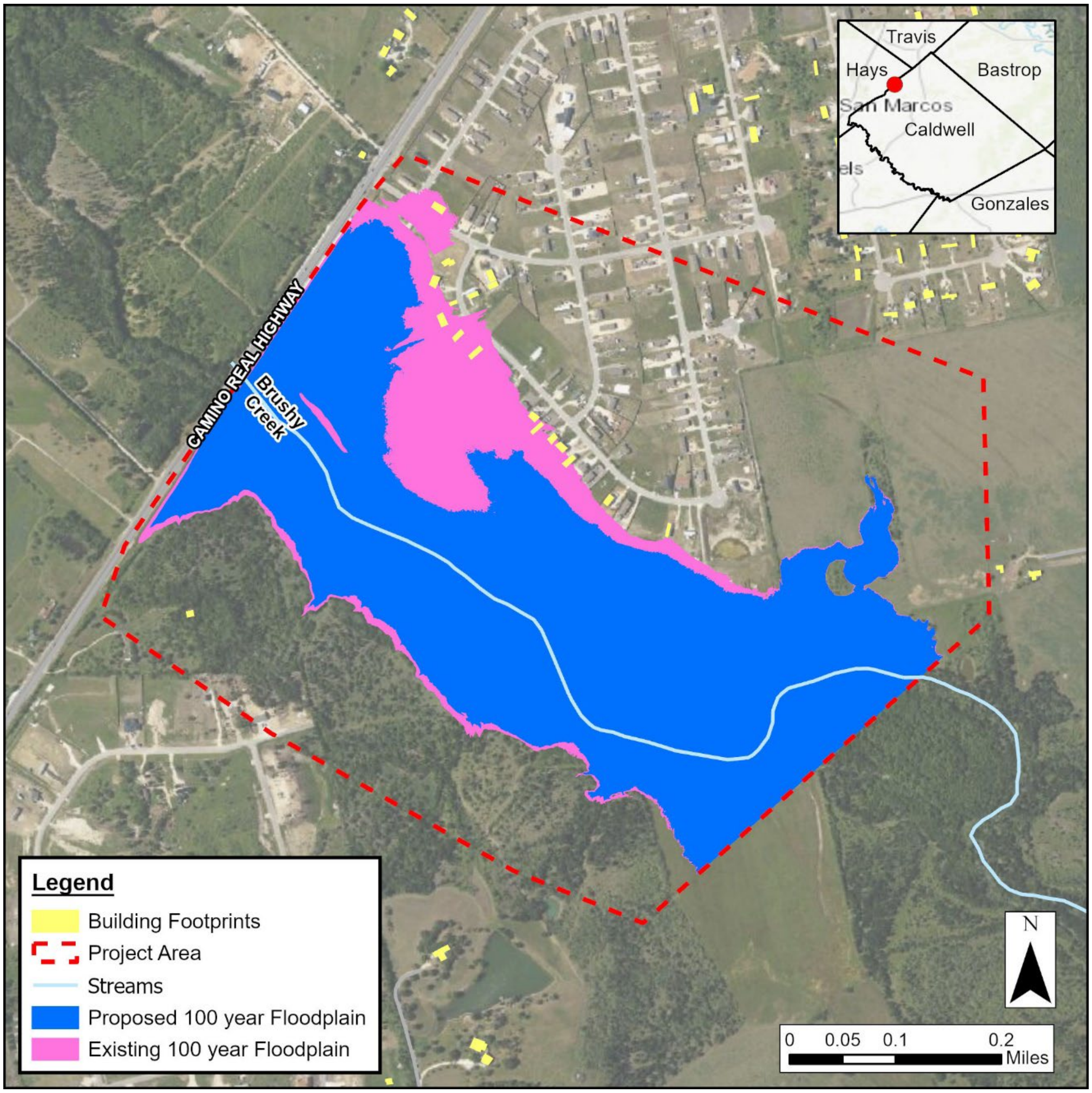

Figure 5-11C. Project CC-11 flood risk reduction for the 100-year event.

5.3.12 Project CC-12 – Boggy Creek Channel Improvements Near SH 142

This flood problem area on Boggy Creek was identified based on the results of the 1D hydraulic analysis. Under existing conditions, 2 residential structures lie within the 100-year floodplain, with depths of 22 inches and 19 inches. In addition, 2 commercial structures are flooded to depths of 4 inches and 10 inches during the 100-year storm event. Please see **Figure 5-12A** for a view of the study area.

This channel improvement project on Boggy Creek is intended to mitigate flooding of 2 residential structures and 3 commercial structures south of SH 142. To increase channel capacity and protect the structures, approximately 72,000 cubic yards of channel excavation is proposed along 3,200 linear feet of Boggy Creek. The proposed benching has a bottom width of 250 feet with 4:1 side slopes. Please see **Figure 5-12B** for a depiction of the proposed improvements.

During the 100-year storm event, the proposed channel improvements remove 2 commercial structures and 2 residential structures from the floodplain. The proposed improvements also reduce the depth of flooding at 2 additional residential structures by 16 inches. Please see **Figure 5-12C** for a depiction of the 100-year flood risk reduction.

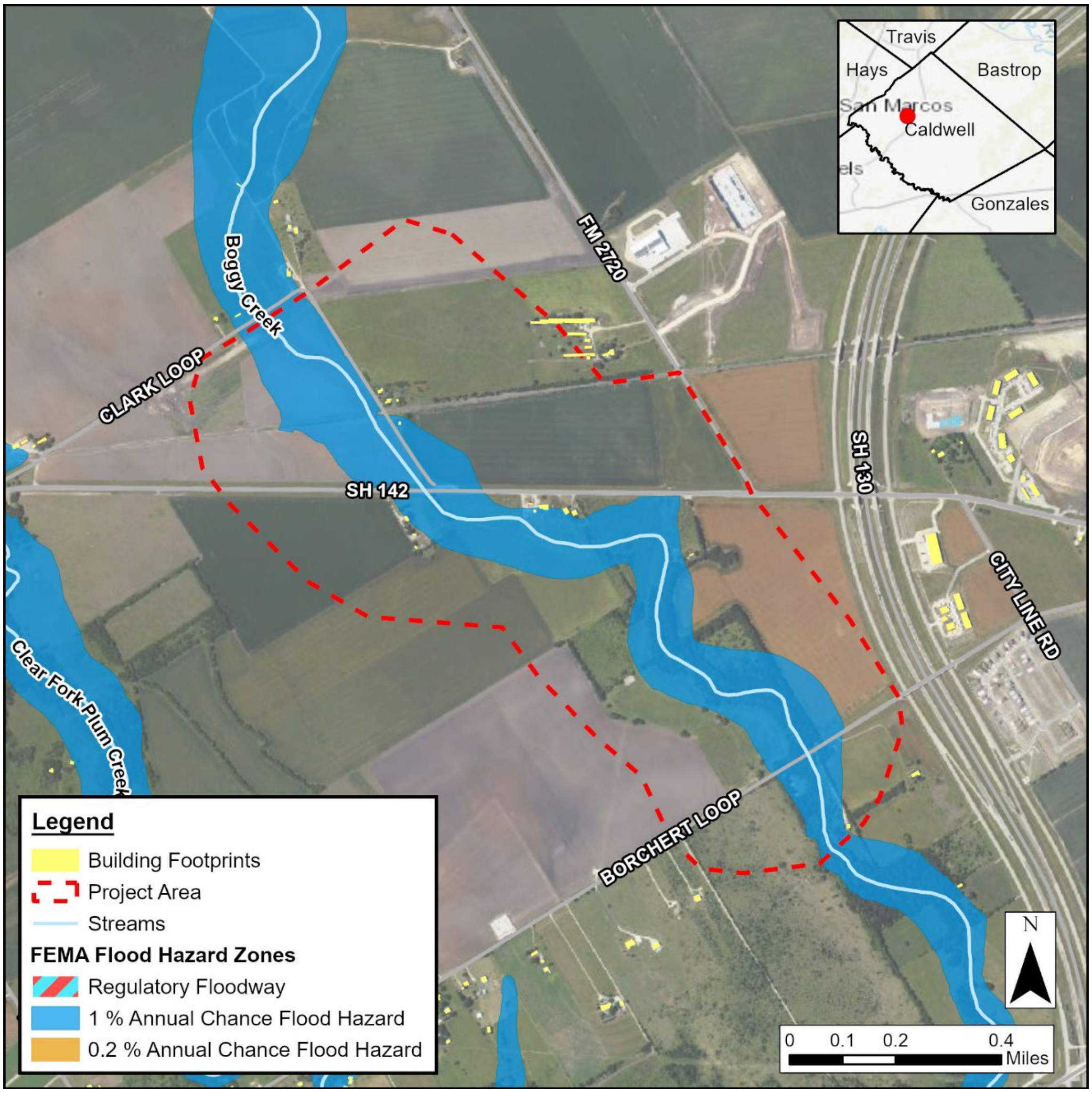

Figure 5-12A. Project CC-12 study area location.

Figure 5-12B. **Project CC-12 proposed improvements.**

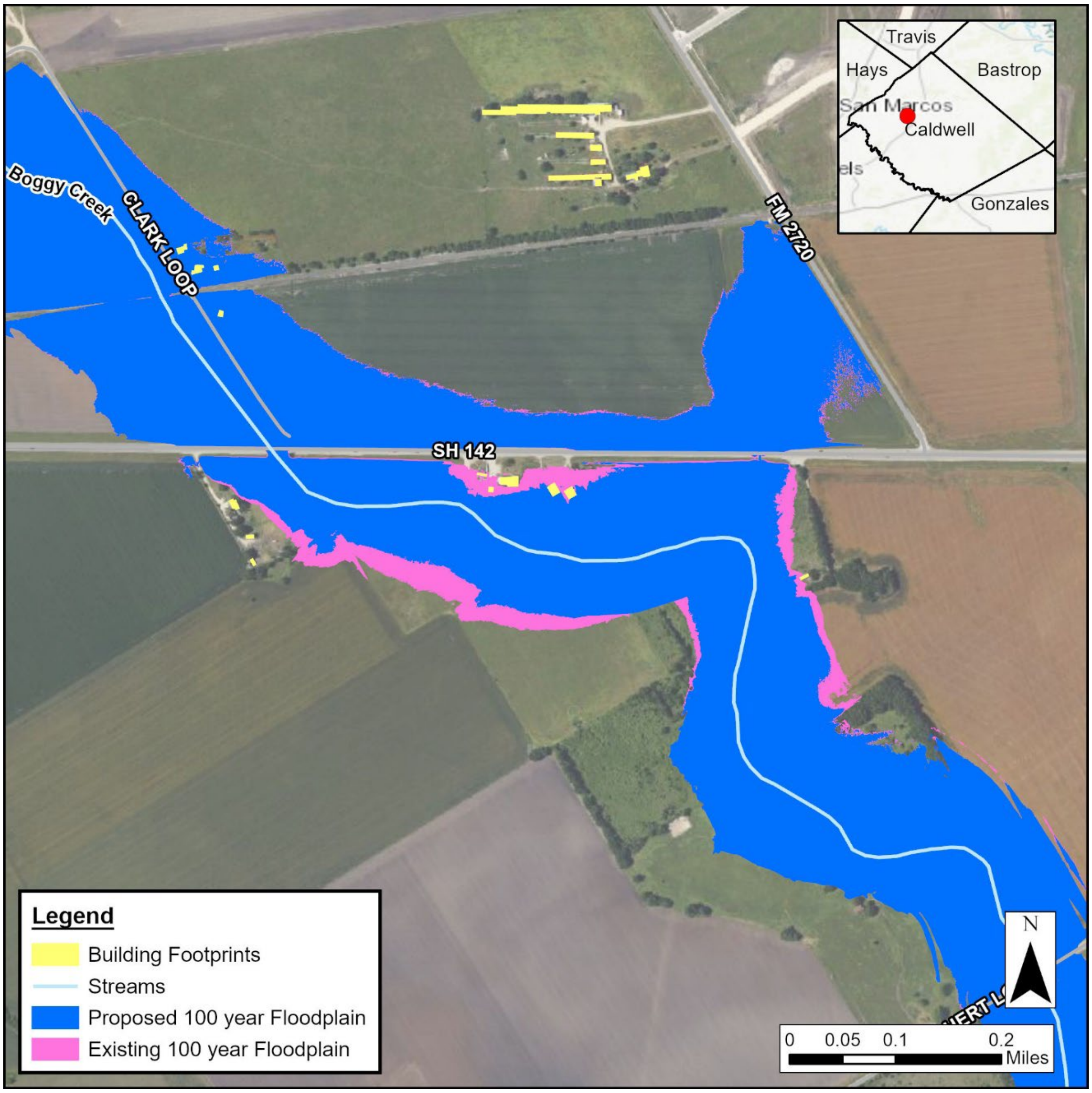

Figure 5-12C. Project CC-12 flood risk reduction for the 100-year event.

5.3.13 Project CC-13 – CR 218 at Boggy Creek and Clear Fork Plum Creek

The low water crossing on CR 218 (Boggy Creek Road) was identified by Caldwell County as a high-priority flood hazard area. During Hurricane Harvey in 2017, the roadway was closed for 5 days. CR 218 lies just upstream of the confluence of Clear Fork Plum Creek and Boggy Creek, and the low water crossings associated with both streams are located approximately 1,050 feet from one another. Based on preliminary modeling, both crossings have less than a 2-year level-of-service, with maximum 2-year flooding depths of 50 inches and 24 inches at the Clear Fork Plum Creek and Boggy Creek crossings, respectively. During the 100-year storm event, the maximum depths of flooding increase to 120 inches and 63 inches, making the roadway impassable for nearly 28 hours. Please see **Figure 5-13A** for a view of the study area.

The improvement project at CR 218 was developed to improve the level-of-service of the crossings on Boggy Creek and Clear Fork Plum Creek. At the Boggy Creek crossing, the proposed improvements involve raising the road deck approximately 0.8 feet and upgrading the existing 5 ft CMP to 6 – 10 ft x 6 ft concrete box culverts. To provide additional capacity in the channel upstream and downstream of the crossing, approximately 1,000 linear feet of channel improvements are proposed with a bottom width of 80 feet and 4:1 side slopes. A smaller channel is also proposed through a meander on the upstream side of the crossing to direct flow away from the roadway and toward the main channel. This smaller channel is approximately 400 linear feet in length, with a 15 ft bottom width and 4:1 side slopes. At the Clear Fork Plum Creek crossing, the proposed improvements involve raising the road deck approximately 1.5 feet and upgrading the existing 5 ft CMP to 6 – 10 ft x 8 ft concrete box culverts. To provide additional capacity in the channel upstream and downstream of the crossing, approximately 2,100 linear feet of channel improvements are proposed with a bottom width of 200 feet and 4:1 side slopes. Please see **Figure 5-13B** for a depiction of the proposed improvements.

The proposed drainage improvements at the two low water crossings on CR 218 provide a 2-year level-of-service for the roadway. The maximum 2-year flooding depths on the roadway are reduced from 24 inches to 0 inches at the Boggy Creek crossing and from 50 inches to 0 inches at the Clear Fork Plum Creek crossing. This reduction in flooding also allows the roadway to be passable for the duration of the 2-year storm event, whereas it is impassable for nearly 4 hours under existing conditions. During the 100-year storm event, the maximum depths of flooding are reduced from 63 inches to 47 inches at the Boggy Creek crossing and from 120 inches to 68 inches at the Clear Fork Plum Creek crossing. The length of time the roadway is impassable is reduced from 15.8 hours to 6.3 hours at the Boggy Creek crossing and from 27.7 hours to 14.7 hours at the Clear Fork Plum Creek crossing. In addition to the benefits at the roadway crossings, the 100-year depth of flooding is reduced by 4 inches at one residential structure. Please see **Figure 5-13C** for a depiction of the 100-year flood risk reduction.

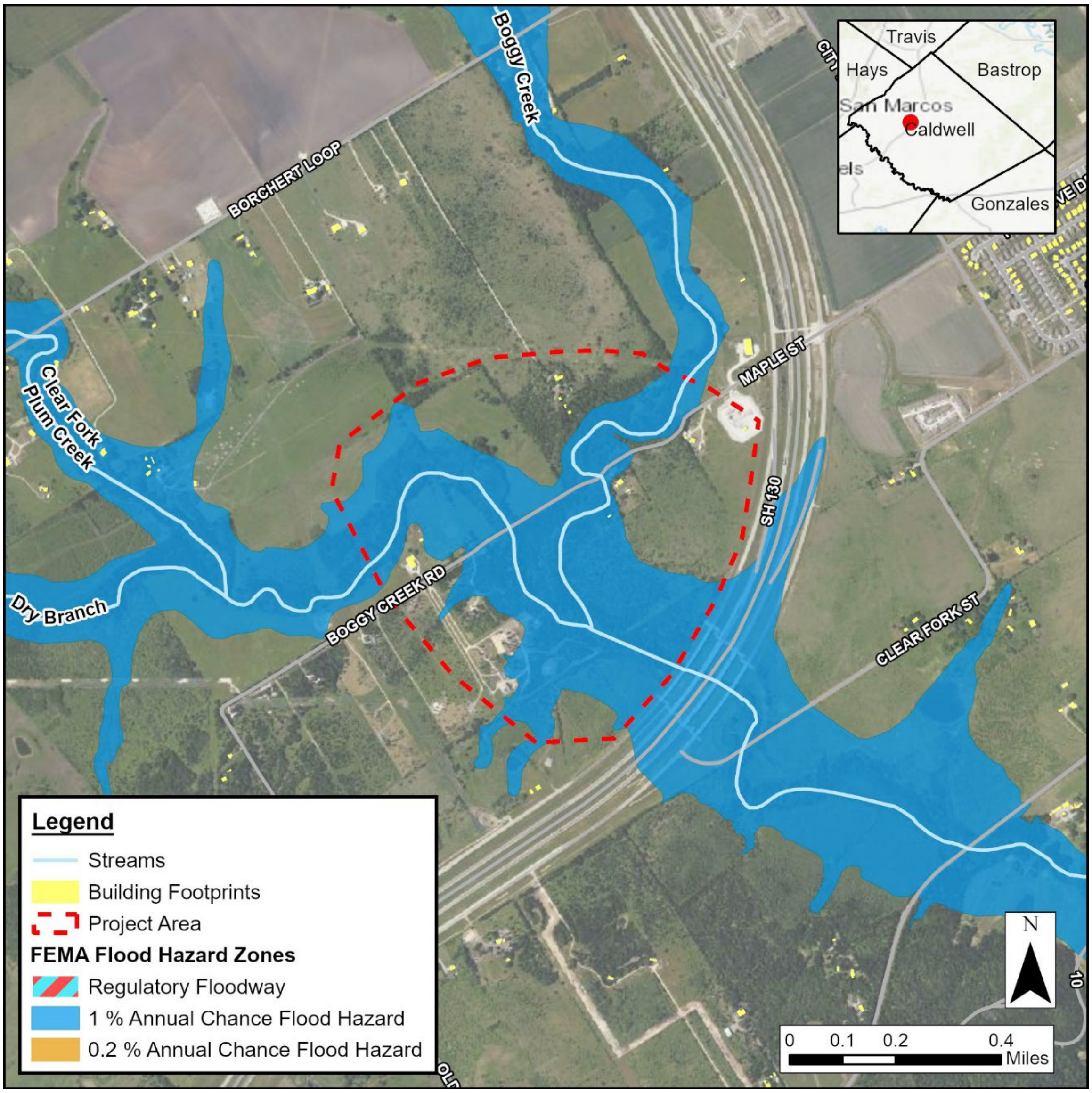

Figure 5-13A. Project CC-13 study area location.

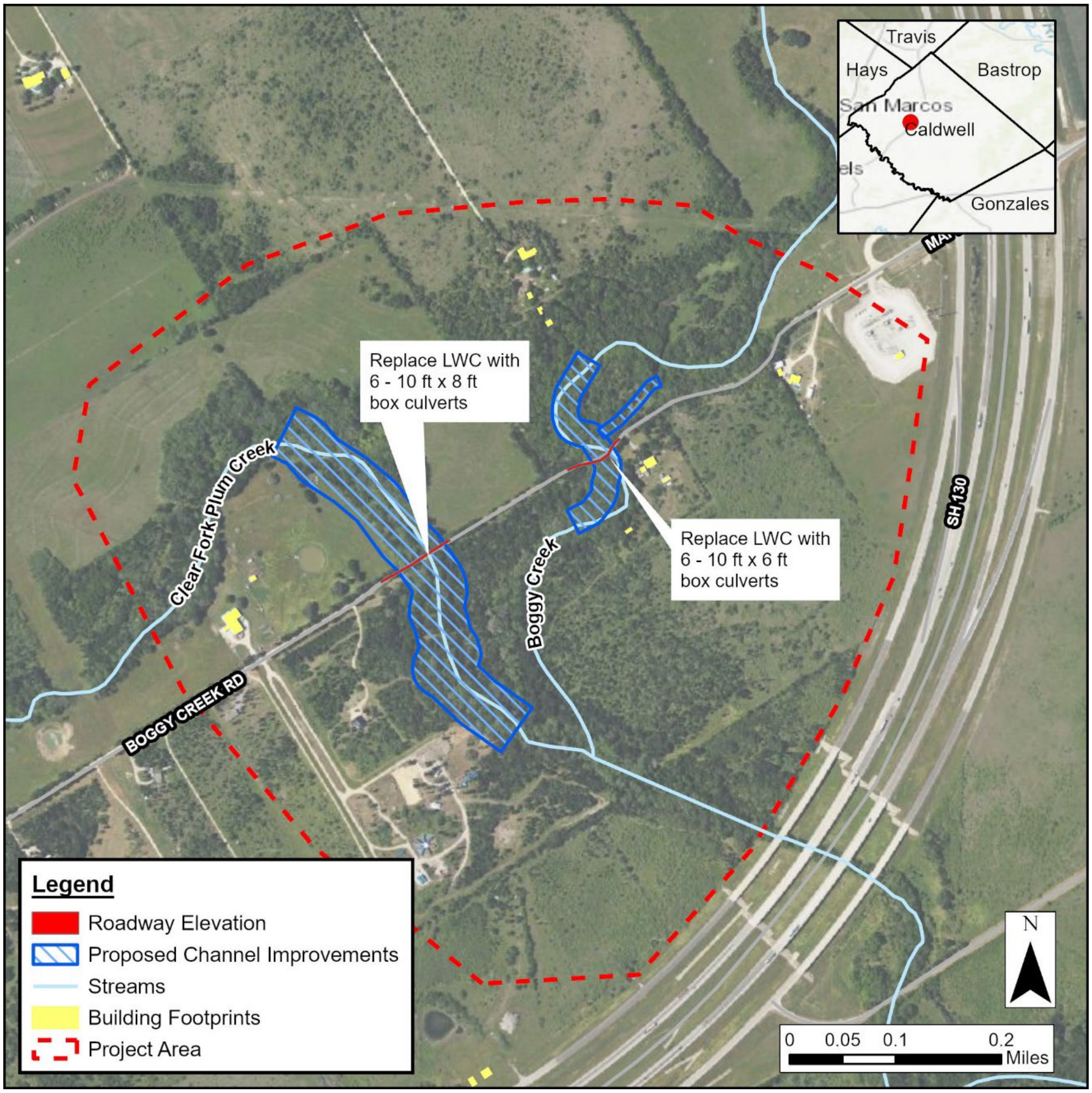

Figure 5-13B. Project CC-13 proposed improvements.

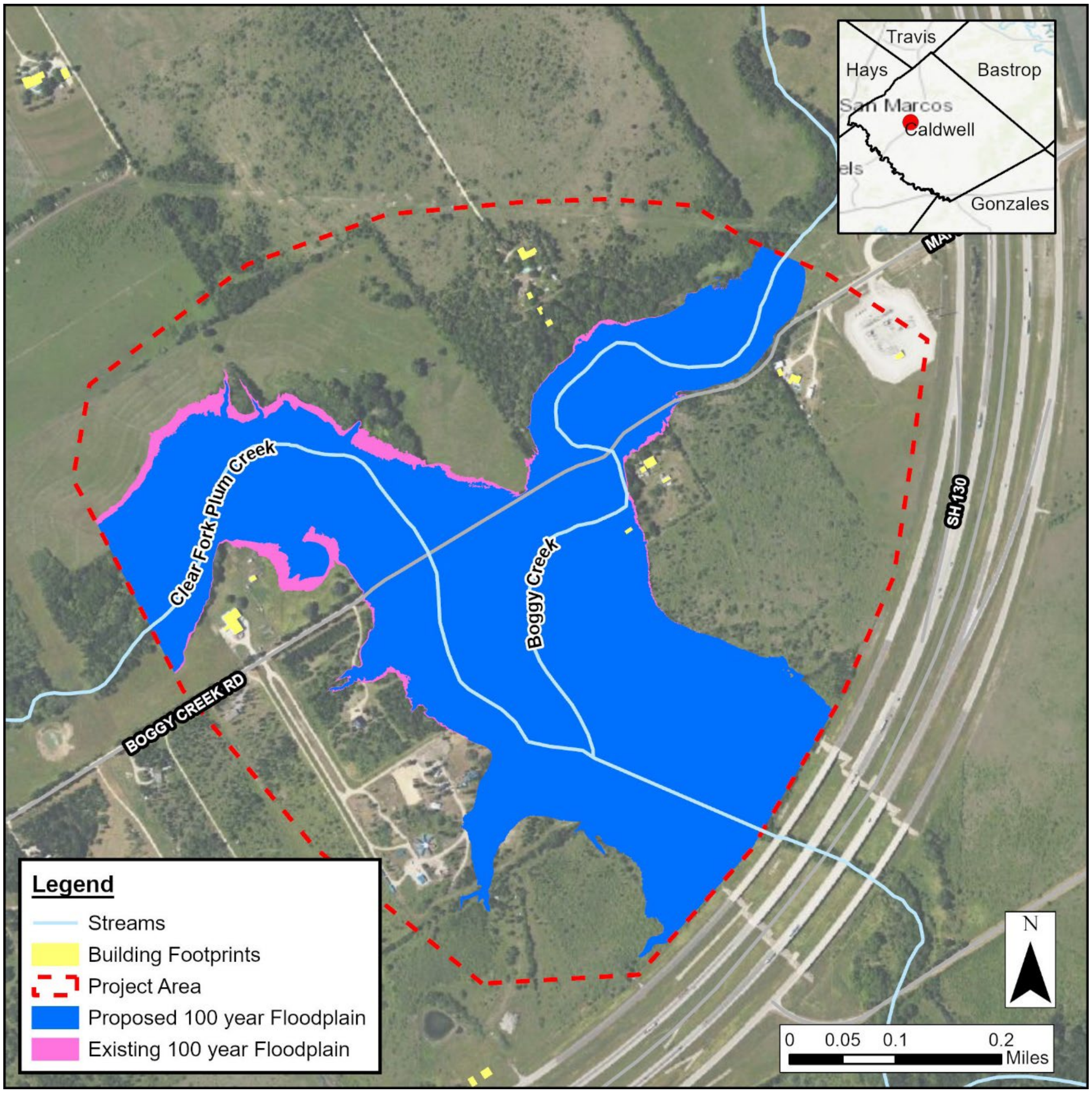

Figure 5-13C. Project CC-13 flood risk reduction for the 100-year event.

5.3.14 Project CC-14 – CR 227 at Brushy Creek

The low water crossing on CR 227 (Rocky Road) at Brushy Creek was identified by Caldwell County as a high-priority flood hazard area. A drowning occurred in 1998, and the roadway was closed for 16 days during Hurricane Harvey in 2017. Based on preliminary modeling, the roadway has less than a 2-year level-of-service, with a maximum 2-year flooding depth of 81 inches, making the roadway impassable for several days. This flood hazard is largely due to the presence of NRCS Dam Site 14R located approximately 4,000 feet downstream of the low water crossing. Please see **Figure 5-14A** for a view of the study area.

The Brushy Creek project at CR 227 (Rocky Road) was developed to improve the level-of-service for the low water crossing. The proposed mitigation alternative involves improvements to the existing channel to provide more capacity on the north and south side of the opening, as well as replacing the 3 existing 60-inch RCPs with 5 – 10 ft x 10 ft box culverts. The project also includes approximately 1,050 linear feet of roadway improvements at the crossing, raising the roadway elevation by 6.5 ft. Please see **Figure 5-14B** for a depiction of the proposed improvements.

Based on preliminary modeling, the proposed drainage improvements at CR 227 provide a 2-year level-of-service for the crossing. The maximum 2-year depth of flooding is reduced from 81 inches to 4 inches. This reduction in flooding allows the roadway to be passable for the duration of the 2-year storm event, whereas it is impassable for nearly 6 days under existing conditions. Due to the presence of NRCS Dam Site 14R downstream of the crossing, benefits during the 100-year storm are minimal, with the maximum depth of flooding being reduced from 285 inches (23.8 feet) to 209 inches (17.4 feet). The length of time the roadway is impassable is reduced from about 15 days to approximately 12 days. Please see **Figure 5-14C** for a depiction of the 100-year flood risk reduction.

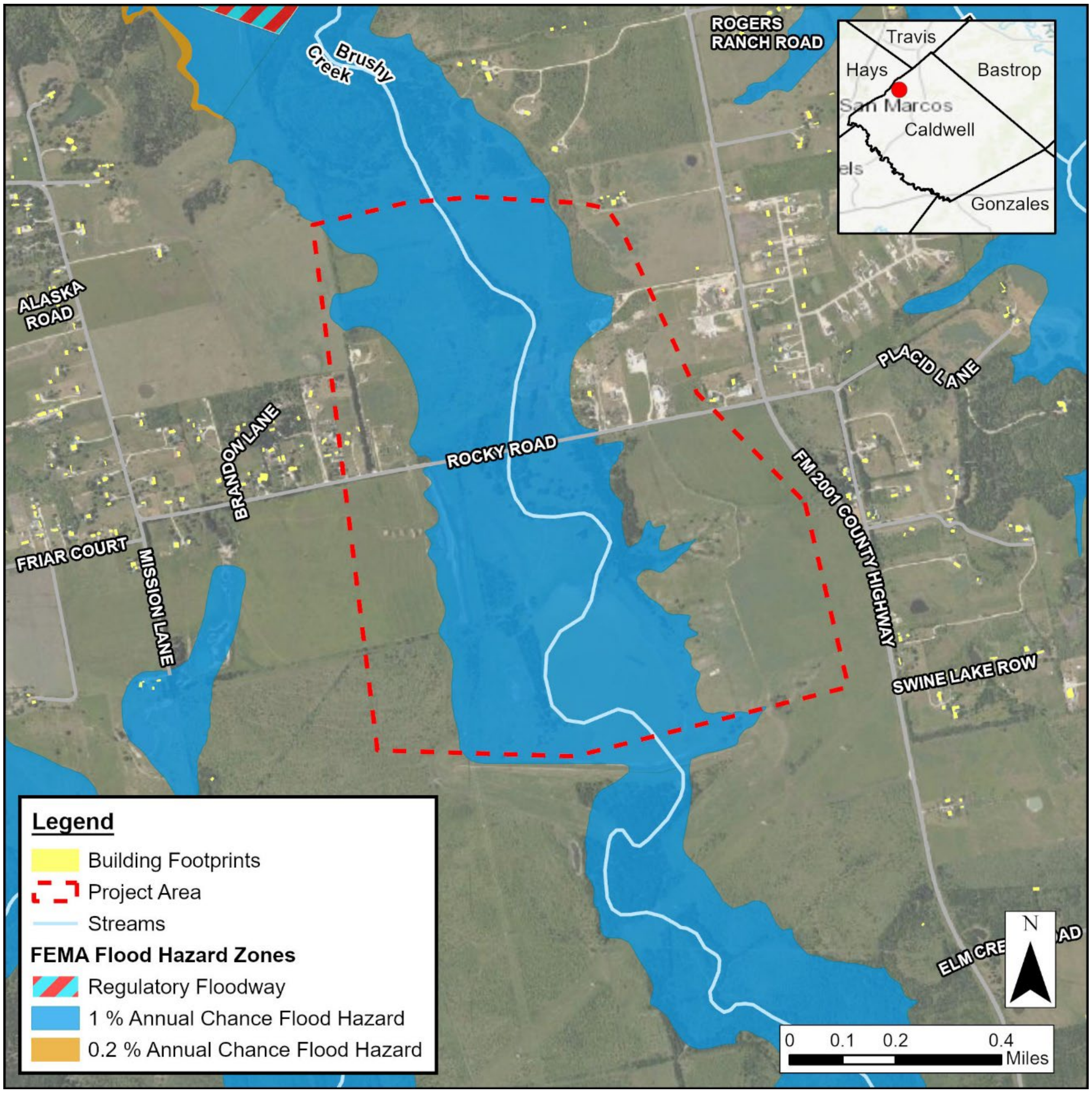

Figure 5-14A. Project CC-14 study area location.

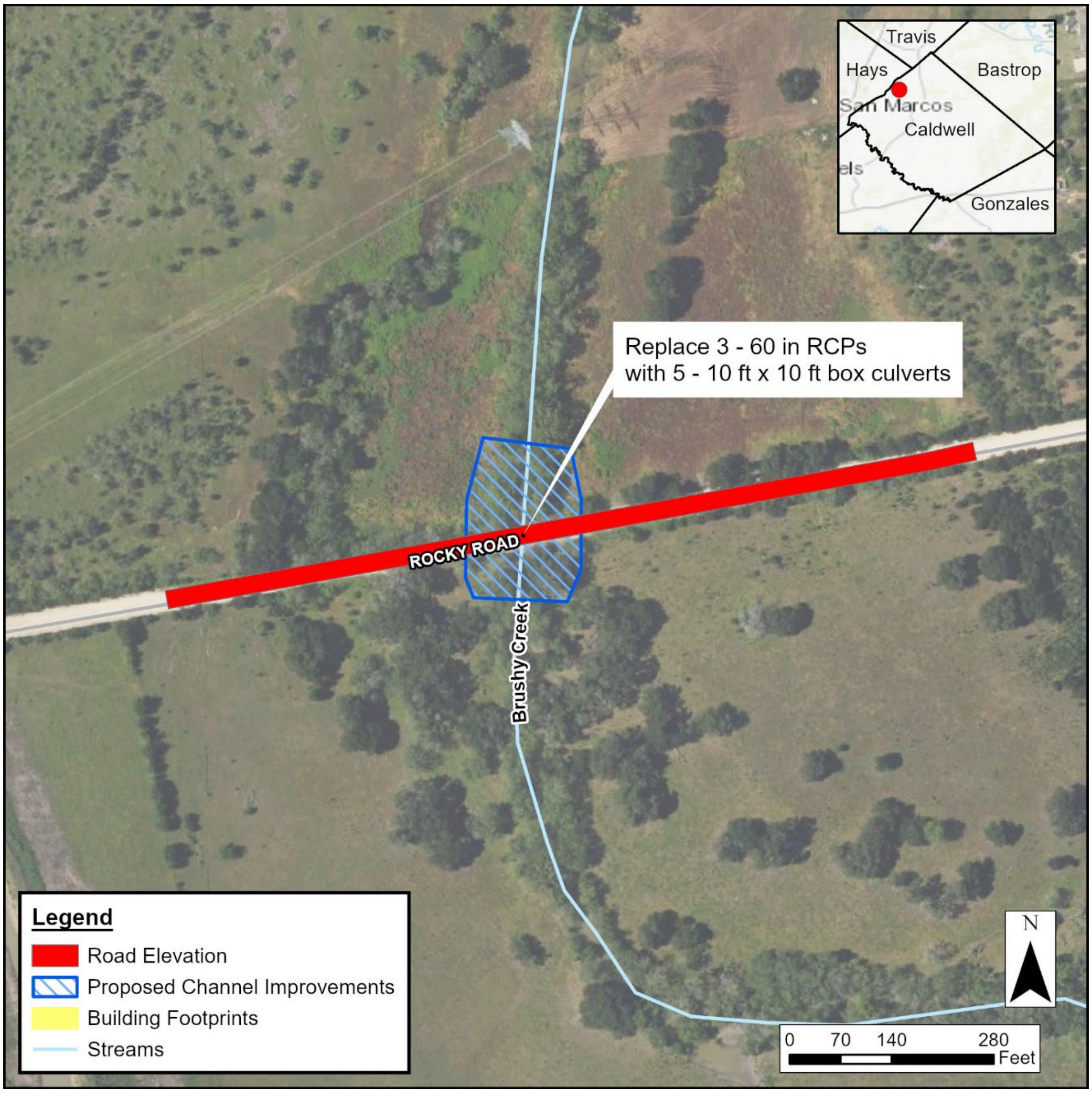

Figure 5-14B. Project CC-14 proposed improvements.

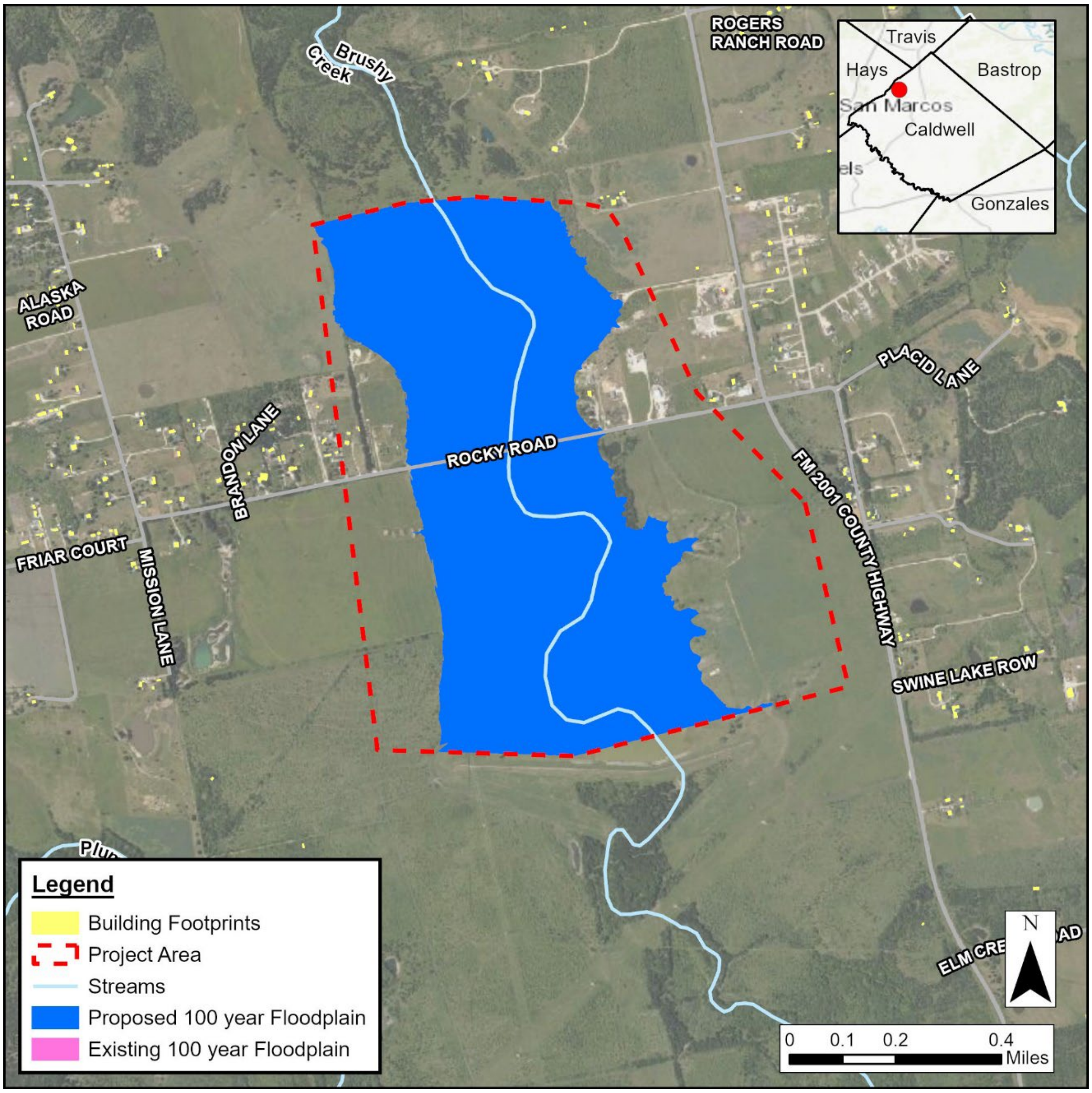

Figure 5-14C. Project CC-14 flood risk reduction for the 100-year event.

5.4 Estimate of probable cost

An opinion of probable cost was prepared for each of the proposed projects based on local and TxDOT average low bid tabulations. **Table 5-5** summarizes the total estimated cost for each project, including construction, engineering, easement acquisition, and permitting. The construction costs include a 25% contingency to account for uncertainties in the preliminary design and analysis. Itemized construction cost estimates for each project are provided in **Appendix K**.

Table 5-5. Caldwell County Flood Mitigation Projects – total cost estimates.

Project Identifier	Flood Mitigation Project Title	Total Estimated Cost
CC-1	Cedar Creek Channel Improvements Near Christian Drive	$14,654,000
CC-2	CR 170 Low Water Crossing Improvements at Lytton Creek	$4,877,000
CC-3	CR 172 Low Water Crossing Improvements at Lytton Creek	$4,574,000
CC-4	CR 141 at Hines Branch	$2,893,000
CC-5	SH 80 Low Water Crossing Improvements at Morrison Creek	$20,224,000
CC-6	Salt Branch Drainage Improvements in Luling	$5,798,000
CC-7	CR 233 and FM 2001 at Plum Creek	$7,934,000
CC-8	Plum Creek Channel Improvements Near CR 227	$5,587,000
CC-9	Hemphill Creek Drainage Improvements Near FM 1984	$19,790,000
CC-10	US 183 at Clear Fork Plum Creek	$16,501,000
CC-11	Brushy Creek Channel Improvements Near Las Estancias II	$9,622,000
CC-12	Boggy Creek Channel Improvements Near SH 142	$6,113,000
CC-13	CR 218 at Boggy Creek and Clear Fork Plum Creek	$7,836,256
CC-14	CR 227 at Brushy Creek	$3,504,000

5.5 Project constraints

An environmental constraints table including data regarding endangered species, historic preservation, and wetlands has been prepared for the 14 FMPs and is provided in **Appendix K**. Each of these projects will likely require local permitting and stormwater pollution prevention plans (SWPPP), as well as additional permitting with regulatory agencies, including those listed below:

- Federal Emergency Management Agency (FEMA)
- U.S. Army Corps of Engineers (USACE)
- U.S. Fish and Wildlife Services (USFWS)
- Texas Commission on Environmental Quality (TCEQ)
- Texas Historical Commission

Due to the rural location of many of the project sites, oil and gas pipeline data were reviewed on the Railroad Commission of Texas website. Drainage improvements were preliminarily designed to avoid conflicts with oil and gas infrastructure as much as possible. However, any conflicts will need to be verified and addressed during final design. Similarly, the locations of existing utilities (water, gas, sewer, electrical, and telecommunications) were preliminarily identified and noted based on aerial imagery reflecting manholes, lift stations, power poles, valves, pedestals, etc. For projects where potential utility conflicts were evident, the construction cost estimates were adjusted to account for utility relocation. Any utility conflicts will need to be verified and addressed during final design.

5.6 Benefit-cost analysis

The benefit-cost analysis (BCA) for each of these FMPs was prepared using the TWDB BCA Input Workbook version 1.2 and the FEMA BCA Toolkit version 6.0. A project life of 30 years was assumed for these analyses. Existing and proposed damages for low-water crossings were generally quantified for the 2-, 10-, and 100-year storm events. In cases where there were no existing damages in the 2-year storm, the 10-, 25-, and 100-year storm events were used for the BCA. The BCAs for each FMP are summarized in **Table 5-6** below. The BCA worksheets for each project are provided in **Appendix K**.

Table 5-6. Caldwell County Flood Mitigation Projects – benefit-cost analysis summary.

Project ID	Flood Mitigation Project Title	Benefit Categories	Storm Events Analyzed	Final BCR
CC-1	Cedar Creek Channel Improvements Near Christian Drive	Residential Structures	10-, 25-, 100-year	0.0
CC-2	CR 170 Low Water Crossing Improvements at Lytton Creek	Low-Water Crossing	2-, 10-, 100-year	0.1
CC-3	CR 172 Low Water Crossing Improvements at Lytton Creek	Low-Water Crossing	2-, 10-, 100-year	0.5
CC-4	CR 141 at Hines Branch	Low Water Crossing	2-, 10-, 100-year	0.2
CC-5	SH 80 Low Water Crossing Improvements at Morrison Creek	Residential Structures and Low Water Crossing	2-, 10-, 100-year	0.5
CC-6	Salt Branch Drainage Improvements in Luling	Residential Structures and Low Water Crossing	2-, 10-, 100-year	0.7
CC-7	CR 233 and FM 2001 at Plum Creek	Residential Structures and Low Water Crossing	2-, 10-, 100-year	0.5
CC-8	Plum Creek Channel Improvements Near CR 227	Residential Structures and Commercial Structures	2-, 10-, 100-year	0.1
CC-9	Hemphill Creek Drainage Improvements Near FM 1984	Residential Structures and Low Water Crossing	2-, 10-, 100-year	0.4
CC-10	US 183 at Clear Fork Plum Creek	Residential Structures and Commercial Structures	10-, 25-, 100-year	0.1
CC-11	Brushy Creek Channel Improvements Near Las Estancias II	Residential Structures	10-, 25-, 100-year	0.1
CC-12	Boggy Creek Channel Improvements Near SH 142	Residential Structures and Commercial Structures	10-, 25-, 100-year	0.1
CC-13	CR 218 at Boggy Creek and Clear Fork Plum Creek	Residential Structures and Low Water Crossing	2-, 10-, 100-year	0.0
CC-14	CR 227 at Brushy Creek	Low Water Crossing	2-, 10-, 100-year	2.3

5.7 No negative impact

In accordance with the *TWDB Technical Guidelines for Regional Flood Planning*, “No Negative Impact means that a project will not increase flood risk of surrounding properties. Using best available data, the increase in flood risk must be measured by the 100-year frequency storm event water surface elevation and peak discharge. It is recommended that no rise in water surface elevation or discharge should be permissible, and that the analysis extent must be vast enough to prove proposed project conditions are equal to or less than existing conditions.”

Based on the preliminary modeling for the 14 FMPs described in this memorandum, the following statements are valid:

- 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.

The *TWDB Technical Guidelines for Regional Flood Planning* state, “Maximum increase of 2D Water Surface Elevations must round to 0.3 feet (< 0.35 ft) measured at each computational cell.” Any localized rises greater than 0.35 feet evident in the preliminary modeling will likely be resolved with further refinements during final design, or the rises will be entirely contained within the public right-of-way, project property, or easement.

This report is prepared to serve as certification of no negative impact for the 14 FMPs discussed herein. As the projects are advanced, the impact analyses should be updated to reflect final design and confirm no negative impacts. A no negative impact determination table in accordance with the *TWDB Technical Guidelines for Regional Flood Planning* is shown in **Table 5-7** and has also been included in **Appendix L**.

Table 5-7. Caldwell County Flood Mitigation Projects – no negative impact determinations.

FMP ID	Region Number	FMP Name	FMP Meets ALL No Negative Impacts Requirements from Exhibit C Section 3.6.A (Yes/ No)	Negative Impact Description	Planning Level Mitigation Plan (Yes/ No)	Mitigation Plan Description	No Negative Impact Determination (Yes/No)	Basis of No Negative Impact Determination	Model ID	Model Name	Model Submitted
103000062	10	Cedar Creek Channel Improvements Near Christian Drive	Yes	None	No	NA	Yes	Model and Study	100000000062	CFPP_CED_CHRISTI AN	Yes
103000063	10	CR 170 Low Water Crossing Improvements @ Lytton Creek	No	Localized rises up to 0.40 feet evident in the preliminary 2D modeling just upstream of CR 170.	Yes	Localized rises will be resolved during final design, or the rises will be entirely contained within the public right-of-way, project property, or easement.	Yes	Model and Study	100000000063	CFPP_LYT_CR170	Yes
103000064	10	CR 172 Low Water Crossing Improvements @ Lytton Creek	Yes	None	No	NA	Yes	Model and Study	100000000064	CFPP_LYT_CR172	Yes
113000074	11	Caldwell County CR 141 @ Hines Branch	Yes	None	No	NA	Yes	Model and Study	113000000074	CFPP_HIN_CR141	Yes
113000075	11	Caldwell County SH 80 Low Water Crossing Improvements @ Morrison Creek	Yes	None	No	NA	Yes	Model and Study	113000000075	CFPP_MOR_SH80	Yes
113000076	11	Caldwell County Salt Branch Drainage Improvements in Luling	Yes	None	No	NA	Yes	Model and Study	113000000076	CFPP_SLT_LULING	Yes
113000077	11	Caldwell County CR 233 and FM 2001 @ Plum Creek	Yes	None	No	NA	Yes	Model and Study	113000000077	CFPP_PLC_CR233_FM2001	Yes
113000078	11	Caldwell County Plum Creek Channel Improvements Near CR 227	Yes	None	No	NA	Yes	Model and Study	113000000078	CFPP_PLC_CR227	Yes
113000079	11	Caldwell County Hemphill Creek Drainage Improvements Near FM 1984	Yes	None	No	NA	Yes	Model and Study	113000000079	CFPP_HEM_FM1984	Yes
113000080	11	Caldwell County US 183 @ Clear Fork Plum Creek	Yes	None	No	NA	Yes	Model and Study	113000000080	CFPP_CLFP_US183	Yes
113000081	11	Caldwell County Brushy Creek Channel Improvements Near Las Estancias II	Yes	None	No	NA	Yes	Model and Study	113000000081	CFPP_BRU_LASESTANCIAS	Yes
113000082	11	Caldwell County Boggy Creek Channel Improvements Near SH 142	Yes	None	No	NA	Yes	Model and Study	113000000082	CFPP_BOC_SH142	Yes
113000083	11	Caldwell County CR 218 @ Boggy Creek and Clear Fork Plum Creek	Yes	None	No	NA	Yes	Model and Study	113000000083	CFPP_BOC_CLFP_CR218	Yes
113000084	11	Caldwell County CR 227 @ Brushy Creek	Yes	None	No	NA	Yes	Model and Study	113000000084	CFPP_BRU_CR227	Yes

5.8 Flood early warning system

A flood early warning system (FEWS) applies stream gage, precipitation gage, radar rainfall, reservoir level gage, forecasting, and other real time information to known characteristics of watersheds, drainage networks, or models in order to predict, prepare for, and respond to flood conditions within a community. Caldwell County and its incorporated areas do not currently own nor operate a FEWS program; however, as evident in the County's 2020 Hazard Mitigation Plan, the County has proposed actions to develop and enhance FEWS capabilities. These proposed actions include promotion and expansion of citizen participation and enrollment in the "Warn Central Texas" emergency notification system, acquisition and installation of fixed barriers and warning lights at high flood hazard roadways, community education on the dangers of low water crossings through the installation of warning signs and promotion of the "Turn Around, Don't Drown" Program, and acquisition and distribution of NOAA weather radios.

As part of this FPPS, Doucet contacted other entities in the region, including the Guadalupe-Blanco River Authority, the City of Austin Watershed Protection Department, and Hays County, to discuss existing FEWS networks, their potential for expansion into Caldwell County, and recommendations for FEWS development in Caldwell County.

5.8.1 Guadalupe-Blanco River Authority

The Guadalupe-Blanco River Authority was contacted for input on Caldwell County's flood early warning system. While GBRA does not operate any FEWS equipment, they recommended that Caldwell County coordinate with both the Region 10 Lower Colorado-Lavaca and Region 11 Guadalupe Flood Planning Groups, particularly in relation to the availability of funding for FEWS upgrades through the TWDB FIF program.

5.8.2 ATXFloods.com

A partnership between the City of Austin Watershed Protection Department, Capital Area Council of Governments (CAPCOG), and numerous communities in Central Texas created ATXFloods.com. This website utilizes data from stream gages throughout the service area to provide flooded road closure information to the public. Caldwell County is one of the participating communities, and residents may access the website to view the current status of roadways throughout the County (see screenshot in **Figure 5-15**). Based on the stage readings at stream gages and field observations, roadways are assigned classifications of "Open," "Closed," or "Caution." The website also provides links to additional educational and technical resources, such as Austin's Flood Safety website (atxfloodsafety.com).

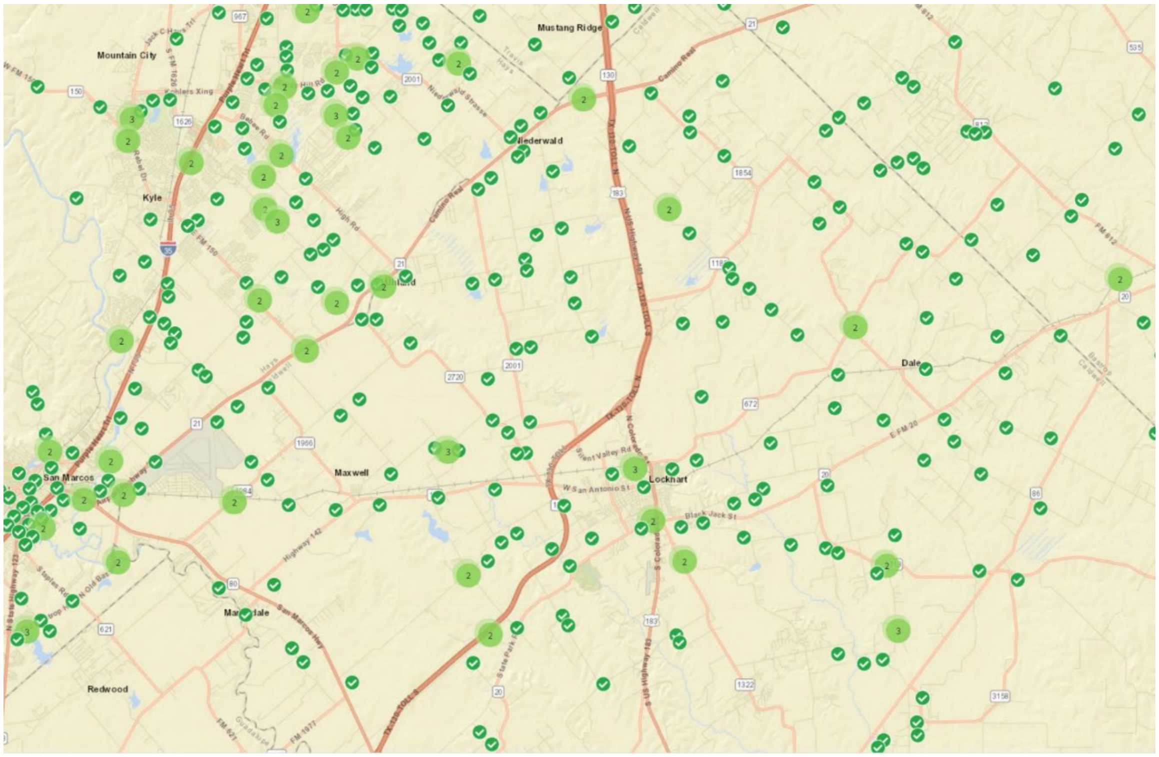

Figure 5-15. Screenshot of ATXFloods.com showing gage locations in Caldwell County.

5.8.3 WarnCentralTexas.org

Another resource sponsored by CAPCOG is WarnCentralTexas.org, which enables residents in many Central Texas communities to register for emergency notifications from local emergency response teams by phone, email, or text message. Caldwell County is one of the participating communities in this partnership. The system is designed to send messages to devices that accept voice, email, or SMS text content, as well as alphanumeric pagers. Local jurisdictions can send customized messages to users notifying them of specific incidents in the area, including recommended courses of action or responses. In addition, registered users can elect to receive automated alerts from the National Weather Service during a dangerous storm event. To receive notifications through this system, users in the CAPCOG region must register their devices using their cell phone numbers and/or email addresses.

5.8.4 Hays County

The Hays County Office of Emergency Services (OES) was contacted for information regarding their flood early warning system components. Doucet staff spoke with Hays County OES director, Mike Jones. Currently, Hays County maintains gages at 30 locations, 5 of which are equipped with cameras. Two of these gages are located on dams, and the others are located at roadway crossings.

Hays County has contracted with Water & Earth Technologies (WET) to operate and maintain the equipment and has been very satisfied with their services. This vendor also maintains an online mapping platform for Hays County (WETMap) showing various gage data readings, including precipitation, stage, discharge, and open/closed status (see **Figure 5-16**). This mapping platform is available to the public and can be accessed through the Hays County OES website at www.haysinformed.com. Emergency services personnel monitor this gage information, as well as precipitation forecast data from TexMesonet, to provide updates to County Commissioners, residents, and social media accounts if dangerous conditions are expected at monitored locations. The OES also makes use of the County's computer-aided dispatch system (CAD), which monitors and logs emergency calls, to identify and close flooded crossings at non-gaged locations.

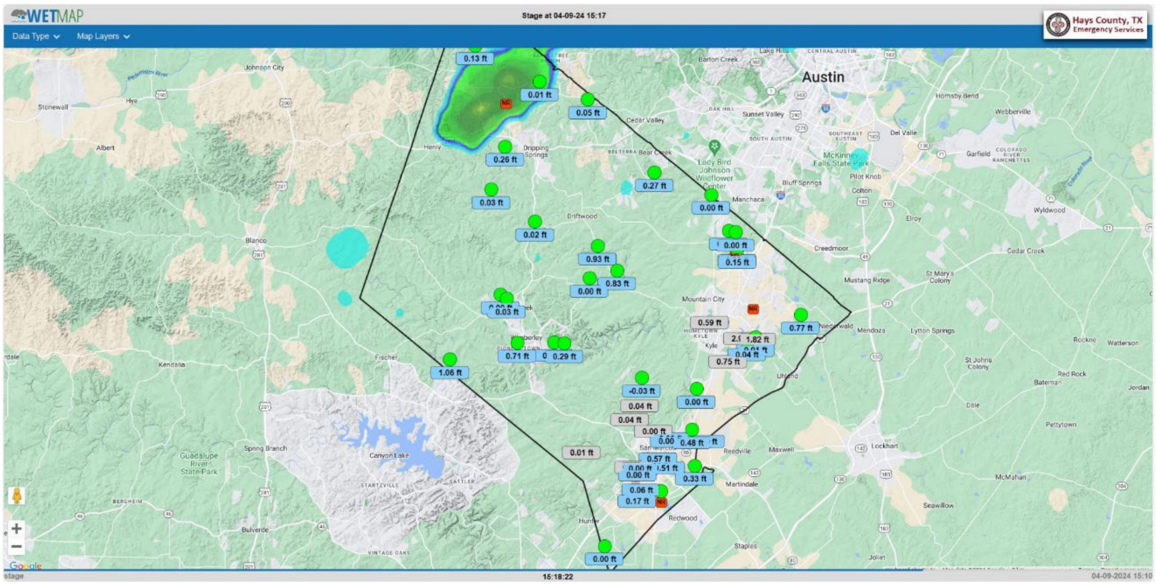

Figure 5-16. Screenshot of WETMap showing gage data readings in Hays County.

Based on discussions with Hays County, the equipment and installation costs at each gage vary depending on the specific types of equipment and appurtenances installed. For a gage that is fully equipped with flashers and communication equipment, but without a camera, the cost is estimated to be approximately $15,000 - $22,000. For gages installed near roadways, Hays County recommended the installation of a protective barricade, estimated to cost approximately $5,000. They also recommended the purchase of a maintenance plan for the gage equipment, including preventive maintenance, rather than simply replacing damaged equipment. Depending on the equipment options chosen, it is estimated that a single gage would cost approximately $20,000 - $30,000 upon installation. According to the NOAA National Weather Service Flood Warning Systems Manual and the TWDB Flood Early Warning Systems (FEWS) Guidance Document for Texas, annual operations and maintenance costs should be estimated at 10-15% of the initial system costs (approximately $2,000 - $4,500 annually per gage).

According to Hays County, their existing monitoring and reporting system could be scaled up to incorporate additional gages in Caldwell County. The City of San Marcos will be incorporating 10 new gages into the Hays County system in the near future. It is reasonable that Caldwell County could follow this example by purchasing and installing new gage equipment to be included in the Hays County monitoring system, including the online WETMap platform. Hays County welcomed the opportunity to discuss this FEWS expansion with Caldwell County.

5.9 Recommendations

To reduce risk to life and property at known flood problem areas in the community, it is recommended that Caldwell County implement the fourteen (14) proposed flood mitigation construction projects discussed in this section. In addition, it is recommended that further analysis be carried out for the twenty (20) flood mitigation evaluations listed in **Table 5-2**, which will help identify the extent of flood risk at those locations and provide alternatives for future flood mitigation projects. Regarding FEWS, it is recommended that Caldwell County encourage its personnel and residents to make use of the existing flood monitoring and reporting resources available at ATXFloods.com and WarnCentralTexas.org. Finally, Caldwell County should contact the Hays County OES Director, Mike Jones, to discuss the possibility of incorporating additional gages into Hays County's existing FEWS network. These steps will be instrumental in developing the County's emergency response protocols to protect the life and property of Caldwell County residents.

6 Implementation and phasing plan

Based on input from the public meetings, a project implementation and phasing plan was developed. The implementation and phasing plan considered items such as project prioritization, funding sources, project duration, easement requirements, environmental impact of the proposed improvements, and benefit/cost ratio.

6.1 Project prioritization

To aid Caldwell County in prioritizing the potential projects, the FMPs were ranked according to the Regional Flood Planning Group criteria and scores listed in **Table 6-1**. For each category, the projects received a score between 0 and 10. The project rankings are shown in **Table 6-2**, which were determined by summing the total score for all the categories. In cases where projects received the same score, those with a higher BCR were assigned a higher ranking.

Table 6-1. TWDB regional flood planning project scoring criteria.

Scoring Categories	Scoring Metrics	Score
Severity - Pre-Project Average Depth of Flooding (100-Year)	Baseline average flood depth > 3.5 ft	10
	Baseline average flood depth > 2 ft	8
	Baseline average flood depth > 1 ft	6
	Baseline average flood depth > 0.5 ft	4
	Baseline average flood depth < 0.5 ft	2
Severity - Community Need	>75% of project community affected (by population)	10
	50%-75% of project community affected	7
	25%-50% of project community affected	4
	<25% of project community affected	1
Flood Risk Reduction	Reduced risk to >75% of structures in floodplain	10
	Reduced risk to <75% of structures in floodplain	7
	Reduced risk to <50% of structures in floodplain	4
	Reduced risk to <10% of structures in floodplain	1
	Reduced risk to 0 structures in floodplain	0
Flood Damage Reduction	Flood damage reduction >95%	10
	Flood damage reduction > 75%	8
	Flood damage reduction > 50%	6
	Flood damage reduction > 25%	4
	Flood damage reduction < 25%	2
Critical Facilities Damage Reduction	Reduced risk for >75% of critical facilities in floodplain	10
	Reduced risk for <75% of critical facilities in floodplain	7
	Reduced risk for <50% of critical facilities in floodplain	4
	Reduced risk for <10% of critical facilities in floodplain	1
	Reduced risk for 0 structures in floodplain	0
Life and Safety	Life/injury risk percentage >50%	10
	Life/injury risk percentage >40%	8
	Life/injury risk percentage >30%	6
	Life/injury risk percentage >20%	4
	Life/injury risk percentage <20%	2
Water Supply	Involves directly increasing water supply availability and connection to user	10
	Directly benefits water availability in aquifer but no direct connection to user	7
	Indirectly benefits water availability (e.g., recharges aquifers naturally more)	4
	No impact on water supply	0

Table 6-1. TWDB regional flood planning project scoring criteria (continued).

Scoring Categories	Scoring Metrics	Score
Social Vulnerability	SVI between 0.75-1.00 (high vulnerability)	10
	SVI between 0.5-0.75 (moderate to high vulnerability)	7
	SVI between 0.25-0.5 (low to moderate vulnerability)	4
	SVI between 0.01-0.25 (low vulnerability)	1
Nature-Based Solutions	>75% of the project cost is nature-based	10
	> 50% of the project cost is nature-based	7
	>25% of the project cost is nature-based	4
	<25% of the project cost is nature-based	1
Multiple Benefits	Project delivers benefits in 4 or more wider benefit categories	10
	Project delivers benefits in 3 wider benefit categories	7
	Project delivers benefits in 2 wider benefit categories	4
	Project delivers benefits in only 1 wider benefit category	1
	Project does not deliver any wider benefits	0
Operations and Maintenance	Project will have low operation and maintenance requirements	10
	Project will have regular operation and maintenance requirements	7
	Project will have high operation and maintenance requirements	4
	Project will have extensive operation and maintenance requirements	1
Regulatory Obstacles	Project has few administrative and regulatory requirements	10
	Project has a typical number of administrative and regulatory requirements	6
	Project has a high number of administrative and regulatory requirements	2
Environmental Benefit	Project will deliver a high level of environmental benefits	10
	Project will deliver a moderate level of environmental benefits	6
	Project will deliver a low level of environmental benefits	3
	Project does not provide any environmental benefits	0
Environmental Impact	Project has no adverse environmental impacts	10
	Project will have adverse impacts in 1 environmental category	6
	Project will have adverse impacts in 2-3 environmental categories	3
	Project will have adverse impacts in 4+ environmental categories	0
Mobility	Project protects major and minor access routes and emergency service access	10
	Project protects all major access routes and all emergency service access	7
	Project protects some major access routes and most emergency service access	4
	Project provides no change to major, minor, or emergency access routes	0

Table 6-2. Caldwell County Flood Mitigation Project ranking.

Rank	Project Identifier	Flood Mitigation Project Title	Score	BCR
1	CC-5	SH 80 Low Water Crossing Improvements @ Morrison Creek	73	0.5
2	CC-9	Hemphill Creek Drainage Improvements Near FM 1984	70	0.4
3	CC-7	CR 233 and FM 2001 @ Plum Creek	69	0.5
4	CC-10	US 183 @ Clear Fork Plum Creek	63	0.1
5	CC-11	Brushy Creek Channel Improvements Near Las Estancias II	60	0.1
6	CC-14	CR 227 @ Brushy Creek	57	2.3
7	CC-8	Plum Creek Channel Improvements Near CR 227	57	0.1
8	CC-6	Salt Branch Drainage Improvements in Luling	55	0.7
9	CC-4	CR 141 @ Hines Branch	55	0.2
10	CC-1	Cedar Creek Channel Improvements Near Christian Drive	55	0.0
11	CC-13	CR 218 @ Boggy Creek and Clear Fork Plum Creek	54	0.0
12	CC-3	CR 172 Low Water Crossing Improvements @ Lytton Creek	53	0.5
13	CC-2	CR 170 Low Water Crossing Improvements @ Lytton Creek	53	0.1
14	CC-12	Boggy Creek Channel Improvements Near SH 142	48	0.1

6.2 Construction phasing

The phasing of construction on these fourteen (14) projects will likely be driven primarily by public input, right-of-way and easement acquisition timeframes, and funding availability. In general, construction phasing should move from downstream to upstream; however, the projects presented here are not dependent on one another, which will allow the County to construct them in any order.

6.3 Funding sources

This section provides a brief summary of state and federal grant programs and other sources that may provide partial or full funding for planning, design, permitting, and construction activities related to the FMPs and FMEs recommended as part of this FPPS.

Municipal Funding Sources

- Capital Improvements Plan (CIP)
- Drainage Utility Fees
- General Fund
- General Obligations Bond (GO)
- Revenue Bond
- Special Assessment Bond
- Tax Increment Financing

State Funding Sources

- TWDB
    - Regional Flood Plan / Flood Infrastructure Fund
    - State Flood Plan / Flood Infrastructure Fund
    - Clean Water State Revolving Fund
    - Research and Planning Fund Grants
    - State Participation and Storage Acquisition Program
    - FEMA Cooperating Technical Partner (CTP) Program

- General Land Office (GLO)
  - Community Development Block Grant Program Disaster Recovery (CDBG-DR)
  - Community Development Block Grant Program Mitigation (CDBG-MIT)
- Texas Commission on Environmental Quality (TCEQ)
  - Texas Clean Rivers Program

Federal Funding Sources

- Federal Emergency Management Agency (FEMA)
  - Flood Hazard Mapping Program
  - Flood Mitigation Assistance (FMA) Grants
  - Hazard Mitigation Grant Program (HMGP)
  - Pre-Disaster Mitigation (PDM) Grant Program
- U.S. Department of Housing and Urban Development (HUD)
  - Disaster Relief/Urgent Needs Fund of Texas
  - Community Development Block Grant (CDBG) Program
- National Resources Conservation Service (NRCS)
  - Watershed Protection and Flood Prevention Program
  - Watershed Surveys and Planning
  - Wetland Reserve Program
  - Emergency Watershed Protection Program
- U.S. Army Corps of Engineers (USACE)
  - Emergency Advance Measures for Flood Prevention
  - Emergency Rehabilitation of Flood Control Works
  - Emergency Streambank and Shoreline Protection
  - Floodplain Management Services
  - Nonstructural Alternatives to Structural Rehabilitation of Damaged Flood Control Works
  - Planning Assistance to States
  - Small Flood Control Projects

7 References

Compass PTS JV. November 2016. "San Marcos HUC-8 Subshed, TX Base Level Engineering (BLE) Results."

Compass PTS JV. June 2018. "Lower Colorado-Cummins Watershed, TX Base Level Engineering (BLE) Results."

Halff. June 30, 2022. "Texas Water Development Board CTP Flood Risk Project Mapping Activity Statement No. 23, Plum Creek Watershed."

Halff. April 17, 2020, "Texas Water Development Board CTP Flood Risk Project Mapping Activity Statement No. 14, Lower Colorado-Cummins Watershed."

Halff. September 2013. "Lower Guadalupe River Basin Interim Feasibility Study – Phase 1, Technical Report Notebook (TRN) Appendix B.1 Engineering Analysis – Hydrology, Lower Guadalupe, Blanco, and San Marcos Watersheds."

Halff. March 2014. Lower Guadalupe River Basin Interim Feasibility Study – Phase 1, Technical Report Notebook (TRN) Appendix D.1 Engineering Analysis – Hydraulics, Guadalupe, Blanco, and San Marcos River Watersheds."

Halff. March 2014. Lower Guadalupe River Basin Interim Feasibility Study – Phase 1, Technical Report Notebook (TRN) Appendix E – Preliminary Alternatives Development and Benefit-Cost Analysis."

Halff. May 2015. "Lower Guadalupe River Basin Interim Feasibility Study – Phase 2, Technical Report Notebook (TRN) Engineering Analysis – Hydrology and Hydraulics, Cypress, Bear, Upper San Marcos, Bypass, Plum, Mays, Peach, and Spring Creek Watersheds."

H_2O Partners, Inc. September 19, 2018. "Guadalupe-Blanco River Authority Hazard Mitigation Action Plan."

H_2O Partners, Inc. April 2, 2020. "Caldwell County Hazard Mitigation Action Plan 2020."

Interagency Flood Risk Management (InFRM). September 2016. "Hydrology Report for the San Marcos River Basin."

Lower Colorado-Lavaca Regional Flood Planning Group. Amended July 2023. "Lower Colorado-Lavaca Regional Flood Plan."

National Weather Service. April 20, 2012. "Flood Warning Systems Manual."

Natural Resources Conservation Service. June 1986. "Technical Release 55 – Urban Hydrology for Small Watershed."

North Central Texas Council of Governments. Revised September 2014. "iSWM Technical Manual – Hydrology."

Paul Rodman, U.S. Army Corps of Engineers. October 1977. "Effects of Urbanization on Various Frequency Peak Discharges."

Region 11 Guadalupe Flood Planning Group. Amended July 2023. "2023 Amended Regional Flood Plan – Region 11 Guadalupe."

Texas Water Development Board. 2021. "Exhibit C – Technical Guidelines for Regional Flood Planning."

Texas Water Development Board. 2021. "Exhibit D – Data Submittal Guidelines for Regional Flood Planning."

Texas Water Development Board. 2022. "Flood Early Warning Systems (FEWS) Guidance Document for Texas."

Thomas Nelson, U.S. Army Corps of Engineers. September 1970. "Synthetic Unit Hydrograph Relationships, Trinity River Tributaries, Fort Worth-Dallas Urban Area."

U.S. Army Corps of Engineers. 1968. "Report on Hurricane 'Beulah' – 8-21 September 1967."