Upper Cypress Creek Watershed Flood Protection Planning Study Final Report

Prepared for:
Texas Water Development Board

November 16, 2012

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For Waller County, City of Waller, and City of Prairie View

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Type or Print Name	PE#	Date

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EXECUTIVE SUMMARY

The Cypress Creek Watershed, located in Waller County has been the source of frequent flooding. As a result of the flooding, local officials applied for a Flood Protection Planning Grant to aid in the creation of new hydrologic and hydraulic modeling as well as flood damage reduction alternative analyses to aid in planning efforts.

Hydrologic and hydraulic modeling was performed on the Cypress Creek watershed and all of its tributaries in Waller County. Detailed LiDAR elevation data as well as cross-section and bridge/culvert surveys where available were used to enhance the accuracy of the models. The modeling resulted in updated and more accurate flows and water surface elevations for the 2, 5, 10, 25, 50, 100, 250, and 500-yr events. The resulting hydraulic data was then used to analyze various flood reduction alternatives for the City of Waller, City of Prairie View, and Waller County.

Several flood reduction alternatives were analyzed during the flood damage reduction analysis portion of the study. Each alternative was evaluated by cost and potential for producing a benefit-to-cost ratio greater than one. Alternatives were recommended for the City of Waller and City of Prairie View that consist of upstream detention and improving culverts at Business 290 and the railroad. Non-structural alternatives were also considered for the City of Waller and City of Prairie View. Alternatives for Waller County included coordination with Harris County for the Cypress Creek Overflow study and improving crossings that do not adequately convey flow downstream. A typical standard for conveyance is that county-maintained roads should pass at least the 5-yr flow and state-maintained roads should pass at least the 25-yr flow. Bridges and culverts that do not meet these standards should be considered for improvement.

1.0 Introduction and Background

The Upper Cypress Creek watershed is located near the eastern edge of Waller County and northwestern corner of Harris County (see Figure 1). The Upper Cypress Creek watershed drains about 79 square miles and consists of Live Oak Creek and Tributaries, Mound Creek and Tributaries, Snake Creek, and Cypress Creek. The terrain is generally characterized by level to undulating farmland rising to the northwest with a timber belt of hardwoods along streams in most places. The Upper Cypress Creek watershed contains several different land use types including the urban area of the City of Waller, rural subdivisions in the county and City of Prairie view, agricultural lands, and lands set aside for preservation by the Katy Prairie Conservancy. It should be noted that the watershed is split between Harris and Waller Counties with most of the flow through the City of Waller originating in Harris County. The elevations vary from 115 ft. above sea level (NAVD 88) at the county-line to about 317 feet above sea level in the headwaters above the City of Waller. Annual rainfall in the watershed is on average 41.67 inches per year.

Significant floods have occurred in Waller County in 1929, 1935, 1960, 1966, 1979, 1981, 1983, 1984, 1994, and 1998. Most recently, the City of Waller experienced flooding from a rainfall event that occurred on July 12, 2012. The worst flooding occurred along Middle Fork Mound Creek just upstream of Business 290 as seen in Figure 2. Also shown in Figure 2, is a building that was flooded with at least 6 inches of water. During the 1994 flood, the most destructive in recent memory, the railroad crossings were washed out at Middle and West Fork Mound Creek and several business and homes were flooded upstream of Middle and East Fork Mound Creek. The flood hazard sources include local stream flooding due to inadequate stream capacity and restrictions in the channels including undersized culverts at Business 290 and the railroad. Local officials in the study area recognize that the restrictions within the creek channels back water up resulting in additional flooding. These flood waters, in-turn, pose a major risk to both life and property in the Cities of Waller and Prairie View.

As a result of frequent flooding and the potential for increased development in the area, Waller County took a pro-active lead in applying for a Flood Protection Planning Grant from the Texas Water Development Board (TWDB), which was awarded in 2010. Waller County teamed with the Cities of Waller and Prairie View to assess the local drainage problems and to evaluate the overall flooding problems from a regional perspective. To facilitate regional input into the planning process, three public meetings were held within the Upper Cypress Creek region. All three meetings were held at the Waller County Community Center in Prairie View, TX on October 21, 2010, June 1, 2011, and August 16, 2012. A copy of the public notices can be seen in Figure 3. These public meetings served to inform the public about the planning study and to gather information that could be used to enhance and confirm the study results and conclusions. This study has resulted in new planning and regulatory information for use in floodplain management as well as flood reduction alternative analyses for the City of Waller, City of Prairie View, and Waller County.

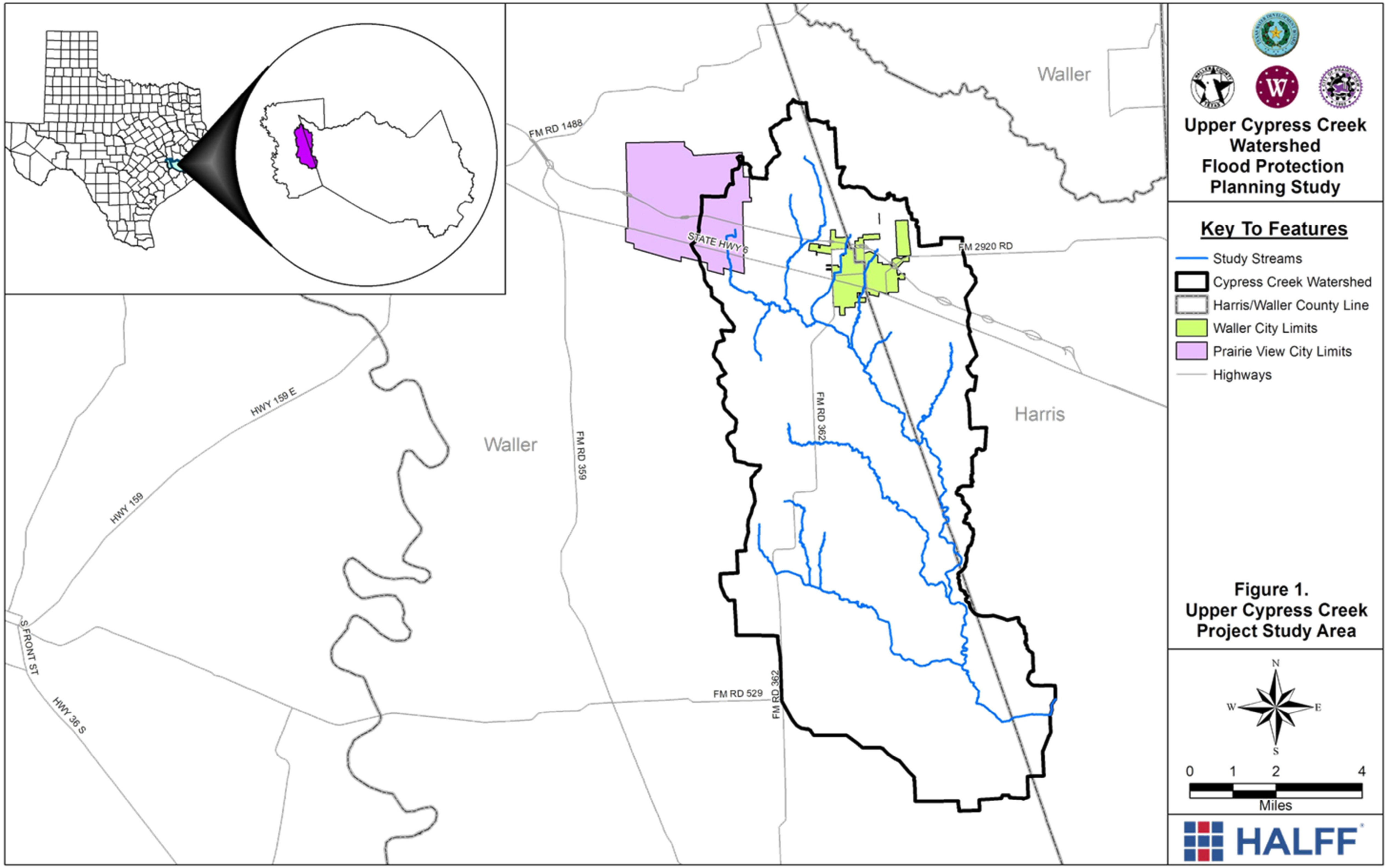


Figure 1.
Upper Cypress Creek Project Study Area

Figure 2: Flooding from July 12, 2012 Event in Waller, TX

This report presents the results of hydrologic, hydraulic, and alternative analyses of the Upper Cypress Creek watershed. Halff Associates was responsible for existing conditions hydrologic and hydraulic models for Cypress Creek and all of its tributaries in Waller County. Halff Associates also performed the flood damage reduction alternative analysis for the watershed in Waller County. Items discussed in this report include:

- Hydrologic Analysis
- Hydraulic Analysis
- Existing Conditions Results
- Flood Damage Reduction Alternative Analysis
- Alternative Recommendation

NOTICE TO PUBLIC

The City of Prairie View, The City of Waller, and Waller County Announce a Public Meeting for the Cypress Creek Flood Protection Planning Project

The Public Meeting will commence from 5:00 PM to 7:00 PM on Thursday, October 21, 2010, at the Waller County Community Center in Prairie View. The Community Center is located at 200 FM 1098, Prairie View, TX. The purpose of this meeting will be to update the various communities on the overall status of this project including the purpose, geographic area, and schedule. The public is invited to attend and provide feedback needed to enhance the overall quality of this project. For more information, please contact Stephen Reiter, PE (Halff Associates, Inc.) at (713) 523-7161 or sreiter@halff.com.

NOTICE TO PUBLIC

The City of Prairie View, The City of Waller, and Waller County Announce a Public Meeting for the Cypress Creek Flood Protection Planning Project

The Public Meeting will commence from 5:00 PM to 7:00 PM on Wednesday, June 1, 2011, at the Waller County Community Center in Prairie View. The Community Center is located at 200 FM 1098, Prairie View, TX. The purpose of this meeting will be to update the various communities on the overall status of this project including the purpose, geographic area, and schedule. The public is invited to attend and provide feedback needed to enhance the overall quality of this project. For more information, please contact Stephen Reiter, PE (Halff Associates, Inc.) at (713) 523-7161 or sreiter@halff.com.

NOTICE TO PUBLIC

The City of Prairie View, The City of Waller, and Waller County Announce a Public Meeting for the Cypress Creek Flood Protection Planning Project

The Public Meeting will commence from 10:00 AM to 12:00 PM on Thursday, August 16, 2012, at the Waller County Community Center in Prairie View. The Community Center is located at 200 FM 1098, Prairie View, TX. The purpose of this meeting will be to update the various communities on the overall status of this project including the purpose, geographic area, flood reduction alternatives and remaining schedule. The public is invited to attend and provide feedback needed to enhance the overall quality of this project. For more information, please contact Orval Rhoads, Waller County Engineer, at (979) 826-7670 or Daniel Harris, PE (Halff Associates, Inc.) at (512) 777-4600.

Figure 3: Copies of Notices Posted for the Three Public Meetings

2.0 Watersheds

The watershed for Cypress Creek was originally delineated as part of the Tropical Strom Alison Recovery Project (TSARP) by Harris County Flood Control District (HCFCD) using the best available LiDAR at that time. The TSARP delineation was then compared to the latest 2008 Houston Galveston Area Council (HGAC) LiDAR and adjusted to better match existing drainage networks. New HGAC 1 meter LiDAR data (2008) with a vertical Root Mean Squared Error (RMSE) of 0.22 feet was used. A total of 47 sub-basins were delineated from the headwaters upstream of the City of Waller to the limit of study at the Waller/Harris County boundary. Figure 4 illustrates the overall watershed delineation for Upper Cypress Creek along with each sub-basin. Table 1 is a summary of stream names and drainage areas for each sub-basin.

Table 1: Sub-basin Names and Areas

Sub-Basin	Stream Name	Drainage Area (acres)	Drainage Area (mi^2)
CYP_01	Cypress Creek	774.0	1.21
CYP_02	Cypress Creek	2237.2	3.50
CYP_03	Cypress Creek	1008.3	1.58
CYP_04	Cypress Creek	2692.8	4.21
CYPT_01	Cypress Creek Tributary	1817.6	2.84
EFMC_01	East Fork Mound Creek	713.7	1.12
EFMC_02	East Fork Mound Creek	421.7	0.66
EFMC_03	East Fork Mound Creek	360.0	0.56
LMC_01	Little Mound Creek	1506.7	2.35
LMC_02	Little Mound Creek	2067.7	3.23
LOC_01	Live Oak Creek	415.6	0.65
LOC_02	Live Oak Creek	1198.1	1.87
LOC_03	Live Oak Creek	823.0	1.29
LOC_04	Live Oak Creek	2390.6	3.74
LOC_05	Live Oak Creek	1071.2	1.67
LOCT_01	Live Oak Tributary 1	218.1	0.34
LOCT_02	Live Oak Tributary 1	2183.8	3.41
LOCT4_01	Live Oak Tributary 4	2865.9	4.48
MC_01	Mound Creek	998.0	1.56
MC_02	Mound Creek	633.2	0.99
MC_03	Mound Creek	1184.0	1.85
MC_04	Mound Creek	304.4	0.48
MC_05	Mound Creek	663.4	1.04
MC_06	Mound Creek	613.7	0.96
MC_07	Mound Creek	495.3	0.77
MC_08	Mound Creek	2140.4	3.34

MC_09	Mound Creek	1914.4	2.99
MC_10	Mound Creek	647.4	1.01
MCT_01	Mound Creek Tributary 7.62	568.3	0.89
MCT_02	Mound Creek Tributary 7.62	754.8	1.18
MFMC_01	Middle Fork Mound Creek	366.2	0.57
MFMC_02	Middle Fork Mound Creek	449.2	0.70
MFMC_03	Middle Fork Mound Creek	615.8	0.96
MFMC_04	Middle Fork Mound Creek	461.3	0.72
SC_01	Snake Creek	2219.2	3.47
SC_02	Snake Creek	2456.1	3.84
SC_03	Snake Creek	2437.7	3.81
SCT2_01	Snake Creek Tributary 2	616.3	0.96
SFMC_01	South Fork Mound Creek	600.5	0.94
UNT_01	Live Oak Unnamed Tributary	378.8	0.59
UNT_02	Live Oak Unnamed Tributary	498.7	0.78
WFMC_01	West Fork Mound Creek	886.9	1.39
WFMC_02	West Fork Mound Creek	1202.3	1.88
WFMC_03	West Fork Mound Creek	436.5	0.68
WFMC_04	West Fork Mound Creek	410.0	0.64
WFMCT_01	West Fork Mound Creek Tributary	243.8	0.38
WFMCT_02	West Fork Mound Creek Tributary	640.7	1.00

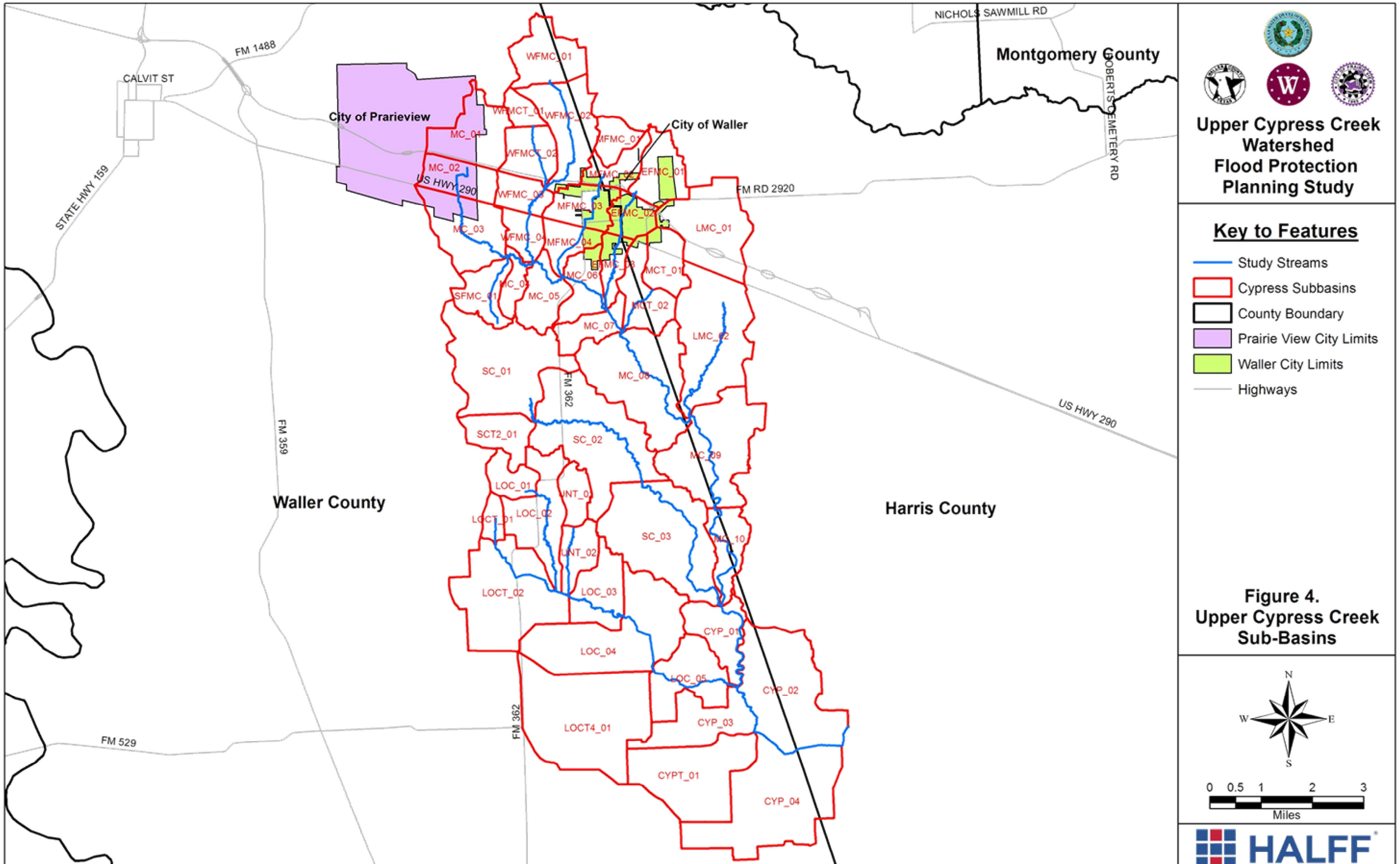


Figure 4.
Upper Cypress Creek Sub-Basins

3.0 Hydrologic Analysis

A detailed hydrologic analysis was performed on the Upper Cypress Creek watershed with the goal of providing a validated base conditions model for use in developing flood damage reduction alternatives, and helping to quantify the impacts of these alternatives to the surrounding area. The hydrologic analysis was conducted with the aid of the US Army Corps of Engineers HEC-HMS software, version 3.3, and was used to develop peak flows and flow hydrographs for existing land use conditions 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year events. The effective hydrologic model was obtained from HCFCD and was then updated and enhanced with more detail to reflect existing conditions. Further details of the hydrologic analysis for the Upper Cypress Creek watershed can be found in Appendix A.

4.0 Hydraulic Analysis

Hydraulic analyses were performed for Upper Cypress Creek and its tributaries from the headwaters upstream of the City of Waller to the limit of study at the Waller/Harris County boundary for a total length of about 80 river miles using HEC-RAS software, version 4.1. Cross-section layouts were kept as close as possible to the effective HCFCD models where applicable and new models were created where needed. Surveys from the effective HCFCD models were applied to the updated hydraulic models as no new survey data was collected for this study. The hydraulic analysis was conducted to develop existing conditions peak stages for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency events. Further details of the hydraulic analysis for the Upper Cypress Creek watershed can be found in Appendix A.

5.0 Results of Hydrologic and Hydraulic Analyses

The existing conditions hydrologic and hydraulic analyses resulted in validated flood hazard information that is useful for planning and regulatory purposes. Specifically, the analyses resulted in base flood elevations for the 2-, 5-, 10-, 25-, 50-, 100-, 250- and 500-year rainfall events and a floodplain for the 100-yr event throughout the Upper Cypress Creek watershed within Waller and Harris Counties. The resulting 100-yr floodplain delineation is illustrated in the map entitled *Upper Cypress Watershed Updated 100-yr Floodplain* included in Appendix D. The water surface elevation profiles for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency events are provided in Appendix A.

Although this is new and, in some places, detailed information, there are sources of uncertainty in the hydrologic and hydraulic models that could affect the flows and stages calculated. One source of uncertainty is areas of shallow flooding and diversion of flows that appear to occur during higher flood events. It is apparent that these areas will provide significant storage and attenuation of flows during larger events, but it is often challenging to sufficiently incorporate these areas into a one dimensional model. An attempt was made to account for one such overflow that occurs from Cypress Creek to the east into an adjacent watershed. This overflow is represented in the hydraulic model for Cypress Creek as a long lateral weir. In the effective Flood Insurance Rate Map (FIRM) this overflow area is designated as a shallow flooding zone.

Another source of uncertainty is the lack of a flow gauge with data to calibrate the models. While a full calibration was not possible, the models were compared to anecdotal flooding information provided by City of Waller officials for the October 1994 flood event. The information provided was approximate flood depths and locations of inundated structures from the October 1994 flood event on West, Middle and East Fork Mound Creek in the City of Waller. Gauge corrected radar rainfall for the October 1994 event was obtained from HCFCD and input into the HEC-HMS model producing flows along Mound Creek and its tributaries. These flows were applied to the hydraulic models to produce flood elevations for the October 1994 event. Table 2 shows the comparison of model results to the anecdotal information for the October 1994 flood event. A comparison of the modeled October 1994 flood event to the updated 100-yr floodplain is illustrated in Figure 5.

Table 2: Comparison of Modeled to Observed Flood Depths for October 1994 Event

Location	Observed Depth	Modeled Depth
Middle Fork, Bois D'Arc St.	3-4 feet	3.5 feet
Middle Fork, Bois D'Arc at D St.	3-4 feet	3.2 feet
Middle Fork, Upstream Bus. 290	4-5 feet	4 feet
Middle Fork, over Bus. 290	2 feet	1 foot

6.0 Alternatives Analysis – City of Waller

The Middle and East Forks of Mound Creek have been a source of frequent flooding for the citizens of the City of Waller. Major floods have occurred in the City of Waller as recently as 1994 and 1998. The City of Waller became a participant in the Upper Cypress Creek Watershed Flood Protection Planning Study in large part to determine the best (e.g. most cost effective) alternatives to reduce potential flood damages. A baseline alternative analysis was performed using hydraulic model results and impacts to existing structures. Details of the alternatives analysis are provided in Appendix B.

A total of four structural alternatives were evaluated for Middle and East Fork Mound Creek. The first two alternatives consisted of detaining flood flows upstream of US 290 which would reduce the 100-yr recurrence interval discharge to a 25-yr discharge. When these alternatives were tested, they were found to be ineffective at reducing flood elevations as a result of the culverts under Business 290 and the railroad being undersized. The second two alternatives involved improving the culvert capacity under Business 290 and the railroad at both Middle and East Fork Mound Creek coupled with the upstream detention. The upstream flood elevations on both Middle and East Fork Mound Creek were significantly improved when the culvert capacity under Business 290 and the railroad is increased. It should be noted that the upstream detention must be in place before the culverts are improved to avoid adverse downstream impacts. Benefits from the detention plus culvert improvement alternatives for both East and Middle Fork Mound Creek include the removal of 39 habitable structures from the 100-yr floodplain valued at a total of $2,018,320. A 100-yr floodplain comparison between existing and improved conditions with affected structures is shown in Figure 6. It is recommended that a FEMA grant

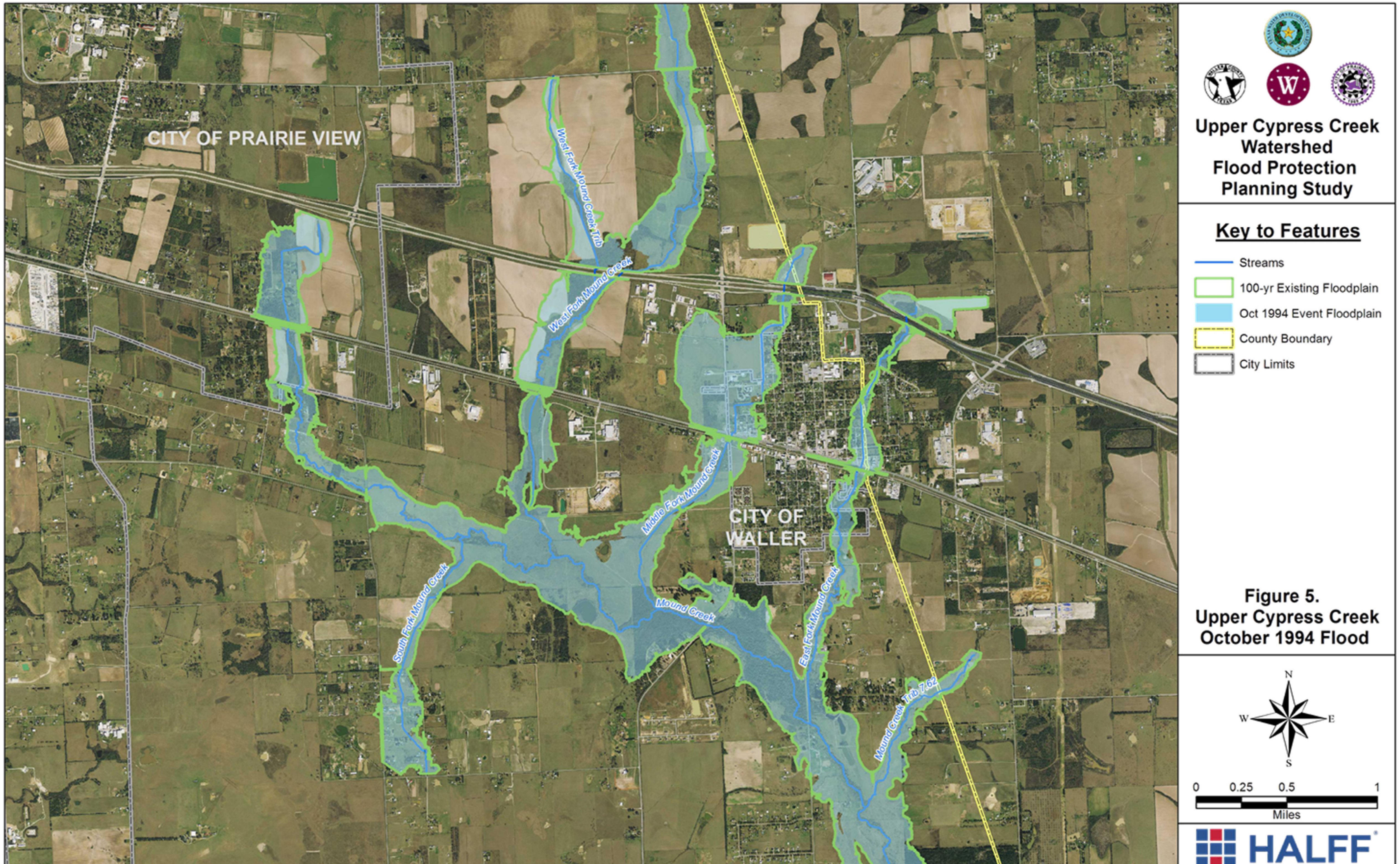


Figure 5.
Upper Cypress Creek
October 1994 Flood

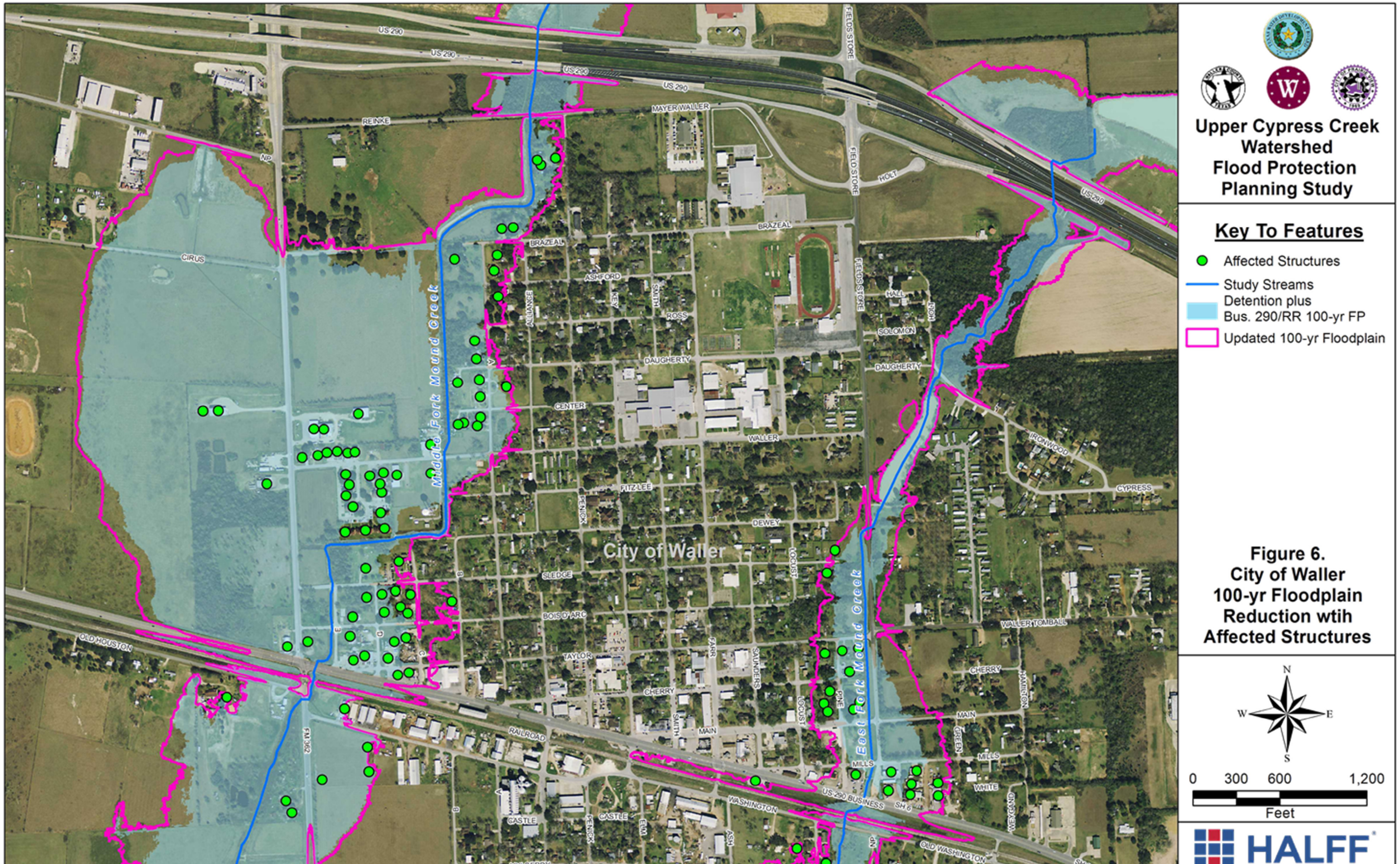


Figure 6.
City of Waller
100-yr Floodplain
Reduction wtih
Affected Structures

be considered for the culvert improvements and that the City of Waller partner with Harris County to help build the detention ponds.

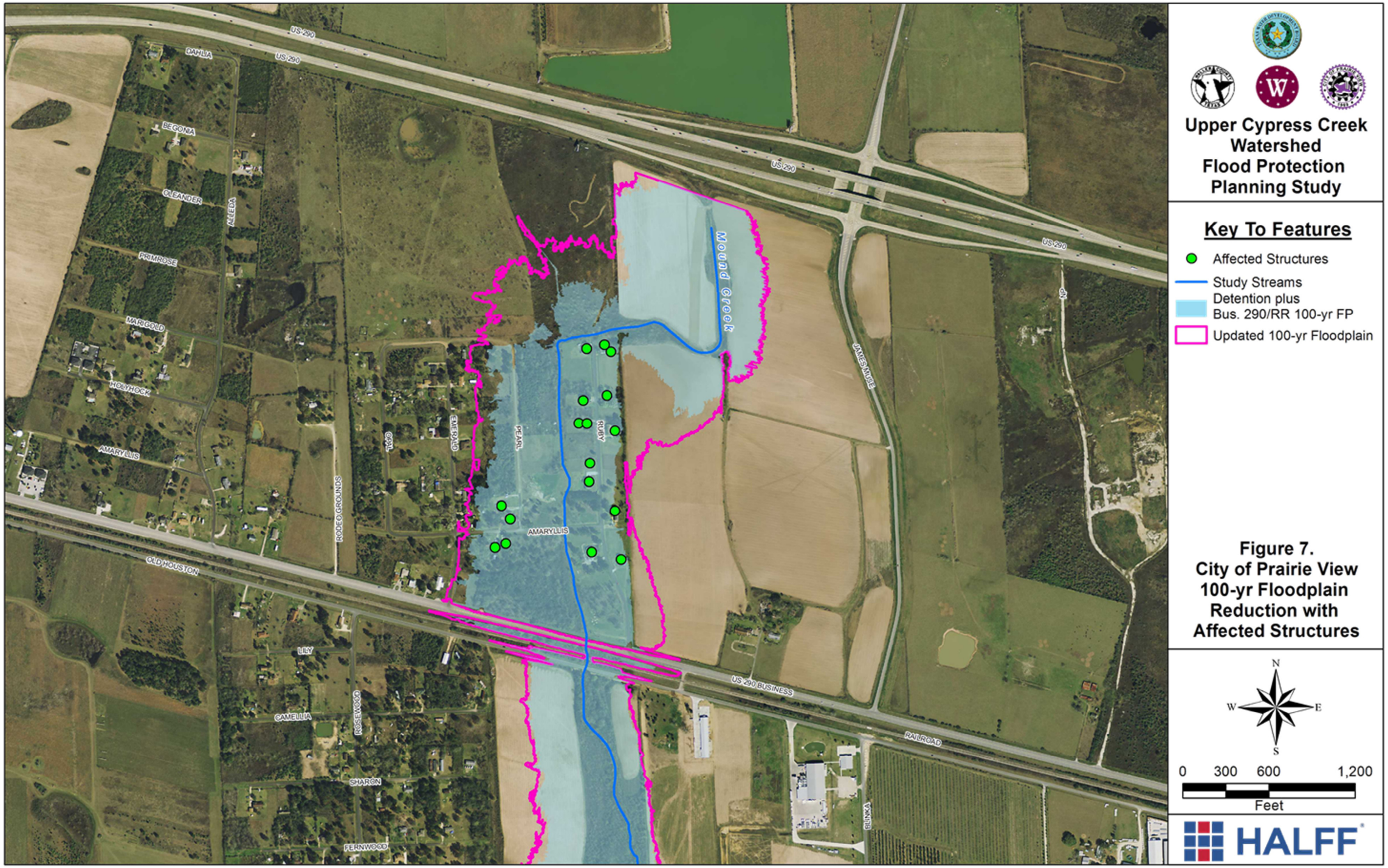
The City of Waller was also concerned about possible flooding impacts on West Fork Mound Creek as a result of future development into the West Fork Mound Creek watershed. Currently there is very little development in this watershed which lies in the City of Waller's ETJ, just to the West of the city. The alternative analyzed for West Fork Mound Creek consisted of determining fully developed (future) condition flows for the watershed and sizing a regional detention, located upstream of US 290, that would reduce the future flow to existing levels. The proposed regional detention can be funded by a development fee and built out in stages as development increases in the watershed. If a developer opts out of the development fee, they would be required to provide onsite detention to reduce their runoff to pre-development levels.

Non-structural City of Waller flood damage reduction alternatives considered include incorporation of data produced into the local floodplain ordinance and buyout of affected houses. All information produced from this study may be submitted to FEMA via the LOMR process and will be available to the City of Waller for regulation under their floodplain ordinance. Buyout of affected structures is not advisable because of the cost associated with purchasing 105 affected structures and political issues associated with the area being predominantly lower income. Because of the issues associated with buying out affected homes, it was decided to focus mainly on structural alternatives in the alternatives analysis. Further details of the alternatives analysis are located in Appendix B. A summary of environmental constraints associated with implementing the recommended alternatives is located in Appendix C.

7.0 Flood Damage and Alternative Analysis – City of Prairie View

Upper Mound Creek has been a source of frequent flooding for residents living along Ruby Lane in the City of Prairie View. The houses along Ruby Lane flood during both low and high frequency events since they are located in close proximity to the stream channel. The City of Prairie View became a participant in the Upper Cypress Creek Watershed Flood Protection Planning Study in large part to determine the best (e.g. most cost effective) alternatives to reduce potential flood damages to these frequently flooded houses. A baseline alternative analysis was performed using hydraulic model results and impacts to existing structures. Details of the alternatives analysis are provided in Appendix B.

One structural and one non-structural alternative were developed for Upper Mound Creek to reduce the flood damages. The structural alternative consists of upstream detention coupled with improvements to the Business 290 culvert. The railroad crossing at Upper Mound Creek provides adequate conveyance of flood flows and does not need to be improved. The upstream flood elevations on Upper Mound Creek are significantly improved when the culvert capacity under Business 290 is increased. It should be noted that the upstream detention must be in place before the culverts are improved to avoid adverse downstream impacts. Benefits from the detention plus culvert improvement alternatives for Upper Mound Creek includes a 100-yr flood elevation reduction of approximately 1.4 feet and the removal of one habitable structure from the 100-yr floodplain valued at $115,250. A 100-yr floodplain comparison between existing and improved conditions with affected structures is shown in Figure 7.


US-290
DAHLIA
BEGONIA
OLEANDER
PRIMROSE
MARIGOLD
HOLLYHOCK
AMARYLLIS
OLD HOUSTON
PEARL
RUBY
EMERALD
RODEO GROUNDS
Mound Creek
JAMES MUSE
US 290 BUSINESS
RAILROAD
LILY
CAMELLIA
ROSEWOOD
SHARON
FERNWOOD
BLINKA
Upper Cypress Creek Watershed Flood Protection Planning Study
Key To Features
Affected Structures
Study Streams
Detention plus Bus. 290/RR 100-yr FP
Updated 100-yr Floodplain
Figure 7.
City of Prairie View 100-yr Floodplain Reduction with Affected Structures
N
W
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0
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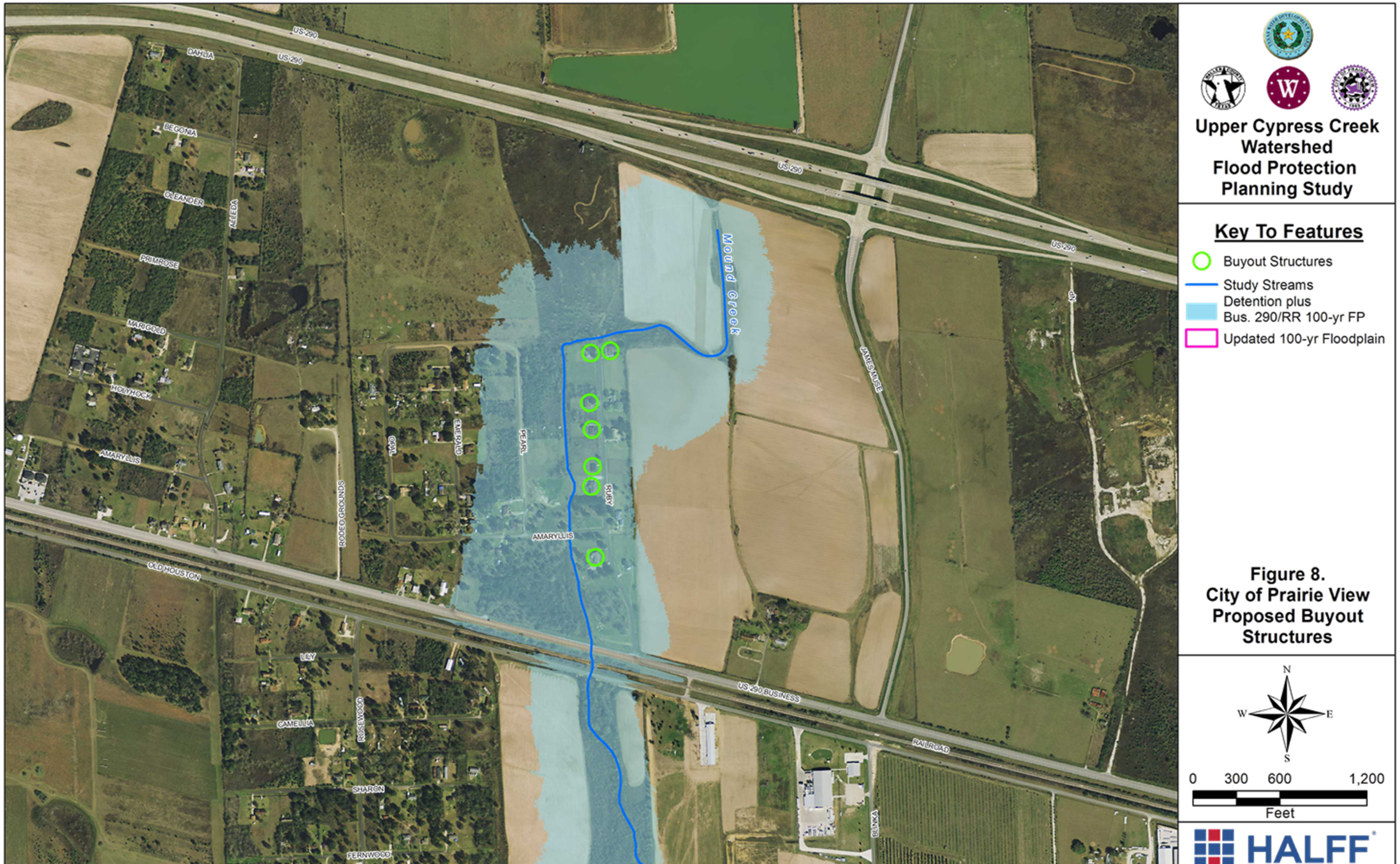

Figure 8.
City of Prairie View
Proposed Buyout
Structures

The non-structural solution suggested for Upper Mound Creek consists of buying out the frequently flooded houses along Ruby Street. There are seven homes shown in Figure 8 that lie between Ruby Street and Upper Mound Creek that are recommended for the buyout alternative. The total appraised value of these homes is $594,050. Other benefits of this alternative, other than reducing flood damages, include using the purchased land as a greenbelt or park that can be used by the residents of the neighborhood as well as citizens of Prairie View. Further details of the alternatives analysis are located in Appendix B. A summary of environmental constraints associated with implementing the recommended alternatives is located in Appendix C.

8.0 Flood Damage and Alternative Analysis – Waller County

There are two recommendations for Waller County to promote flood damage reduction. First, it is recommended that Waller County consider improving road crossings that do not effectively convey flood flows. County maintained roads should typically convey at least the 5-yr flow and State maintained roads should typically convey the 25-yr flow. A table containing roads that do not meet these standards is included in Appendix B. Improving roads to meet these standards will create better emergency access to rural neighborhoods and homes by allowing the roads to be passable longer during flooding conditions.

The second recommendation is for Waller County to cooperate with HCFCD in developing solutions to decrease the Cypress Creek overflow into Addicks Reservoir. Because flooding does not stop at political boundaries it is recommended that Waller County cooperate in this effort to reduce the overflow from Cypress Creek. Another benefit of cooperation is that HCFCD has shown willingness to help fund some of the flood reduction projects in the City of Waller in return considering Cypress Creek overflow reduction alternatives that can be implemented within Waller County. Further details of these two recommendations can be found in Appendix B.

9.0 Alternatives Summary

Alternatives that reduce existing flood damages are summarized in Table 3. The summary includes cost estimates, value of structures removed from the 100-yr floodplain and ratio of structure value to cost. For the Business 290 and railroad culvert improvement alternatives, it is assumed that the upstream detention will be installed first as a separate project; therefore the cost of the detention was not included in the project cost for these alternatives. The proposed regional detention on West Fork Mound Creek was not included in the summary since it is needed to prevent flood damages to future development and the value of future development was not quantified. Any Cypress Creek overflow reduction alternative is likely to have an acceptable benefit to cost ratio due to the number of structures affected in Harris County. Calculation of this ratio for the Cypress Creek overflow reduction alternative was beyond the scope of this flood protection study as the benefits occur outside the project limits.

Table 3: Alternative summary with benefit ratios

Community	Project	Cost	Value of Homes Removed	Benefit Ratio
City of Waller	E. Fork Upstream Detention	$257,871	$525,560	2.04
City of Waller	E. Fork Bus. 290/RR Improv.	$613,365	$1,121,503	1.83
City of Prairie View	Upper Mound Home Buyout	$594,050	$594,050	1.00
City of Waller	M. Fork Bus. 290/RR Improv.	$936,332	$896,819	0.96
City of Waller	M. Fork Upstream Detention	$396,937	$211,800	0.53
City of Prairie View	Upper Mound Bus. 290 Improv.	$545,084	$115,250	0.21

APPENDIX A: Hydrologic and Hydraulic Analysis of the Upper Cypress Creek Watershed

A.1 Hydrologic Analysis

A hydrologic analysis was performed in the Upper Cypress Creek watershed utilizing the HEC-HMS software, version 3.5. The purpose of this hydrologic analysis was to develop peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency rainfall events. The hydrologic model required the selection of various parameters. These parameters are as follows:

1. Precipitation Parameters
2. Rainfall Runoff Loss Parameters
3. Unit Hydrograph Parameters
4. Flood Routing Parameters

Each of these sets of parameters is discussed in further detail below.

A.2 Precipitation

The Alternating Block method was used to develop frequency rainfall patterns for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year rainfall events. According to the HCFCD Hydrology and Hydraulics Guidance Manual, USGS rainfall depth-duration frequency relationships were determined for three hydrologic regions across Harris County. It was determined that the Upper Cypress Creek watershed could use the same USGS rainfall totals as Hydrologic Region 1 in the Harris County map below (Figure A1). These rainfall totals used in the HMS model also matched the data used in the previous detailed study.

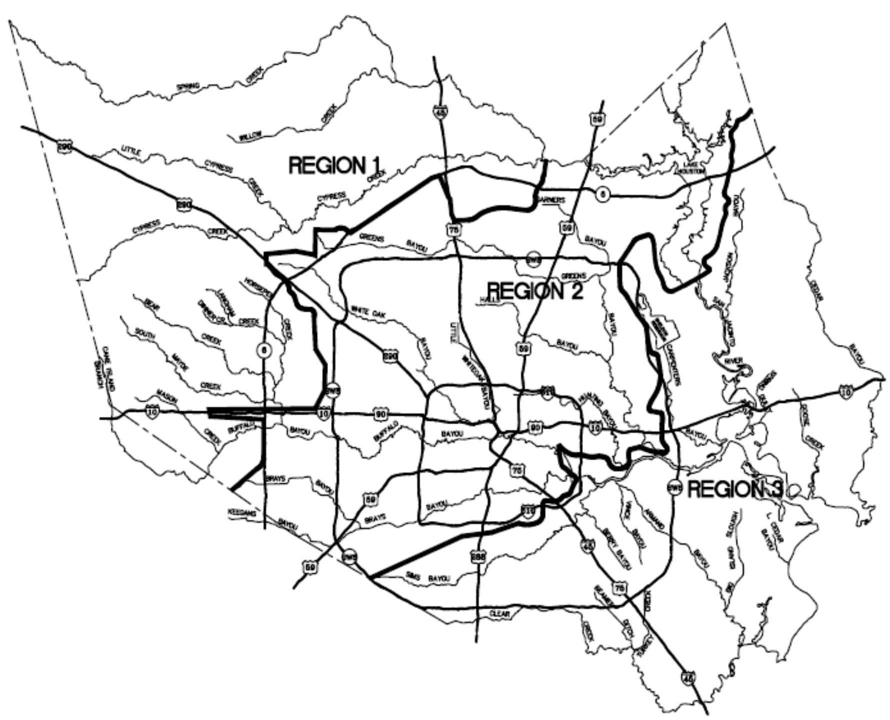

Figure A1: Harris County Hydrologic Region Map

The following table provides rainfall totals for various frequencies and durations for Hydrologic Region 1. All rainfall amounts have been rounded to the nearest 0.1 inch.

Table A1: Frequency Rainfall Depths for Hydrologic Region 1

Duration	Duration (hours)	Recurrence Interval (years)							
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	250-yr	500-yr
		Depth (inches)							
5 min	**0.08**	0.7	0.9	1.0	1.1	1.2	1.3	1.4	1.5
15 min	**0.25**	1.1	1.4	1.5	1.8	2.0	2.2	2.5	2.7
30 min	**0.50**	1.4	1.8	2.1	2.4	2.7	3.0	3.5	3.9
60 min	**1.00**	1.9	2.5	2.8	3.4	3.8	4.2	4.9	5.5
2 hr	**2.00**	2.2	3.0	3.5	4.2	4.9	5.5	6.6	7.5
3 hr	**3.00**	2.5	3.3	3.9	4.8	5.6	6.5	7.8	9.0
6 hr	**6.00**	2.9	4.0	4.9	6.1	7.2	8.5	10.4	12.2
12 hr	**12.00**	3.4	4.8	5.9	7.4	8.7	10.2	12.6	14.7
24 hr	**24.00**	4.1	5.8	7.1	9.0	10.6	12.4	15.2	17.7

A.3 Rainfall-Runoff Losses

All rainfall-runoff losses were computed using the Green and Ampt loss method according to the HCFCD Hydrology and Hydraulics Guidance Manual. The following values for the Green and Ampt method taken from the effective hydrology model as instructed in the Hydrology and Hydraulics Guidance Manual were used in the updated HEC-HMS model to provide a reasonable and adequate replacement for the previously used Exponential Loss function parameters.

Initial Loss =	0.048	inches
Volume Moisture Deficit =	0.46	
Wetting Front Suction =	4.33	inches
Hydraulic Conductivity =	0.079	in/hr

A.4 Unit Hydrograph Method

The Clark unit hydrograph method was used to develop the hydrographs and corresponding peak discharges for each sub-basin. The Clark Time of Concentration (Tc) and Storage Coefficient (R) for each sub-basin were calculated using formulas derived by the HCFCD in the early 1980s. Ponded areas required for determining percent ponding were calculated by delineating rice fields and farm ponds from aerial photos. The percent urbanization parameter was estimated based on % impervious cover as described in the HCFCD drainage criteria manual. Other parameters used in this method such as percent channel improvement and percent channel conveyance were calculated using channel data but were not always necessary due to 85% of the Cypress Creek sub-basins being rural in nature. Clark Unit Hydrograph parameters are shown in Table A2. A description of the parameters, as provided by the HCFCD, used to calculate Tc and R is as follows:

Drainage Area (A): the area within the watershed being analyzed, in square miles.

Watershed Length (L): the total length of the hydraulically longest watercourse in the watershed, from the outlet point to the upstream watershed boundary, in miles.

Length to Centroid (Lca): the distance along the longest watercourse from the outlet point to a point opposite the computed centroid of the drainage area, in miles.

Channel Slope (S): the weighted channel slope, measured along the longest watercourse and computed between station equal to 10 percent and 85 percent of L, in feet per mile.

Watershed Slope (So): the watershed slope, measured along an average overland watercourse, from the bank of the main watercourse to the watershed divide, and computed between stations equal to 10 percent and 85 percent of the total overland watercourse length, in feet per mile.

Percent Land Urbanization (DLU): the portion of the drainage area developed for residential, industrial, commercial, or institutional use, measured from aerial photos, in percent of total drainage area.

Percent Channel Improvement (DCI): the portion of the longest watercourse with an improved channel, measured from aerial photos or construction drawings, expressed as a percentage of the total definable channel length.

Percent Channel Conveyance (DCC): the ratio of discharge carried in the channel to the total discharge, measured at several representative cross-sections along the main watercourse from the outlet to the upstream end of the main channel at the watershed boundary or the terminus of the channel, expressed in percent.

Percent Ponding (DPP): Portion(s) of a drainage area where runoff is retarded from reaching a watercourse because of physical obstructions (i.e. levees, ponds, rice fields, swamps, etc.), measured in percent of total drainage area.

The equations HCFCD developed for calculating Tc and R which were utilized for this project are as follows.

$Tc = D*[1-(0.0062*(0.30*(DLU)+0.70*(DCI)))]*(Lca/\sqrt{S})^{1.06}$

$D = 2.46$ if $So<=20$ ft./mi.

$D = 3.79$ if $So>20$ ft./mi/ but $So<40$ ft./mi.

$D = 5.12$ if $So>40$ ft./mi.

$Tc+R = 7.25*(L/\sqrt{S})^{0.706}$ (if $DLU <= 18\%$)

$Tc+R = (4295[DLU]^{-0.678}*[DCC]^{-0.967})*(L/\sqrt{S})^{0.706}$ (if DLU > 18%)

Tc = Time of Concentration
DLU = % Land Urbanization
DCI = % Channel Improvement
Lca = Length to Centroid
S = Channel Slope
So = Watershed Slope
L = Watershed Length
DCC = % Channel Conveyance
R = Storage Coefficient

Table A2: Clark Unit Hydrograph Parameters for Upper Cypress Watershed Sub-Basins

SUB-BASIN	DRAINAGE AREA (mi^2)	WATERSHED LENGTH (mi)	LENGTH TO CENTROID (mi)	CHANNEL SLOPE (ft/mi)	OVERLAND SLOPE (ft/mi)	DEVELOPMENT %	CHANNEL IMPROVEMENT %	CONVEYANCE %	PONDING %	TC (HR)	TC+R	R (HR)
CYP_01	1.21	3.53	1.47	2.50	10.29	0	0	100	0	2.27	12.77	10.50
CYP_02	3.50	2.83	1.20	4.94	6.07	0	0	100	3	1.27	8.61	7.33
CYP_03	1.58	2.77	2.10	11.05	8.19	0	0	100	0	1.51	6.37	4.85
CYP_04	4.21	4.82	1.77	3.72	5.23	0	0	100	0	2.25	13.84	11.59
CYPT_01	2.84	3.20	0.89	6.19	8.39	0	0	100	0	0.83	8.65	7.83
EFMC_01	1.12	1.95	0.48	8.47	8.44	3	0	100	5	0.36	5.47	5.11
EFMC_02	0.66	1.27	0.89	9.58	35.96	22	0	100	4	0.97	3.23	2.26
EFMC_03	0.56	2.08	1.18	15.29	29.37	7	0	100	0	1.05	4.64	3.59
LMC_01	2.35	2.56	2.36	2.74	11.76	4	0	100	1	3.56	9.86	6.30
LMC_02	3.23	4.46	0.75	10.73	25.90	6	0	100	0	0.79	9.02	8.23
LOC_01	0.65	1.57	2.24	2.55	11.50	0	0	100	0	3.52	7.16	3.63
LOC_02	1.87	3.74	0.88	16.41	11.66	0	0	100	1	0.49	6.85	6.36
LOC_03	1.29	2.05	1.12	4.82	37.17	0	0	100	0	1.86	6.90	5.04
LOC_04	3.74	3.08	1.07	6.47	10.87	0	0	100	0	0.98	8.29	7.31
LOC_05	1.67	2.77	1.61	2.60	10.25	0	0	100	0	2.45	10.62	8.17
LOCT_01	0.34	1.13	0.51	17.12	17.90	0	0	100	6	0.27	2.90	2.63
LOCT_02	3.41	4.09	1.60	10.35	5.86	0	0	100	0	1.17	8.59	7.42
LOCT4_01	4.48	3.69	2.04	8.81	4.69	0	0	100	1	1.65	8.45	6.80
MC_01	1.56	1.83	0.63	24.08	14.47	3	0	100	4	0.28	3.61	3.33
MC_02	0.99	1.19	0.40	9.19	35.87	8	0	100	1	0.43	3.75	3.32
MC_03	1.85	3.05	1.43	8.76	31.02	7	0	100	1	1.74	7.41	5.67
MC_04	0.48	1.45	0.68	9.96	30.53	1	0	100	1	0.75	4.18	3.43
MC_05	1.04	1.85	0.98	10.71	26.99	1	0	100	3	1.06	4.85	3.79
MC_06	0.96	1.66	0.63	1.51	34.23	9	0	100	1	1.82	8.95	7.13
MC_07	0.77	1.48	0.95	3.90	41.76	4	0	100	2	2.35	5.91	3.56
MC_08	3.34	3.30	1.85	3.92	40.91	1	0	100	1	4.75	10.39	5.64
MC_09	2.99	3.69	1.49	3.89	27.52	0	0	100	1	2.82	11.29	8.47
MC_10	1.01	2.95	1.52	2.71	71.80	0	0	100	3	4.71	10.93	6.22
MCT_01	0.89	1.39	0.67	30.54	35.75	4	0	100	1	0.40	2.74	2.34
MCT_02	1.18	2.38	0.83	14.90	32.90	2	0	100	0	0.74	5.15	4.41
MFMC_01	0.57	1.31	0.63	11.99	14.14	0	0	100	0	0.41	3.64	3.24
MFMC_02	0.70	1.90	0.61	18.41	6.43	5	0	100	5	0.31	4.08	3.77
MFMC_03	0.96	1.19	0.79	7.28	31.57	35	0	100	1	0.96	2.51	1.56
MFMC_04	0.72	1.54	0.48	15.53	38.90	15	0	100	0	0.39	3.73	3.34
SC_01	3.47	3.42	1.86	10.93	8.05	2	0	100	1	1.33	7.42	6.09
SC_02	3.84	4.22	2.17	12.13	13.54	1	0	100	1	1.49	8.30	6.81
SC_03	3.81	4.13	2.61	16.70	10.98	0	0	100	4	1.53	7.30	5.77
SCT2_01	0.96	2.10	0.77	25.16	13.47	2	0	100	0	0.34	3.92	3.58
SFMC_01	0.94	2.06	0.92	22.05	10.76	6	0	100	1	0.43	4.05	3.62
UNT_01	0.59	1.51	0.60	0.78	9.83	0	0	100	4	1.63	10.55	8.92

SUB-BASIN	DRAINAGE AREA (mi^2)	WATERSHED LENGTH (mi)	LENGTH TO CENTROID (mi)	CHANNEL SLOPE (ft/mi)	OVERLAND SLOPE (ft/mi)	DEVELOPMENT %	CHANNEL IMPROVEMENT %	CONVEYANCE %	PONDING %	TC (HR)	TC+R	R (HR)
UNT_02	0.78	1.77	0.98	24.41	30.80	0	0	100	0	0.68	3.51	2.83
WFMC_01	1.39	2.57	1.52	7.23	16.97	2	0	100	2	1.34	7.02	5.69
WFMC_02	1.88	3.32	1.73	14.28	17.43	4	0	100	1	1.07	6.62	5.55
WFMC_03	0.68	1.41	0.68	9.80	28.22	5	0	100	0	0.75	4.14	3.39
WFMC_04	0.64	1.74	0.69	9.07	50.85	6	0	100	3	1.07	4.93	3.86
WFMCT_01	0.38	1.13	0.58	4.40	15.25	0	0	100	1	0.63	4.67	4.04
WFMCT_02	1.00	1.72	0.93	19.83	28.17	3	0	100	0	0.72	3.71	3.00

A.5 Flood Routing

Flood routing through channel reaches in the hydraulic model was calculated using the Modified Puls routing method. This method was used because of its ability to account for the attenuation of the flood hydrograph associated with the effects of bridge/culvert backwater effects and overbank storage. Storage-outflow data for the Modified Puls routing method was extracted from the existing conditions hydraulic models for the Upper Cypress Creek watershed.

A.6 Peak Discharges

Peak discharges were computed at the downstream end of each sub-basin. Table A3 displays peak discharge results from the HEC-HMS model with Modified Puls routing.

Table A3: Computed Peak Discharges along El Campo Tributary

Stream	HEC-HMS Node	HEC-RAS X-Section	Q 2 (cfs)	Q 5 (cfs)	Q 10 (cfs)	Q 25 (cfs)	Q 50 (cfs)	Q 100 (cfs)	Q 250 (cfs)	Q 500 (cfs)	Oct 1994 (cfs)
Cypress	J-SC_03_MC_10	32390	2630	6360	8850	13150	16900	21260	27950	34240	N/A
	J-CYP_01	23784	2580	6300	8780	13160	16850	21290	28070	34480	N/A
	J-LOC_05_CYP_01	19694	3130	8170	11380	17090	21870	27650	36700	45380	N/A
	J-CYP_02	14317	3150	8190	11460	17320	22270	28220	37580	46520	N/A
	J-CYPT_01	13016	3180	8310	11650	17640	22710	28820	38440	47630	N/A
	Junction-Outfall	5828	3100	7830	11310	17440	22690	28900	38990	48240	N/A
Live Oak	J-LOC_01	43071	110	200	260	340	410	490	610	720	N/A
	J-LOC_02	33690	250	470	630	870	1080	1330	1710	2040	N/A
	J-LOC_02_LOCT1_02_UNT_02	26897	820	1510	1890	2530	3110	3800	4870	5970	N/A
	J-LOC_03	20875	820	1650	2160	2970	3700	4520	5780	7000	N/A
	J-LOC_04	12410	470	1710	2370	3440	4400	5540	7320	9020	N/A
	J-LOCT4_01	10211	940	2130	2980	4400	5690	7210	9590	11860	N/A
	J-LOC_05	5311	870	2110	3120	4660	6070	7730	10290	12740	N/A
Live Oak Trib1	J-LOCT_01	12487	100	170	200	260	310	360	440	510	N/A
	0.39*(J-LOCT_02)	7088	100	190	240	320	390	480	600	720	N/A
	0.65*(J-LOCT_02)	5266	260	480	610	830	1020	1240	1570	1870	N/A
	J-LOCT_02	4131	400	740	940	1270	1560	1910	2420	2880	N/A
Live Oak UNT	J-UNT_01	7859	60	100	130	170	210	250	320	380	N/A
	J-UNT_02	3358	210	360	440	570	680	790	970	1130	N/A
Snake	SC_01	44514	460	840	1040	1370	1660	1970	2470	2910	N/A
	J-SC_01_SCT2_01	39945	640	1170	1450	1910	2300	2730	3410	4010	N/A
	J-SC_02	26338	770	1520	2000	2880	3600	4430	5660	6740	N/A
Trib 7.62	J-MCT_01	6270	280	490	580	750	880	1020	1230	1420	630
	J-MCT_02	3187	400	770	950	1250	1510	1780	2200	2580	1140
Little Mound	J-LMC_01	17955	270	510	650	870	1050	1270	1590	1890	N/A
	J-LMC_02	7015	480	940	1220	1680	2060	2500	3180	3820	N/A

Stream	HEC-HMS Node	HEC-RAS X-Section	Q 2 (cfs)	Q 5 (cfs)	Q 10 (cfs)	Q 25 (cfs)	Q 50 (cfs)	Q 100 (cfs)	Q 250 (cfs)	Q 500 (cfs)	Oct 1994 (cfs)
East Fork	J-EFMC_01	14975	180	320	390	520	620	730	910	1060	720
	J-EFMC_02	10831	340	610	730	930	1110	1280	1550	1810	1200
	J-EFMC_03	3680	340	670	870	1160	1410	1680	2060	2420	1590
Middle Fork	J-MFMC_01	13641	140	240	290	380	450	520	640	740	390
	J-MFMC_02	12897	270	490	600	770	920	1080	1330	1550	840
	J-MFMC_03	8759	590	940	1120	1400	1640	1870	2250	2580	1480
	J-MFMC_04	2831	630	1080	1320	1710	2030	2370	2890	3350	1910
West Fork	J-WFMC_01	24912	200	350	440	580	700	830	1030	1220	610
	J-WFMC_02	17097	370	720	920	1250	1530	1840	2320	2780	1400
	J-WFMCT_02_WFMC_02	11474	550	1110	1430	1930	2360	2850	3570	4250	2090
	J-WFMC_03	6853	590	1180	1500	2060	2590	3220	4100	4890	2370
	J-WFMC_04	2262	640	1280	1650	2270	2820	3510	4530	5450	2640
West Fork Trib	J-WFMCT_01	7139	70	130	160	210	250	290	360	430	200
	J-WFMCT_02	3292	260	460	590	810	980	1180	1490	1740	780
South Fork	0.20*(SFMC_01)	8230	40	70	80	110	130	150	180	220	90
	0.45*(SFMC_01)	6329	90	160	200	260	300	350	440	510	210
	0.80*(SFMC_01)	4887	170	300	360	470	550	650	810	930	390
	SFMC_01	3014	210	360	430	570	670	790	970	1130	470
Mound Creek	J-MC_01	78583	150	360	480	630	740	860	1040	1180	670
	J-MC_02	75178	240	480	640	860	1020	1200	1450	1800	1030
	J-MC_03	66208	440	840	1110	1510	1850	2230	2800	3290	1740
	J-SFMC_01	62084	570	1090	1420	1940	2380	2880	3640	4300	2160
	J-MC_04	60142	600	1160	1540	2120	2600	3170	4020	4770	2350
	J-MC_04_WFMC_04	57759	1220	2420	3150	4330	5340	6590	8460	10130	4990
	J-MC_05	55226	1250	2530	3330	4670	5700	7030	9030	10940	5470
	J-MC_05_MFMC_03	52741	1580	3190	4230	5960	7210	8840	11330	13760	7220
	J-MC_06	48841	1580	3290	4390	6180	7540	9220	11840	14350	7720
	J-MC_06_EFMC_03	46228	1790	3780	5040	7070	8730	10560	13570	16480	9260
	J-MC_07	44881	1830	3870	5200	7300	9060	10950	14100	17110	9770
	J-MC_07_MCT_02	42724	1940	4160	5620	7910	9910	11960	15450	18750	10860
	J-MC_08	32839	2000	4380	6030	8750	10950	13400	17290	21010	N/A
	J-MC_08_LMC_02	27080	2300	5070	7030	10230	12840	15740	20330	24690	N/A
	J-MC_09	19120	2330	5160	7300	10680	13500	16630	21540	26170	N/A
	J-SC_03_MC_10	15972	2630	6360	8850	13150	16900	21260	27950	34240	N/A

A.7 Hydraulic Analysis

A hydraulic analysis was performed for the Upper Cypress Watershed utilizing the HEC-RAS software, version 4.1. The purpose of this hydraulic analysis was to develop flood profiles for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency rainfall events. Cypress Creek, Mound Creek, Little Mound Creek, Mound Creek Tributary 7.62, and East, Middle, Lower West, and South Forks of Mound Creek currently have detailed Zone AE floodplains and Live Oak and Tributaries, Snake Creek, Upper West Fork Mound Creek, and West Fork Mound Creek Tributary are currently approximate Zone A floodplains on the current effective Waller/Harris County Flood Insurance Rate Maps (FIRM). The new hydraulic analyses conducted along Cypress Creek, Little Mound Creek, Mound Creek Tributary 7.62, East Fork Mound Creek, and Mound creek to the confluence with East Fork Mound Creek are detailed hydraulic analyses totaling 22.2 stream miles. The new hydraulic analyses for Live Oak and its tributaries, Snake Creek, Middle Fork, West Fork, West Fork Tributary, South Fork and Mound Creek from the confluence with East Fork to the US 290 are limited detail hydraulic analyses totaling 36.8 stream miles. Note that new survey must be added to the models for South Fork, Lower West Fork, Middle Fork and Mound Creek from the East Fork confluence to US 290 if they are to be submitted as a LOMR to FEMA as they are currently detailed Zone AE streams as noted above. The new detailed study utilizes detailed channel and bridge survey data taken from the current HCFCD hydraulic models. The locations of the detailed bridge surveys used in this study are listed in Table A4 below. The river station is measured in feet from the outfall of the Upper Cypress watershed study area.

Table A4. Structure survey locations

Stream	Road	Station
Cypress Creek	Pipeline	1899
	Pipeline	8100
	Private Road	8157
	Hebert Road	24151
East Fork	Charter Street	742
	Private Road	1956
	Private Road	2002
	Private Road	2199
	Private Road	2331
	Private Road	2406
	Ross Road	5922
	Washington Road	9226
	RR Crossing	9301
	Business 290	9475
	Private Walkway	9639
	Mills Road	9742
	Main Street	10033
	Taylor Street	10620

Stream	Road	Station
	Field Store Road	11406
	Ironwood Road	12605
	US Hwy 290	14376
Little Mound	Betka Road	10418
Mound Creek	Mathis Road	30766
	Private Road	31713
	Penick Street	46267

Non-surveyed cross-sections were cut from LiDAR elevation data. All detailed survey (2001 HCFCD) and LiDAR data (2008 HGAC 67 cm horizontal RMSE, 9.25 cm vertical RMSE) were collected using the NAD 83 horizontal datum, and the NAVD 88 vertical datum. Structures located on streams modeled with limited detail methods were estimated using LiDAR elevation data, aerial photos, and field visits.

The computed peak discharges from the hydrologic model were input into the hydraulic model to develop flood profiles for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency events. All Manning's n-values were selected from a combination of aerial photos, site visits, and the table found in section 4.3.5 of the HCFCD Policy, Criteria, and Procedure Manual. The downstream boundary condition for Cypress Creek and all tributary models was set to normal depth. Water surface elevations for the various frequencies at the upstream end of Cypress Creek were entered as a known water surface downstream boundary condition in the Mound Creek hydraulic model since Mound Creek is a continuation of Cypress Creek.

A.8 Flood Profiles

Flood profiles for existing conditions were computed along the study streams for the various frequency events previously mentioned. The results for each stream can be seen in Figures A2-A15.

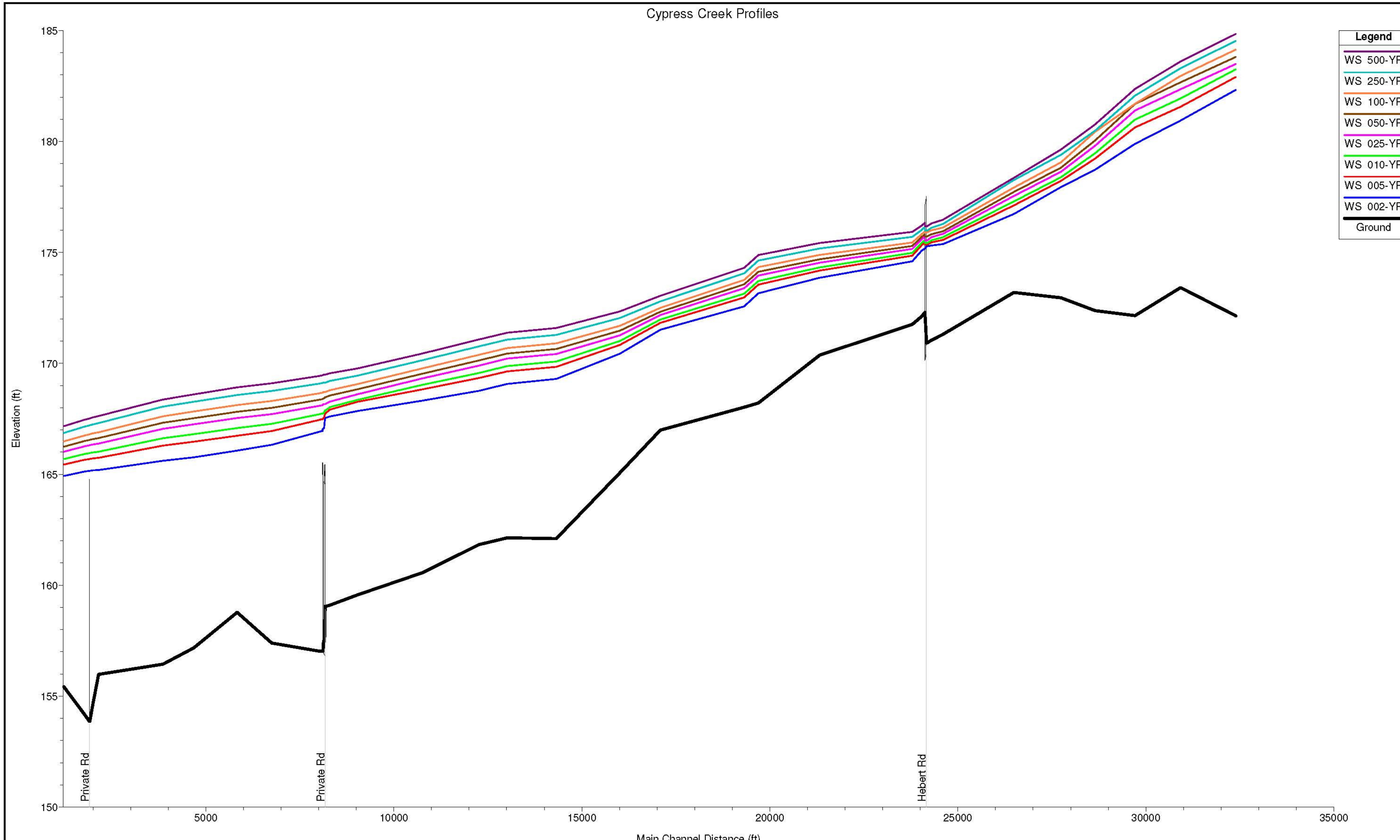

Figure A2: Cypress Creek Frequency Profiles

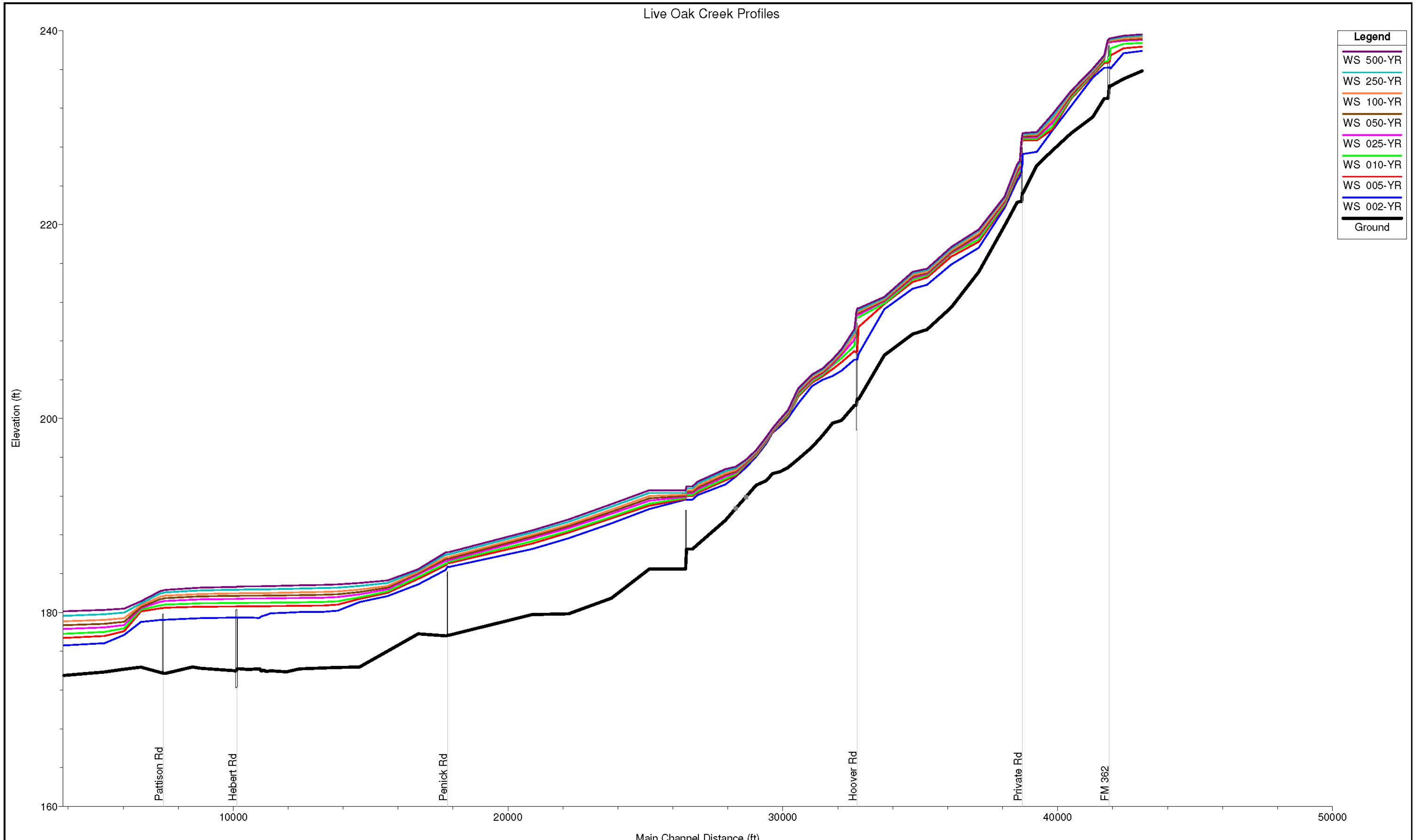

Figure A3: Live Oak Creek Frequency Profiles

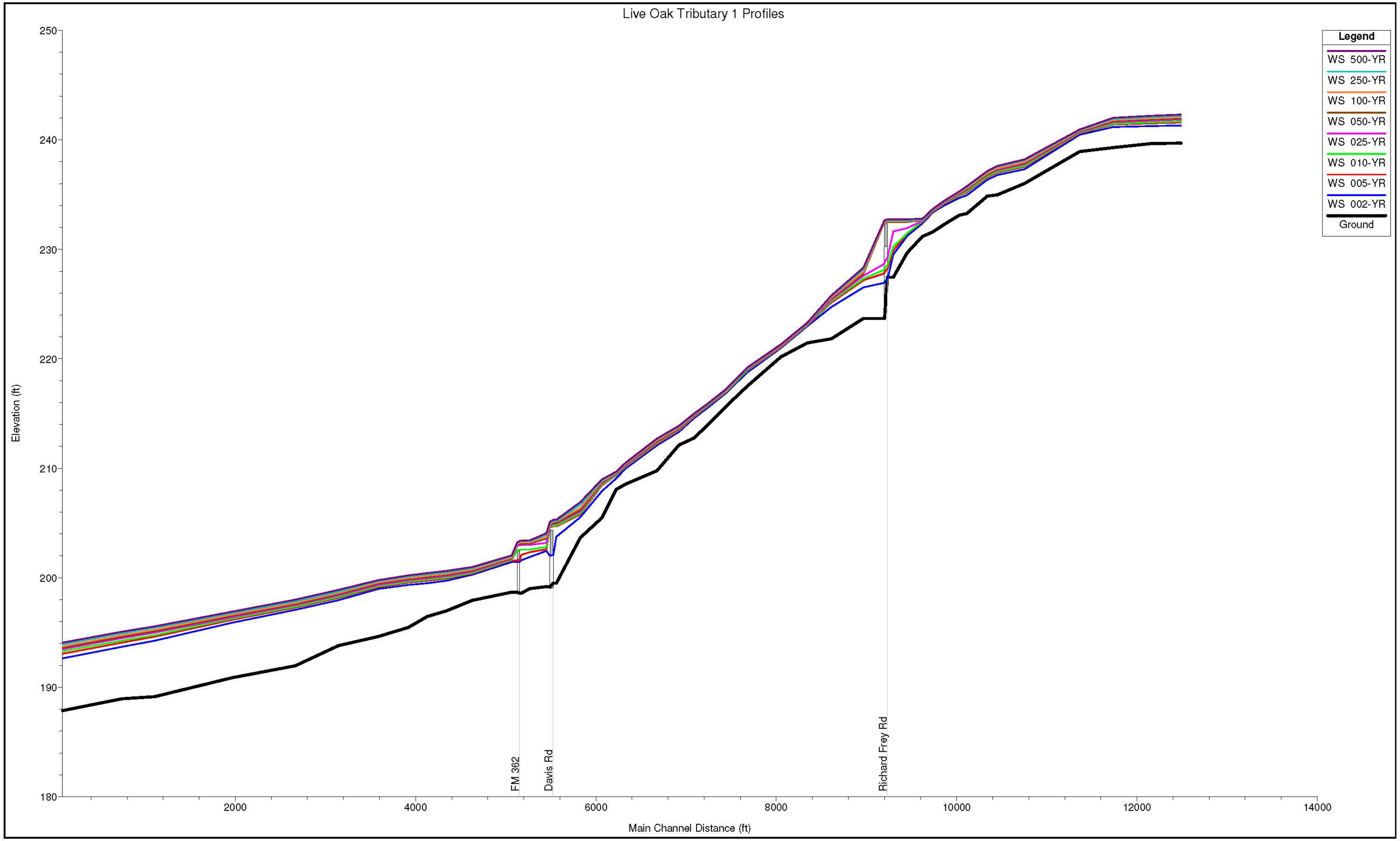

Figure A4: Live Oak Creek Tributary 1 Frequency Profiles

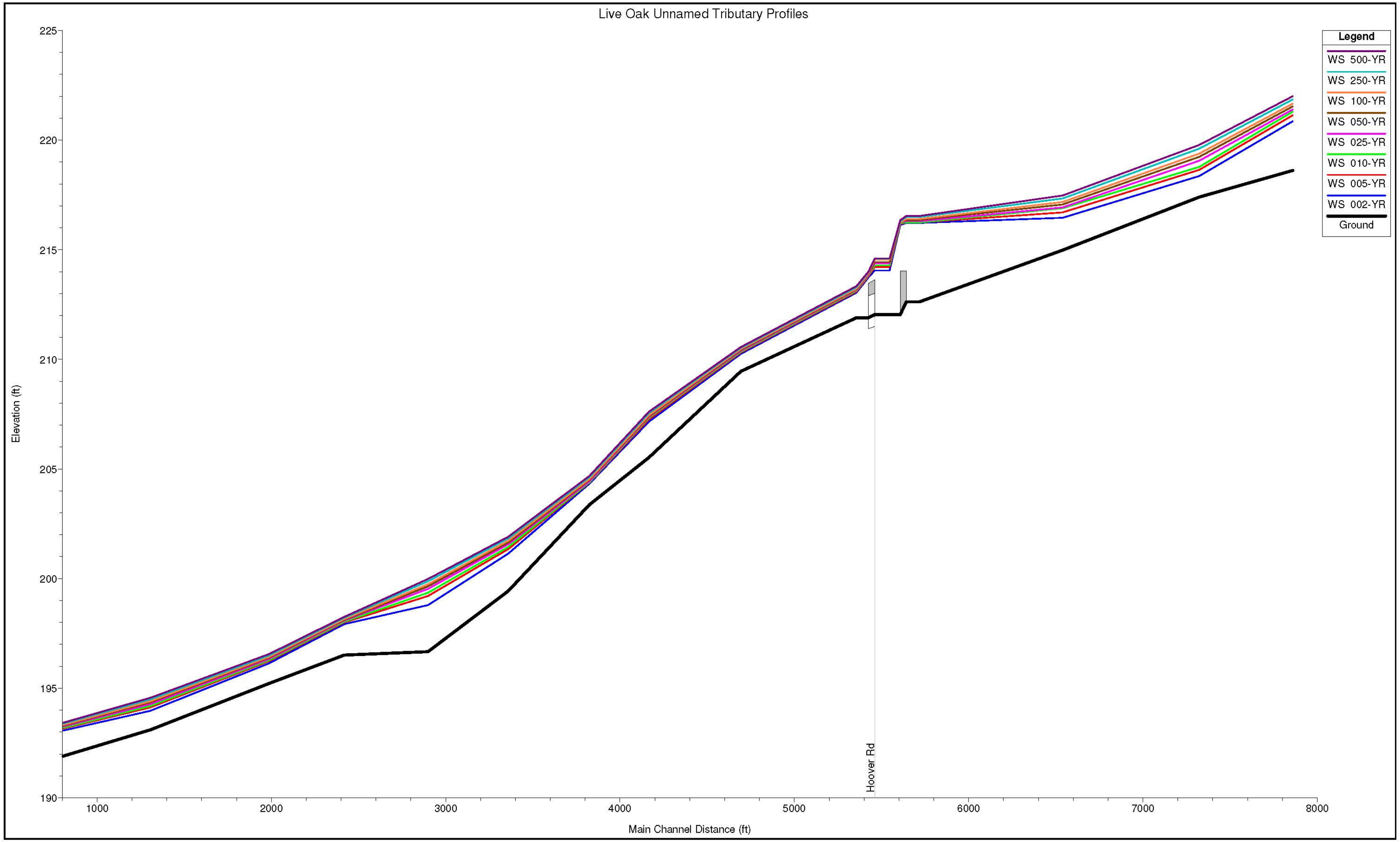

Figure A5: Live Oak Creek Uunamed Tributary Frequency Profiles

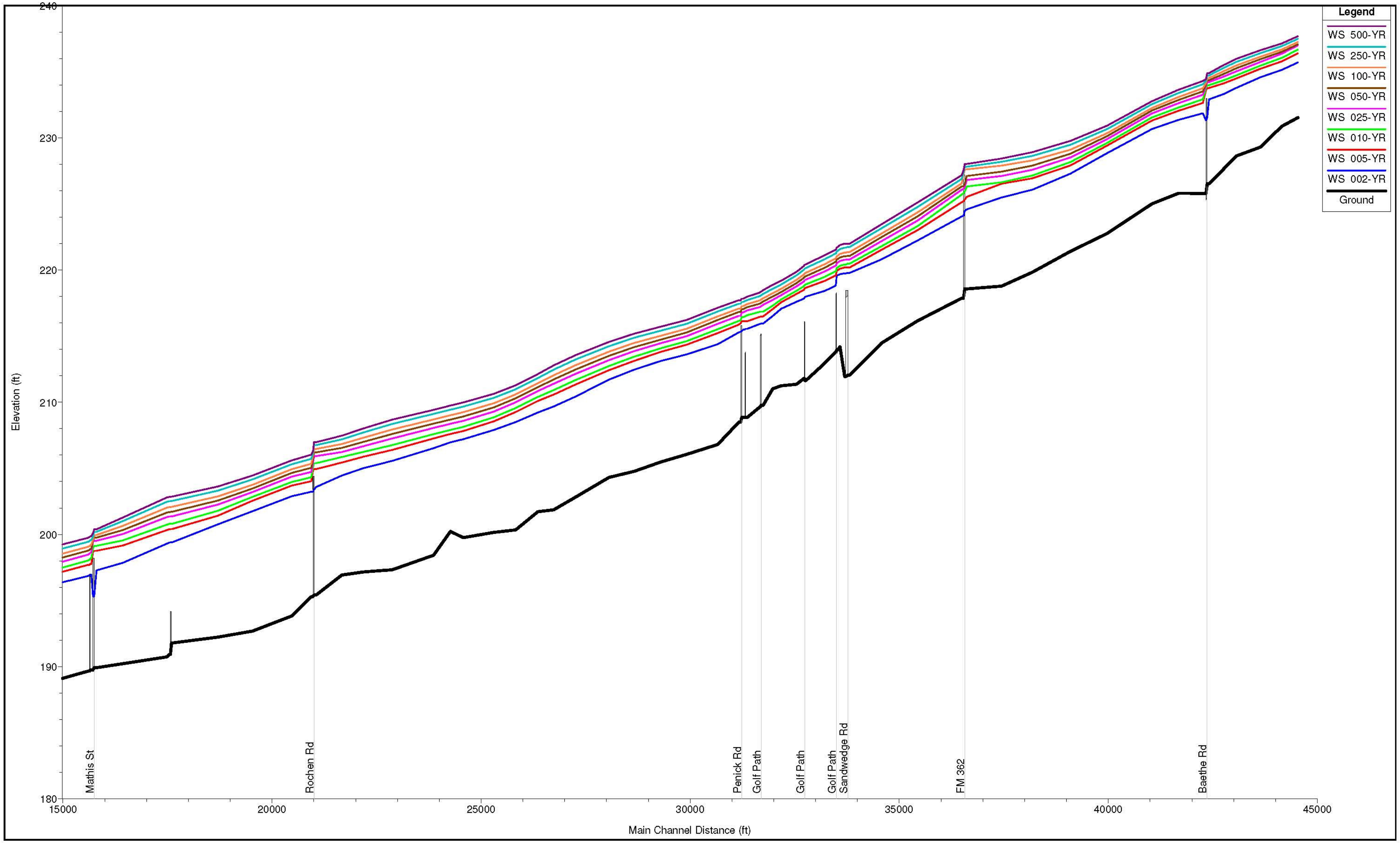

Figure A6: Snake Creek Frequency Profiles

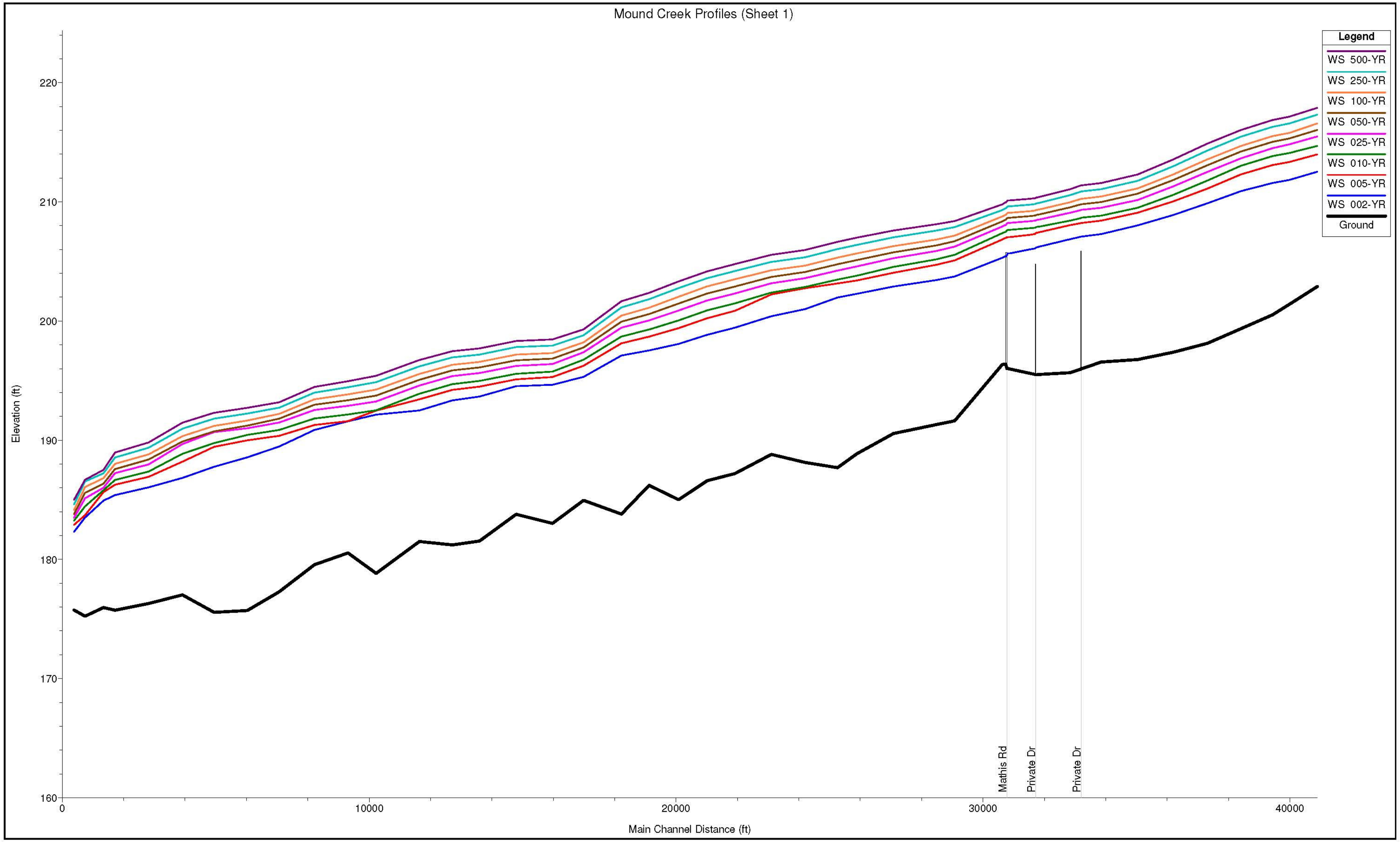

Figure A7: Mound Creek Frequency Profiles (Sheet 1)

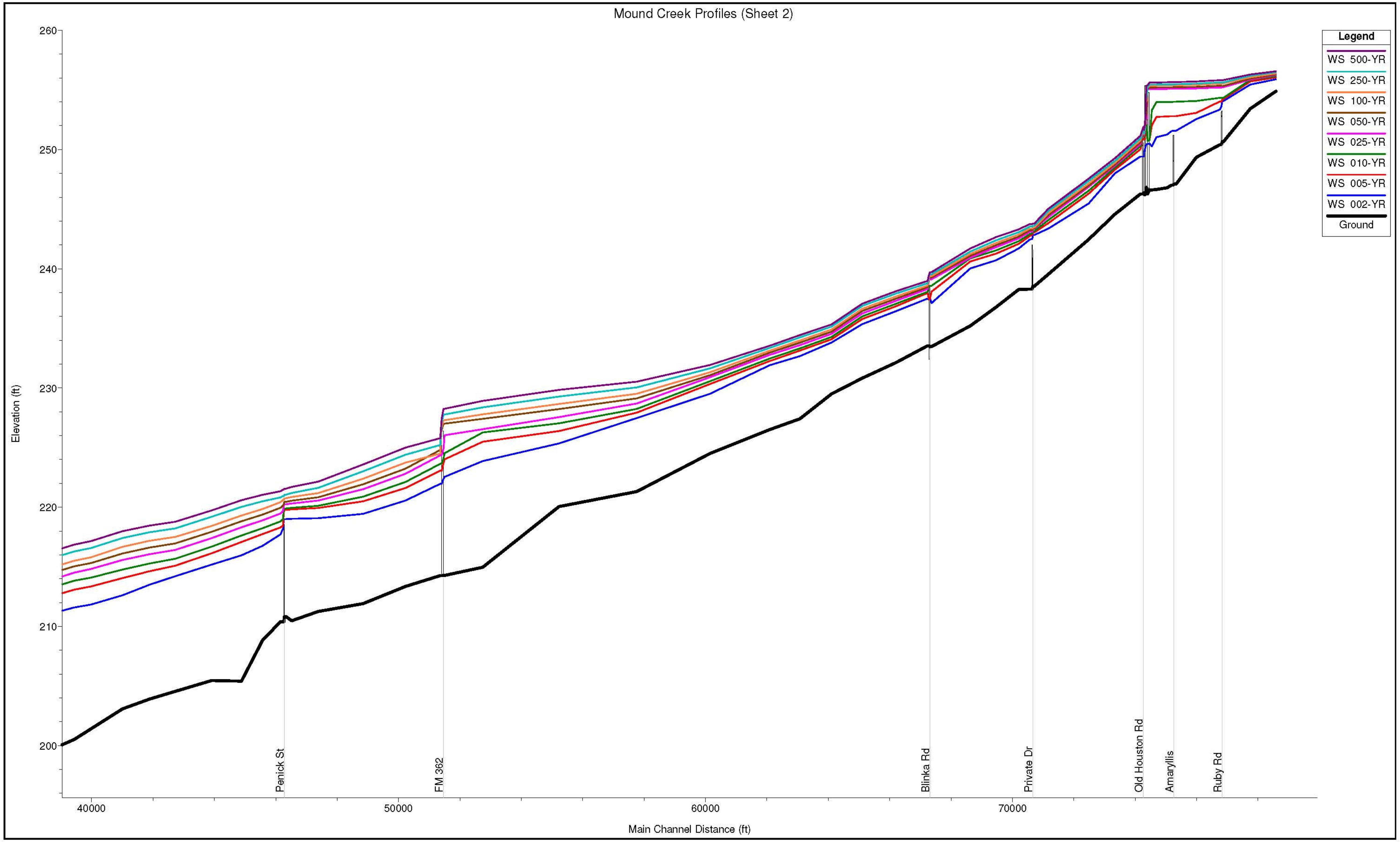

Figure A8: Mound Creek Frequency Profiles (Sheet 2)

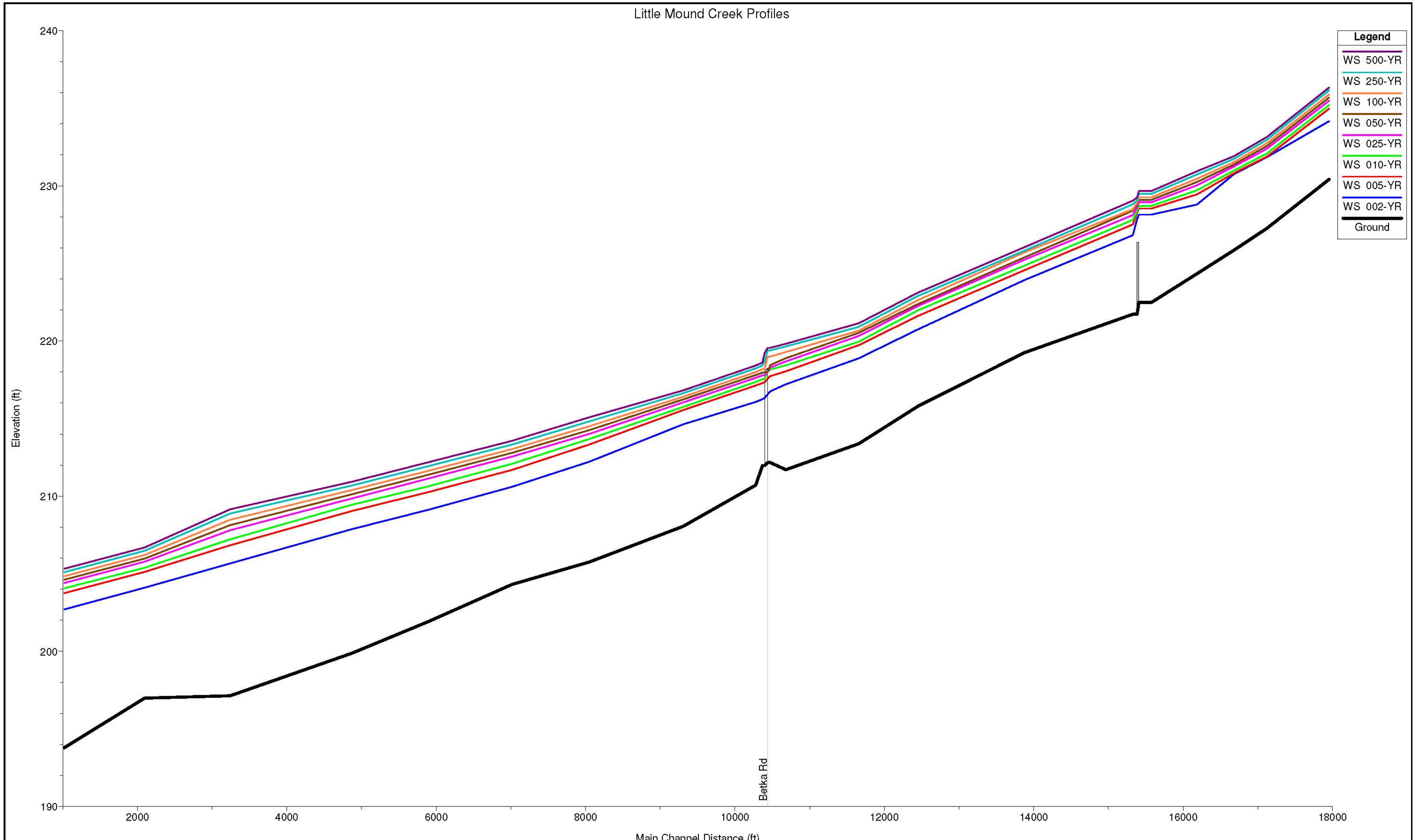

Figure A9: Little Mound Creek Frequency Profiles

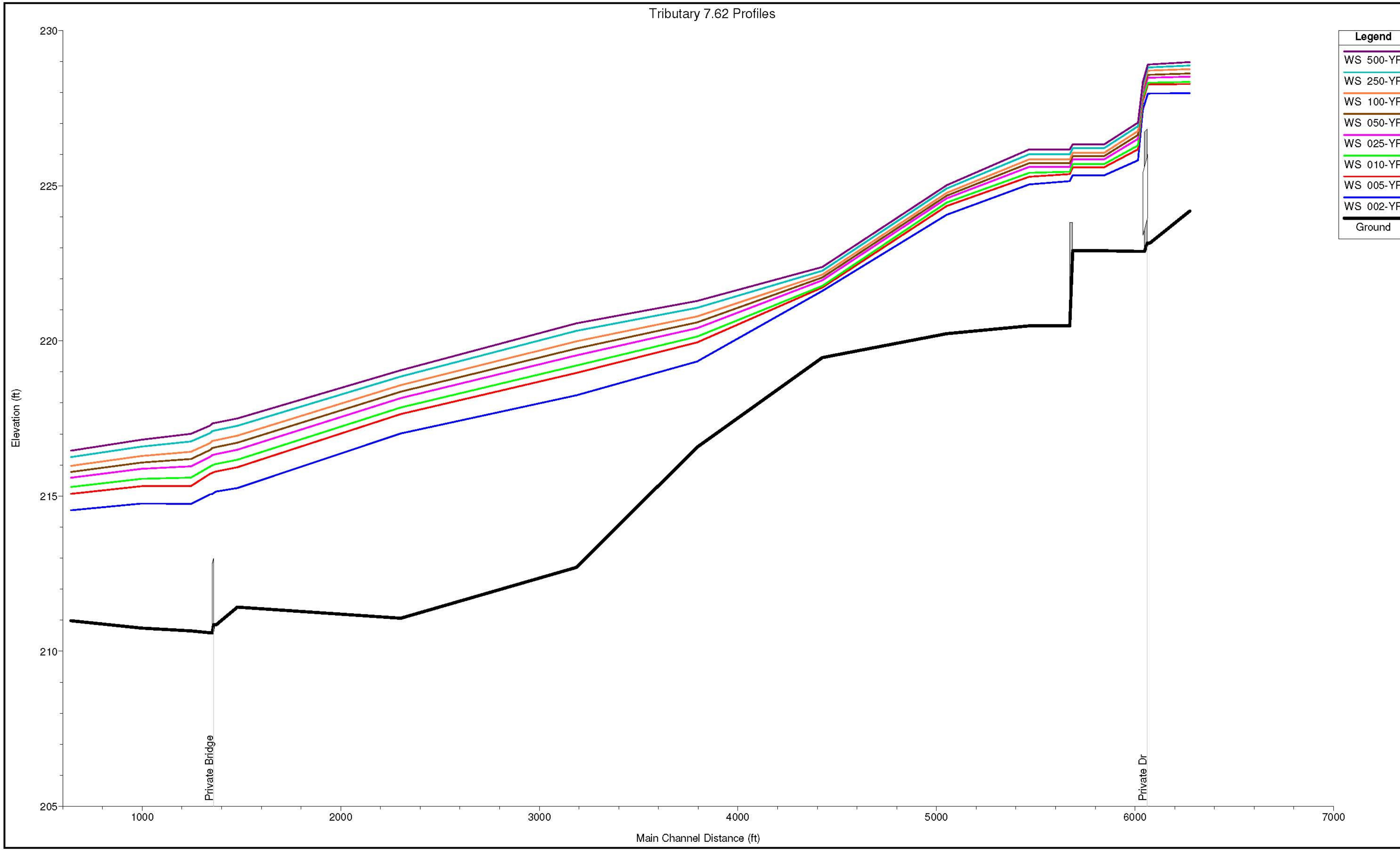

Figure A10: Mound Creek Tributary 7.62 Frequency Profiles

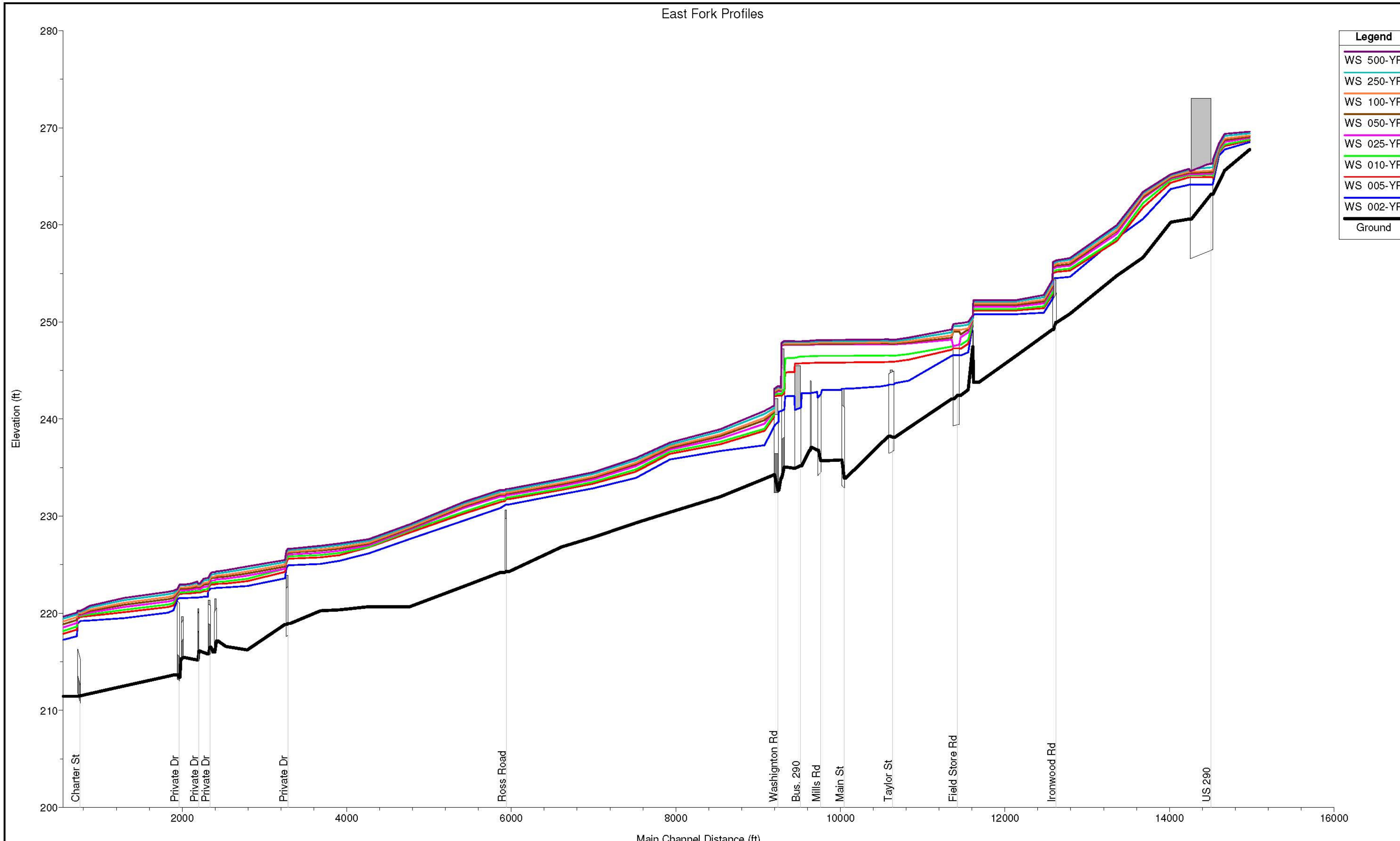

Figure A11: East Fork Mound Creek Frequency Profiles

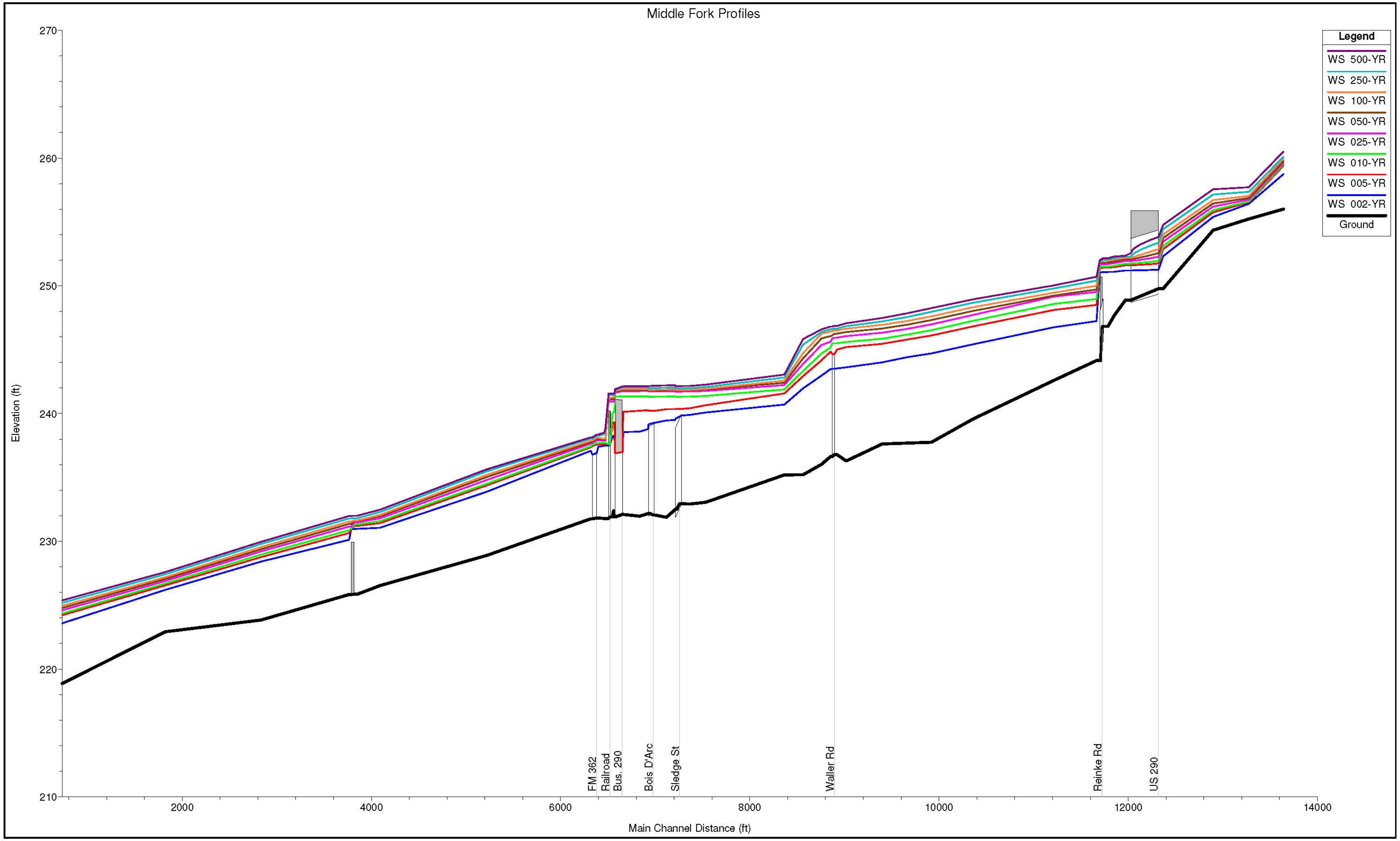

Figure A12: Middle Fork Mound Creek Frequency Profile

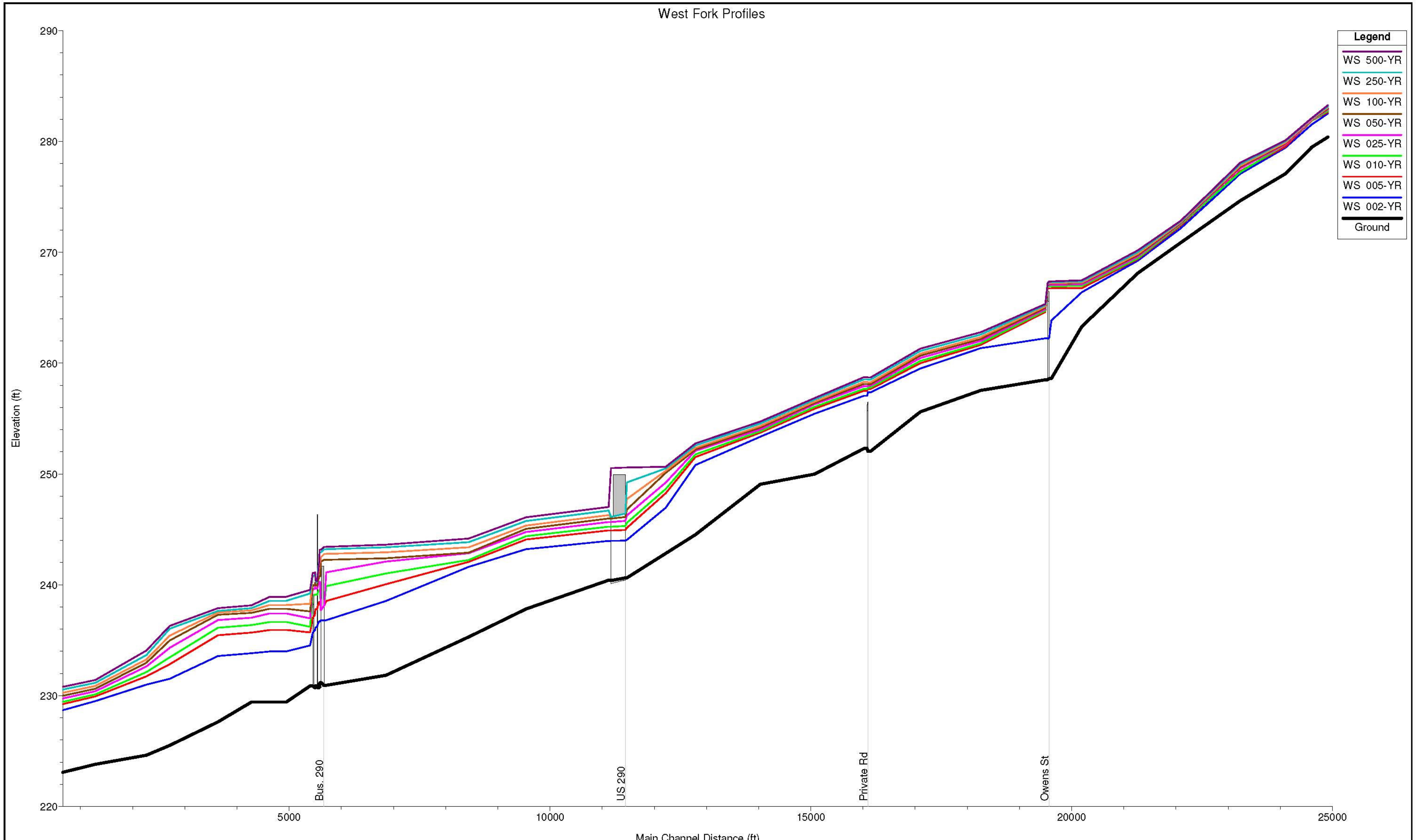

Figure A13: West Fork Mound Creek Frequency Profile

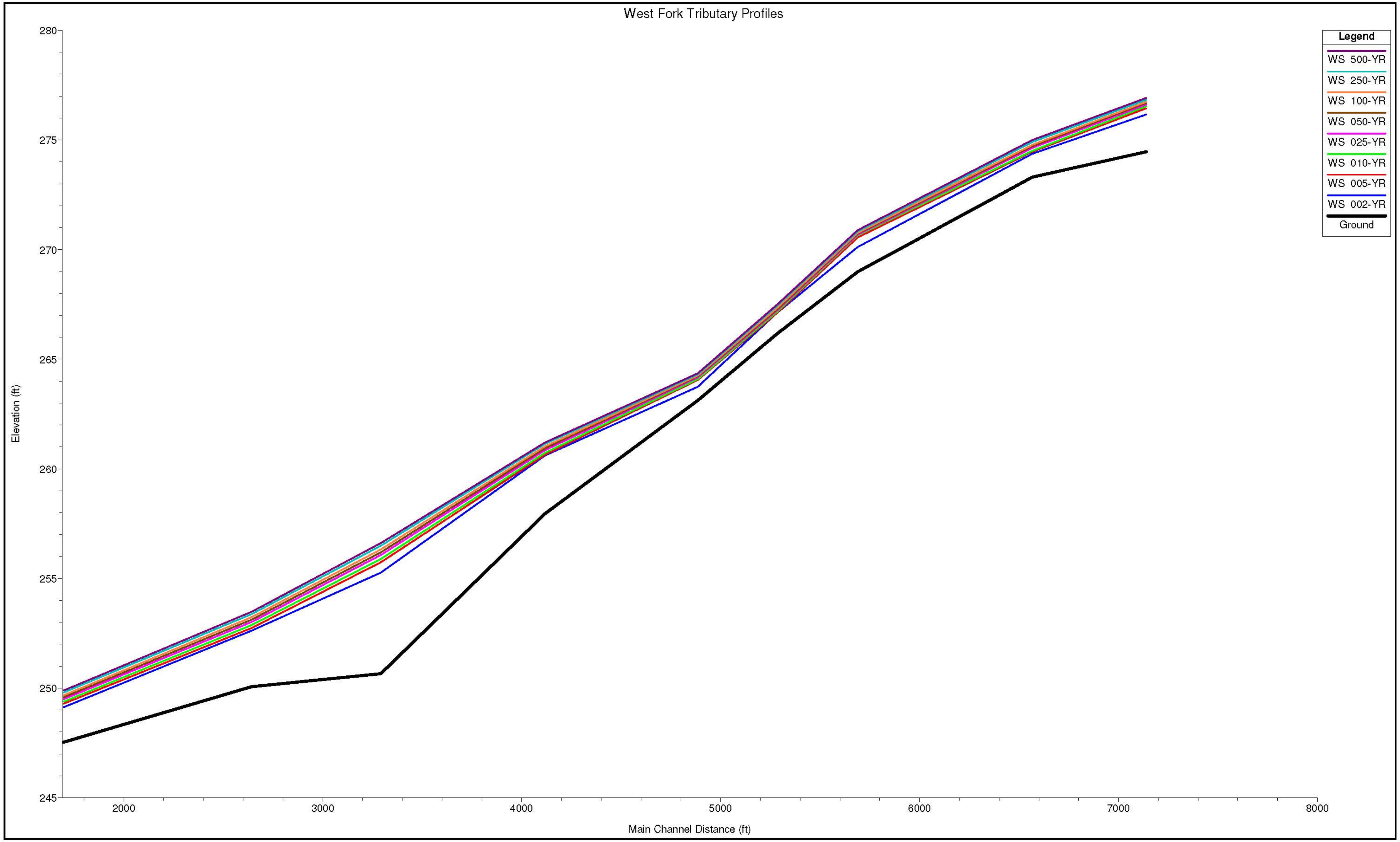

Figure A14: West Fork Mound Creek Tributary Frequency Profile

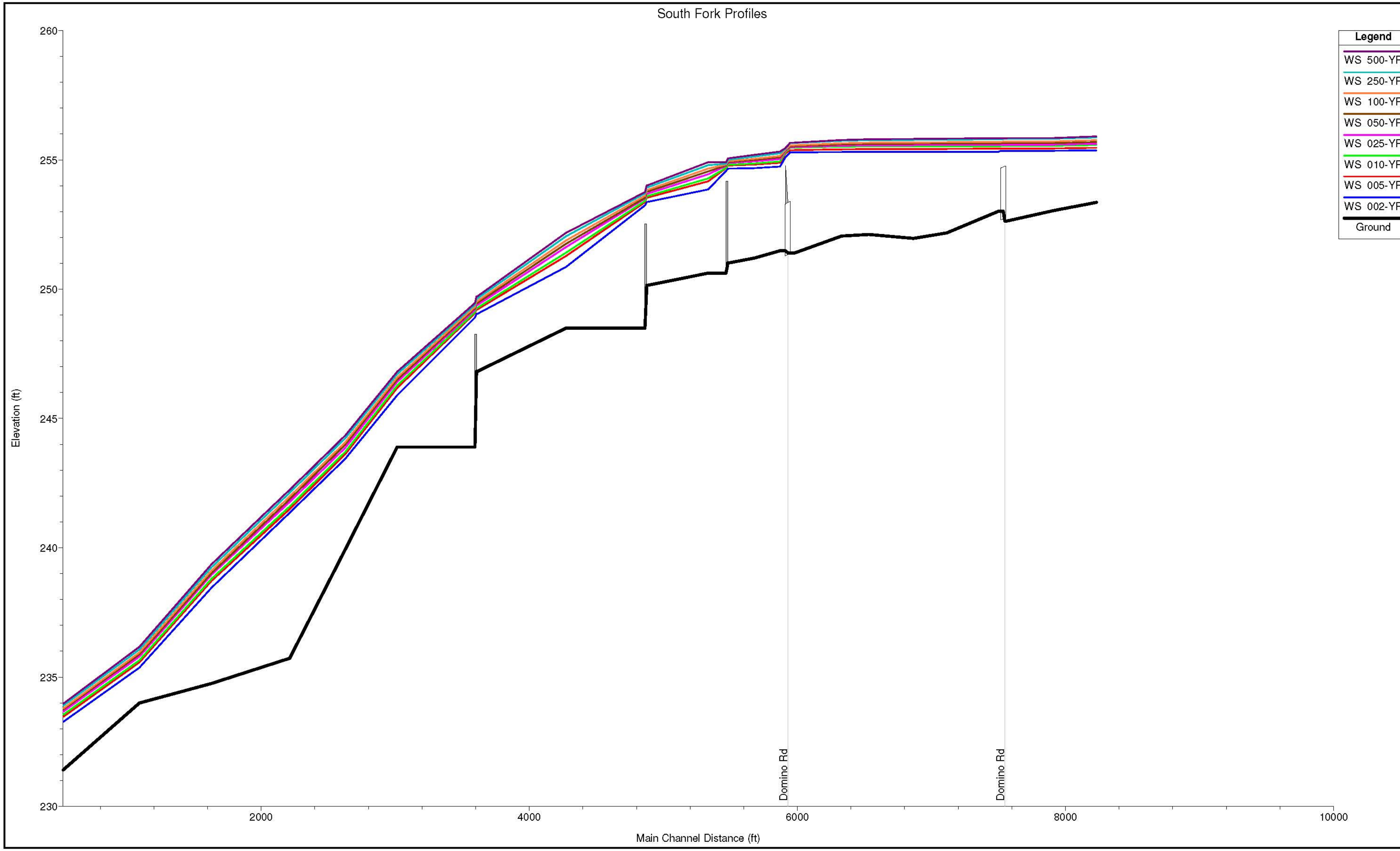

Figure A15: South Fork Mound Creek Frequency Profile

A comparison was made between the results from this study and the current effective base flood elevations and discharges listed in the Waller County current effective FEMA Flood Insurance Study. The 100-yr flood elevation comparisons are shown in Figures A16 through A22 and discharge comparisons are displayed in Table A5.

Differences in the water surface profiles and discharges can be attributed to many factors. Following is a list of reasons the results could be different:

1. Spills and diversions were accounted for in the new model.
2. Hydrologic and Hydraulic parameters were calculated with different methodology.
3. Differences in the amount and accuracy of field survey available.
4. The use of detailed LiDAR topographic data.
5. Physical watershed changes may have occurred.

Table A5: Waller County Current Effective FIS Discharges vs. New Model Discharge

Stream	Station	FIS 10-yr	New Model 10-yr	FIS 50-yr	New Model 50-yr	FIS 100-yr	New Model 100-yr	FIS 500-yr	New Model 500-yr
Cypress	19694	11075	11380	20391	21870	25485	27650	40336	45380
Trib 7.62 to Mound	3187	1406	950	2116	1510	2443	1780	3429	2580
East Fork Mound	3680	1657	870	2593	1410	3052	1680	4438	2420
	3680	1320	870	2040	1410	2400	1680	3490	2420
	10831	990	730	1620	1110	1850	1280	2750	1810
	14975	810	390	1380	620	1610	730	2250	1060
Middle Fork Mound	2831	1040	1320	1890	2030	2330	2370	3550	3350
West Fork Mound	2262	2165	1650	3618	2820	4304	3510	6200	5450
South Fork Mound	3014	691	430	1093	670	1276	790	1760	1130
Mound	15972	6932	8850	12853	16900	16179	21260	25158	34240
	27080	6510	7030	11710	12840	14670	15740	22780	24690
	42724	5560	5620	9310	9910	11270	11960	17020	18750
	78583	1300	480	1980	740	2330	860	3150	1180

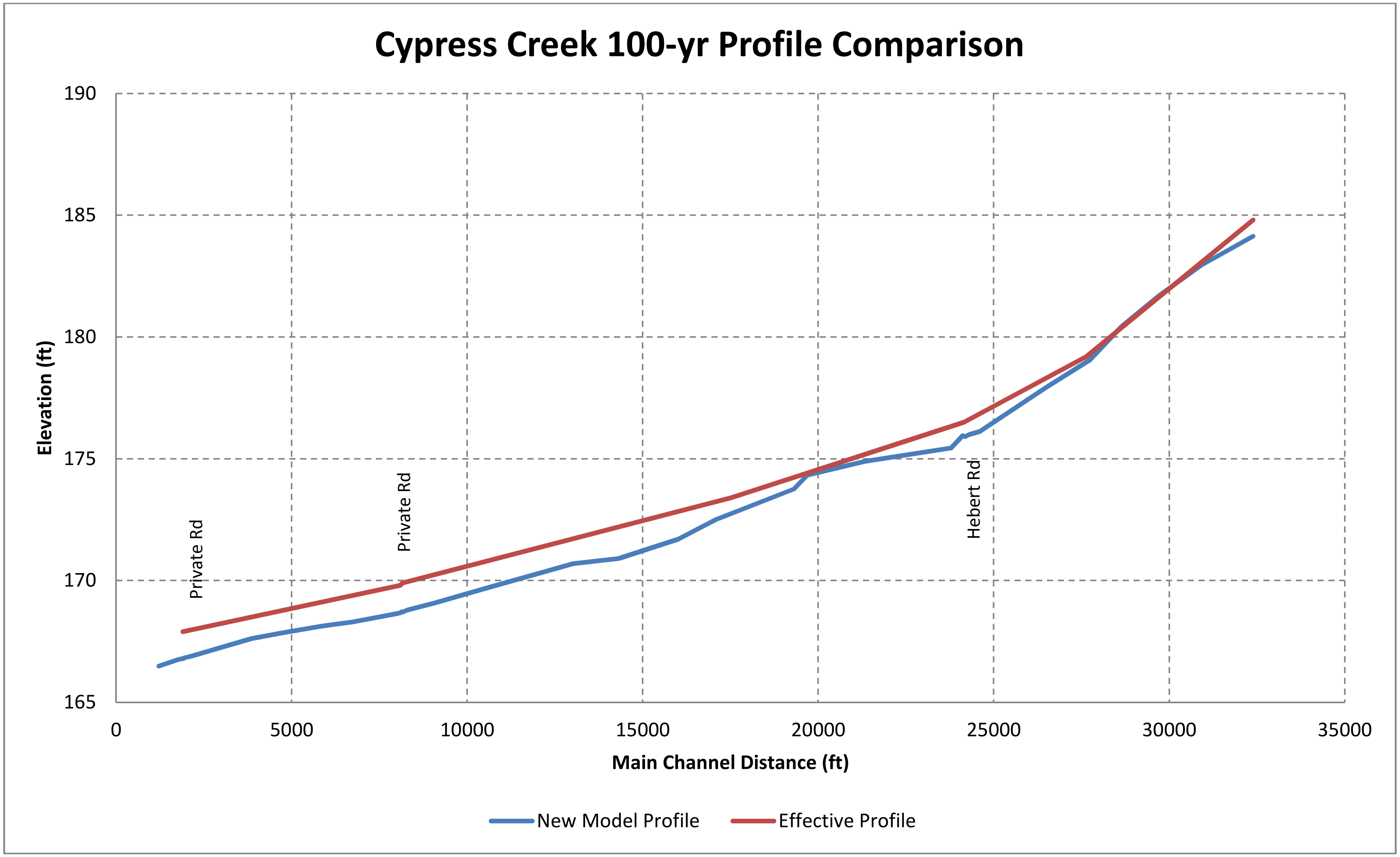

Figure A16: Cypress Creek 100-yr Profile Comparison to FEMA Current Effective

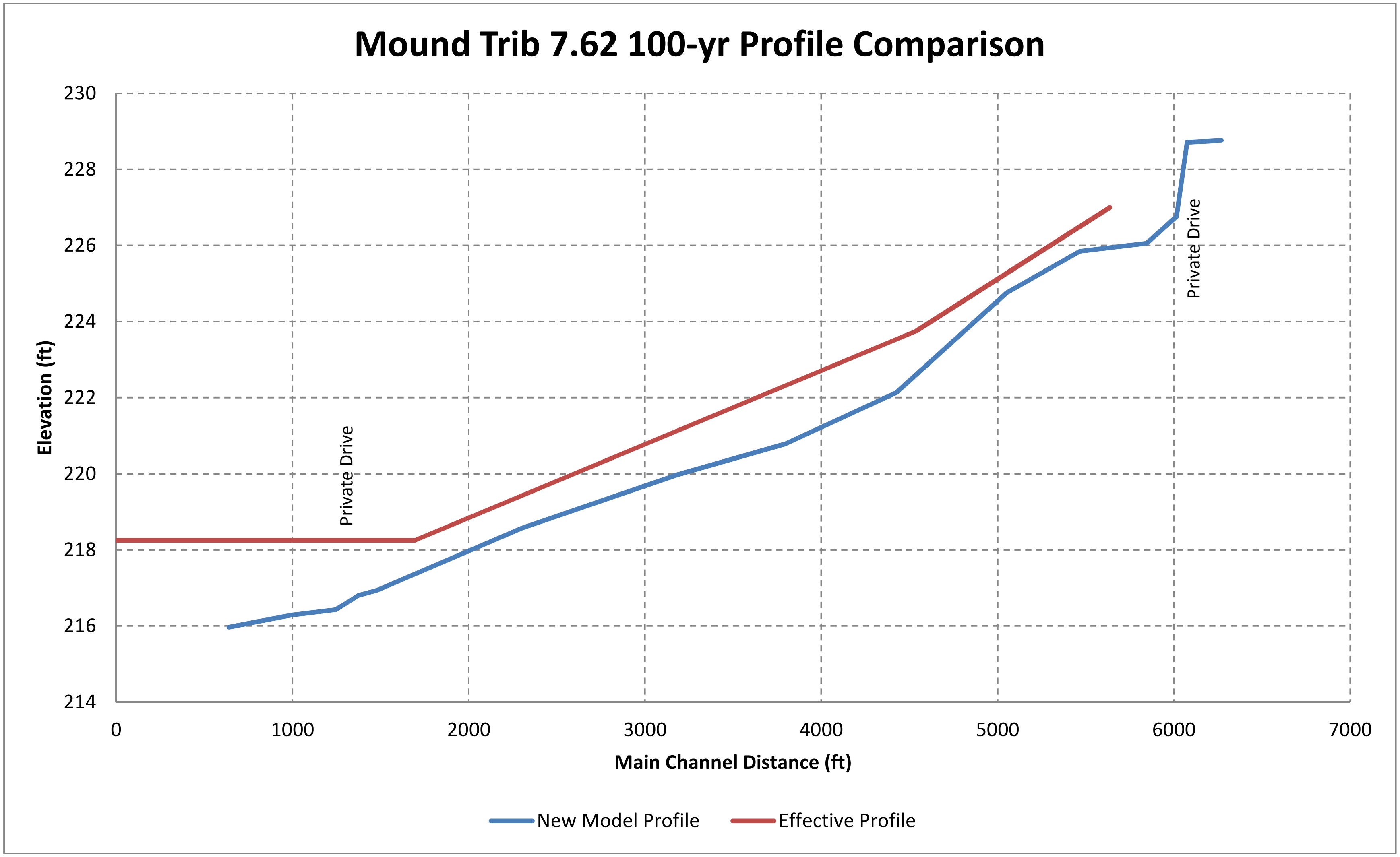

Figure A17: Mound Creek Tributary 7.62 100-yr Profile Comparison to FEMA Current Effective

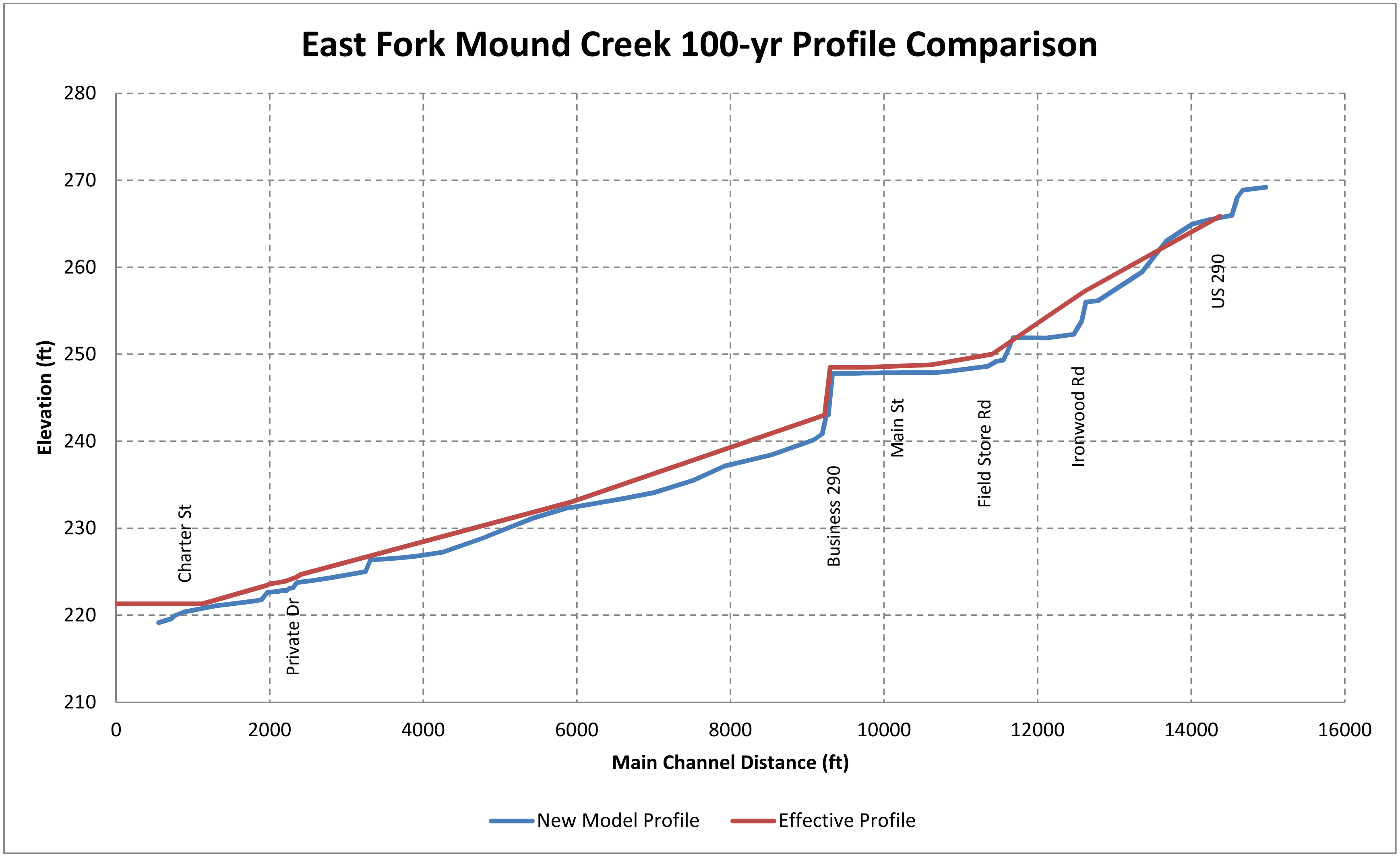

Figure A18: East Fork Mound Creek 100-yr Profile Comparison to FEMA Current Effective

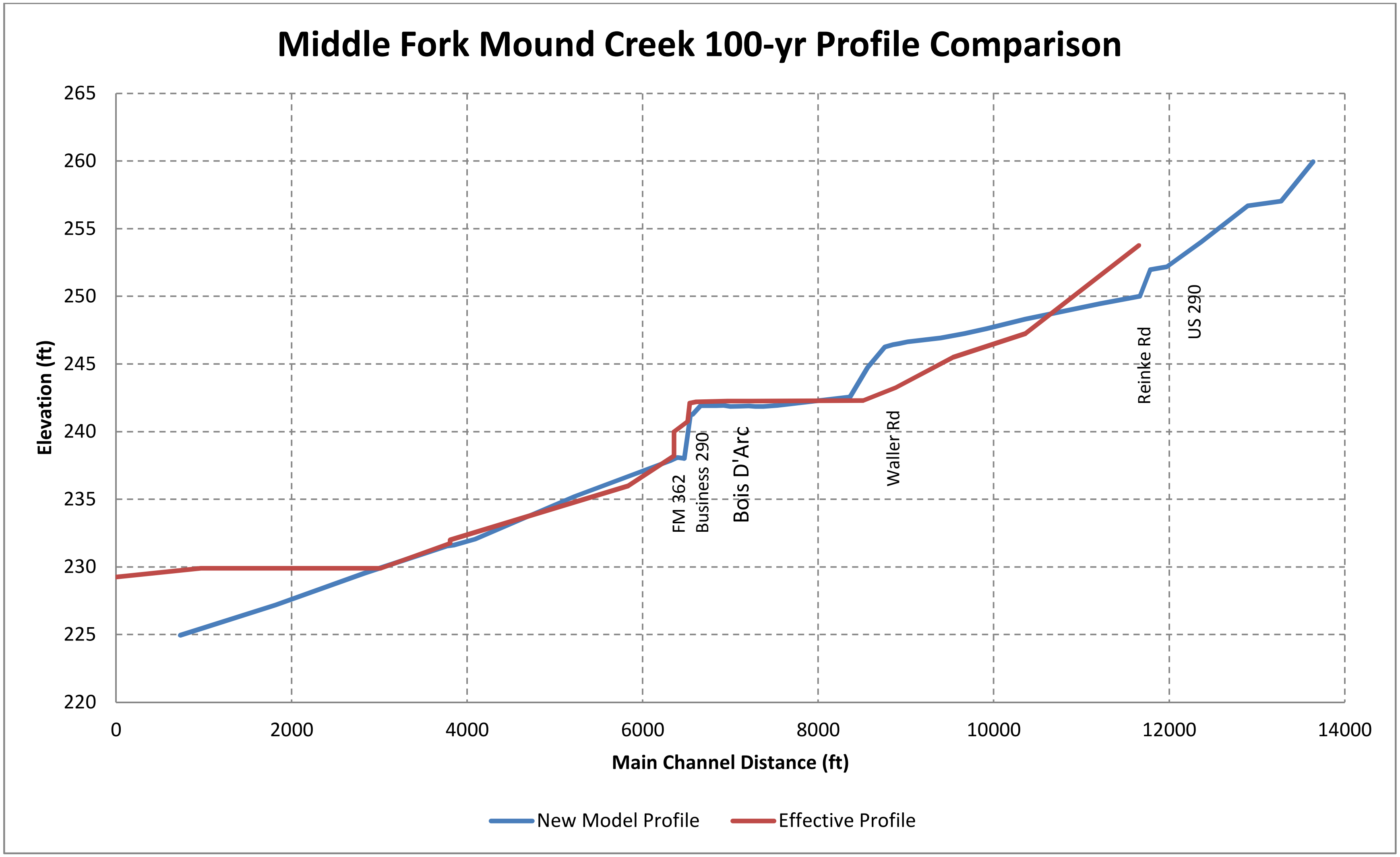

Figure A19: Middle Fork Mound Creek 100-yr Profile Comparison to FEMA Current Effective

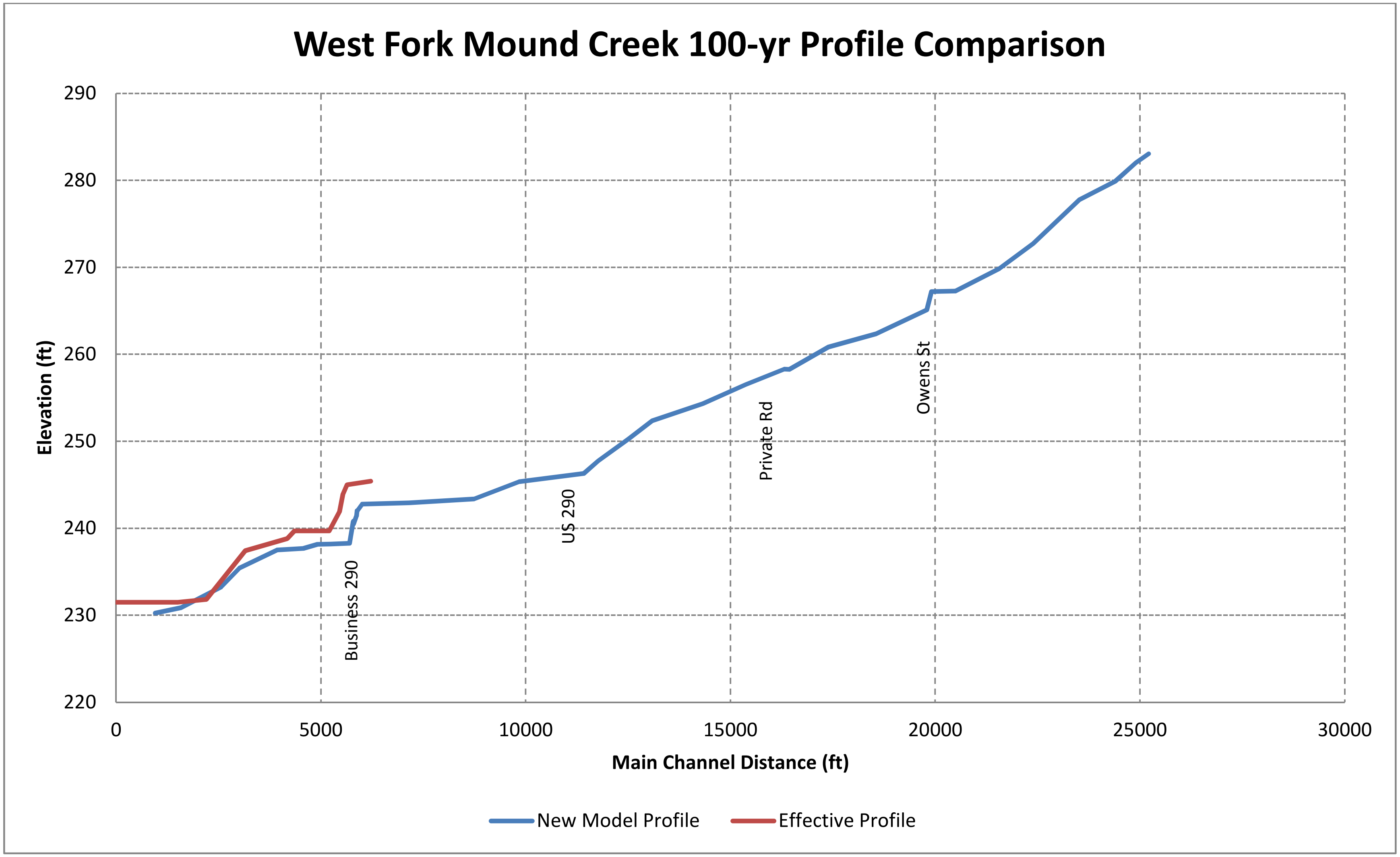

Figure A20: West Fork Mound Creek 100-yr Profile Comparison to FEMA Current Effective

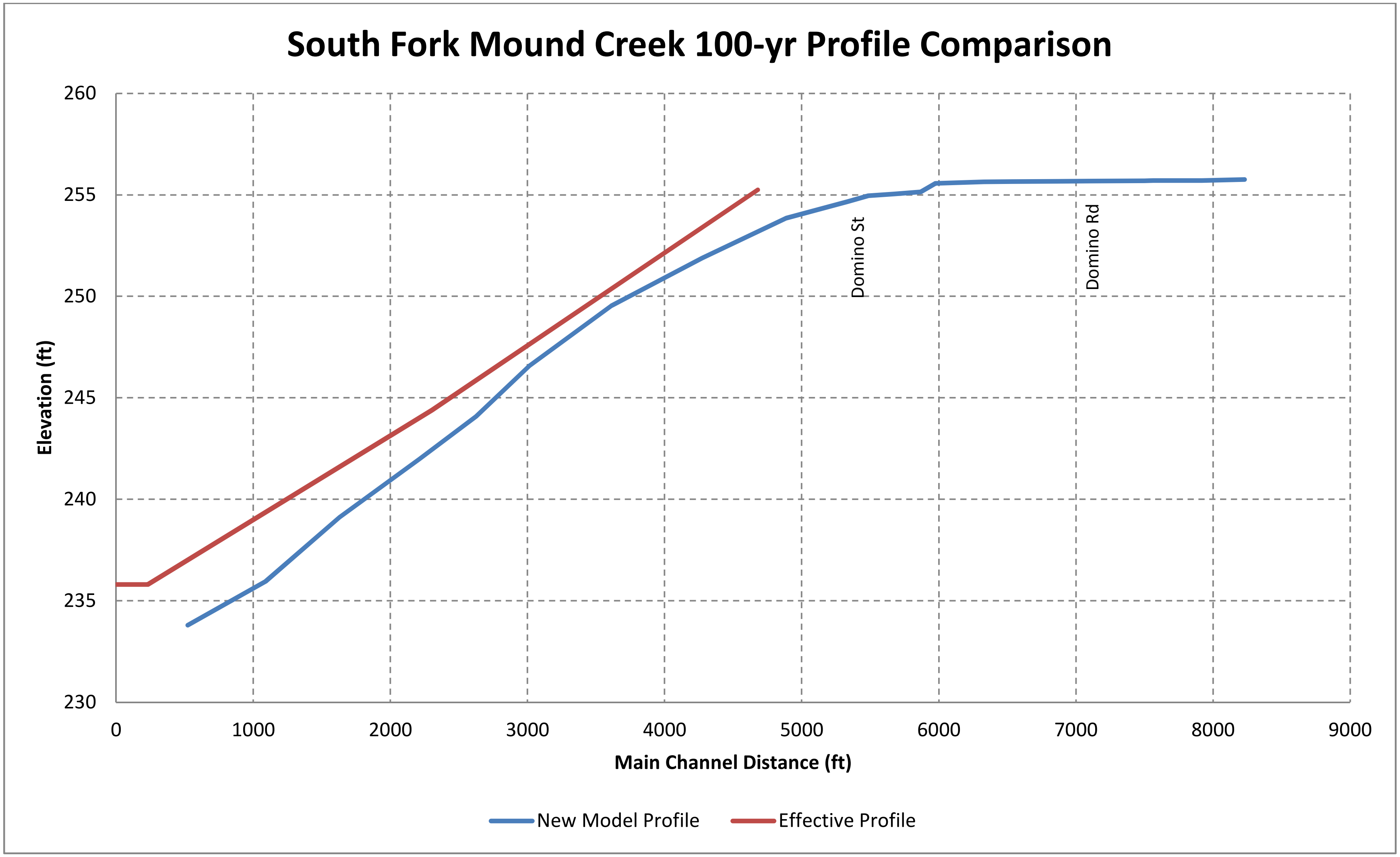

Figure A21: South Fork Mound Creek 100-yr Profile Comparison to FEMA Current Effective

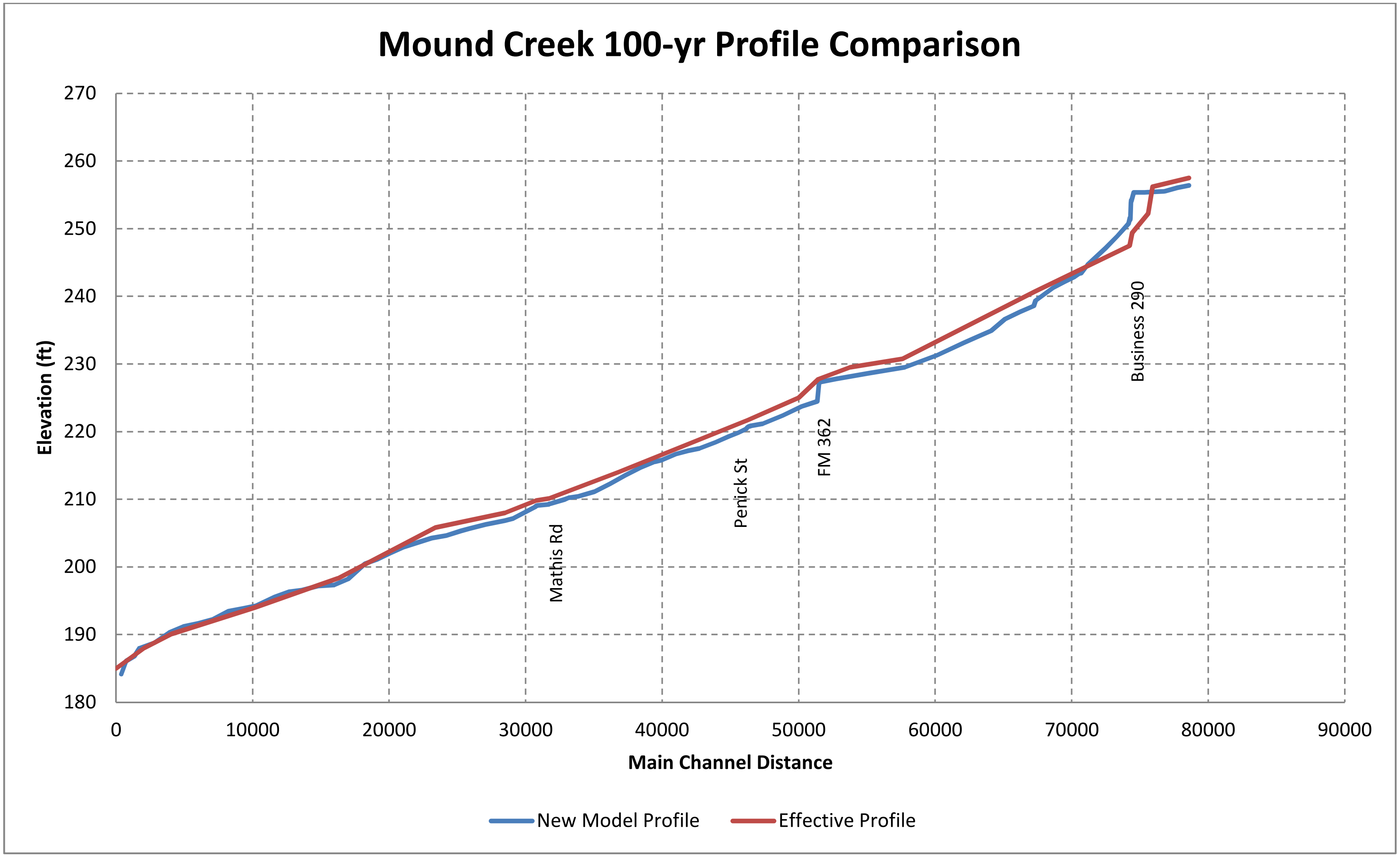

Figure A22: Mound Creek 100-yr Profile Comparison to FEMA Current Effective

APPENDIX B: Flood Damage Reduction Alternative Analysis for the Upper Cypress Creek Watershed

B.1 Introduction

The alternative analysis for the Upper Cypress Creek watershed included flood damage reduction alternatives for the City of Waller, City of Prairie View and Waller County. A map summarizing the recommended alternatives for each entity is included in the map entitled *Upper Cypress Watershed Flood Reduction Alternatives* in Appendix D. Most of the flood damages in the watershed are associated with Middle and East Fork Mound Creek running through the City of Waller followed closely by Upper Mound Creek running through the eastern corner of the City of Prairie View. Potential funding sources for the alternatives recommended below include FEMA grant programs such as the Hazard Mitigation Grant Program, Severe Repetitive Loss Grants, and Flood Mitigation Assistance Grants. These grants must be combined with matching local funds from the affected communities.

B.2 City of Waller Alternatives

A total of five structural flood damage reduction alternatives were considered within the City of Waller. These alternatives are described in Table B1 below. Four of the five alternatives focused on reducing flood elevations on Middle and East Forks of Mound Creek. The fifth focused on maintaining the current flood elevations under fully developed conditions on West Fork. The alternatives analyzed for each creek are discussed in detail below.

Table B1: City of Waller Alternative Descriptions

Alternative Name	Description
Upstream Detention Only - East Fork	Using borrow-site pond, provide 142 ac-ft of storage
Upstream Detention with Culvert Improvement - East Fork	Using borrow-site pond, provide 142 ac-ft of storage, add 2 additional 4X6 concrete box culverts to Business 290, and add 2 additional 72-inch concrete pipes to railroad
Upstream Detention Only - Middle Fork	Using borrow-site pond, provide 203 ac-ft of storage
Upstream Detention with Culvert Improvement - Middle Fork	Using borrow-site pond, provide 203 ac-ft of storage, add 4 additional 6X5 concrete box culverts to Business 290, and add 8 additional 48-inch concrete pipes to railroad
Regional Detention - West Fork	Using staged construction as development occurs ultimately provide 270 ac-ft of storage to maintain current flood elevations under full developed future conditions

East Fork Mound Creek Alternatives:

There were two options analyzed for East Fork Mound Creek: detention upstream of US 290 and a combination of detention and improvements to the culverts under Business 290 and the railroad.

Upstream Detention

The upstream detention would utilize available volume in an existing borrow-site pond just north of US 290 to reduce the 100-yr inflow to a 25-yr outflow. Excavation will be minimized if at least 8.2 feet of free board is available in the existing pond to create a total of approximately 142 ac-ft of storage. The pond will have to be retrofitted with inflow and outflow structures consisting of a possible combination of pipes, overflow weirs and/or pumps. The pond will capture runoff from the watershed upstream of US 290 including water flowing down both sides of Stokes Road.

A comparison of existing and "with detention" 100-yr floodplains for East Fork Mound Creek can be seen in Figure B1 and a profile comparison can be seen in Figure B2. The comparisons reveal that the impact of the detention pond is diminished because the Business 290 and railroad culverts are undersized and pond water on the upstream side. The upstream detention alternative removes nine habitable structures from the 100-yr floodplain for a total approximate appraised value of $526,560. A preliminary estimate of probable cost for the design and construction of the upstream pond is shown in Table B2.

Table B2: Preliminary probable cost estimate for upstream detention East Fork Mound Creek

Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	36"	8	LF	60	60	$28,800
Headwall	36"	1	EA	4000	4	$16,000
Cut and restore paving	N/A	1	SY	60	70	$4,200
Excavation (Channel)	N/A	1	CY	6.5	3655	$23,758
Erosion Control	N/A	1	LF	27.54	220	$6,059
Concrete Rip Rap	5"	1	CY	310.56	293	$91,059
Mobilization Item	N/A	1	LS	16988	1	$16,988
Engineering Design	N/A	1	LS	28029	1	$28,029
					SUM:	**$214,893**
			SUM + 20% Contingency			**$257,871**

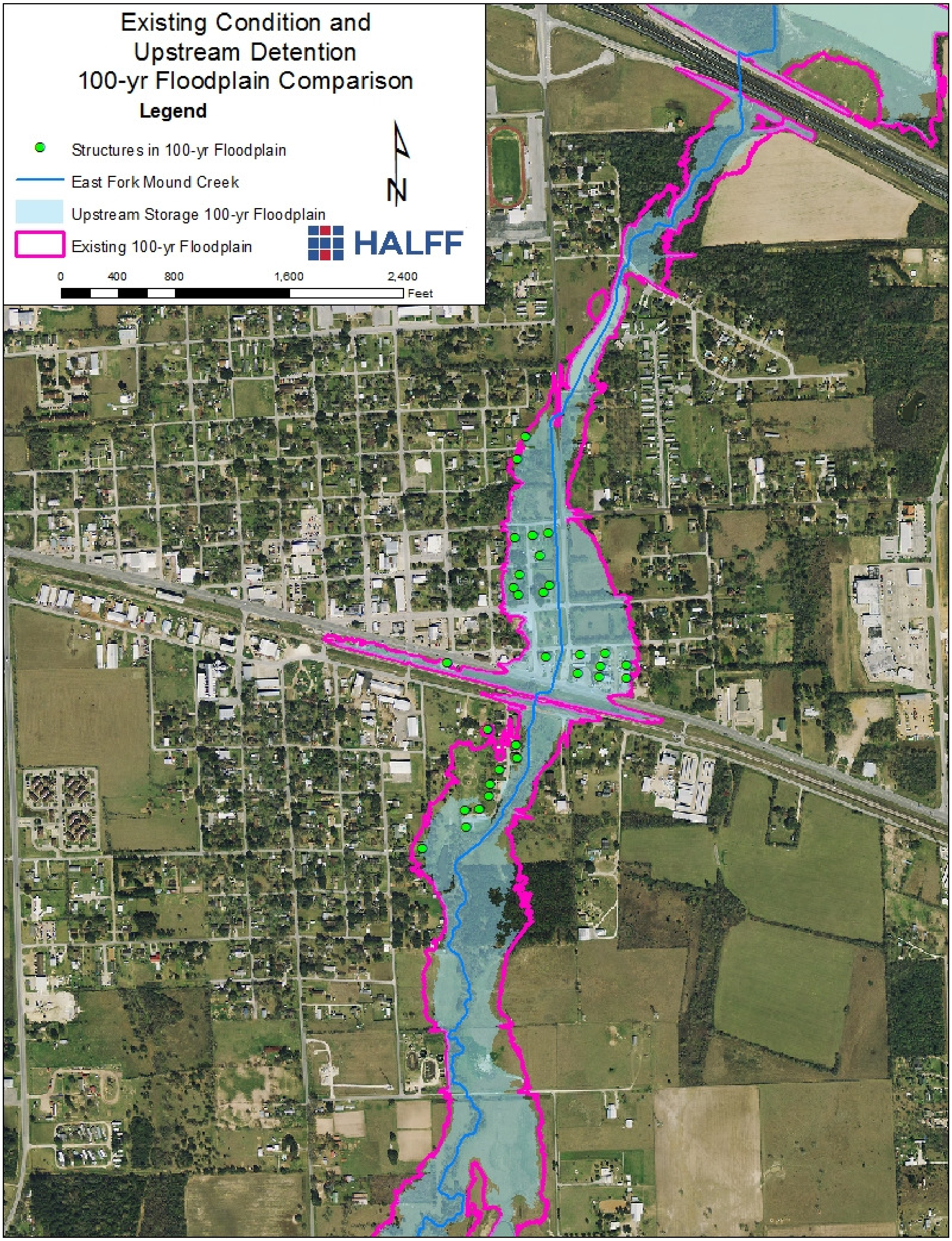

Figure B1: 100-yr Floodplain comparison between existing and upstream detention alternative (East Fork)

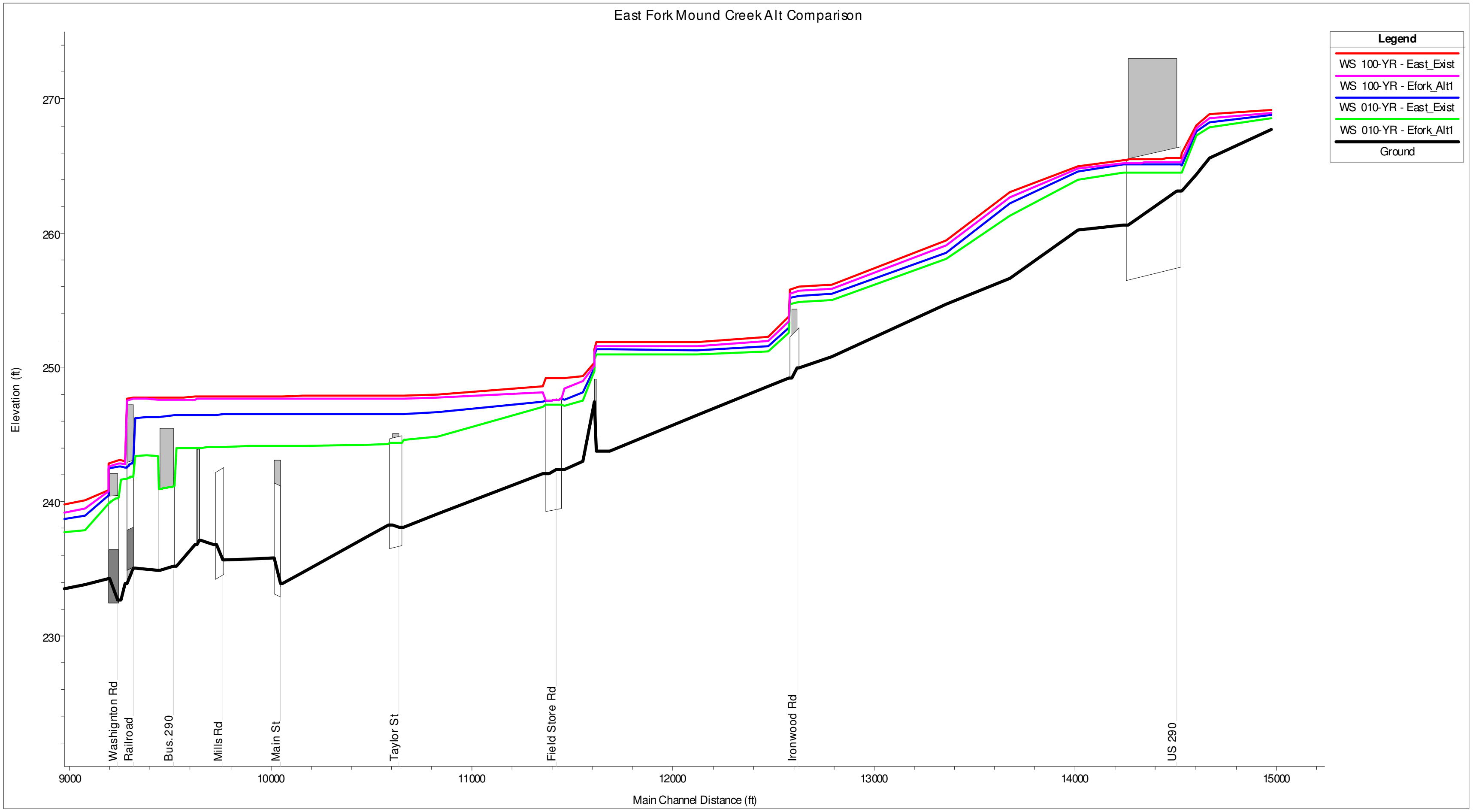

Figure B2. 100-yr and 10-yr profile comparison between existing and upstream detention (East Fork)

Upstream Detention with Business 290/RR Culvert Improvements

To have any significant flood reduction impact along East Fork Mound Creek, the culvert openings under Business 290 and the railroad must be increased to reduce upstream ponding. The target for improving the culverts was to pass at least the 25-yr flow without overtopping Business 290 or the railroad. To accomplish this goal, it is recommended that two additional 8-ft X 6-ft concrete boxes should be added to Business 290 and two additional 72-in concrete pipes should be added to the railroad. It is also recommended that any excess sediment and debris be removed from the channel near the culvert openings to promote optimal flow through the culverts.

A comparison of existing and "Upstream Detention with Culvert Improvements" 100-yr floodplains for East Fork Mound Creek can be seen in Figure B3 and a profile comparison can be seen in Figure B4. The comparisons reveal that improving the culvert openings under Business 290 and the railroad will greatly reduce the impact of flooding upstream of Business 290. It should be noted that culvert improvements should only be put in place after the proposed upstream detention is completed. The upstream detention mitigates any potential downstream impacts that could occur by improving the culverts under Business 290 and the railroad. The upstream detention with Business 290/railroad culvert improvements alternative removes 21 habitable structures from the 100-yr floodplain for a total approximate appraised value of $1,121,503. A preliminary estimate of probable cost for the design and construction of the culvert improvements is shown in Table B3. The total preliminary estimate of probable cost for the Business 290 and railroad culvert improvements is $613,365. This cost does not include the cost of the upstream detention, which is recommended to be completed as a separate project.

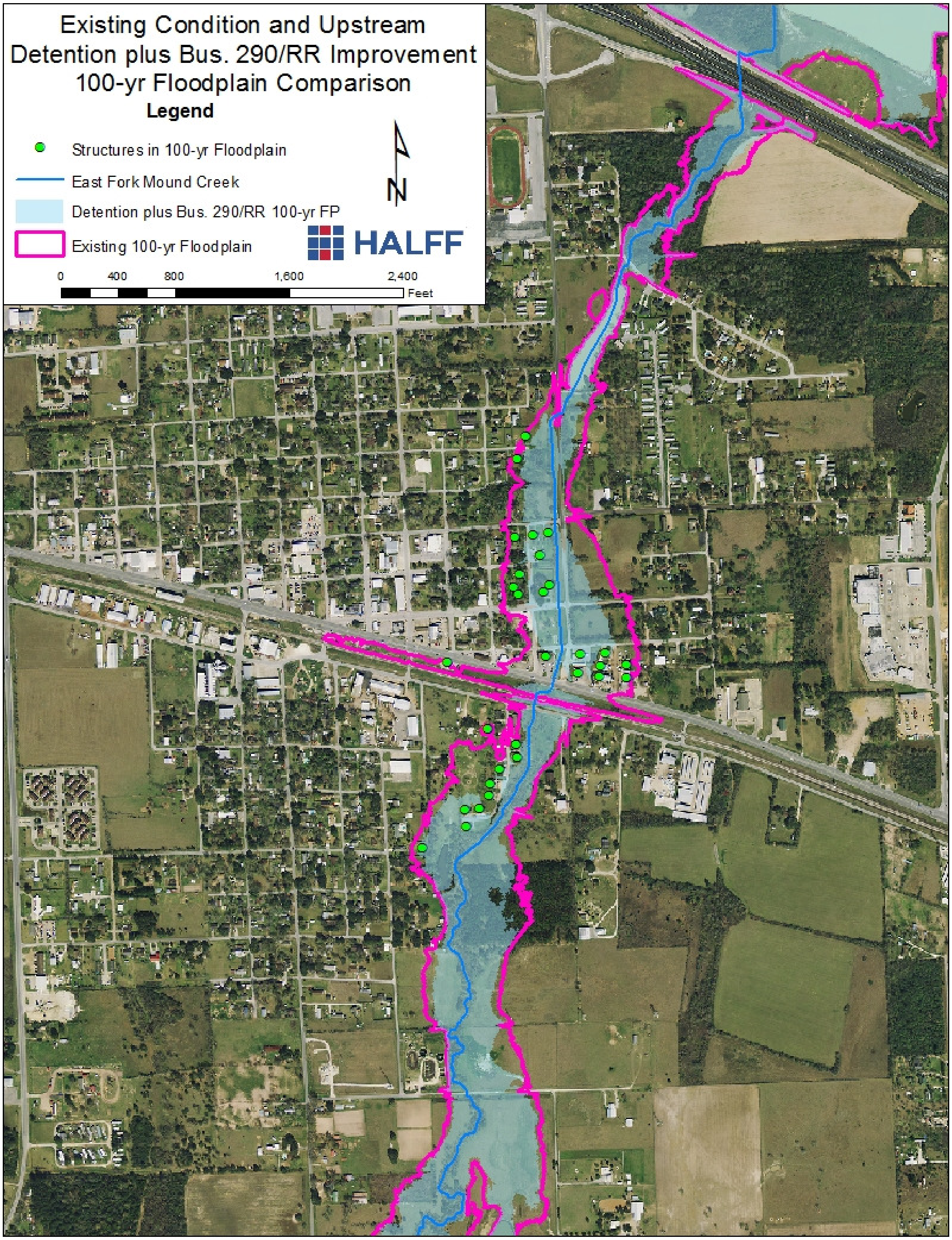

Figure B3: 100-yr Floodplain comparison between existing and detention plus culvert improvement alternative (East Fork)

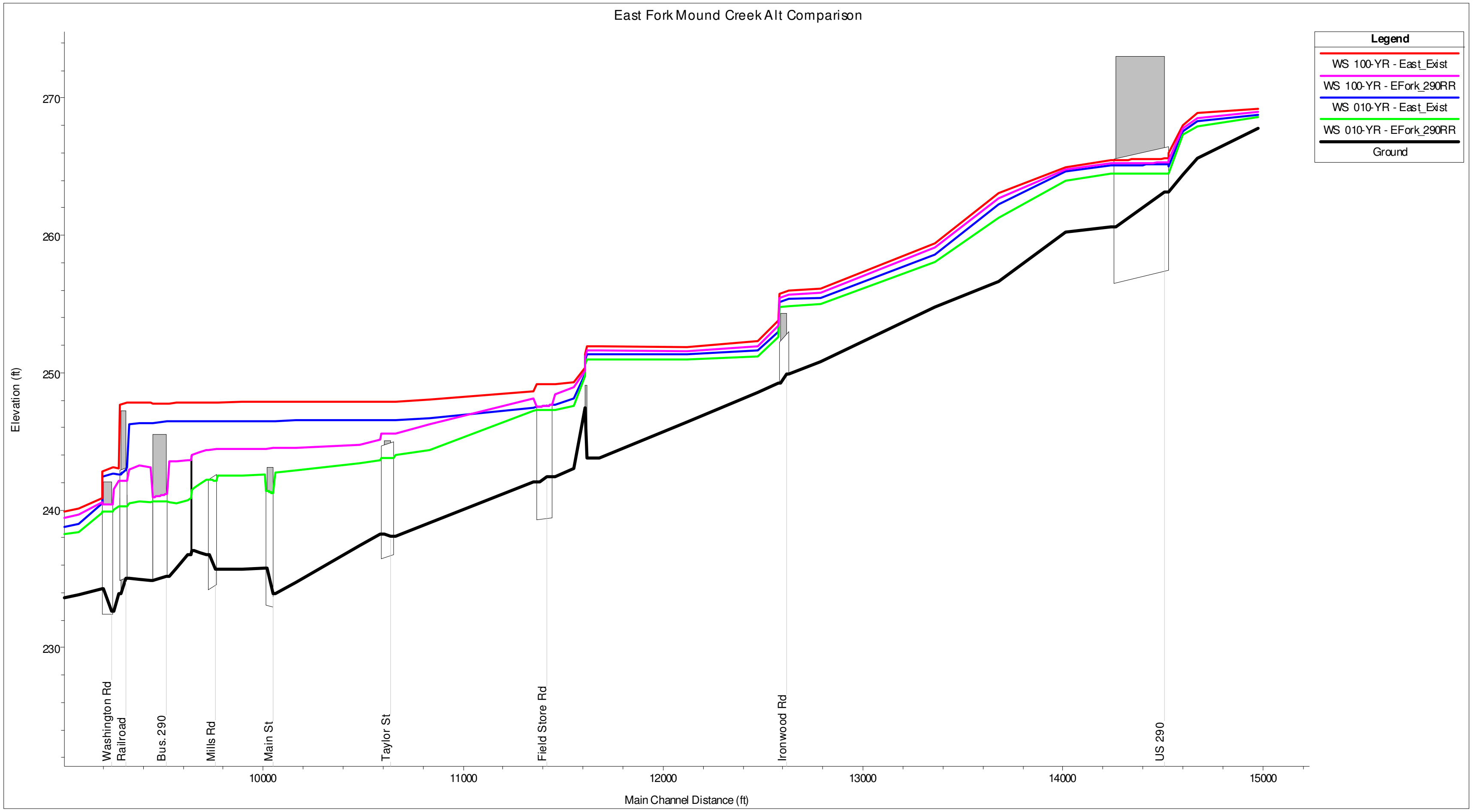

Figure B4: 100-yr and 10-yr profile comparison between existing and detention plus culvert improvement alternative (East Fork)

Table B3: Preliminary probable cost estimate for Bus. 290/RR culvert improvements East Fork Mound Creek

Bus. 290 East Fork						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	8' x 6'	2	LF	242.19	70	$33,907
Wingwall	7'	2	EA	20198	N/A	$40,396
Cut and restore paving	N/A	N/A	SY	60	156	$9,333
Guard Rail	N/A	N/A	LF	20	325	$6,500
Guard Rail End Treatment	N/A	4	EA	2302.88	N/A	$9,212
Mow Strip	N/A	N/A	CY	306.9	8	$2,463
Excavation (Roadway)	N/A	N/A	CY	4.26	300	$1,278
Erosion Control	N/A	1	LF	27.54	35	$964
Rip Rap	5"	N/A	CY	310.56	110	$34,267
Traffic Control	N/A	1	LS	2000	1	$2,000
Mobilization Item	N/A	1	LS	13832	1	$13,832
Engineering Design	N/A	1	LS	23200	1	$23,200
					SUM:	**$177,351**
				SUM + 20% Contingency		**$212,821**
RR East Fork						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation (J&B)	72"	2	LF	1000	34	$68,000
Headwall	72"	2	EA	22500	2	$45,000
Erosion Control	N/A	1	LF	27.54	35	$964
Rip Rap	5"	N/A	CY	310.56	31	$9,705
Mobilization Item	N/A	1	LS	12367	1	$12,367
Engineering Design	N/A	1	LS	20400	1	$20,400
					SUM:	**$156,436**
				SUM + 20% Contingency		**$187,723**
					Total	**$400,544**

Middle Fork Mound Creek Alternatives:

There were two options analyzed for Middle Fork Mound Creek: detention upstream of US 290 and a combination of detention and improvements to the culverts under Business 290 and the railroad.

Upstream Detention

The upstream detention may utilize available volume in an existing borrow-site pond just north of US 290 to reduce the 100-yr inflow to a 25-yr outflow. Excavation will be minimized if at least 11.7 feet of free board is available in the existing pond to create a total of approximately 203 ac-ft of storage. The pond will have to be retrofitted with inflow and outflow structures consisting of a possible combination of pipes, overflow weirs and/or pumps. The main channel of Middle Fork Mound Creek will have to be rerouted so that water can be diverted to the existing pond site if it is to be used. The pond will capture runoff from the watershed upstream of US 290.

A comparison of existing and "with detention" 100-yr floodplains for Middle Fork Mound Creek can be seen in Figure B5 and a profile comparison can be seen in Figure B6. The comparisons reveal that the impact of the detention pond is diminished because the Business 290 and railroad culverts are undersized and ponding water on the upstream side. The upstream detention alternative removes seven habitable structures from the 100-yr floodplain for a total appraised value of $211,800. A preliminary estimate of probable cost for the design and construction of the upstream pond is shown in Table B4 assuming the existing pond can provide all the storage that is necessary.

Table B4: Preliminary probable cost estimate for upstream detention Middle Fork Mound Creek

Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	36"	4	LF	40	60	$9,600
Headwall	36"	1	EA	4000	2	$8,000
Excavation (Channel)	N/A	1	CY	6.5	13640	$88,660
Erosion Control	N/A	1	LF	27.54	900	$24,786
Rip Rap	5"	1	CY	310.56	420	$130,435
Mobilization Item	N/A	1	LS	26150	1	$26,150
Engineering Design	N/A	1	LS	43150	1	$43,150
					SUM:	**$330,781**
				SUM + 20% Contingency		**$396,937**

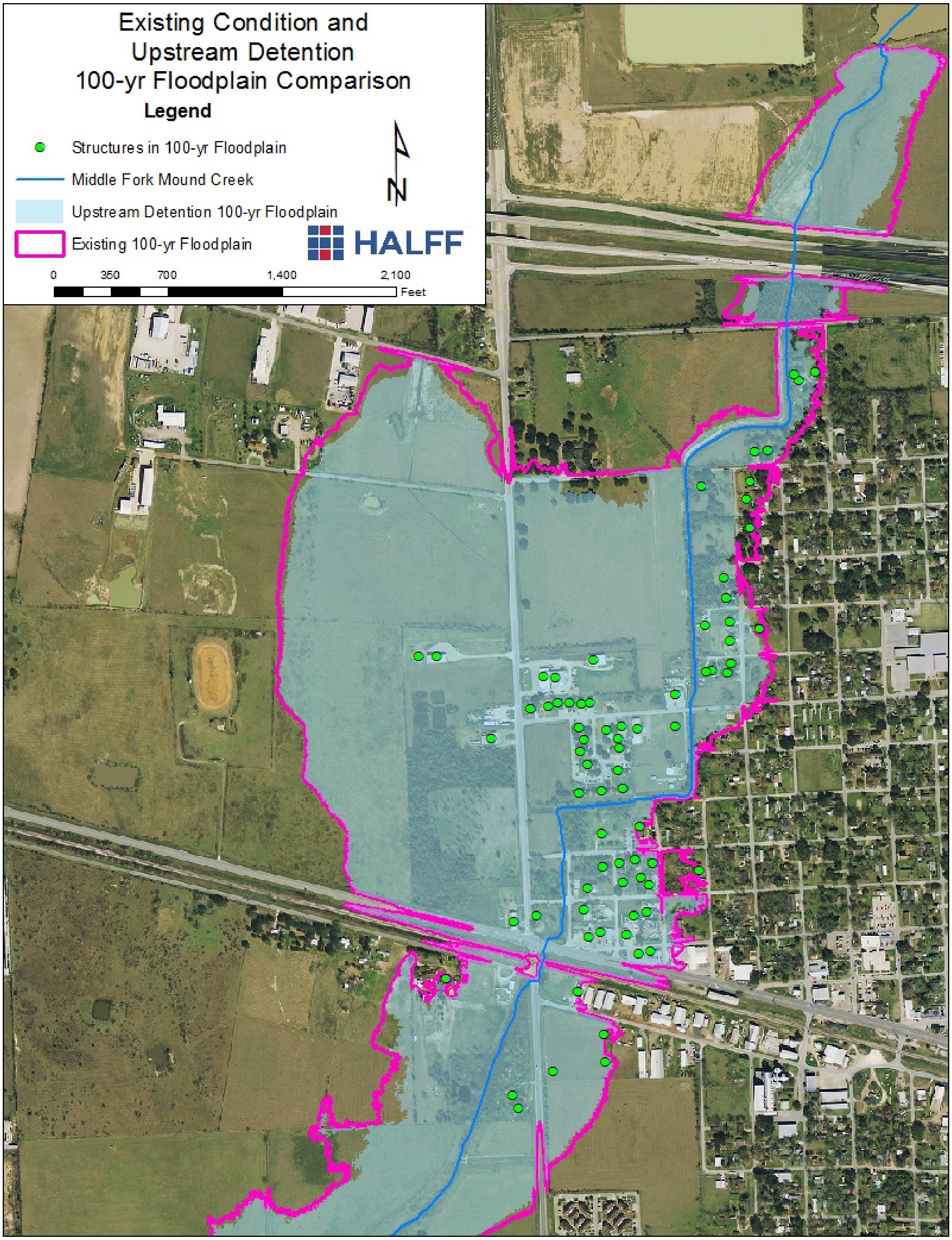

Figure B5: 100-yr Floodplain comparison between existing and upstream detention alternative (Middle Fork)

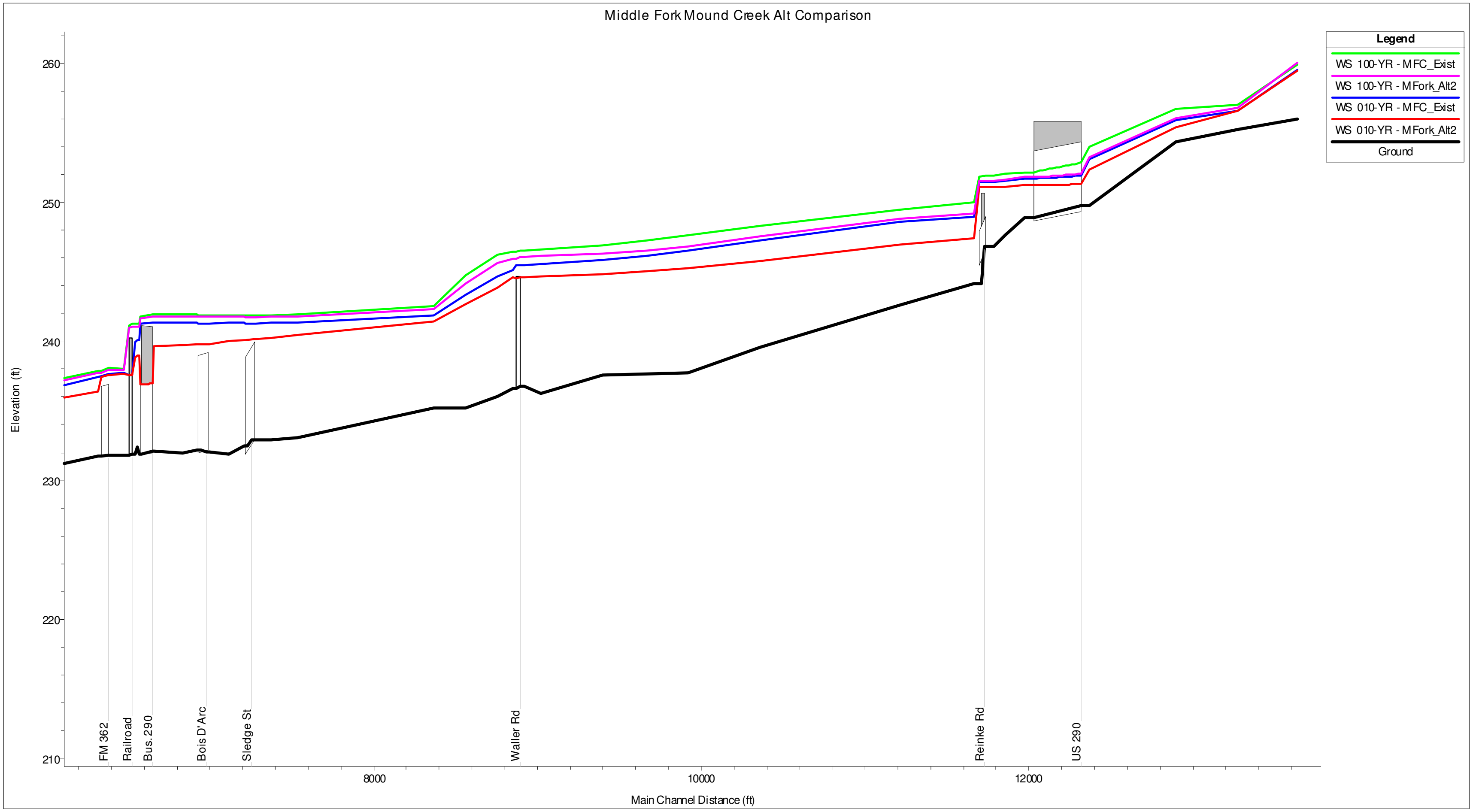

Figure B6: 100-yr and 10-yr profile comparison between existing and upstream detention (Middle Fork)

Upstream Detention with Business 290/RR Culvert Improvements

To have any significant flood reduction impact along Middle Fork Mound Creek, the culvert openings under Business 290 and the railroad must be increased to reduce upstream ponding. The target for improving the culverts was to pass at least the 25-yr flow without overtopping Business 290 or the railroad. To accomplish this goal, it is recommended that four additional 6-ft X 5-ft concrete boxes should be added to Business 290 and eight additional 48-in concrete pipes should be added to the railroad. The culverts under the railroad are in addition to the existing bridge opening. It is also recommended that any excess sediment and debris be removed from the channel near the culvert openings to promote optimal flow through the culverts.

A comparison of existing and "Upstream Detention with Culvert Improvements" 100-yr floodplains for Middle Fork Mound Creek can be seen in Figure B7 and a profile comparison can be seen in Figure B8. The comparisons reveal that improving the culvert openings under Business 290 and the railroad will greatly reduce the impact of flooding upstream of Business 290. It should be noted that culvert improvements should only be put in place after the proposed upstream detention is completed. The upstream detention mitigates any potential downstream impacts that could occur by improving the culverts under Business 290 and the railroad. The upstream detention with Business 290/railroad culvert improvements alternative removes 18 habitable structures from the 100-yr floodplain for a total appraised value of $896,819. A preliminary estimate of probable cost for the design and construction of the culvert improvements is shown in Table B5. The total preliminary estimate of probable cost for the Business 290 and railroad culvert improvements is $936,332. This cost does not include the cost of the upstream detention, which is recommended to be completed as a separate project.

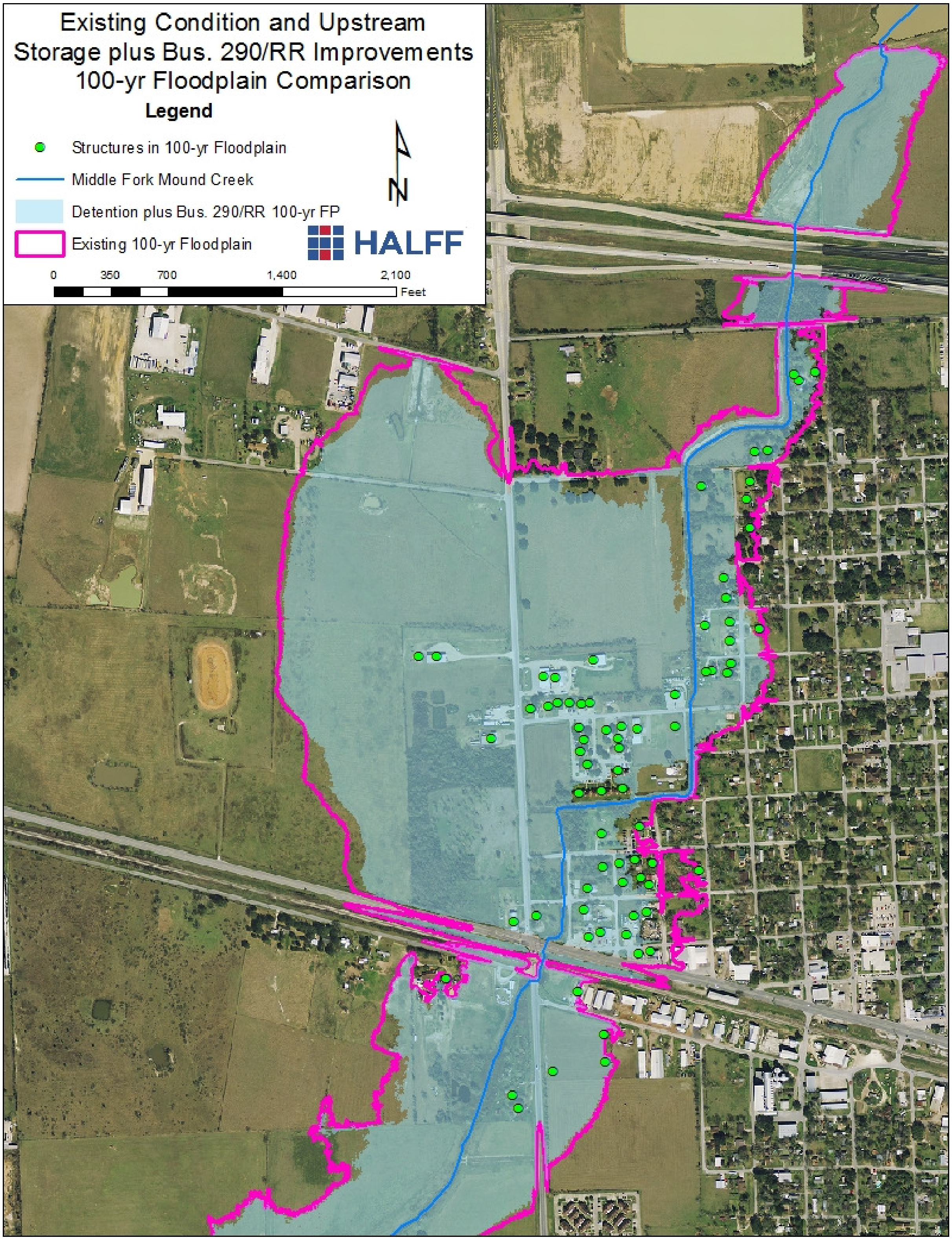

Figure B7: 100-yr Floodplain comparison between existing and detention plus culvert improvement alternative (Middle Fork)

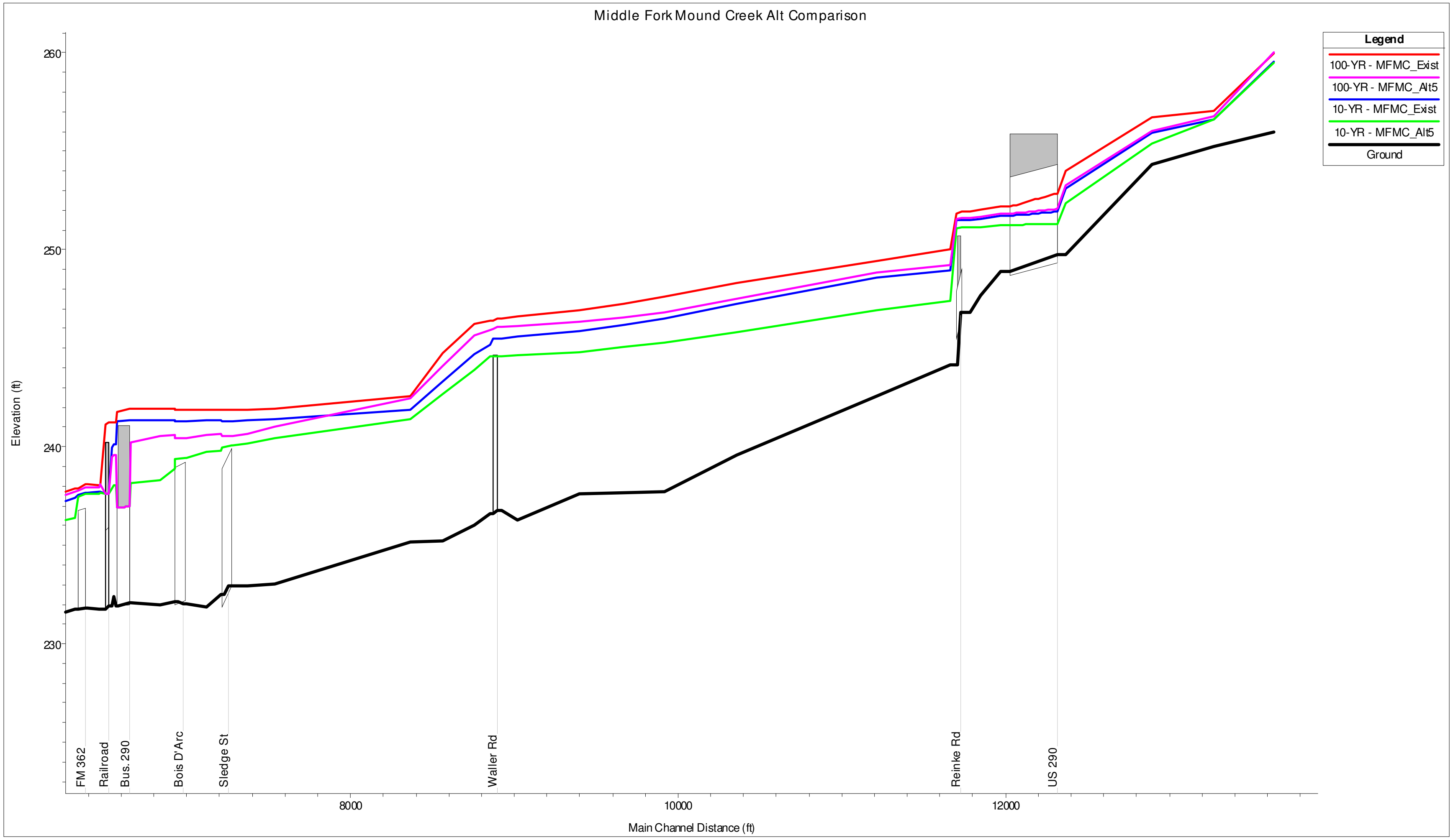

Figure B8: 100-yr and 10-yr profile comparison between existing and detention plus culvert improvement alternative (Middle Fork)

Table B5: Preliminary probable cost estimate for Bus. 290/RR culvert improvements Middle Fork Mound Creek

Bus. 290 Middle Fork						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	6' X 5'	4	LF	300	70	$84,000
Wingwall	6'	2	EA	14290	2	$28,580
Cut and restore paving	N/A	1	SY	90	467	$42,000
Guard Rail	N/A	1	LF	25	460	$11,500
Guard Rail End Treatment	N/A	4	EA	2302.88	N/A	$9,212
Mow Strip	N/A	1	CY	306.9	11	$3,486
Excavation	N/A	1	CY	4.26	550	$2,343
Erosion Control (RFD)	N/A	1	LF	27.54	60	$1,652
Rip Rap	5"	1	CY	310.56	80	$24,845
Traffic Control	N/A	1	LS	2000	1	$2,000
Mobilization Item	N/A	1	LS	20960	1	$20,960
Engineering Design	N/A	1	LS	34590	1	$34,590
					SUM:	**$265,167**
				SUM + 20% Contingency		**$318,201**
RR Middle Fork						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation (J&B)	48"	8	LF	550	34	$149,600
Headwall	48"	1	EA	13100	2	$26,200
Erosion Control (RFD)	N/A	1	LF	27.54	60	$1,652
Rip Rap	5"	1	CY	310.56	65	$20,129
Mobilization Item	N/A	1	LS	19760	1	$19,760
Engineering Design	N/A	1	LS	32600	1	$32,600
					SUM:	**$249,941**
				SUM + 20% Contingency		**$299,930**
					Total	**$618,131**

West Fork Mound Creek Alternatives:

There is currently very little development along West Fork Mound Creek. Therefore, any flood reduction measures under the existing condition will not be cost effective. However, steps should be taken to plan for future development in the area between US 290 and Business 290 as it fills in the area along West Fork Mound Creek. A future condition scenario was run for West Fork Mound Creek that assumes fully developed conditions (80% impervious cover) between US 290 and Business 290 to determine the amount of storage required so that there is no increase from the existing 100-yr flood elevations.

An upstream detention pond is proposed to mitigate for future development along West Fork Mound Creek. The storage required is approximately 270 ac-ft, which would cover an area of 45 acres at an average depth of 6 ft. The recommended location for the proposed detention pond is just upstream of US 290 at the confluence with the West Fork Mound Creek Tributary. Figure B9 shows a 100-yr and 10-yr event profile comparison of existing versus future conditions with detention. Note that the proposed detention lowers future flooding to existing elevations. A preliminary estimate of probable cost for the design and construction of the proposed detention pond is presented in Table B6. The cost is much higher than the Middle and East Fork detention options since there is no existing pond that can provide storage and the proposed pond requires a large amount of excavation (approx. 435,600 CY). Funding options for this detention pond include a storm water fee to be assessed to developers in lieu of onsite detention.

Table B6: Preliminary probable cost estimate for proposed detention West Fork Mound Creek

Detention West Fork						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	36"	6	LF	40	60	$14,400
Headwall	36"	1	EA	4000	2	$8,000
Excavation (Channel)	N/A	1	CY	6.5	435600	$2,831,400
Erosion Control	N/A	1	LF	25	1000	$25,000
Rip Rap	5"	1	CY	125	420	$52,500
Mobilization Item	N/A	1	LS	30000	1	$30,000
Engineering Design	N/A	1	LS	40000	1	$40,000
					SUM:	**$3,001,300**
					SUM + 20% Contingency	**$3,601,560**

<u>Recommendations</u>:

The detention plus culvert improvements at Business 290 and the railroad provide the most reduction in flood elevations on both Middle and East Fork Mound Creek. However, this option is still likely not to have a Benefit-Cost (B/C) ratio greater than one when the detention and culvert improvements are lumped together in the same project. It is recommended that the City of Waller construct the detention ponds on Middle Fork and East Fork upstream of US 290 separately without FEMA grant funds. The Business 290/railroad culvert improvements can then be addressed as a separate project which is more likely to have a B/C ratio greater than one and be eligible for a FEMA grant. Further refinement of the flood reduction benefits and costs is needed to determine a B/C ratio. The upstream detention projects must be constructed before the culvert improvements, otherwise there will be potential downstream impacts resulting from increased flows through the improved culverts. It is also essential that TxDOT and Union Pacific be involved in the culvert improvement project for the purposes of cooperation and possible funding. It is also recommended that a staged construction plan be prepared for the proposed regional detention on West Fork Mound Creek. The proposed regional detention can be funded by a development fee assessed to developers in lieu of onsite detention and built out in stages as development increases in the watershed. If a developer opts out of the development fee, they would be required to provide onsite detention to reduce their runoff to pre-development levels.

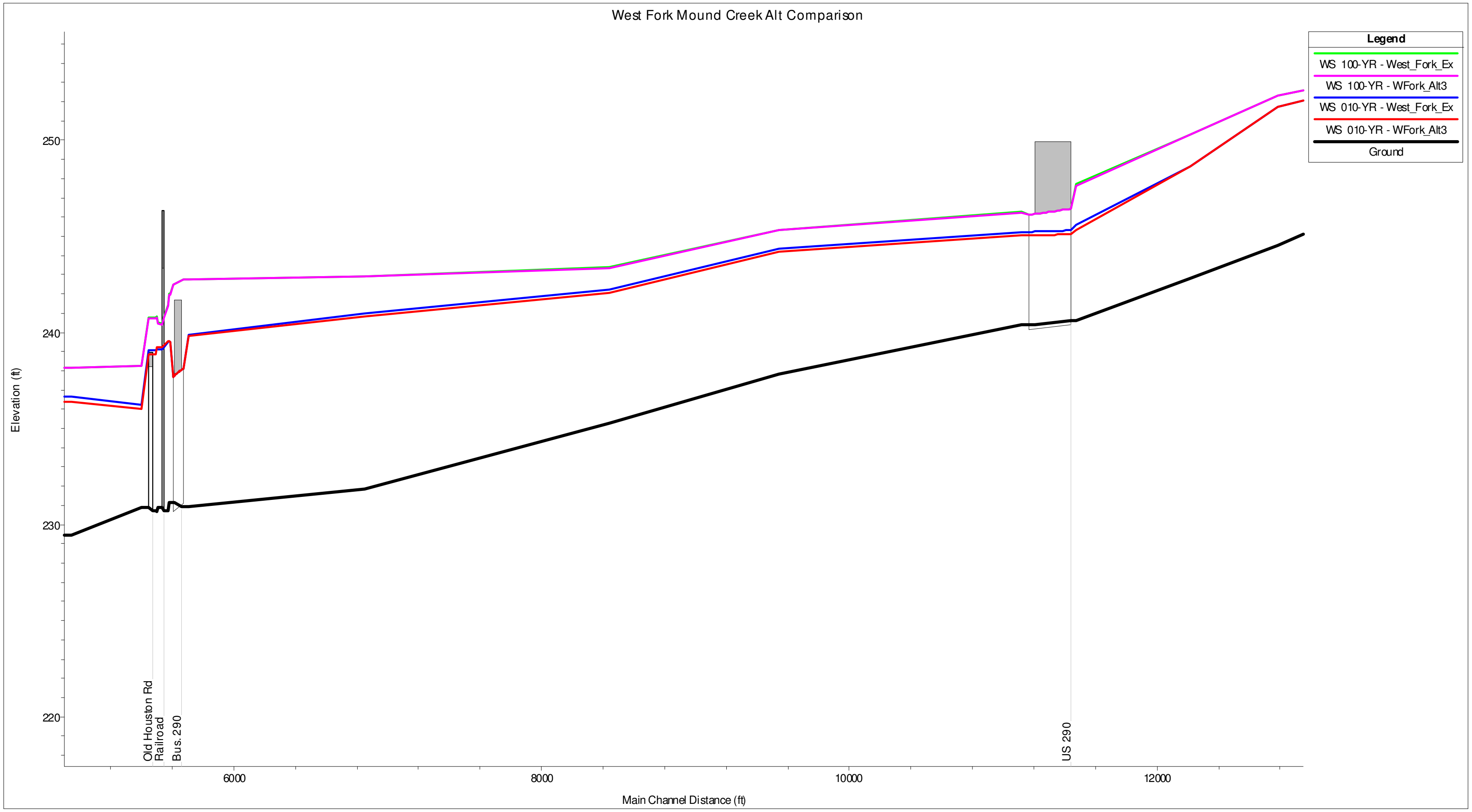

Figure B9: 100-yr and 10-yr profile comparison between existing and future detention alternative (West Fork)

B.3 City of Prairie View Alternatives

A total of two structural and one non-structural flood damage reduction alternatives were considered within the City of Prairie View. These alternatives are described in Table B7 below. The two structural alternatives focused on reducing flood elevations on Upper Mound Creek between Business 290 and US 290 where several houses are located within the 100-yr floodplain. The non-structural alternative focused on buying out several of the homes located closest to the creek. The three alternatives analyzed are discussed in detail below.

Table B7: City of Prairie View Alternative Descriptions

Alternative Name	Description
Channel Clearing/Improvement	Enlarge and clear channel to a 35 ft. bottom width with 4:1 side slopes from US 290 to Business 290.
Upstream Detention with Culvert Improvement	Using borrow-site pond, provide 240 ac-ft of storage and add 4 additional 4X4 concrete box culverts
Home Buyout	Buyout up to seven houses between Mound Creek Channel and Ruby Street that are subject to frequent flooding

Channel Clearing\Channel Improvement Alternative

The City of Prairie View requested a channel clearing/channel improvement alternative be investigated for Upper Mound Creek between US 290 and Business 290. A channel modification consisting of a 35-ft bottom width and 3 to 1 side slopes was applied to the hydraulic model between Business 290 and US 290. The resulting 100- and 10-yr profiles seen in Figure B10 show very little improvement over the corresponding existing water surface elevations. Therefore, the requested alternative was modeled and determined to be ineffective at reducing flooding because flood elevations are controlled by the backwater from Business 290. No cost estimate was created for this alternative since it did not effectively lower flood elevations.

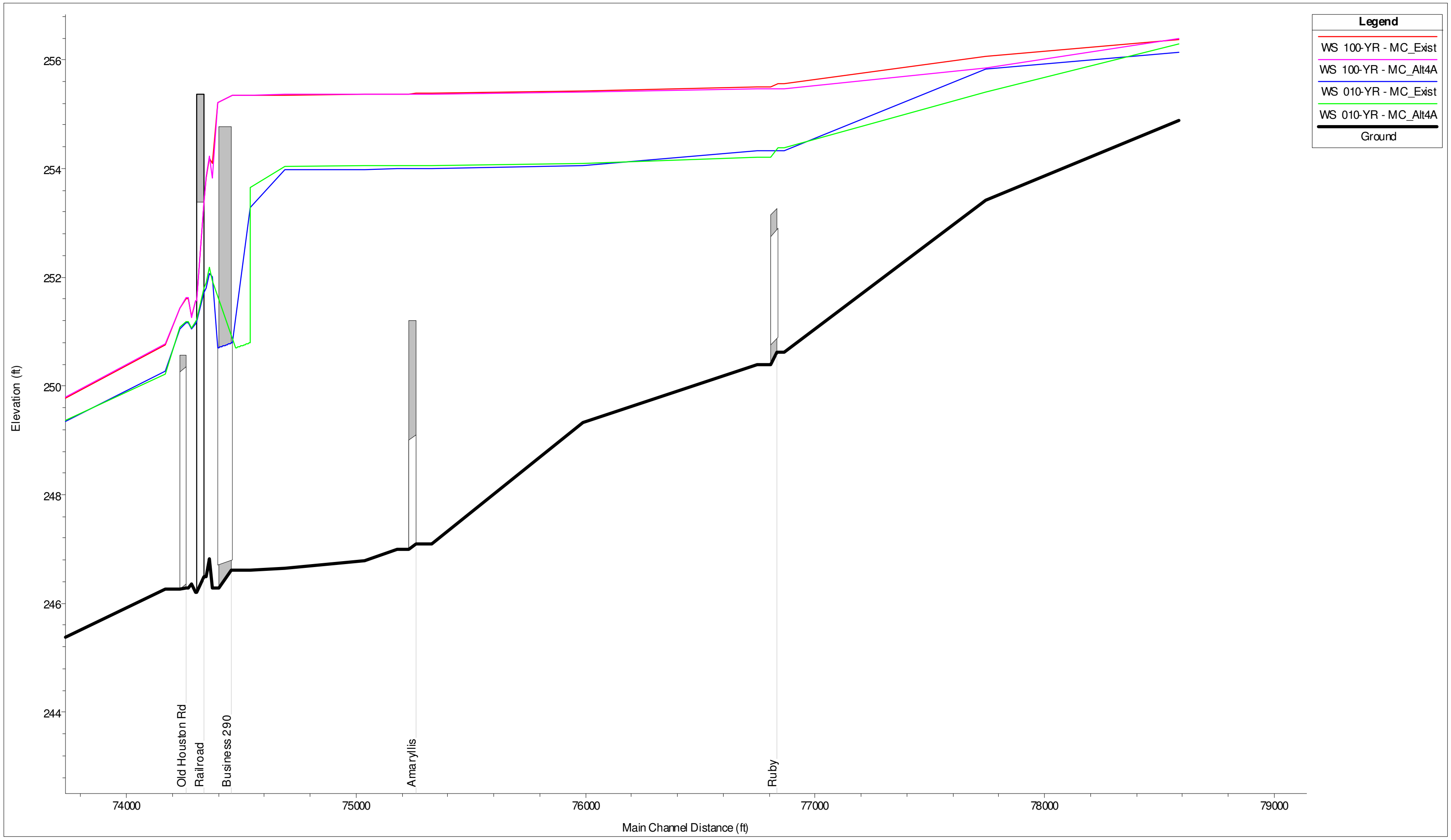

Figure B10: 100-yr and 10-yr profile comparison between existing and channel improvement alternative (Upper Mound)

Upstream Detention with Business 290 Culvert Improvements

To have any significant flood reduction impact along Upper Mound Creek, the culvert opening under Business 290 must be increased to reduce upstream ponding. The target for improving the culverts was to pass at least the 25-yr flow without overtopping Business 290. To accomplish this goal, it is recommended that four additional 4-ft X 4-ft concrete boxes should be added to Business 290 and up to 240 ac-ft of runoff should be detained upstream of US 290. It is also recommended that any excess sediment and debris be removed from the channel near the culvert openings to promote optimal flow through the culverts.

A comparison of existing and "Upstream Detention with Culvert Improvement" 100-yr floodplains for Upper Mound Creek can be seen in Figure B11 and a profile comparison can be seen in Figure B12. The comparisons reveal that improving the culvert openings under Business 290 will greatly reduce the impact of flooding upstream of Business 290. It should be noted that culvert improvements should only be put in place after the proposed upstream detention is completed. The upstream detention assumes storage is available in the existing borrow pit pond upstream of US 290 and mitigates any potential downstream impacts that could occur by improving the culverts under Business 290. The upstream detention with Business 290 culvert improvement alternative removes one habitable structure from the 100-yr floodplain for a total approximate appraised value of $115,250. However, 100-yr flood elevations are reduced by 1.4 ft. and 10-yr flood elevations are reduced by 1.9 ft. A preliminary estimate of probable cost for the design and construction of the culvert improvement and upstream detention is shown in Table B8. The total preliminary estimate of probable cost for the upstream detention plus the culvert improvements is $545,084.

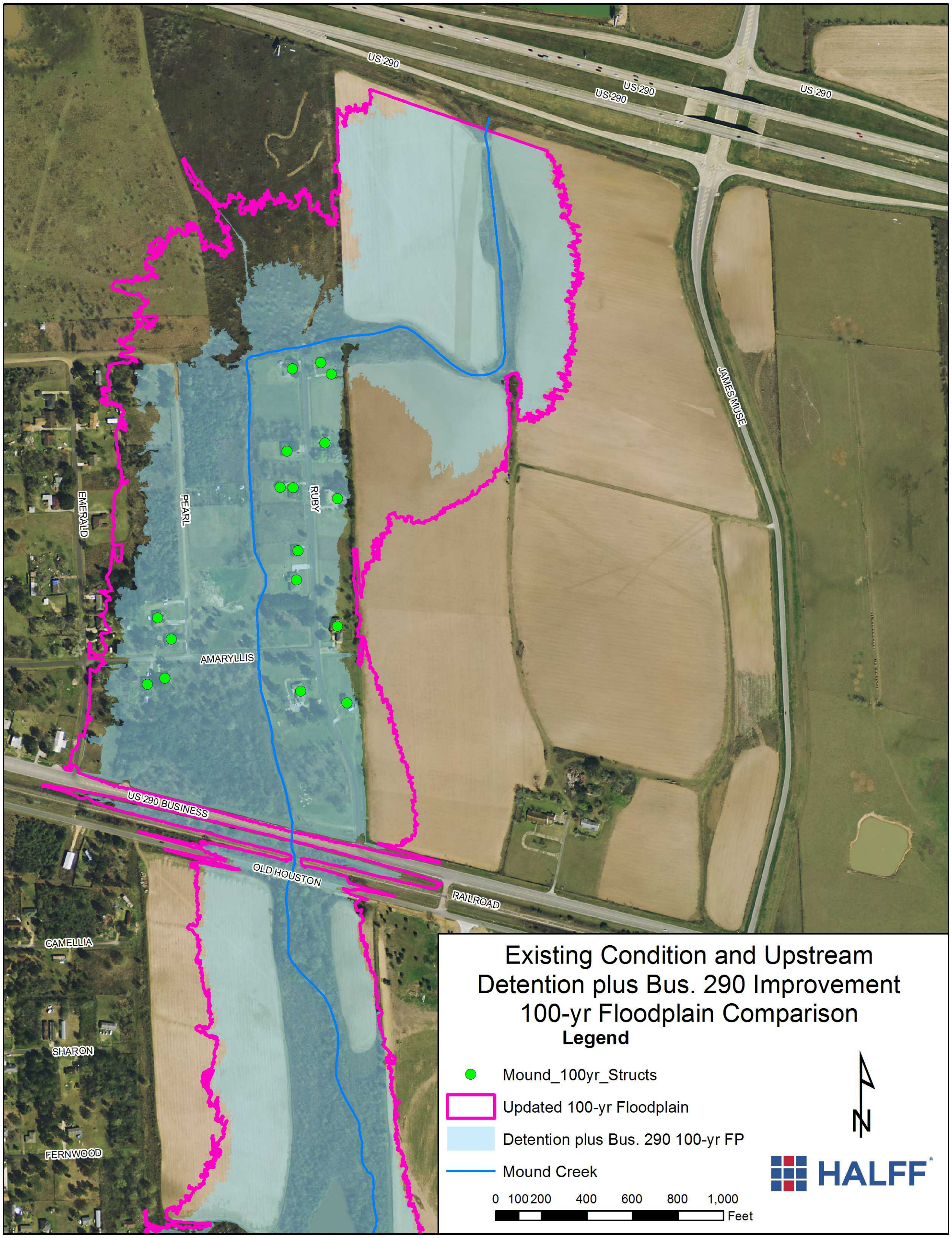

Figure B11: 100-yr Floodplain comparison between existing and detention plus culvert improvement alternative (Upper Mound)

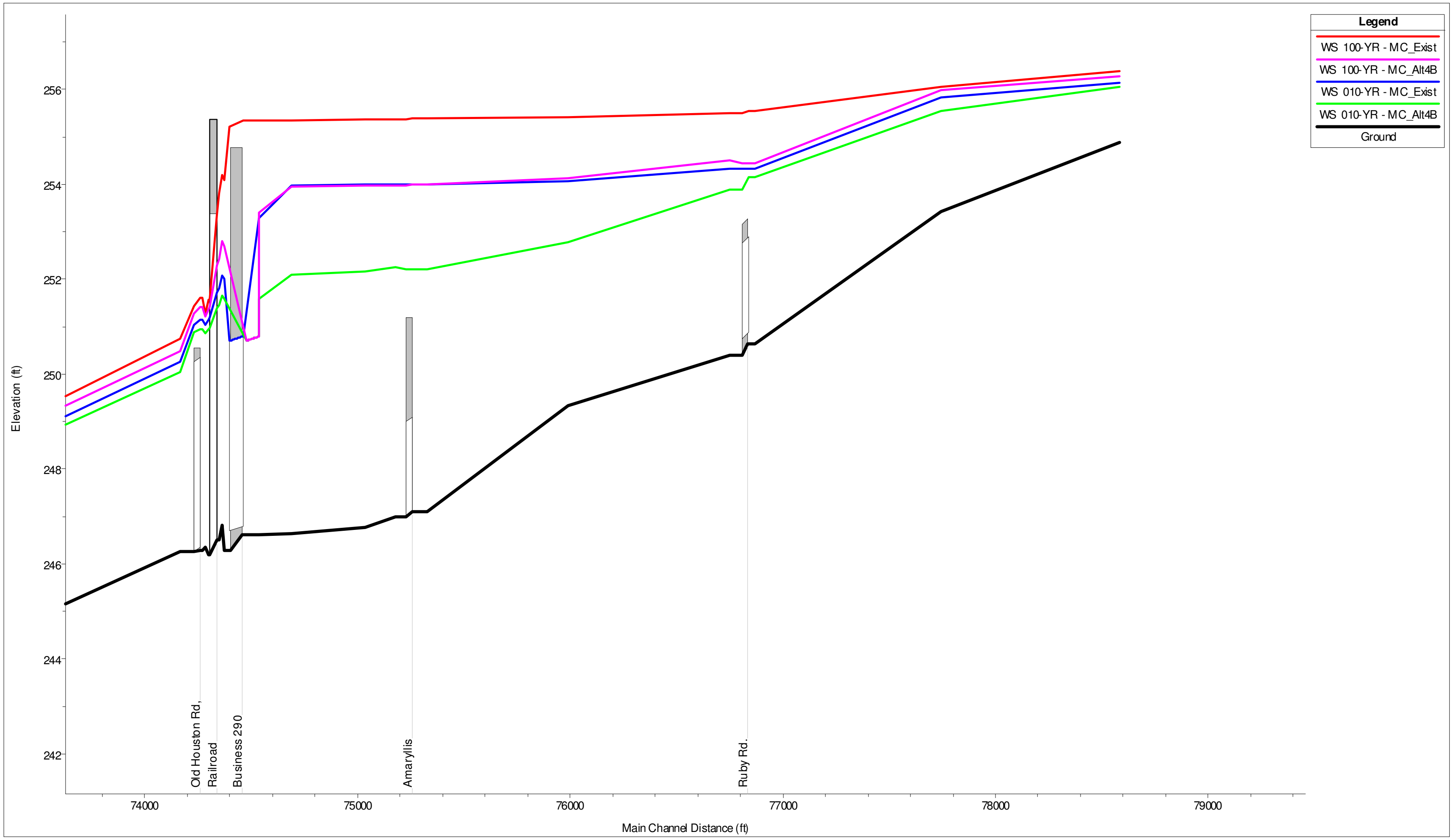

Figure B12: 100-yr and 10-yr profile comparison between existing and upstream detention plus culvert improvement alternative (Upper Mound)

Table B8: Preliminary probable cost for detention plus Bus. 290 culvert improvements Upper Mound Creek

Bus. 290 Mound Creek						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	4' X 4'	4	LF	108	70	$30,240
Wingwall	4'	2	EA	4700	2	$9,400
Cut and restore paving	N/A	1	SY	100	467	$46,667
Guard Rail	N/A	1	LF	60	460	$27,600
Guard Rail End Treatment	N/A	4	EA	2302.88	4	$9,212
Mow Strip	N/A	1	CY	306.9	11	$3,486
Excavation	N/A	1	CY	4.26	200	$852
Erosion Control (RFD)	N/A	1	LF	60	60	$3,600
Rip Rap	5"	1	CY	310.56	64	$19,876
Traffic Control	N/A	1	LS	2000	1	$2,000
Mobilization Item	N/A	1	LS	15290	1	$15,290
Engineering Design	N/A	1	LS	$25,230.00	1	$25,230
					SUM:	**$193,452**
				SUM + 20% Contingency		**$232,142**

Detention Mound Creek						
Item	Size	Number	Units	Unit Price	Quantity	Total Price
Culvert Installation	36"	4	LF	40	60	$9,600
Headwall	36"	1	EA	4000	2	$8,000
Excavation (Channel)	N/A	1	CY	6.5	1500	$9,750
Erosion Control	N/A	1	LF	30	1800	$54,000
Rip Rap	5"	1	CY	310.56	420	$130,435
Mobilization Item	N/A	1	LS	18500	1	$18,500
Engineering Design	N/A	1	LS	30500	1	$30,500
					SUM:	**$260,785**
				SUM + 20% Contingency		**$312,942**

Home Buyouts

There are seven homes within the 10-yr floodplain that lie within 400-ft of Mound Creek (Figure B12). If these homes are flooded frequently, serious consideration should be given to buying out these homes. The total appraised value of the seven homes in question is $594,050. It may be possible to obtain a FEMA grant to cost share for the buyouts possibly making this option much more cost effective than any structural solution. If the surrounding undeveloped lots are also obtained the city may consider creating a community park/greenbelt that would enhance the surrounding neighborhood as well as the City.

Figure B13. Houses to be considered for buyout option.

B.4 Waller County Alternatives

Outside of the Cities of Waller and Prairie View flood damages are minimal within the project area. However, there are two recommendations for actions that can be taken by the County to help reduce flood impacts. First, the County should ensure that public roads are passable under flood conditions to ensure the best emergency access possible to rural neighborhoods and residents. Second, Waller County should work with Harris County Flood Control District on a solution to the Cypress Creek Overflow to Addicks Reservoir just downstream of the project study limits.

Stream Crossing Improvements:

Emergencies do not cease during a flood event. Therefore, it is important that County and State maintained roads should remain as passable as possible during flood events. To help with this initiative, the County and State maintained stream crossings along the modeled reaches were evaluated to determine whether they produced adequate conveyance of flood flows. The criteria used to determine adequate conveyance, derived from TxDOT standards, is that county maintained roads should convey at least the 5-yr event and State maintained roads should convey at least the 25-yr event. Table B9 shows the results from the hydraulic model for structures that do not meet the above conveyance criteria. It is recommended that the County consider improving these crossings to increase conveyance allowing the roads to be passable during frequent flooding events.

Table B9: Structures within study area that do not meet conveyance criteria

Stream	Road	Frequency Passed
Cypress Creek	Hebert Road	None
East Fork	Charter Street	None
	Ross Road	None
Live Oak	Pattison Road	2-yr
	Hebert Road	None
	Penick Road	None
	Hoover Road	5-yr
	FM 362	10-yr
Live Oak Trib 1	FM 362	5-yr
	Davis Road	2-yr
Live Oak Unnamed Trib	Hoover Road	None
Middle Fork	FM 362	2-yr
Mound Creek	Mathis Road	None
	Penick Street	None
Snake Creek	Mathis Street	2-yr
	Rochen Road	2-yr
	Penick Road	None
	Sandwedge Road	2-yr
	Baethe Road	2-yr
South Fork	Domino Street	None
	Domino Road	None
West Fork	Owens Street	2-yr

Cooperation with Cypress Creek Overflow Issues:

The Harris County Flood Control District has recently formed a Committee to address the flood overflow issues from Cypress Creek into the Addicks Reservoir watershed. Because flooding does not stop at political boundaries it is recommended that Waller County cooperate in this effort to reduce the overflow from Cypress Creek. Previous HCFCD studies have shown that approximately 20,000 ac-ft of the overflow volume originates above the Waller County line. A potential impoundment location at the confluence of Cypress and Live Oak Creeks is shown in Figure B14. An area of 2,500 acres at an average 8-ft depth is required to store the entire 20,000 ac-ft. Further discussion and study will be required to determine the best location and exact required volume for the proposed impoundment. Another benefit of cooperation is that HCFCD has shown willingness to help fund some of the flood reduction projects in the City of Waller in return considering Cypress Creek overflow reduction alternatives that can be implemented within Waller County.

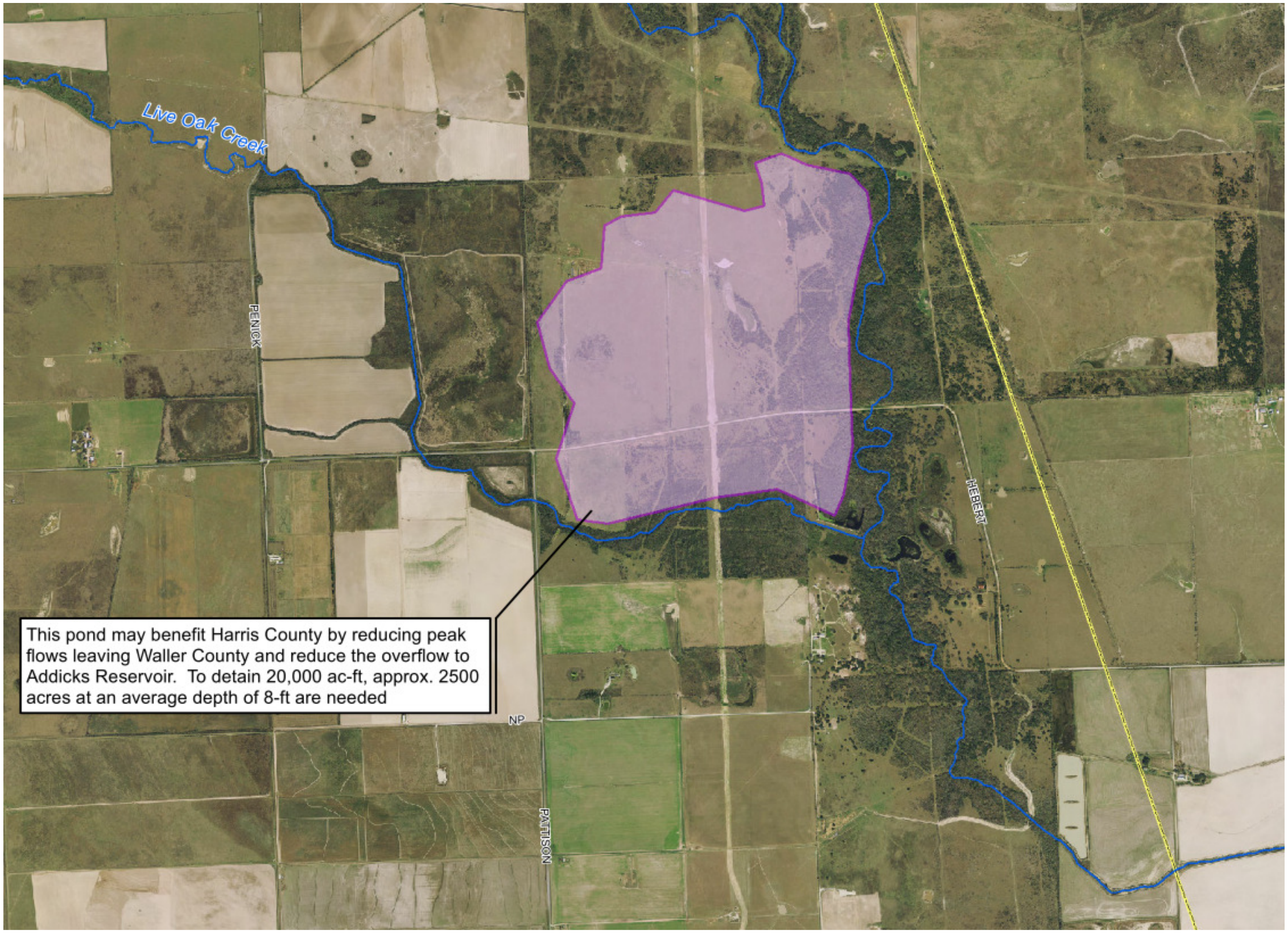

Figure B14: Proposed impoundment location to help reduce Cypress Creek overflow to Addicks Reservoir

APPENDIX C: Environmental Constraints Summary

C.1 Introduction

For the purposes of the environmental constraints review, the study area includes the Upper Cypress watershed. The study area is in both Waller and Harris Counties approximately 40 miles east of Houston. Numerous sources were reviewed to identify potential environmental constraints in the study area. Items included: socio-economic data, Texas Parks & Wildlife threatened and endangered species by county & element of occurrence locations, United States Fish & Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD) and Texas General Land Office (GLO) species habitat, protected areas and national wetland inventory, Texas Commission of Environmental Quality (TCEQ) hazardous materials including leaking petroleum storage tank locations (LPST), cultural resources data from the Texas Historical Commission (THC), and other spatial information including roads, railroads, and waterwells. An online Texas Railroad Commission (TRC) mapper was utilized to extrapolate the locations of various well data including: shut-in oil/gas, oil, gas, plugged oil/gas, permitted locations, injection/disposal, and dry wells. Oil and gas pipeline data was also gathered from the TRC. The occurrences of these constraints are displayed in Figure C1.

C.2 Socio-economics/Environmental Justice

Executive Order (EO) 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" requires each Federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations."

The study area is located in Census Tracts 6802, 6803, 6804, 6805, 5560, and 5431, as defined by the United States Census Bureau (USCB) 2010 Census. These Census Tracts have a total population of 32,787 while Waller and Harris Counties have a combined total population of 3,921,392. According to the Texas Almanac, the primary industries in Waller and Harris Counties vary, but include petroleum refining, agribusiness, construction, and education. Demographic data was reviewed to determine if a minority or low-income persons have the potential to be adversely affected by the proposed project. The data was retrieved from the USCB on August 16, 2012. Block group data from the 2010 Census indicates that approximately 62 percent of the population in the project area is comprised of minorities. Although income data is not available in the 2010 Census, the American Community Survey (ACS) provides a 5 year average of income and poverty information for the investigated geographies. The ACS is an ongoing nationwide survey that provides social, economic, and housing data every year. All ACS data are estimates; therefore, the USCB provides a margin of error (MOE) for every ACS estimate. The 2012 United States Department of Health and Human Services (USDHHS) poverty guideline for a family or household of four is $23,050. The ACS data for 2006-2010 indicate that the median household income for Waller and Harris Counties is $47,324 (MOE +/-2,979) and $51,444 (MOE +/-301), respectively. The average median household income for the study area Census Tracts is $48,929 with an average MOE of +/-$7,789. Therefore, the County and Census Tracts data show that the median household income in 2010 for all investigated geographies is greater than the 2012 USDHHS poverty guideline; however, the 2006-2010 ACS data indicates that low-income individuals live in the project area.

Although minority and low-income persons are located within the project area, the proposed action is not expected to have adverse or disproportionate impacts on minority or low-income populations. The benefits of the flood control project are expected to equally benefit all residents in Waller and Harris Counties. Public outreach planning for any future public involvement activities should take into consideration low-income and minority population.

C.3 Biological Resources

USFWS does not list any federal threatened and endangered species in Waller County; however, TPWD lists 19 state threatened and endangered species. USFWS lists 2 federal threatened and endangered species in Harris County and TPWD lists 26 state threatened and endangered species. This data was retrieved from the USFWS and TPWD county lists of Texas special species for Wallis and Harris Counties on August 15, 2012.

In addition, a database search for protected species was conducted using the Texas Natural Diversity Database (TXNDD) on August 21, 2012. The search revealed three Element Occurrence Records (records of sightings of rare or endangered species) or managed areas within 1.5 miles of the study area, which are shown in Figure C1. Given the small proportion of public versus private land in Texas, the TXNDD does not include a representative inventory of rare resources in the state. Although it is based on the best data available to TPWD regarding rare species, the data cannot provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in any area. The data cannot substitute for on-site evaluation by qualified biologists. The TXNDD information is intended to assist users in avoiding harm to rare species or significant ecological features. Refer all requests back to the TXNDD to obtain the most current information.

GLO has delineated species habitats and protected areas. None of these areas were identified in the study area. A field visit by a qualified biologist is recommended prior to construction to determine the presence or absence of suitable habitat for these protected species.

C.4 Wetlands

Wetlands are identified as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. A search of the USFWS national wetland inventory (NWI) database indicates that there are numerous wetlands in the study area. These wetlands may be jurisdictional under Section 404 of the Clean Water Act and may require a permit prior to filling or dredging. Figure C1 shows NWI locations within the Upper Cypress watershed. It is recommended that a jurisdictional determination be performed in the field prior to construction in order to determine potential impacts to the waters of the United States.

C.5 Potential Hazardous Materials

The Texas Commission of Environmental Quality known hazardous materials database was reviewed for the study area. The data includes superfund sites, municipal solid waste sites, permitted industrial hazardous waste sites, and LPST locations. One municipal solid waste site and ten LPST locations were identified within the study area. The level of contamination at the LPST sites range from "minor soil contamination" to "ground water impacts". Seven of the ten LPSTs have been listed as "case closed".

As seen on Figure C1**,** numerous wells are also located within the limits of the study area. These locations, along with the identified pipelines, are from the TRC's website. Once the perimeters of the project are established during the design phase, a comprehensive database review and site visit are recommended to determine the level of assessment necessary. A Phase I Environmental Assessment may be needed prior to construction.

C.6 Physical Constraints

Physical constraints, such as railroads and roads, are depicted in Figure C1 according to Texas Natural Resource Information Systems (TNRIS) data. Other constraints, such as water wells, are also shown. A field reconnaissance is recommended prior to construction to determine any conflicts with existing infrastructure.

C.7 Cultural Resources

Cultural resources are structures, buildings, archeological sites, districts (a collection of related structures, buildings, and/or archeological sites), cemeteries, and objects. Both federal and state laws require consideration of cultural resources during project planning. At the federal level, the National Environmental Policy Act and the National Historic Preservation Act of 1966, as amended, among others, apply to projects such as this one. In addition, state laws such as the Antiquities Code of Texas apply to these projects. Compliance with these laws often requires consultation with the THC/Texas State Historic Preservation Officer and/or federally-recognized tribes to determine the project's effects on cultural resources. Previously identified cultural resources such as cemeteries, national register properties, and historical makers were reviewed from the THC data, and are shown Figure C1. To comply with federal and state laws regarding review and coordination, a site visit by an architectural historian and an archeologist to determine the likelihood of impacts on significant cultural resources would likely be required prior to construction. If any historical or archeological constituents are unexpectedly encountered in the study area during construction operations, appropriate measures should be taken with local, state, and federal officials.

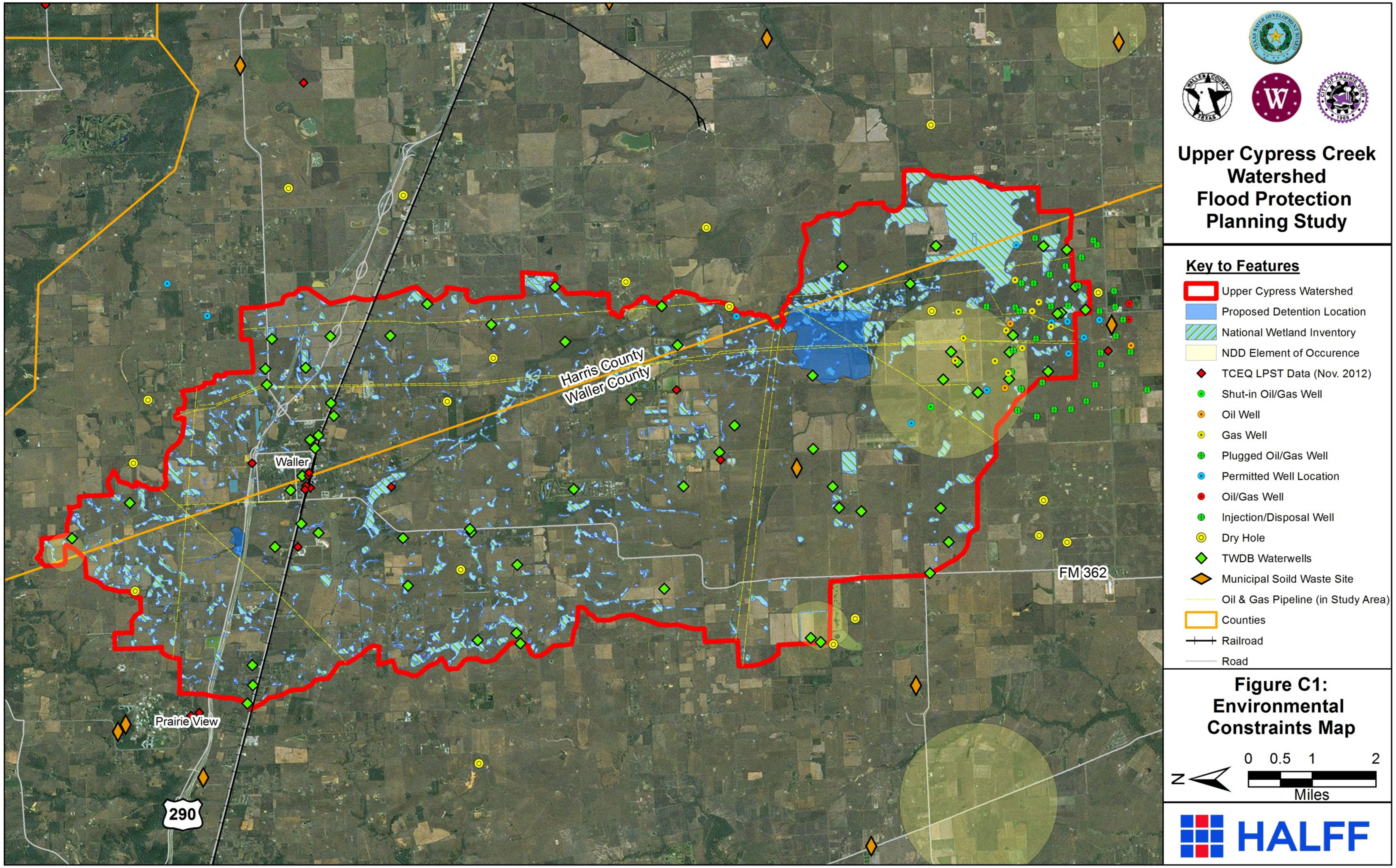

*Figure has been reduced to fit document and is not to scale.
Element of Occurrence Data is sensitive and is not for public use.

All well and pipeline data was georeferenced from TRC data and is for visual purposes only.