North Central Texas Council of Governments

Integrating Transportation and Stormwater Infrastructure

Storm Shifting

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TEXAS WATER DEVELOPMENT BOARD

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integrating **Transportation** & **Stormwater Infrastructure**

Integrating Transportation and Stormwater Infrastructure (TSI) Storm Shifting Analysis

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1 Executive Summary

Task 3.1 (Project Area Hydrology and Hydraulics Assessment and Scenarios) of the 2021 TSI project agreement between the TWDB and the NCTCOG included a deliverable to perform storm shifting to simulate the impact of larger regional storms over the Project Area and perform necessary modeling and analysis of historic regional storms to determine impact if a similar event occurred over the Project Area. The purpose of this analysis is to simulate the impacts of observed regional storms and to provide communities and stakeholders with plausible "what-if" scenarios for emergency planning. This analysis will also allow the study team to demonstrate the impacts that future urban development.

Transposing or shifting a storm event is a scientific and engineering concept that has been well documented since the 1950s (HMR35) (Myers, 1959). The concept is based on the idea that an observed storm could occur over nearby watersheds where the meteorological forces and environment would be the same as the observed storm location. In his landmark paper on storm transposition, Vance Myers of the U.S. Weather Bureau put it this way, "storm experience over a single basin alone is not a dependable indicator of what might occur over that basin in the future… Flood records are broken all the time, by wide margins" (Myers, 1966).

A storm shifting analysis was performed for the Village Creek and Mary's Creek watersheds in the TSI project area, where an observed storm from 2004 was shifted to a position above the Village Creek at Everman and Mary's Creek at Benbrook USGS gages. The peak rainfall intensity of the 2004 observed storm was located between Mansfield and Cedar Hill, approximately over Joe Pool Lake, which has flood storage capacity to manage flood risk downstream. The storm shifting analysis considered shifting the peak rainfall of the event over the Village Creek watershed and Mary's Creek watershed where there is no flood risk management reservoir to regulate flood releases. The result of the storm shifting analysis was an increase in peak discharges in Village Creek at Everman, TX of approximately 3.5 times and an increase in peak discharge in Mary's Creek at Benbrook of approximately 90 times compared to the originally observed events for these watersheds. The increase in discharges resulted in increased flood depths and an increased inundation area. The modeling and analysis for this storm shifting and other analysis throughout the TSI region are provided in this report.

2 Data Sources

This section describes the data that was collected /reviewed for the hydrologic and hydraulic study efforts, including geospatial and climatic information, field observations and previous reports for the pilot study area.

2.1 GIS Data

Data from different sources were gathered and processed using the latest Geographic Information System (GIS) tool.

Table 2-1. GIS Data Sources

Data Type	Data Source	Description of the Data
Study Area	2D Pilot Study	Used as rough outline of the 2D pilot study area above Lake Arlington
Terrain	Texas Water Development Board (TWDB)	Digital Elevation Model (DEM) of the Village Creek pilot area with a 3-ft cell size bathymetry.
Stream Centerlines	InFRM WHA model Data National Hydrography Dataset (NHD)	These stream centerlines layers from the InFRM WHA study and the NHD database.
Roads	Texas Department of Transportation (TXDOT)	Locations of current and future TXDOT roads
Bridges	Texas Department of Transportation (TXDOT)	Locations of current and future TXDOT bridges
Percent Impervious	North Central Texas Council of Governments (NCTCOG) and EPA	Percent impervious raster for the current and future years generated from NCTCOG and EPA ICLUS land use data for the TSI project.
Percent Urban	North Central Texas Council of Governments (NCTCOG) and EPA	Percent urban raster for the current and future years generated from NCTCOG and EPA ICLUS land use data for the TSI project.
Dams	National Inventory of Dams (NID)	Dam locations from the National Inventory of Dams
Reservoirs	US Army Corps of Engineers, Fort Worth District Database (USACE-SWF)	A polygon shapefile of the major lakes and reservoirs in the west fork of the Trinity River basin.

2.2 HEC-HMS Data

For this study, the existing detailed Interagency Flood Risk Management (InFRM) Trinity Watershed Hydrology Assessment (WHA) HEC-HMS model was used to simulate the 2004 storm before and after shifting over Village Creek and Mary's Creek. Prior to performing storm shifting, the HEC-HMS model was enhanced for the TSI project in accordance with the TSI West Study Region HEC-HMS Model Development Standard Operating Procedures (SOP) (USACE 2025). First, additional subbasins were added to the HEC-HMS model at junctions which corresponded to TSI roadway junctions of interest and known flooding locations provided by Tarrant County.

Subbasins were delineated during the InFRM WHA study for the entire Trinity River basin, prior to this storm shifting study. These subbasins extend beyond the area of interest (AOI), but portions of it overlap with areas where Tarrant County noted flood locations. The resulting points shapefile of subbasin outlets was used in conjunction with the Tarrant County known locations of frequent roadway flooding as a guide to estimate runoff. The Village Creek watershed above Lake Arlington from the InFRM WHA study was represented by 3 subbasins but was subdivided into 106 subbasins for the TSI project (Figure 2-1).

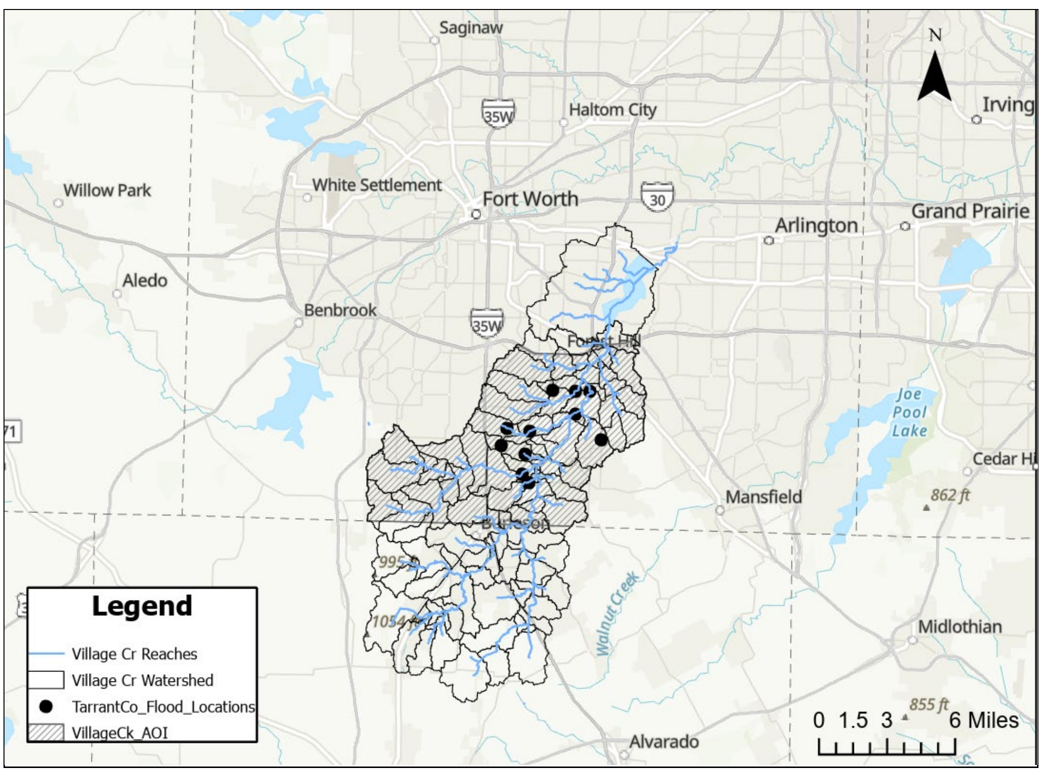

Figure 2-1. Subbasin Outlets and Known Flood Locations in Village Creek Pilot Area for Runoff Analysis.

The Mary's Creek watershed from the InFRM WHA study was represented by a single subbasin but was subdivided into 29 subbasins for the TSI project (Figure 2-2).

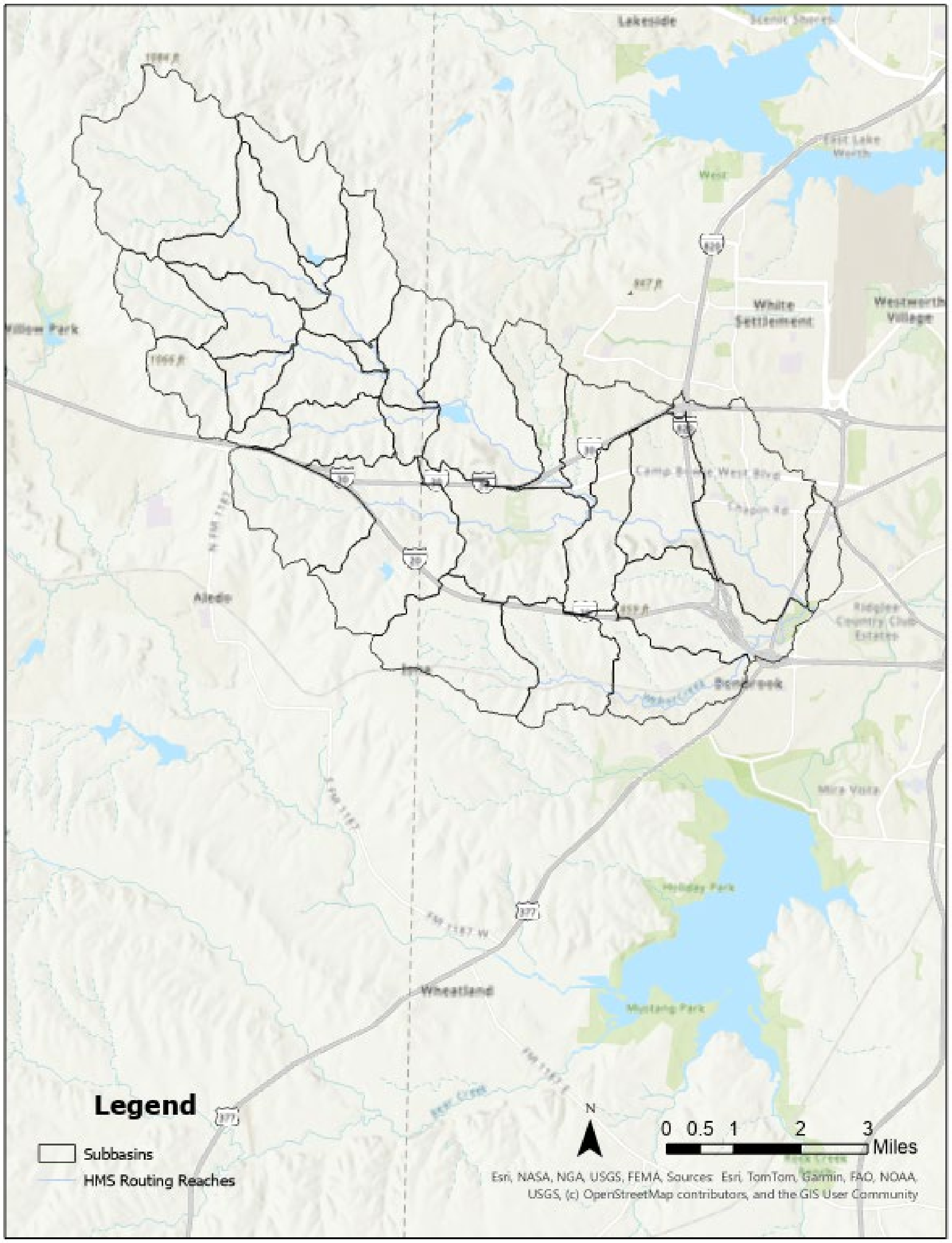

Figure 2-2. Subbasin Outlets in Mary's Creek for Runoff Analysis.

After the watersheds were subdivided into additional subbasins, an existing conditions (2016) basin model was utilized with the additional subbasins and "calibrated" to match the InFRM WHA HEC-HMS results at their common locations. Finally, the existing basin model was updated to match 2020 impervious conditions, and one future condition basin model was created representing the year 2070, based on future conditions data provided by the NCTCOG. These models were used to simulate the 2004 storm shifted to a proposed new location and to evaluate the resulting flood conditions in both the 2020 and 2070 conditions.

2.3 HEC-RAS Data

For this study, the existing FEMA Base Level Engineering (BLE) HEC-RAS model for the Lower West Fork Trinity River was used as the base model to simulate the flooding during the 2004 storm before and after shifting the observed storm events. Prior to performing storm shifting, the HEC-RAS model was enhanced for the TSI project in accordance with the TSI Project West Study Region HEC-RAS Model Development SOP (USACE 2025). A high-resolution digital elevation model (DEM) was used for the development of the hydraulic model with a 1-meter resolution. This DEM was created from the 2024 LiDAR data that Tarrant County provided. A 2021 land use dataset that was provided by the TSI West project was associated with the new geometry. Culvert and bridge data were incorporated into the hydraulic model based on geometric information obtained from Texas Department of Transportation (TxDOT) As-Built drawings. A total of 51 structures were added to the Village Creek model, while 22 were added for Mary’s Creek, including both culverts and bridges, were modeled in the system.

2.3.1 Village Creek

Flow hydrographs and normal depths were assigned as boundary conditions for the Village Creek watershed. Seven external boundary condition lines were connected to the study area, with appropriate friction slopes derived from terrain elevation data. Additionally, 66 flow hydrograph locations were specified in the HEC-RAS model, and corresponding hydrographs generated from the HEC-HMS model were incorporated for simulations (Figure 2-3).

An overlay of the watershed subbasins was used to define hydrograph inflow locations. If a subbasin was located within the study area, local runoff results were directly used. For subbasins located outside the HEC-RAS model domain, cumulative flow hydrographs were applied at junctions to represent inflows from upstream areas.

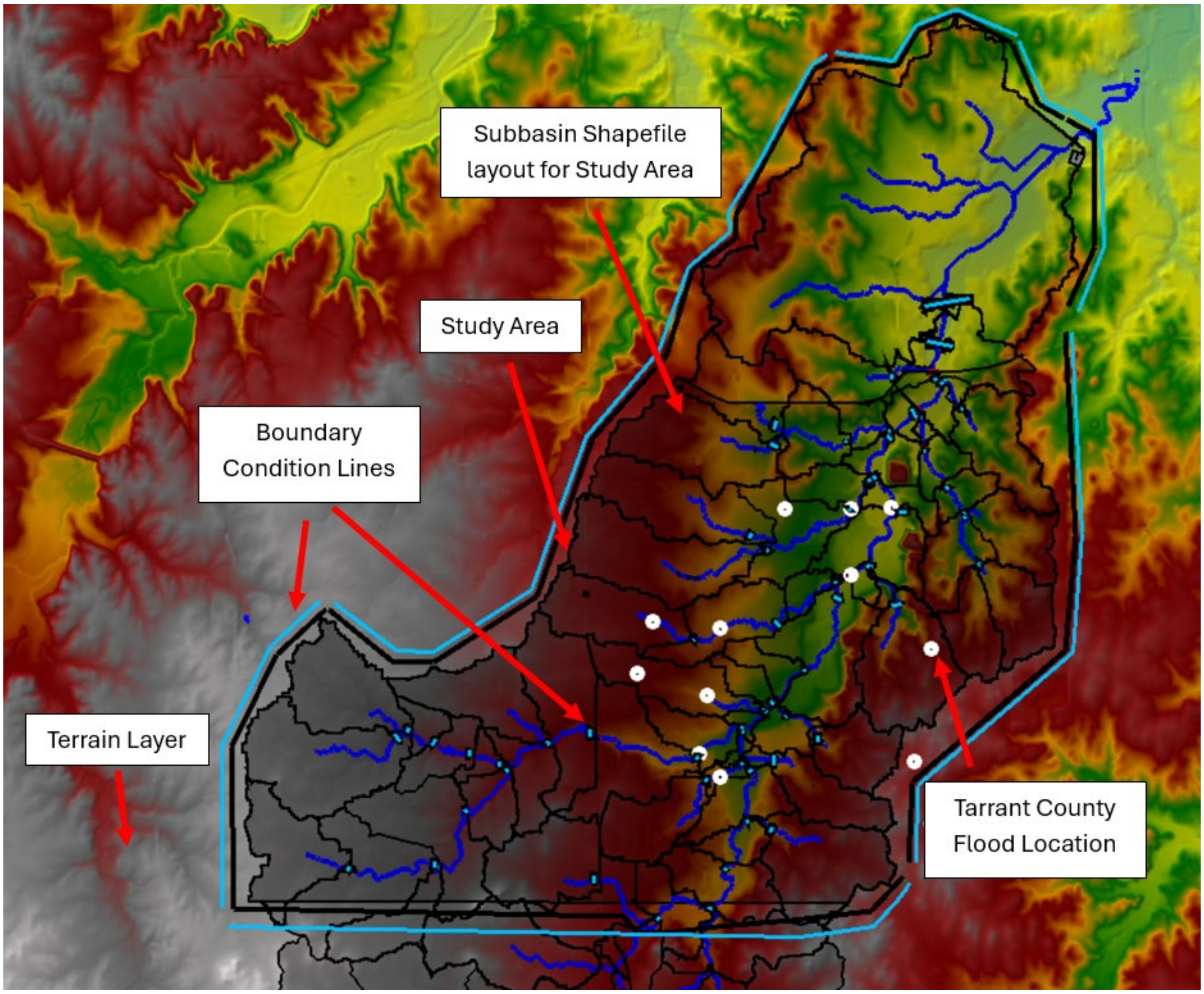

Figure 2-3. RAS-Mapper View of Terrain and Boundary Condition lines for Village Creek Study Area

2.3.2 Mary's Creek

Flow hydrographs and normal depth were assigned as boundary conditions for the Mary's Creek watershed. One external boundary condition line was added at the downstream end of the model, with appropriate friction slope derived from terrain elevation data. Additionally, 3 flow hydrograph locations were specified in the HEC-RAS model, and corresponding hydrographs generated from the HEC-HMS model were incorporated for simulations (Figure 2-4). The Mary's Creek HEC-RAS model developed for TSI had many more elements but the storm study area for the storm shifting analysis is focused between Loop 820 and Hwy 377 where several homes are located within the existing FEMA Floodway (Figure 2-5).

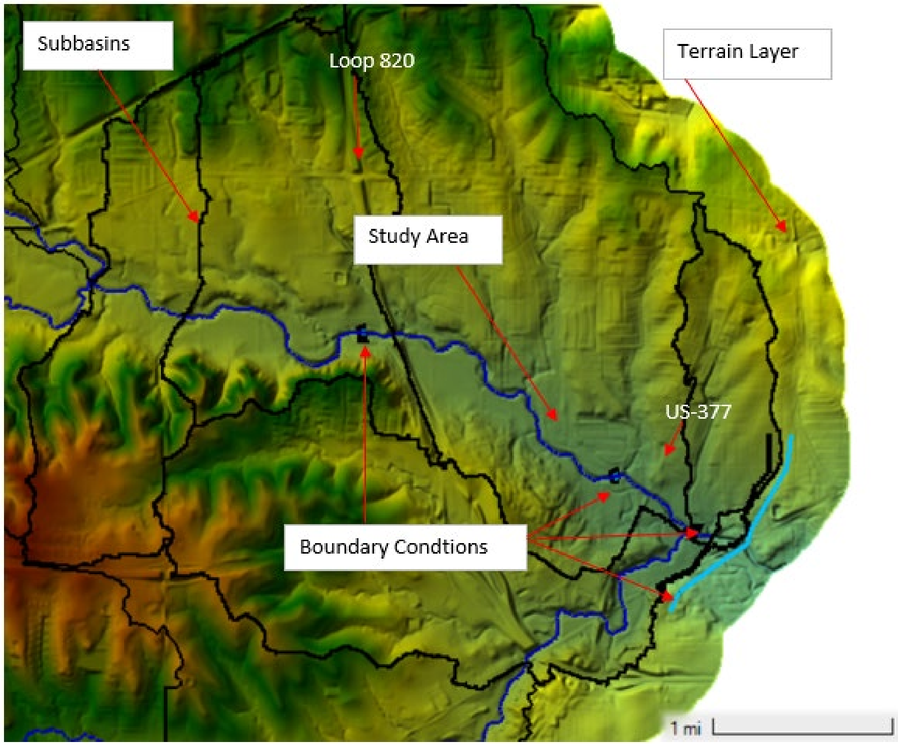

Figure 2-4. RAS-Mapper View of Terrain and Boundary Condition lines for Mary's Creek Study Area

Figure 2-5. Structures Located within the FEMA Floodway between Loop 820 and US-377

2.4 Meteorologic Data

USACE compiled a list of observed regional storms that are suitable for shifting over the TSI project's watersheds of interest. USACE identified these storms by researching calibration events from the Trinity InFRM Watershed Hydrology Assessment (InFRM, 2021), previous USACE studies in the Upper Trinity watershed, the Texas Storm Study (InFRM, 2024), and historic flood reports and storm reports from the U.S. Geological Survey (USGS) and the National Weather Service (NWS). The resulting storm list for the TSI project is provided in Table 2.2.

Table 2-2. TSI Storm List

Storm Dates	Storm Center Location	Storm Type	Storm Duration (hours)	Max Point Depth (inches)	Approx AEP of the Storm*	Hourly Gridded Precip Available
25 May 1908	near Dallas, Texas	Convective	72	15	0.2% AEP (500-yr)	No
April 1922	near Fort Worth, Texas	Convective	24	8	2% AEP (50-yr)	No
May 1949	near Benbrook, Texas	Convective	12	11	0.1% AEP (1,000-yr)	No
03-05 Aug 1978	near Albany, Texas	Tropical	55	32.7	> 1,000-yr	Yes
11-14 Oct 1981	near Clyde, Texas	Tropical	72	23.4	> 1,000-yr	Yes
25-27 Apr 1990	near Sidney, Texas	Convective	24	17.7	> 1,000-yr	Yes
01-03 May 1990	near Anna, Texas	Convective	36	9.1	2% AEP (50-yr)	Yes
17-24 Dec 1991	near Morgan, Texas	Convective	24	8.3	2% AEP (50-yr)	Yes
03-04 Jun 2000	near Joshua, Texas	Convective	24	11.4	1% AEP (100-yr)	Yes
06-09 Jun 2004	near Boyd, Texas	Convective	72	11.4	1% AEP (100-yr)	Yes
28-30 Jul 2004	near Mansfield, Texas	Convective	24	13.7	0.1% AEP (1,000-yr)	Yes
16-18 Jun 2007	near Gainesville, Texas	Convective	7	9	0.5% AEP (200-yr)	Yes
10-19 Sep 2009	near Duncanville, Texas	Convective	72	12	1% AEP (100-yr)	Yes
05-17 Sep 2010	widespread around DFW	Tropical	48	14.3	0.2% AEP (500-yr)	Yes
07-26 May 2015	near Gainesville, Texas	Convective	19 days	21	0.5% AEP (200-yr)	Yes
12-30 Jun 2015	near Nocona, Texas	Tropical	48	13.6	0.2% AEP (500-yr)	Yes
22-29 Oct 2015	near Dawson, Texas	Tropical	48	22.7	> 1,000-yr	Yes
26Nov - 08Dec 2015	near Allen, Texas	Convective	48	9.6	2% AEP (50-yr)	Yes
12-13 Jun 2016	near Richland, Texas	Convective	12	9.2	1% AEP (100-yr)	Yes

3 Storm Shifting

3.1 Storm Selection

The July 2004 storm event was selected for storm shifting modeling due to its proximity to the Village Creek and Mary's Creek watersheds, the 24-hour storm duration, and the high recurrence interval of the event. The July 2004 storm event had a max point rainfall depth of 13.7-inches. Figure 3-1 shows the position of the July 2004 storm in relation to the Village Creek and Mary's Creek.   The storm was shifted approximately 13 miles to the Village Creek Watershed and 31 miles to the Mary's Creek Watershed.

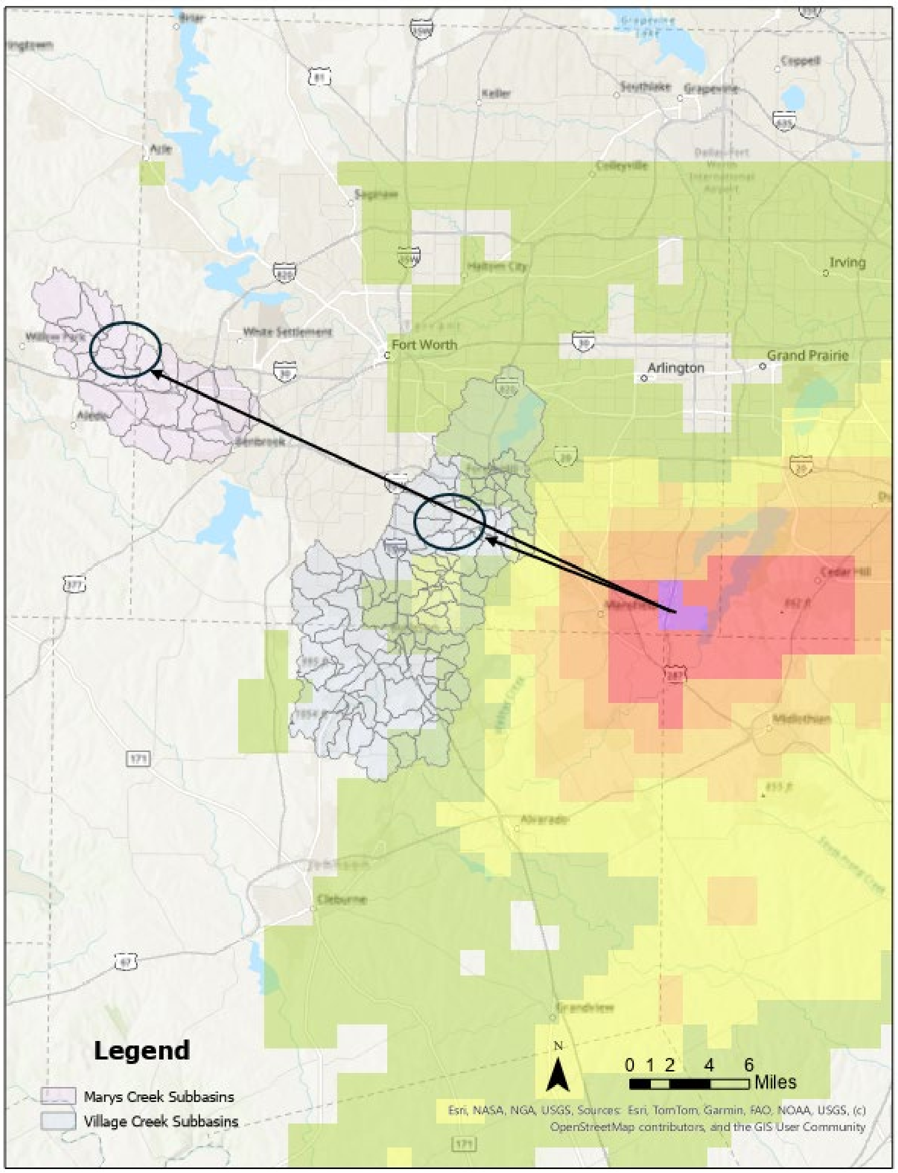

Figure 3-1. Positioning of the Observed and Shifted July 2004 Storms

3.2 HEC-HMS Results

An optimization analysis was performed in HEC-HMS in accordance with the TSI Storm Shifting SOP (USACE 2025) to determine the optimal location of the shifted July 2004 storm event to produce the greatest peak discharge at the critical location. The critical locations for this analysis were the USGS gage 08048970 Village Creek at Everman, TX and Loop 820 along Mary's Creek. Figures 3-2 and 3-3 present a comparison of discharge peaks at the USGS gage 08048970 Village Creek at Everman, TX and USGS gage 08047050 Mary's Creek at Benbrook, TX, before and after the storm shift for current and future conditions. The result of the storm shifting analysis was an increase in peak discharges in Village Creek (Figure 3-2) of approximately 3.5 times and an increase in peak discharge in Mary's Creek (Figure 3-3) of approximately 90 times compared to the originally observed events for these watersheds. In contrast, discharge peaks at certain junctions located farther south were seen diminished discharge peaks due to the shift. Additionally, the shape and orientation of the storm itself may contribute to these variations, as certain configurations can direct more intense rainfall toward specific areas, amplifying or diminishing peak discharges accordingly.

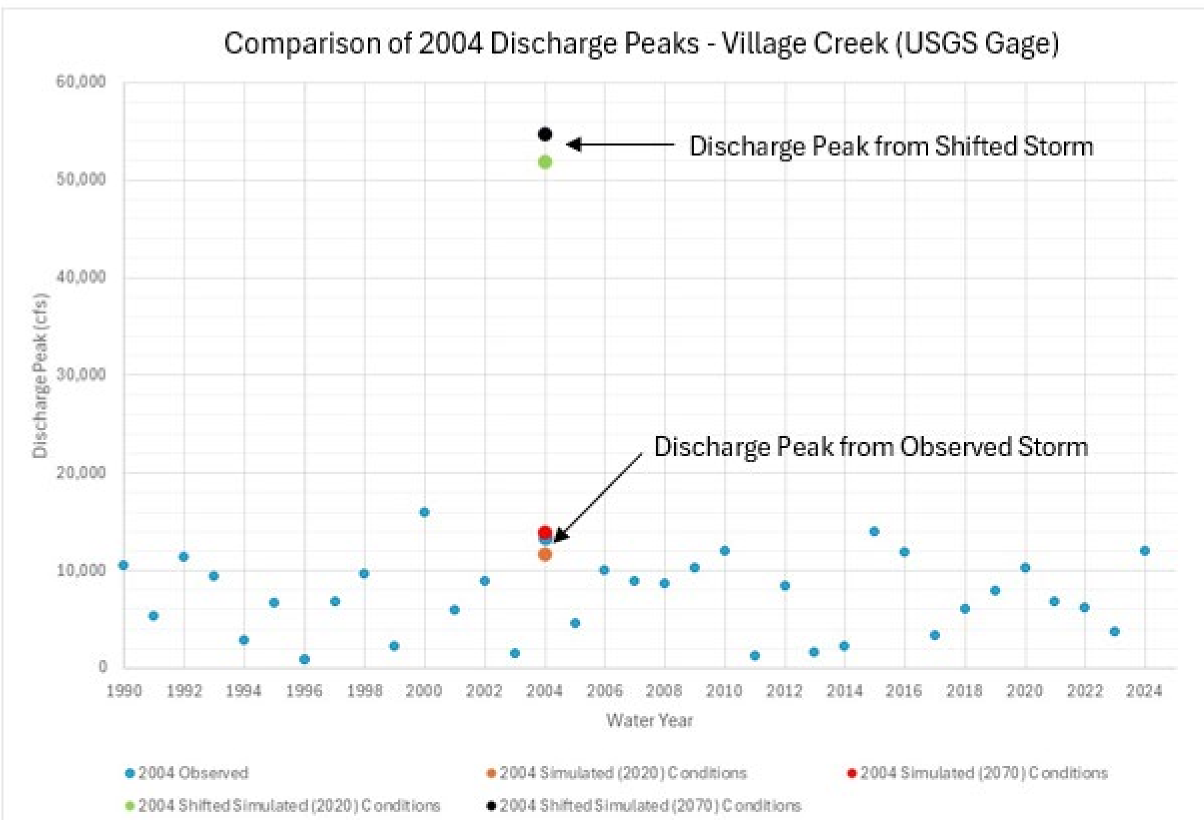

Figure 3-2. Illustration of the Optimized Peak Discharge at USGS 08048970 Village Creek at Everman, TX., During the July 2004 Storm Event for Current and Future Conditions

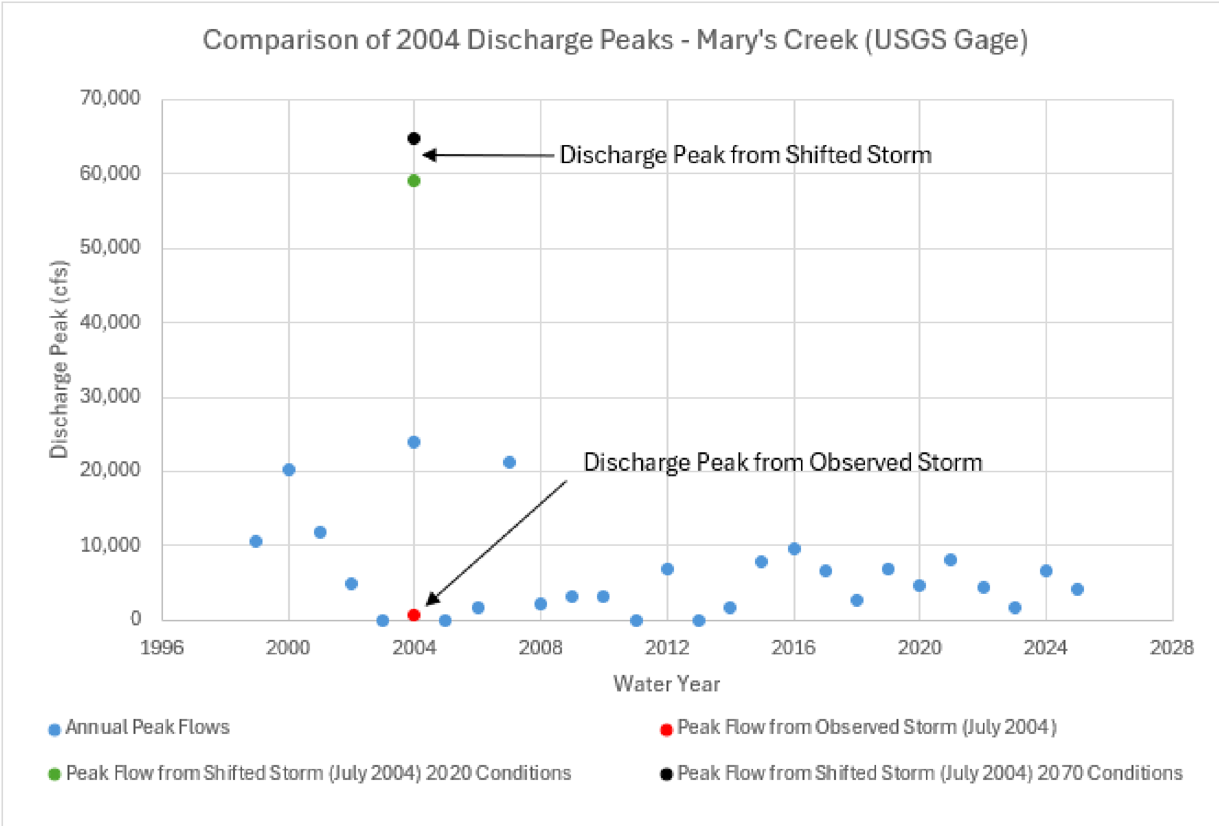

Figure 3-3. Illustration of the Optimized Peak Discharge at USGS 08047050 Mary's Creek at Benbrook, TX., During the July 2004 Storm Event for Current and Future Conditions

3.3 HEC-RAS Results

The discharges from the shifted 2004 event were input into the TSI enhanced HEC-RAS model and the flood inundation was compared to the originally observed flows. The increase in discharges resulted in increased flood depths and an increased inundation area along Village Creek and Mary's Creek. For example, along Village Creek, the flood depths at Shelby Road increased by over 2 feet and the flood depths at Everman Kennedale Burleson Road increased by over 3 feet. Both road crossings along Village Creek are known areas of flooding. Figure 3-3 provides a comparison of the flood inundation maps for the 2004 storm before and after storm shifting were applied. For Mary's Creek the flood depths increased over 20 feet with the observed flood being limited to the lower portion of the channel and the flood from the shifted storm causing significant overbank flooding and roadway overtopping (Figure 3-4).

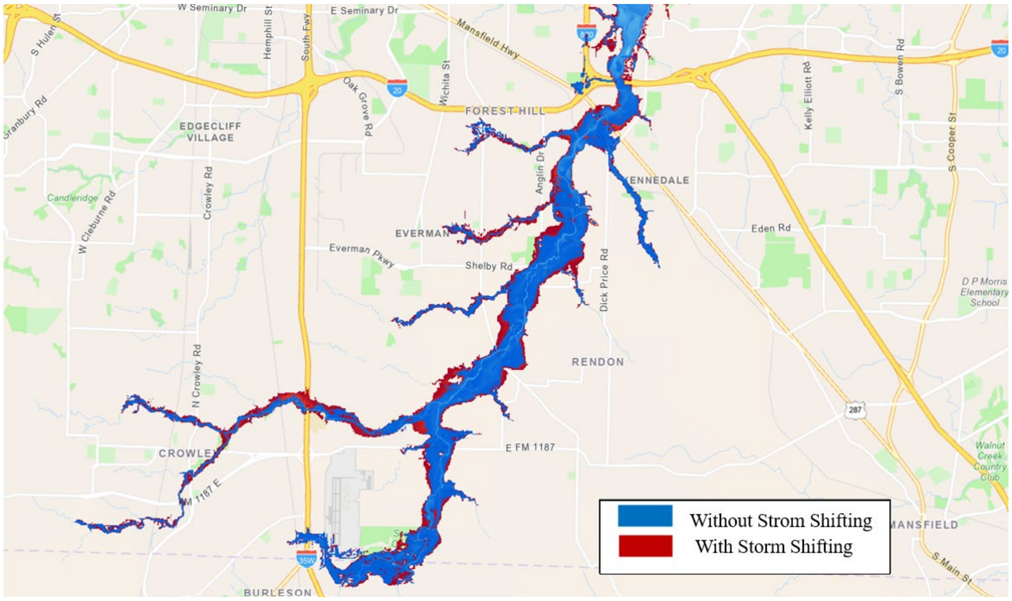

Figure 3-3. Inundation Map Comparison of 2004 Storm Before and After Shifting for Current Conditions Over the Village Creek Watershed

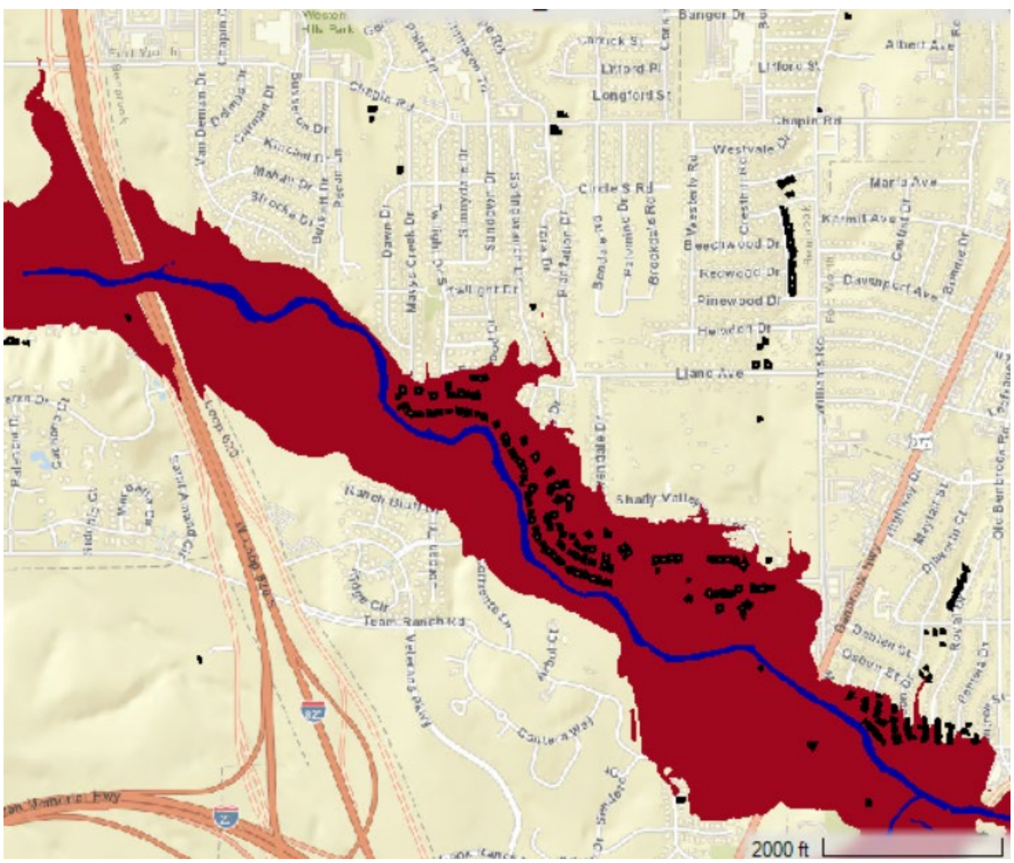

Figure 3-4. Inundation Map Comparison of 2004 Storm Before (Blue) and After (Red) Shifting for Current Conditions Over the Mary's Creek Watershed

4 Conclusion

This study demonstrates the profound impact of storm shifting on understanding a community's true flood vulnerability. By repositioning the historical July 2004 storm from its observed location over Joe Pool Lake—an area with flood control measures—to the unprotected watersheds of Village Creek and Mary's Creek, the analysis revealed a dramatically different and more severe flooding scenario.

The results were striking: the shifted storm produced peak discharges approximately 3.5 times higher in Village Creek and an extraordinary 90 times higher in Mary’s Creek compared to the observed event. These surges in flow led to significant increases in flood depths—exceeding 3 feet at key road crossings on Village Creek and over 20 feet along Mary’s Creek—and substantially expanded the flood inundation area.

This analysis underscores a critical principle: a community's own flood history is not a complete indicator of its future risk. As meteorological conditions can cause a storm to track slightly differently, this study provides a plausible "what-if" scenario that is essential for comprehensive flood hazard assessment. The information from storm shifting equips communities and emergency managers with a more realistic understanding of potential flood hazards, allowing for better-informed emergency planning, infrastructure development, and ultimately, the creation of a more resilient community.

5 References

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