North Central Texas Council of Governments

Integrating Transportation and Stormwater Infrastructure

Corridor Development Certificate Program Expansion

July 2026

The Texas General Land Office provided guidance, oversight, and funding for this study.

This study was also funded by the Texas Water Development Board and Texas Department of Transportation.

integrating Transportation & Stormwater Infrastructure

Integrating Transportation and Stormwater Infrastructure (TSI)

Evaluation of Opportunities to Expand the Corridor Development Certificate Process into the TSI Project Area

USACE: Vincent A. Geracci, PE, CFM

1 Executive Summary

Task 3.5 (Managing Land through Strategic Planning and Development Regulations) of the 2021 TSI project agreement between the Texas Water Development Board (TWDB) and North Central Texas Council of Governments (NCTCOG) included a deliverable to "evaluate opportunities to expand the Corridor Development Certificate (CDC) process into the project area." The purpose of this task is to evaluate regulatory, strategic planning elements, and tools that could be adopted in a relatively short-term timeframe that would enhance the communities existing flood damage prevention regulations. The expansion of the CDC program into communities within the TSI project area would be one potential tool to accomplish this purpose.

The expansion of the CDC program would provide communities with the opportunity to adopt the CDC Common Regional Criteria, which requires floodplain development to maintain existing floodplain storage volumes while ensuring no flood elevation increases. Adopting these criteria would help stabilize flood risks as the floodplain develops in the short term, while separate TSI mitigation solutions are pursued for the greater project area in the long term. Additionally, communities that choose to participate in the CDC program would be able to maintain a CDC consolidated floodplain model (CDC Consolidated Model) as a tool to assist floodplain development, similar to the model currently maintained by the United States Army Corps of Engineers (USACE) and NCTCOG along the Trinity River and its tributaries. Maintaining this CDC Consolidated Model would provide the community with a more holistic watershed analysis that assesses the cumulative impacts of floodplain developments, rather than the piece-meal approach typically employed for each new development. The modeling tool would also provide developers with a consistent modeling approach and process to follow, which would streamline floodplain development reviews and ensure the Common Regional Criteria is followed.

Due to the size and scope of the TSI project area, a smaller scale pilot study was developed to evaluate the process of expanding the CDC program. The Town Creek watershed in the City of Weatherford was selected for the pilot study due to the expressed interest by the City of

Weatherford and the availability of existing modeling. Existing hydrologic and hydraulic models for Town Creek were available from the Federal Emergency Management Agency (FEMA) Flood Risk Identification (FRI) study prepared in March 2020. These existing models were leveraged to develop CDC models based on 2055 future conditions. The purpose of this report is to document the process followed in the pilot study and provide guidance to communities interested in replicating this process.

The general steps to convert existing models to CDC expansion models are as follows:

1. Obtain and review existing FEMA (or best available) hydraulic model.
2. Obtain and review existing FEMA (or best available) hydrologic model.
3. Convert hydrologic model to CDC methodology
    a. Determine USACE Fort Worth District Initial and Constant Losses
    b. Determine USACE Fort Worth District Synder Unit Hydrograph parameters
    c. Develop 2055 Land Use conditions percent impervious and urbanized
    d. Set up Frequency Storm simulations for the CDC storm events
4. Develop the Standard Project Flood (SPF) storm in USACE's Hydrologic Engineering Center's Meteorological Visualization Utility Engine (HEC-MetVue) simulation platform
5. Develop the SPF hydrologic simulation with gridded precipitation
6. Add a new plan to the hydraulic model for the CDC expansion run
7. Incorporate CDC flows into the hydraulic model for the 100-year flood, or 1% annual exceedance probability (AEP) flood, and SPF profiles
8. Compare the CDC expansion results to the existing condition results
9. Develop inundation mapping for the CDC extents
10. Import the CDC expansion plans into the CDC Consolidated Model

This report provides the detailed explanation of each step performed for the Town Creek pilot study. This report also addresses how these steps may differ for other communities who may be interested in joining the CDC program but have different types of available models. Finally, this report addresses the programmatic steps and implications of expanding the CDC program to new communities in the TSI study area.

2 CDC Program and Background

2.1 Purpose

The Corridor Development Certificate (CDC) Program affirms local government authority for local floodplain management and establishes a set of Common Regional Criteria and procedures for development within the Trinity River Corridor. The goal of the CDC Program is the stabilization of flooding risks along the Trinity River Corridor in North Central Texas. The CDC Program incorporates future watershed conditions as a consideration in floodplain development decisions. As floodplain development continues, standards have been established to ensure that this development does not exacerbate flooding. The CDC Program is intended to be consistent and complementary with other member community floodplain permit requirements. Each member community retains development authority within its jurisdiction. The CDC Program does not replace or substitute for other state or federal programs. Member communities may choose to incorporate the CDC Common Regional Criteria into existing permitting strategies for other floodplains throughout their respective communities.

2.2 History

The United States Army Corps of Engineers (USACE) - Fort Worth District completed the Final Regional Environmental Impact Statement Trinity River and Tributaries – 1988 (TREIS) which determined that the cumulative impact of allowing individual development projects in the upper Trinity River floodplain could be both measurable and significant. The TREIS also indicated that the permitting approach adopted by the USACE had the potential to significantly reduce flood hazards. Based on the TREIS findings, the USACE issued a Record of Decision (ROD) in April 1988 specifying criteria the USACE would use to evaluate Section 404 permit applications in the TREIS study area. In response to the TREIS and its ROD, the cities and counties in the Trinity River Corridor formed the Trinity River Corridor Steering Committee (Steering Committee), facilitated by the North Central Texas Council of Governments (NCTCOG). The Steering Committee adopted a Draft Statement of Principles for Common Permit Criteria (January 1988), a Resolution for a Joint Trinity River Corridor Development Certificate Process (December 1988), and a Regional Policy Position on the Trinity River Corridor (January 1989). The Steering Committee approved the first edition of the CDC Manual on 23 May 1991. Nearly two years later, all member communities officially amended their floodplain ordinances to adopt the CDC Common Regional Criteria and process.

2.3 CDC Consolidated Model

The USACE - Fort Worth District, in cooperation with the NCTCOG Flood Management Task Force, created a first-ever CDC Consolidated Model in 2023 representing both the FEMA and CDC programs within a combined geo-referenced HEC-RAS model. The CDC Consolidated Model is part of a streamlined process which addresses the requirements of both programs. It improves efficiency and demonstrates a continued emphasis on proactive flood risk management in the Upper Trinity watershed. However, each of the six hydraulic unit code (HUC)-10

watersheds are rapidly developing. The TSI project area ultimately flows into the current CDC area of jurisdiction, and as such, will inevitably impact future flooding in the Dallas-Fort Worth Metroplex. Therefore, it is imperative to consider expanding the CDC program into the TSI area to help mitigate negative flooding impacts resulting from future development, both in the study area and downstream.

3 CDC Expansion

3.1 Solicited Stakeholder Interest

The TSI Technical Advisory Group (TAG), TSI Steering Committee, and other advisory groups solicited stakeholder interest in a smaller focus area (West Phase One Area) regarding expanding the CDC Program into their respective communities. The West Phase One Area (Figure 3-1) consists of 48 cities, and 7 counties (Dallas, Ellis, Hood, Johnson, Parker, Tarrant, and Wise) in addition to the water and wastewater providers and other stakeholders. Seven communities that currently do not participate in the CDC program with the largest population in the West Phase One Area, according to NCTCOG 1 January 2023 estimates, are Mansfield, Burleson, Midlothian, Weatherford, Crowley, Decatur, and Bridgeport.

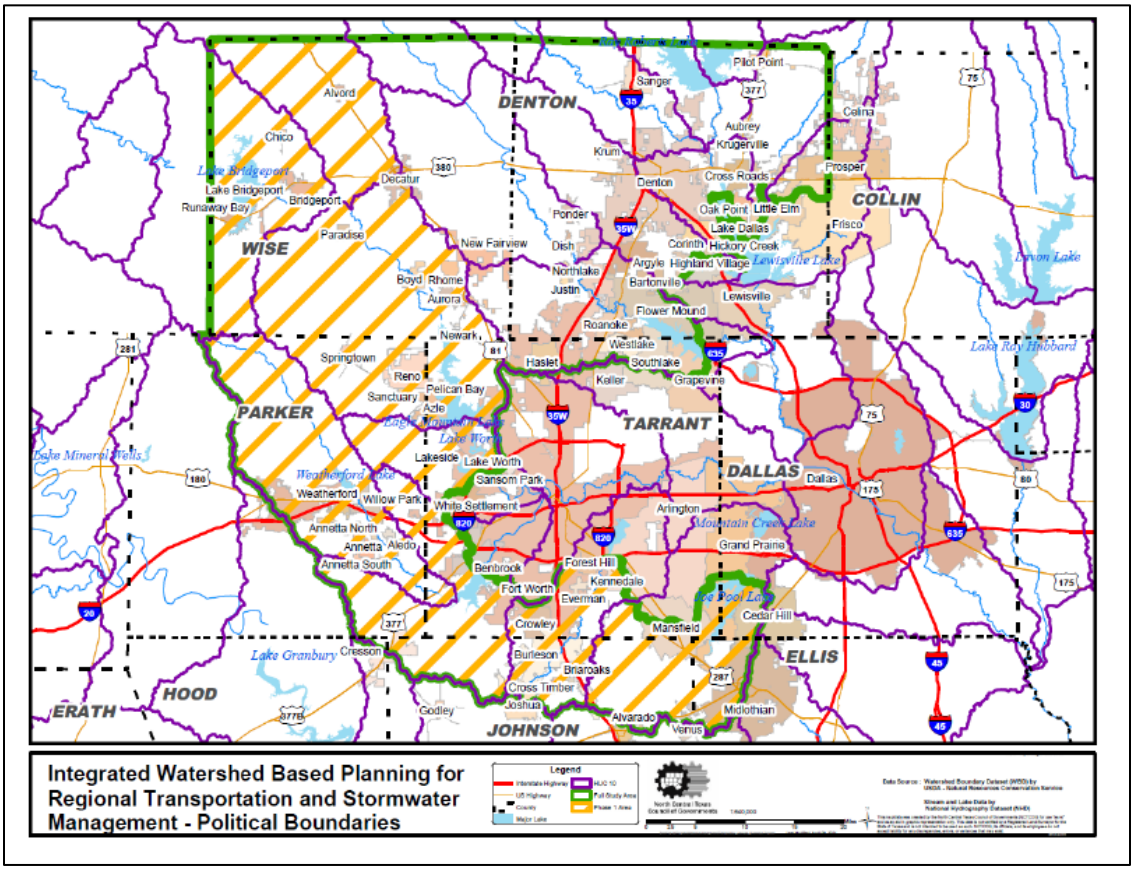


Figure 3-1. TSI West Phase One Project Area

3.2 Pilot Study Selection

The city of Weatherford expressed interest in participating in this pilot study in May 2024 through James Hotopp, City Manager of Weatherford, who is a representative of the NCTCOG TSI Steering Committee. Prior to May 2024, the TSI TAG met with the City of Weatherford and other participants several times from March 2023 to May 2024 to explore the process for expanding the CDC program into the TSI study area. Weatherford meets the requirement of expansion of the CDC Consolidated Model into the West Phase One Area because it has an existing model which can be used as a base model to develop a CDC expansion model scenario.

Modeling work by USACE would include developing a future conditions watershed land use runoff model that produces future conditions flood event peak flows. A hydraulic model would be developed, based on the existing model, using these projected flows to produce future conditions flood event water surface profiles. The results of the analyses would be used to compare existing and CDC flows and 100-year flood, or 1% annual exceedance probability (AEP) flood water surface elevations and provide the impact of future development on the local floodplain and assist in the future planning of development within the community. The final Hydrologic Engineering Center – River Analysis System (HEC-RAS) model would be similar in structure to the current CDC Consolidated Model: one unified model project file along with the appropriate Federal Emergency Management Agency (FEMA) and CDC plans.

3.3 Pilot Study Area

The study area is the Town Creek watershed within the City of Weatherford. A Town Creek Flood Risk Identification (FRI) Study was completed in 2020 as part of the FEMA Cooperating Technical Partner (CTP) Program through a partnership with NCTCOG and participation from City of Weatherford and Parker County, Texas. The purpose of this study was to identify flood risks that will ultimately revise the effective FEMA Flood Insurance Study (FIS) and Digital Flood Insurance Rate Maps (DFIRM) for the study stream. The Town Creek FRI study included hydrologic and hydraulic models for the Town Creek watershed that are leveraged for this CDC pilot study. Figure 3-2 shows the Town Creek pilot study location (red) in relation to the overall TSI project study area (black) and the current regulatory extents of the CDC program (green and blue cross-sections).

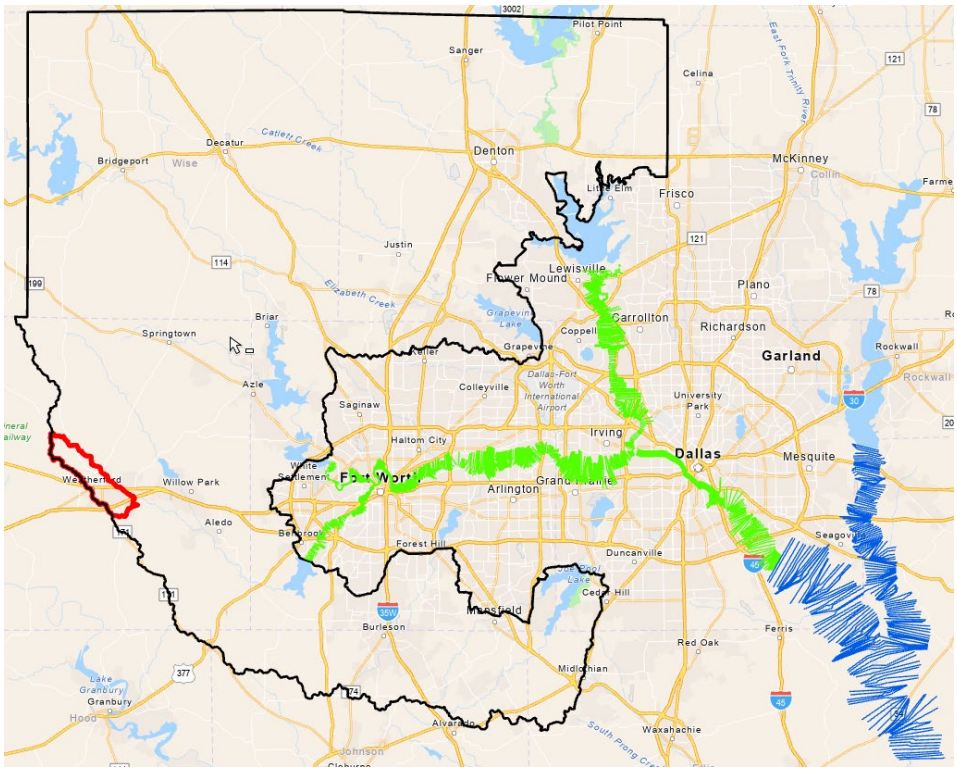


Figure 3-2. Town Creek Pilot Study Location

3.3.1 Town Creek Characteristics

The Town Creek watershed includes a total of 10.4 stream miles draining a total land area of 21.5 square miles at the downstream limit of the FRI study. The watershed area has an estimated affected population of 11,770 people, with the downstream portion of the watershed within Weatherford city limits and the upstream portion in the city's extraterritorial jurisdiction (ETJ). The Town Creek watershed is located in the Town Creek HUC-12 Watershed. Figure 3-3 shows the Town Creek watershed drainage basins from the FRI study and their corresponding areas in square miles.

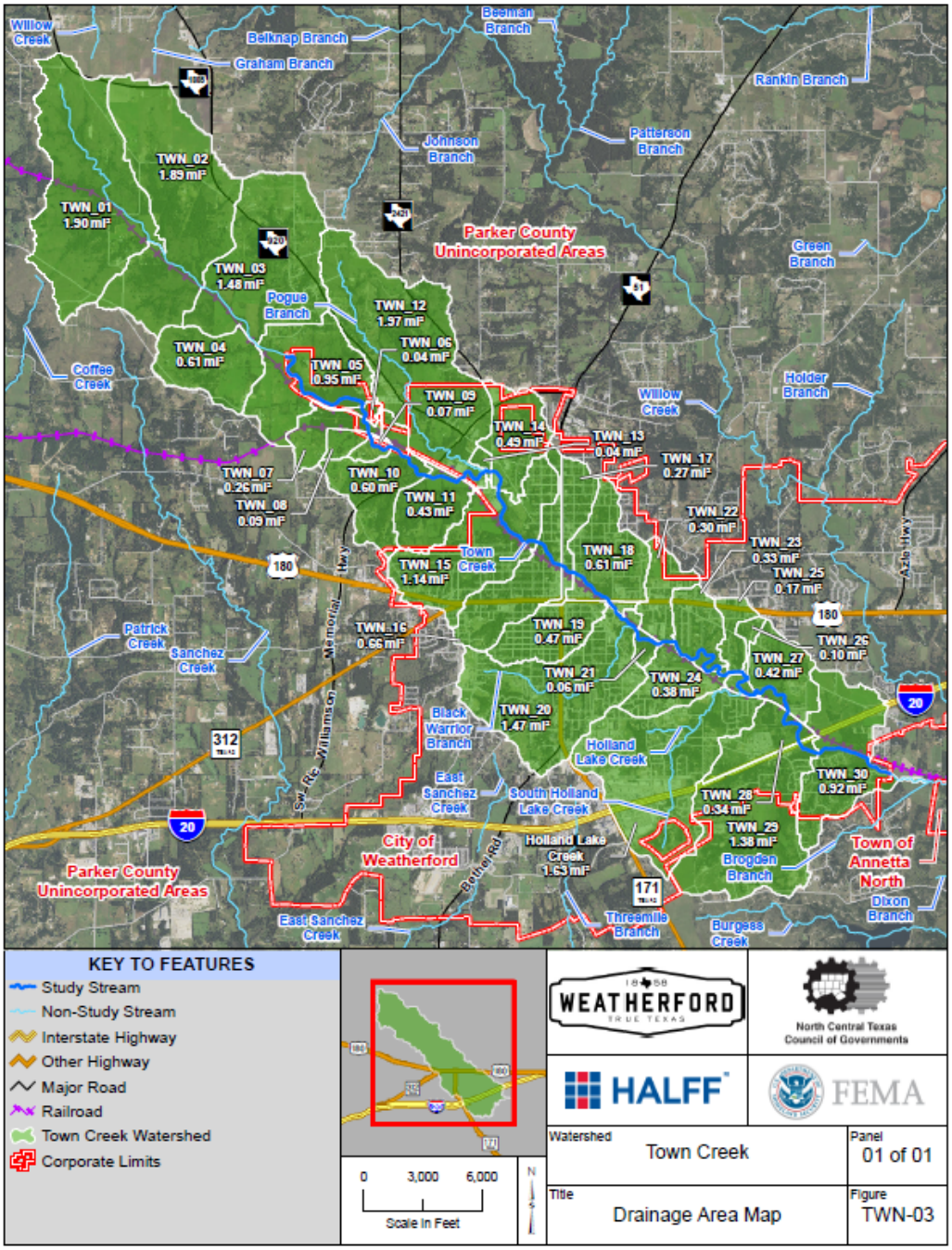


Figure 3-3. Town Creek Subbasin Layout from FRI Study

3.3.2 Town Creek FRI Hydrologic Model

The FRI study developed a hydrologic model for the Town Creek watershed using Hydrologic Modeling System (HEC-HMS) version 4.2 software. The hydrologic model used the Soil

Conservation Service (SCS) Unit Hydrograph method and the National Resources Conservation Service (NRCS) Curve Number loss method to compute runoff.

The soils data for the curve number calculations referenced the 2017 United States Department of Agriculture (USDA) Soil Survey Geographic database. The existing conditions land uses referenced the NCTCOG 2015 data, and the curve numbers were assigned according to the Technical Release (TR)-55 land use categories per NRCS soil type. The existing conditions and future land use conditions curve numbers were calculated, and a separate basin model was included for existing and future conditions. Detailed curve number calculations were provided for existing conditions, but not for the future conditions land use. Therefore, the future land use condition from the FRI model could not be verified and was not used in this CDC expansion study.

The subbasins were delineated based on the Texas Natural Resources Information System (TNRIS) 2011 Light Detection and Ranging (LiDAR) topographic data for Parker County, Texas. The time of concentration was computed for each subbasin using the TR-55 guidelines with a minimum lag time of 10 minutes. The rainfall depths for the frequency storm events were obtained from the NCTCOG integrated Stormwater Management (iSWM) Technical Manual for Hydrology, prior to the update from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 precipitation frequency estimates. The Modified Puls routing method was used for reaches which were also modeled in HEC-RAS and the Muskingum-Cunge method was used for reaches without a HEC-RAS model.

A more detailed analysis of the Holland Lake Creek subbasin in the City of Weatherford was performed by Freese and Nichols in July 2014. The subbasins, reaches, and reservoir HEC-HMS elements from the Freese and Nichols study were imported directly into the Town Creek FRI model to replace a single Holland Lake Creek subbasin. In addition to the reservoirs within the Holland Lake Creek subbasin, one other reservoir was included in the model for Sunshine Lake using the elevation-area storage method and outflow structure parameters.

The updates made to the hydrologic modeling for the CDC pilot study included georeferencing the model and revising the loss and transform methods to the USACE Fort Worth District methods used in the current CDC modeling. Updates were also made to land use assumptions representing the 2055 future conditions, and the rainfall depths were revised to the latest Atlas 14 values. The hydrologic model updates are explained in more detail in Section 5 and the hydrologic model results are provided in Section 6.

3.3.3 Town Creek FRI Hydraulic Model

The FRI study developed a steady flow hydraulic model for Town Creek using HEC-RAS version 5.0.3 software.

The cross-section geometries were developed utilizing field survey data and supplemented by TNRIS 2011 LiDAR topographic data. Channel flow line elevations were interpolated between surveyed sections and LiDAR data was used for the overbanks. The Manning's roughness values were selected based on exiting land use conditions, standard references, aerial photography, and field observations. A normal depth downstream boundary condition was set at the outfall.

Road crossings and low water crossings were surveyed and added to the hydraulic model as bridge and in-line structures. However, low water crossings less than three feet in height were not included as structures in the model. Lateral structures were included in areas where the overbanks would spill over natural or man-made levees, such as railroad embankments. The model assumed that the water spilling over the lateral structures was not lost but reentered the system at the next downstream cross section.

Flow change locations were added at the hydrologic model junction locations. The model included flows for the 10-, 4-, 2-, 1-, 1-minus, 1-plus, and 0.2-percent AEP storm events which corresponds to the 10-year, 25-year, 50-year, 100-year, 100-year minus, 100-year plus, and 500-year storm events. The flows were based on the existing condition hydrologic model results, and future condition flows were not included. The existing condition floodway was also analyzed, and a separate plan was included for the floodway analysis.

The updates made to the hydraulic modeling for the CDC expansion pilot study included revising the flows to the CDC hydrologic model results and remapping the 100-year and 500-year (1% AEP and 0.2% AEP) flood plains based on the updated terrain data. No geometry changes were made to the hydraulic model. The floodway was not re-analyzed with this study. The hydraulic modeling updates are explained in more detail in Section 7 and the hydraulic model results are compared to the FRI study in Section 8.

4 Data Sources

The following data was used in conjunction with the Town Creek FRI study data for the development of this CDC expansion pilot study. The data is sourced from the larger TSI West study area, the TSI HEC-HMS Model Development Standard Operating Procedure (SOP), and the CDC Trinity River and East Fork Trinity River Hydrologic and Hydraulic (H&H) Model Extension.

4.1 GIS Data

The GIS data in the following table was used to develop the CDC modeling for the Town Creek watershed pilot study.

Table 4-1. GIS Data Sources

Data Type	Data Source	Description of the Data
Terrain	TSI_WF_30ft_DEM.tif	DEM of the West TSI Study Area with a 30-ft cell size that was generated from the 2021 TWDB seamless statewide LiDAR data
Percent Impervious	Prct_Imperv_2055_NCTCOG_Mosaic	2055 (future) land use obtained from NCTCOG, used in 2013 CDC update and 2023 CDC East Fork expansion

Data Type	Data Source	Description of the Data
	Lookup_ICLUS_LU_2050_IMP Lookup_ICLUS_LU_2060_IMP	EPA Integrated Climate and Land Use Scenarios Publicly available data for the entire nation through the year 2100
Percent Urbanized	Prct_Urban_2055_NCTCOG_Mosaic	2055 (future) land use obtained from NCTCOG, used in 2013 CDC update and 2023 CDC East Fork expansion
	Lookup_ICLUS_LU_2050_URB Lookup_ICLUS_LU_2060_URB	EPA Integrated Climate and Land Use Scenarios Publicly available data for the entire nation through the year 2100
Percent Sand	raster_per_sand_00_36in_TX_Avg_DCP	Fort Worth District state-wide geospatial grid developed for sand percentage per watershed for determining losses (Rodman, 1977; USACE, 1986)
Dams	Trinity_NID_2016	NRCS flood control structures National Inventory of Dams (NID) (USACE, 2016)
Drainage Divides	S_Subbasins	Drainage divides of Town Creek watershed from FRI study (FEMA FY17 CTP)
Cross-sections	S_XS	HEC-RAS cross-sections along Town Creek from FRI study (FEMA FY17 CTP)
Stream Centerline	S_Profil_Basln	HEC-RAS river reach centerline for Town Creek from FRI study (FEMA FY17 CTP)

5 HEC-HMS CDC Expansion Model Development

The following section details the hydrologic model updates made to the Town Creek FRI model to convert the model to the CDC methodology. The CDC expansion modeling was prepared using the latest HEC-HMS version 4.12 software.

5.1 HEC-HMS Subbasin Locations

The Town Creek FRI study subdivided the watershed based on the 2011 TNRIS LiDAR data using automatic geographic information system (GIS) methods and then manually modified the

subbasins based on storm sewer lines and culverts using aerial imagery, survey data, and field reconnaissance. The total area of the watershed was calculated to be 21.5 square miles. The subbasin layout from the FRI study is shown in Figure 3-3.

The FRI study package provided by the City of Weatherford included shapefiles for the subbasins. However, the HEC-HMS model from the FRI study was developed in an earlier version of HEC-HMS which did not include GIS capabilities to link the subbasin elements to a georeferenced shapefile. More recent versions of HEC-HMS have added this GIS feature and allow the modeler to attach a terrain file to automatically calculate subbasin characteristics and parameters. The subbasin locations from the FRI study were used as a base line for the CDC expansion hydrology.

5.2 HEC-HMS Subbasin Delineations

The subbasins for the CDC expansion model were re-delineated using HEC-HMS built in GIS tools, referencing the updated 2021 TWDB LiDAR terrain. The subbasins were re-delineated using HEC-HMS GIS tools so that the subbasin characteristics (longest flow path, flow path slope, basin relief, etc.) could be automatically calculated in HEC-HMS. These subbasin characteristics are needed to calculate the unit hydrograph parameters for the Fort Worth District transform method. The parameters could have also been calculated outside of HEC-HMS using GIS software, but USACE elected to use the tools built into HEC-HMS to perform the calculations more efficiently within one program. Furthermore, HEC-HMS is a free software to use, so communities without access to GIS software who desire to replicate this process can do so using HEC-HMS.

The HEC-HMS GIS tools include terrain reconditioning options where shapefiles can be referenced to enforce walls and burn stream flow lines. The subbasin boundaries shapefile from the FRI study was used to enforce walls in the terrain to ensure the HEC-HMS GIS subbasin delineation would follow the previous study subbasin layout as closely as possible. For future study areas where a subbasin delineation may not be provided by a previous study, this step can be skipped and the subbasins may be delineated without modifying the terrain. A stream shapefile was also generated based on a one-square-mile stream drainage area and flow paths were manually added parallel to the FRI study subbasin boundaries to reinforce the wall terrain reconditioning. Figure 5-1 below shows the walls in yellow, which match the FRI study subbasin layout, and the streams line in blue. The results of the HEC-HMS watershed delineation and terrain reconditioning process were drainage areas that very closely match the FRI study. Table 5-1 compares the final drainage areas used for the CDC expansion pilot study to the FRI drainage areas in square miles.

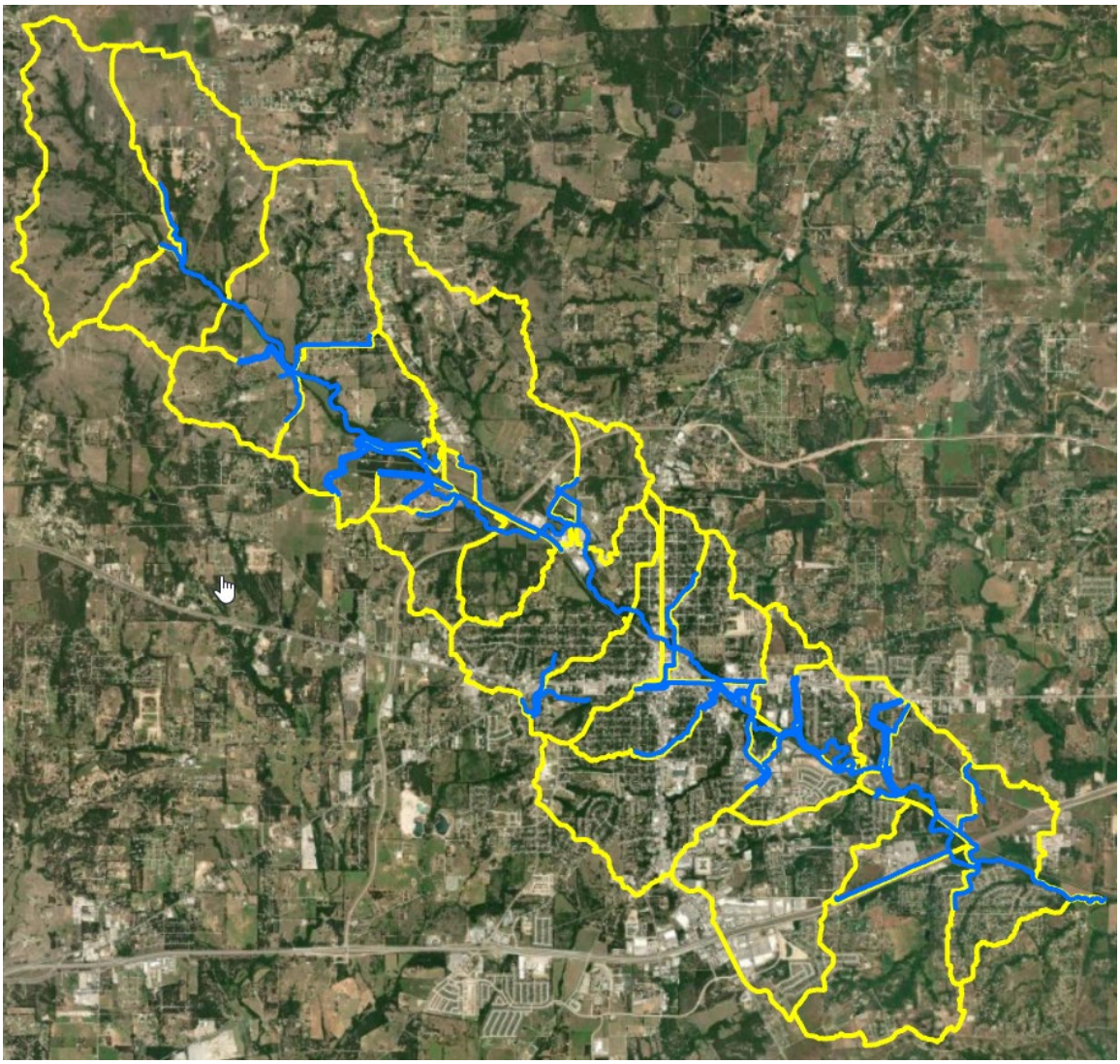


Figure 5-1. HEC-HMS Terrain Reconditioning Walls (yellow) and Streams (blue)

Table 5-1. Town Creek HEC-HMS Subbasin Areas

Subbasin Name	Area (sq mi) FRI Study	Area (sq mi) CDC Expansion
TWN_01	1.905	1.9197
TWN_02	1.889	1.8593
TWN_03	1.481	1.4746
TWN_04	0.608	0.62183
TWN_05	0.949	0.94755
TWN_06	0.043	0.0404
TWN_07	0.262	0.25816
TWN_08	0.093	0.0955044
TWN_09	0.066	0.0656936
TWN_10	0.604	0.59647
TWN_11	0.426	0.42113

Subbasin Name	Area (sq mi) FRI Study	Area (sq mi) CDC Expansion
TWN_12	1.97	1.9753
TWN_13	0.037	0.0357536
TWN_14	0.486	0.49467
TWN_15	1.14	1.1291
TWN_16	0.659	0.66252
TWN_17	0.268	0.26516
TWN_18	0.61	0.61543
TWN_19	0.467	0.47843
TWN_20	1.474	1.4710
TWN_21	0.063	0.0655
TWN_22	0.298	0.30185
TWN_23	0.325	0.33551
TWN_24	0.383	0.38731
TWN_25	0.168	0.17153
TWN_26	0.100	0.10293
TWN_27	0.422	0.42107
TWN_28	0.335	0.33651
TWN_29	1.384	1.3748
TWN_30	0.915	0.93476
Holland Lake Creek	N/A*	1.6284

*The Holland Lake Creek subbasin is subdivided in the FRI model based on the Freese and Nichols study in 2014. However, the subbasin is only modeled as one combined area for simplicity in the CDC expansion model.

5.3 HEC-HMS Parameters

5.3.1 Subbasin Parameters

Percent Imperviousness and Urbanization

Land use assumptions for the CDC expansion study were updated to reflect 2055 future conditions, which is the same horizon year used in the current CDC modeling. A combination of NCTCOG data and the Environmental Protection Agency's (EPA) Integrated Climate and Land Use Scenarios (ICLUS) data was used to determine percent imperviousness and percent urbanization for 2055 future conditions. The EPA ICLUS Shared Socioeconomic Pathways (SSP) 5 and Representative Concentration Pathways (RCP) 8.5 scenario was used where future NCTCOG land used estimates were not available and where ICLUS data produced higher estimates of urbanization. This specific ICLUS scenario assumes higher population growth than other ICLUS scenarios. Table 5-2 is a list of the land use relationships that were used with the NCTCOG data. Table 5-3 is a list of land use relationships that were used with the ICLUS data.

Table 5-2. Percent Urbanization and Impervious Assignments for NCTCOG Land Use

Land Use Code	Description	Examples of Use	Assigned Percent Urbanized	Assigned Percent Impervious
111	Single family	Single family detached units and duplexes	80	41
112	Multi-family	Apartments, condominiums, residential hotels, converted apartments and townhouses (single family attached)	95	70
113	Mobile home	Mobile homes inside mobile home parks and free-standing units outside parks	40	20
114	Group quarters	Nursing homes, group homes, college dormitories, jails, military base personnel quarters	70	60
120	Commercial	Commercial (office and retail)	90	90
121	Office	Generally include and administration functions including corporate and government offices, banks	90	90
122	Retail	Retail trade and services, such as department stores, repair shops, supermarkets, restaurants	95	95
123	Institutional	Churches, governmental facilities, museum, education, hospitals, medical clinics, libraries and military bases	50	40
124	Hotel/motel	Hotels and motels	95	95
125	Institutional/semi-public	School, churches	50	40
126	Education	Schools	50	40
131	Industrial	Manufacturing plants, warehouses, office showrooms	95	90
141	Transportation	Railroads, radio and television communication stations, truck terminals	30	15
142	Roadway	Roadway and right-of-ways	80	35
143	Utilities	Sewage treatment and power plants, power line easements, pump stations, water treatment plants and water systems	70	60
144	Airport	Airport terminals	40	20
146	Runway	Airport runways	100	100
147	Large stadium	Large stadium	95	95
148	Railroad	Railroad	30	15
149	Communication	Communication	50	35
151	Transit	Transit	30	15
160	Mixed use	Areas that contain both commercial (office and retail) and residential uses either in the same facility or in very close proximity	95	90
170	Parks/recreation	Public and private parks, golf courses, cemeteries, public and private tennis courts and swimming pools, amusement parks	10	6

Land Use Code	Description	Examples of Use	Assigned Percent Urbanized	Assigned Percent Impervious
171	Parks/recreation	Public and private parks, golf courses, cemeteries, public and private tennis courts and swimming pools, amusement parks	10	6
172	Landfill	Sanitary landfills, land applications, and similar waste management facilities	10	5
173	Under construction	Land that has undergone site preparation and construction has begun	20	15
174	Cemeteries	Cemeteries	10	6
181	Flood control	Major flood control structures including levies and flood channels	0	0
300	Vacant	Vacant land	0	0
301	Vacant	Vacant land	0	0
302	Residential acreage	Residential homes on acreage	80	41
303	Ranch land	Ranch land	0	0
304	Timberland	Timberland	0	0
305	Farmland	Farmland	5	3
309	Improved acreage	Improved acreage	10	6
401	Parking	Parking	100	100
500	Water	Water	100	100
501	Water	Water	100	100
502	Small water bodies	Small water bodies	100	100

Table 5-3. Percent Urbanization and Impervious Assignments for ICLUS Land Use

EPA Code	EPA Class Name	Assigned Percent Urbanized	Assigned Percent Impervious
0	Natural Water	100	100
1	Reservoirs, canals	100	100
2	Wetlands	0	0
3	Recreation, conservation	0	0
4	Timber	0	0
5	Grazing	0	0
6	Pasture	0	0
7	Cropland	0	0
8	Mining, barren land	0	0
9	Parks, golf courses	10	6
10	Exurban, low density	40	20
11	Exurban, high density	80	41
12	Suburban	80	41
13	Urban, low density	80	41
14	Urban, high density	95	70
15	Commercial	95	95
16	Industrial	95	90
17	Institutional	50	40
18	Transportation	30	15

The “Zonal Statistics as Table” tool was used in ArcGIS Pro to calculate the average percent impervious and percent urbanized values for each subbasin. QGIS is a free open-source GIS platform that could also be used to calculate the basin averages. The ICLUS data was not available for 2055, so the average was taken from the 2050 and 2060 data sets. The NCTCOG and the ICLUS values were compared for each subbasin, and the greater of the two values was used for the percent impervious and percent urbanized.

Initial and Constant Losses

The USACE Fort Worth District Method for determining losses produces a default set of loss rates for each frequency event based on the soil type in each subbasin (Rodman, 1977). The method assumes that the antecedent moisture conditions become wetter, and the losses decrease as the rarity of the flood event increases, which is consistent with other research (McEnroe, 2003). In general, the 2-year (50% AEP) loss rates are intended to correspond to an “average” or “normal” antecedent soil moisture condition, and the 500-year (0.2% AEP) loss rates should correspond to a “wet” soil moisture condition. Table 5-4 summarizes the range of default loss

rates of the Fort Worth District method by frequency and soil type. A geospatial grid of soil sand contribution for the State of Texas developed by the USACE Fort Worth District was used to spatially calculate the percent sand for each subbasin. That percentage of sand value was then used to interpolate between the 0% and 100% sand loss rate values in Table 5-4 to assign the default initial and constant loss rates to each subbasin.

Table 5-4. Default Frequency Loss Rates by Soil Type for the USACE Fort Worth District Method

Annual Exceedance Probability (AEP) %	Initial Abstraction (inches) for Soil with 0% Sand	Infiltration Rate (inches per hour) for Soil with 0% Sand	Initial Abstraction (inches) for Soil with 100% Sand	Infiltration Rate (inches per hour) for Soil with 100% Sand
50%	1.50	0.20	2.10	0.26
20%	1.30	0.16	1.80	0.21
10%	1.12	0.14	1.50	0.18
4%	0.95	0.12	1.30	0.15
2%	0.84	0.10	1.10	0.13
1%	0.75	0.07	0.90	0.10
0.4%	0.61	0.06	0.73	0.09
0.2%	0.50	0.05	0.60	0.08

After calculating the default frequency loss rates based on soil type, an additional adjustment was made to the loss rate parameters. The default initial deficits were increased to account for the presence of NRCS type flood control structures in the watershed that have not been modeled in detail. This adjustment for the NRCS flood control structures was made based on data from the National Inventory of Dams (NID). The only subbasin with an NRCS structure that was not included as a reservoir in the model was the Holland Lake Creek subbasin. In this case, the percent of the subbasin area that was controlled by NRCS type structures was multiplied by the inches of runoff that can typically be stored between the riser and spillway of the NRCS structures in that basin (typically up to 4 inches of runoff). For the frequent storm events (50% to 4% AEP, or 2-year to 25-year), the initial loss due to the NRCS structures was decreased in proportion to the total depth of rain for that event. Table 5-5 and Table 5-6 provide the percent sand and final loss parameters for each subbasin for the various storm event frequencies.

Table 5-5. HEC-HMS Subbasin Loss Parameters (50% to 10% AEP)

Return Interval		50% AEP (2-year)		20% AEP (5-year)		10% AEP (10-year)	
Subbasin Name	Percent Sand	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
Holland Lake Creek	54	2.36	0.23	3.29	0.19	3.89	0.16
TWN_01	22	1.99	0.25	1.71	0.20	1.43	0.17
TWN_02	23	1.98	0.25	1.70	0.20	1.43	0.17
TWN_03	33	1.97	0.25	1.69	0.20	1.42	0.17
TWN_04	41	2.03	0.25	1.74	0.20	1.45	0.18
TWN_05	40	1.94	0.24	1.67	0.20	1.40	0.17

Return Interval		50% AEP (2-year)		20% AEP (5-year)		10% AEP (10-year)	
Subbasin Name	**Percent Sand**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**
TWN_06	44	2.12	0.26	1.82	0.21	1.51	0.18
TWN_07	41	2.09	0.26	1.79	0.21	1.49	0.18
TWN_08	40	2.13	0.26	1.83	0.21	1.52	0.18
TWN_09	41	2.13	0.26	1.82	0.21	1.52	0.18
TWN_10	43	2.04	0.25	1.75	0.20	1.46	0.18
TWN_11	38	2.12	0.26	1.82	0.21	1.52	0.18
TWN_12	46	2.02	0.25	1.73	0.20	1.45	0.17
TWN_13	90	2.08	0.26	1.78	0.21	1.48	0.18
TWN_14	47	2.04	0.25	1.75	0.20	1.46	0.18
TWN_15	47	2.07	0.26	1.78	0.21	1.48	0.18
TWN_16	54	2.05	0.26	1.76	0.21	1.47	0.18
TWN_17	47	2.01	0.25	1.73	0.20	1.45	0.17
TWN_18	46	2.11	0.26	1.81	0.21	1.51	0.18
TWN_19	50	2.10	0.26	1.80	0.21	1.50	0.18
TWN_20	43	2.08	0.26	1.79	0.21	1.49	0.18
TWN_21	41	2.15	0.26	1.84	0.21	1.53	0.18
TWN_22	52	2.13	0.26	1.83	0.21	1.52	0.18
TWN_23	45	2.03	0.25	1.74	0.20	1.46	0.18
TWN_24	64	2.10	0.26	1.80	0.21	1.50	0.18
TWN_25	55	2.02	0.25	1.73	0.20	1.45	0.17
TWN_26	42	2.19	0.27	1.88	0.22	1.56	0.19
TWN_27	44	2.07	0.26	1.77	0.21	1.48	0.18
TWN_28	72	2.18	0.27	1.87	0.22	1.55	0.19
TWN_29	40	2.07	0.26	1.77	0.21	1.48	0.18
TWN_30	49	2.13	0.26	1.83	0.21	1.52	0.18

Table 5-6. HEC-HMS Subbasin Loss Parameters (4% to 0.2% AEP)

Return Interval	4% AEP (25-year)		2% AEP (50-year)		1% AEP (100-year)		0.2% AEP (500-year)	
Subbasin Name	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**
Holland Lake Creek	4.30	0.14	4.39	0.12	4.24	0.09	3.96	0.07
TWN_01	1.24	0.14	1.05	0.12	0.87	0.09	0.58	0.07
TWN_02	1.23	0.14	1.05	0.12	0.87	0.09	0.58	0.07
TWN_03	1.23	0.14	1.04	0.12	0.87	0.09	0.58	0.07
TWN_04	1.26	0.15	1.07	0.13	0.88	0.10	0.59	0.08
TWN_05	1.21	0.14	1.03	0.12	0.86	0.09	0.57	0.07
TWN_06	1.31	0.15	1.11	0.13	0.91	0.10	0.60	0.08
TWN_07	1.29	0.15	1.10	0.13	0.90	0.10	0.60	0.08
TWN_08	1.32	0.15	1.11	0.13	0.91	0.10	0.61	0.08
TWN_09	1.31	0.15	1.11	0.13	0.91	0.10	0.60	0.08
TWN_10	1.26	0.15	1.07	0.13	0.88	0.10	0.59	0.08
TWN_11	1.31	0.15	1.11	0.13	0.91	0.10	0.60	0.08

Return Interval	4% AEP (25-year)		2% AEP (50-year)		1% AEP (100-year)		0.2% AEP (500-year)	
Subbasin Name	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**	**Initial (in)**	**Constant (in/hr)**
TWN_12	1.25	0.15	1.06	0.13	0.88	0.10	0.59	0.08
TWN_13	1.29	0.15	1.09	0.13	0.89	0.10	0.60	0.08
TWN_14	1.26	0.15	1.07	0.13	0.88	0.10	0.59	0.08
TWN_15	1.28	0.15	1.09	0.13	0.89	0.10	0.60	0.08
TWN_16	1.27	0.15	1.08	0.13	0.89	0.10	0.59	0.08
TWN_17	1.25	0.15	1.06	0.13	0.88	0.10	0.59	0.08
TWN_18	1.31	0.15	1.10	0.13	0.90	0.10	0.60	0.08
TWN_19	1.30	0.15	1.10	0.13	0.90	0.10	0.60	0.08
TWN_20	1.29	0.15	1.09	0.13	0.90	0.10	0.60	0.08
TWN_21	1.33	0.15	1.12	0.13	0.91	0.10	0.61	0.08
TWN_22	1.32	0.15	1.11	0.13	0.91	0.10	0.61	0.08
TWN_23	1.26	0.15	1.07	0.13	0.88	0.10	0.59	0.08
TWN_24	1.30	0.15	1.10	0.13	0.90	0.10	0.60	0.08
TWN_25	1.25	0.15	1.07	0.13	0.88	0.10	0.59	0.08
TWN_26	1.35	0.15	1.14	0.13	0.92	0.10	0.62	0.08
TWN_27	1.28	0.15	1.08	0.13	0.89	0.10	0.59	0.08
TWN_28	1.35	0.15	1.13	0.13	0.92	0.10	0.61	0.08
TWN_29	1.28	0.15	1.09	0.13	0.89	0.10	0.59	0.08
TWN_30	1.32	0.15	1.11	0.13	0.91	0.10	0.61	0.08

Snyder's Transform Parameters

USACE developed a method in 1977 to adjust watershed discharge lag times, accounting for the effects of urbanization. The method recognizes that watersheds with similar shapes and characteristics demonstrate a reduction in flood peak travel time and increase in peak discharges as urbanization increases. Model calibration was performed against observed storm data across basins with varying levels of urbanization to develop Urbanization Curves which correlated measurable watershed characteristics to lag time for varying degrees of urbanization. Using the Urbanization Curves, watershed lag times reduce by about half (46%) from a watershed without any urbanization to a fully urbanized watershed. More discussion on the Urbanization Curves can be found in the 1977 USACE Report (Rodman, 1977).

To calculate the lag time, the Snyder Unit Hydrograph Fort Worth District method uses a relationship between the percent sand, the percent urbanized, and other basin characteristics, such as area, longest flow path length, centroidal flow path length, and the 10-85 flow path slope. The percent sand and percent urbanized for each subbasin was calculated in GIS as discussed previously, and the remainder of the subbasin characteristics were automatically calculated in HEC-HMS using the built in GIS tools and the referenced terrain data. A summary of the calculated lag times is provided in Table 5-7 and the detailed calculations are provided in the Appendix.

The Trinity River Watershed Hydrology Assessment (WHA) model was referenced to determine an appropriate peaking coefficient for this region. The WHA model and peaking coefficients were calibrated to gage data for historical storms and provide a reliable baseline for the region. A

peaking coefficient of 0.65 was used for all Town Creek subbasins based on the WHA model values used in the area.

Table 5-7. HEC-HMS Subbasin Snyder's Transform Parameters

Subbasin Name	Lag Time (hr)	Peaking Coeff
TWN_01	0.916	0.65
TWN_02	0.885	0.65
TWN_03	0.681	0.65
TWN_04	0.352	0.65
TWN_05	0.618	0.65
TWN_06	0.137	0.65
TWN_07	0.544	0.65
TWN_08	0.232	0.65
TWN_09	0.205	0.65
TWN_10	0.475	0.65
TWN_11	0.466	0.65
TWN_12	1.011	0.65
TWN_13	0.175	0.65
TWN_14	0.446	0.65
TWN_15	0.520	0.65
TWN_16	0.395	0.65
TWN_17	0.399	0.65
TWN_18	0.553	0.65
TWN_19	0.565	0.65
TWN_20	0.934	0.65
TWN_21	0.198	0.65
TWN_22	0.458	0.65
TWN_23	0.708	0.65
TWN_24	0.479	0.65
TWN_25	0.343	0.65
TWN_26	0.424	0.65
TWN_27	0.322	0.65
TWN_28	0.342	0.65
TWN_29	0.772	0.65
TWN_30	0.803	0.65
Holland Lake Creek	0.811	0.65

Baseflows

For larger study areas with USGS gauge data available for calibration, baseflow may be included and calibrated similar to the current CDC model. However, for this pilot study and given the

limited watershed analysis, no baseflow was assumed for Town Creek. The existing FRI study for Town Creek also assumed no baseflow.

5.3.2 Routing Parameters

No changes were made to the routing parameters when converting the existing FRI study model to the CDC expansion model. The Modified Puls routing method was used for reaches which were modeled in HEC-RAS and the Muskingum-Cunge method was used for reaches without a model. The range of flows in the Modified Puls storage discharges tables were sufficient for the increased CDC expansion discharges, so no changes were made to the tables or the sub-reach values. The range of flows for the storage discharge tables may need to be increased and approximated for higher flows when running the Standard Project Flood (SPF) event.

5.4 HEC-HMS Meteorologic Data

5.4.1 Frequency Storm

The FRI study utilized the Frequency Storm meteorologic method for the 2-, 10-, 25-, 50-, 100-, and 500-year storm events. The FRI study depth duration values were not updated to the latest Atlas 14 rainfall data. The FRI study frequency storm events also assumed a small storm area of 0.000001 square miles to simulate no area reduction. However, depth-area analysis simulation runs were included in the FRI study, with analysis points at every junction starting at J_TNW_12 and downstream. The discharges used in the FRI study HEC-RAS model referenced the flows from the frequency storm events with no area reduction upstream of junction J_TWN_12 and the HEC-RAS model referenced the depth-area analysis flows at junction J_TWN_12 and downstream.

The Frequency Storm meteorologic models were copied for all recurrence intervals and the depth duration data was updated to the latest Atlas 14 rainfall estimates. The Atlas 14 rainfall estimates were sourced from the 2020 iSWM Hydrology Technical Manual in Table 5.12 for Parker County, which uses the centroid of the county as the Atlas 14 analysis point. The TP 40 and TP49 area reduction was applied with a storm area of 21.46 square miles, which is the total watershed area. Simulation Runs were developed for all recurrence intervals based on this area reduction and separate depth-area analyses were also developed for all recurrence intervals with analysis points at each HMS junction. The results were compared, and the depth-area analysis runs produced higher flows, so the higher flows were used in the CDC expansion hydraulic model to be conservative.

The storm duration (1 day), intensity duration (5 minutes), and intensity position (50 percent) values from the existing FRI meteorologic models were not changed for the CDC expansion models.

5.4.2 Standard Project Flood

The SPF was not developed for the Town Creek watershed for this CDC pilot study due to budget and funding constraints. The SPF is a standardized flood developed as a basis for flood protection design and is used in the CDC program since the Dallas Floodway and Fort Worth

Floodway levees along the Trinity River system were designed to SPF standards. The SPF represents approximately 50 percent of the Probably Maximum Flood (PMF) and is commonly equated to an approximately 800-year storm frequency in the Trinity River Corridor. Should the CDC program be expanded to Weatherford along the Town Creek watershed or into any other interested community, the SPF hydrology would need to be developed. A description of the SPF modeling process is provided below for future replication. Communities seeking to develop SPF models for CDC program expansion may contact the USACE Water Resources Branch for more assistance.

The first step to determining the SPF for a given watershed is to calculate the Probable Maximum Precipitation (PMP) in HEC-MetVue using the built in Hydrometeorological Report (HMR) 52 plug-in. To run this plug-in, a shapefile of the overall watershed area is needed. The plug-in uses the watershed boundary shapefile to determine the optimal location and orientation of the PMP for maximum rainfall depths.

Within the HMR52 plug-in editor, the user will need to specify the following settings:

Within the "Computation Options" tab, the "Depth-Area-Duration Curve Options" should be set to "Use Basin Area". The "Storm Size Option" should be set to "Use specific storm size" and the user should enter the total watershed area for the storm size. The "Temporal Hyetograph Distribution Options" should be adjusted to select "Create shorter intervals" for 1-hour intervals with 4 periods to subdivide. Additionally, the 6-hour distribution should be revised from the HMR52 standard distribution to the CDC specific SPF distribution. The user will need to edit the 6-hour distribution to add a new pattern with the ordinal pattern as shown in Figure 5-2 below.

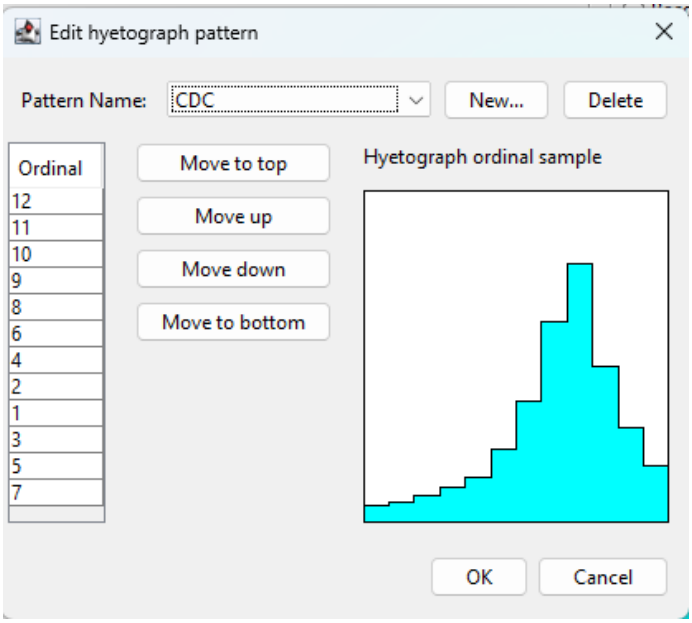


Figure 5-2. CDC PMF Hyetograph Ordinal Distribution

Within the “Run Options” tab, the “Run once for a specified location option” should be selected and the “Rotate storm to align with basin” option should also be selected. Additionally, the “Compute using the same location as D-A-D curve (or centroid if D-A-D curve location not specified)” option should be selected, which will place the center of the storm at the centroid of the watershed shapefile.

Within the “Output Options” tab, the user should input the desired HMR52 output file location and log results file location. The start and end date of the PMP event can also be adjusted in this tab to match the control specification in the HEC-HMS model. Once the settings are updated, select “OK” in the HMR52 editor window to run the HMR52 plug-in routine. The result of the analysis should look similar to the below figure.

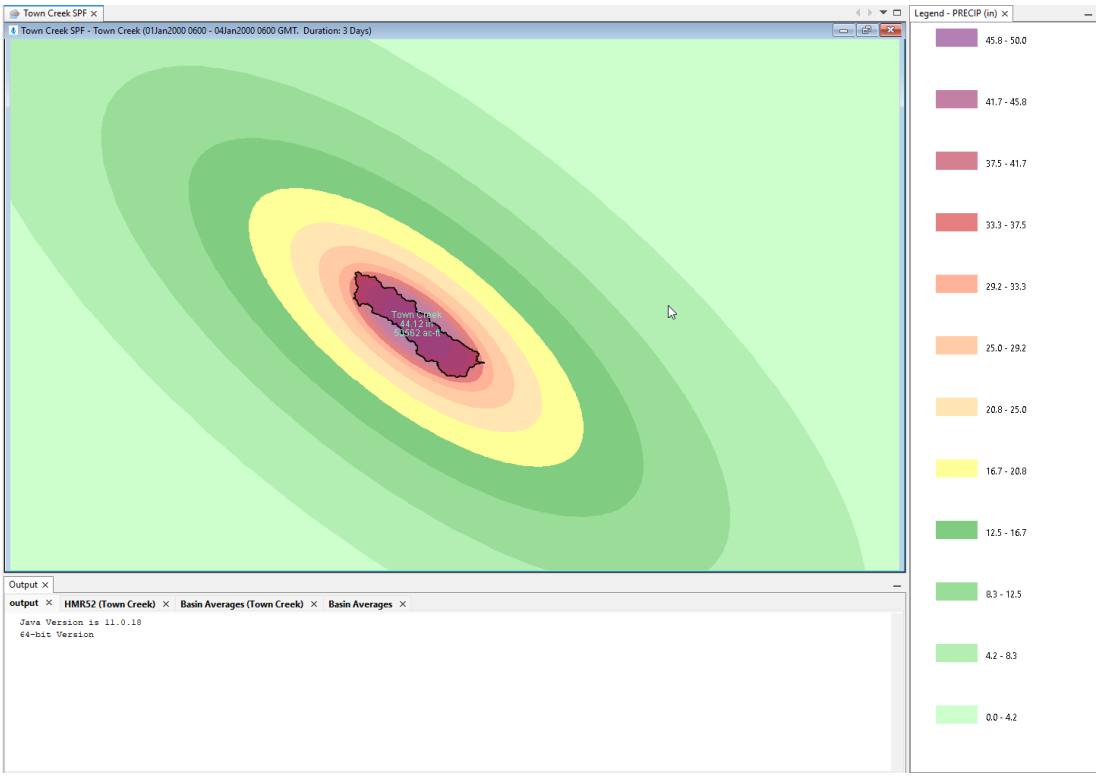


Figure 5-3. HMR52 Storm in HEC-MetVue

Once the PMP storm is determined in HEC-MetVue, the precipitation data can be exported to a gridded Data Storage System (DSS) file using the settings shown in Figure 5-4. The default grid cell size is 2000 meters; however, the user should adjust the size based on the watershed size. For example, a grid cell size of 500 meters was more appropriate for the 21.46 square-mile storm on the Town Creek watershed. When using gridded precipitation in HEC-HMS, the subbasin data needs to be discretized using the same grid cell size. The grid cell size options in HEC-HMS are 50, 100, 200, 500, 1000, 2000, 5000, and 10000 meters. The DSS grid cell size should also select from one of these standard values.

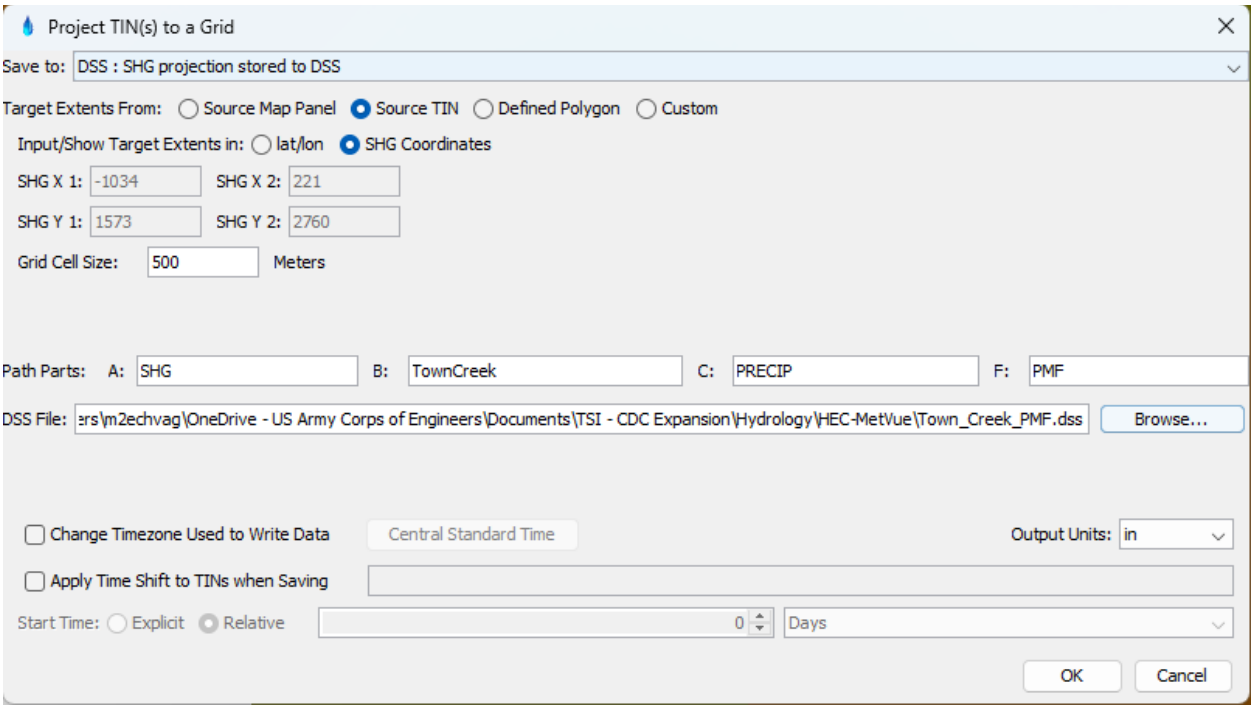


Figure 5-4. HEC-MetVue Export TIN to Gridded DSS

After the PMP gridded DSS precipitation has been exported, it must be added to the HEC-MetVue map, replacing the HMR52 precipitation, by right clicking the "TIN Node" and choosing "Select DSS Paths". All data entries from the DSS file need to be added to the map. The resulting map will look similar to the HMR52 plug-in results. If the added DSS file shows hyetal ellipses that are too gridded and need to be smoothed, the user will need to rerun the HMR52 plug-in then re-export the gridded DSS with a smaller grid size. Once the user is satisfied with the PMP DSS, the precipitation data can be reduced by 50% to create the SPF precipitation. Right clicking anywhere on the map view allows the user to adjust measurement values for the entire triangulated irregular network (TIN) by a constant value, which will be 0.5. After applying the adjustment, the depths of the new precipitation data will be updated in the map view. The user can then follow the process to export the SPF precipitation to another gridded DSS file.

After the gridded DSS precipitation is created for the SPF, the HEC-HMS model must be set up to run with gridded precipitation data. As previously mentioned, the HEC-HMS basin model will need to be discretized to allow the model to run with gridded precipitation data. Each subbasin must be revised to change the "Discretization Method" to "Structured", assigned the standard hydrologic grid (SHG) projection, and the cell size should be set to match the DSS grid size. Once the subbasin discretization is completed, the user can view the grid created by HEC-HMS by turning on the discretization layer in the "Map Layers" viewer. A "Precipitation Gridset" can be created in the "Grid Data Manager", and the SPF gridded DSS file path can be linked to the grid set. Then a "Gridded Precipitation" meteorological model can be set up and the SPF gridset can be referenced to be used as gridded precipitation.

Finally, a new “Control Specification” must be created to run the storm with the same start-/end-date and time from the gridded DSS file. Once the SPF Control Specification is created, a simulation run for the SPF may be created to run the gridded precipitation model. The SPF assumes that the ground is highly saturated prior to the storm, so a basin model such as the 100-year or 500-year should be used in the simulation run, since those higher storm events have the lowest initial and constant loses. The results of the SPF simulation run can be summarized at the relevant flow input junctions and input into the HEC-RAS model to determine the SPF water surface elevations and inundation boundary.

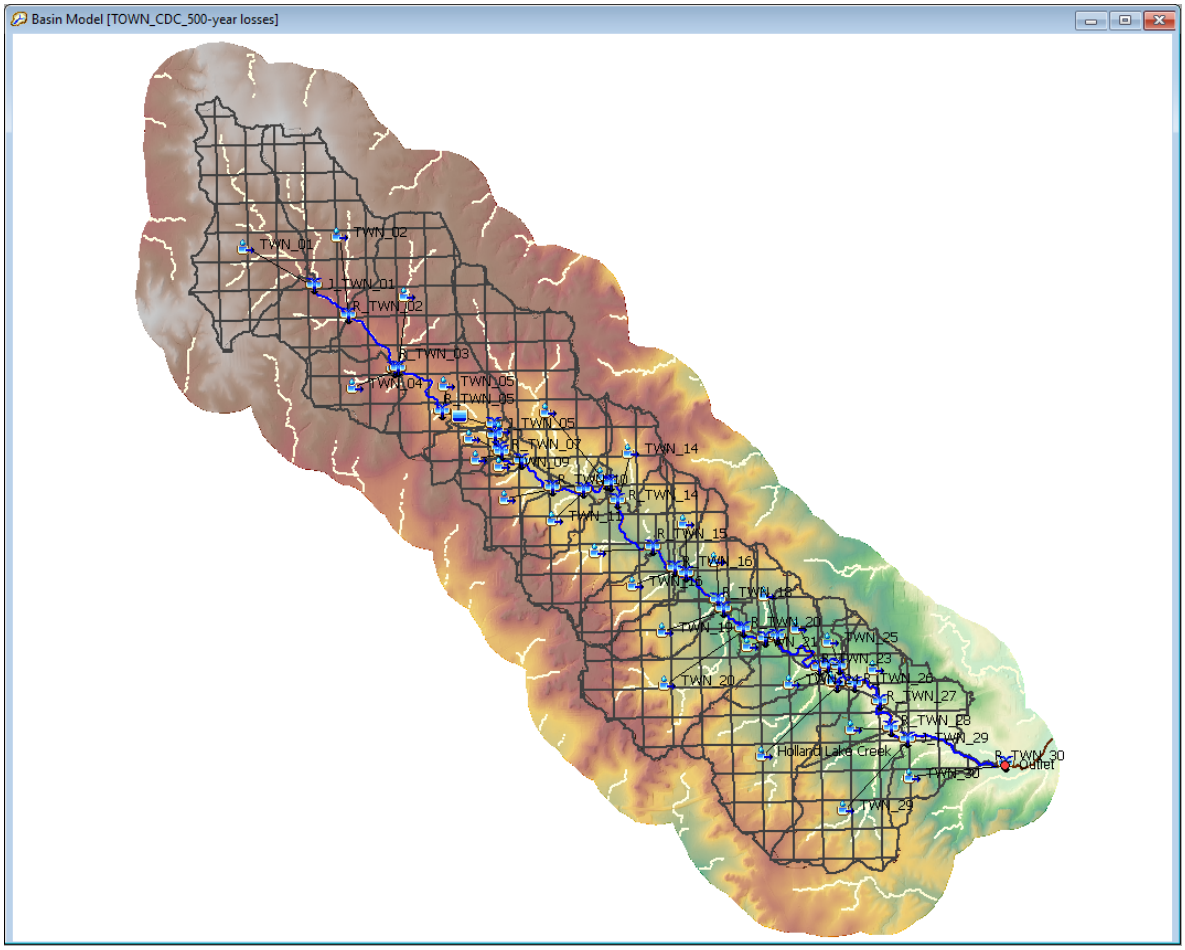


Figure 5-5. Town Creek Watershed with 500-meter Discretization

When running the SPF gridded precipitation, the resultant flows will be much greater than the 100-year and 500-year storm events, so the user should review the routing information to ensure the upper limits of the discharge-storage curves are high enough for the model to run. Additionally, the user should check reservoir elevation-storage tables and discharge rating curves to ensure the tables include high enough values so that the model does not crash.

6 HEC-HMS CDC Expansion Results

The CDC expansion HEC-HMS model was run with depth-area analyses for each frequency storm recurrence intervals. As discussed previously, the depth-area analyses produced higher peak discharges than the uniform storm area depth-area reduction for a 21.46 square-mile storm area. The resulting discharges at each junction represent the 2055 future land use conditions with the CDC hydrologic methodology. The discharge results at significant junctions that were input into the HEC-RAS model began at junction J_TWN_03_04 and included every junction downstream. A summary of the peak discharges at the significant junctions, in cubic feet per second (cfs), is provided in Table 6-1 for all storm recurrence intervals.

Table 6-1. Summary of CDC Expansion 2055 Conditions Discharges for Town Creek

	Frequency and Peak Discharge (cfs)						
HEC-HMS Element Name	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**500-year**
J_TWN_03_04	1700	4100	5700	7200	8300	9400	12100
J_TWN_05	1600	3600	5100	6500	7600	8700	12000
J_TWN_06	1600	3600	5100	6500	7600	8700	12000
J_TWN_07	1600	3700	5200	6600	7700	8800	12200
J_TWN_08	1600	3700	5200	6700	7700	8900	12200
J_TWN_09	1600	3700	5200	6700	7700	8900	12200
J_TWN_10	1700	3800	5300	6900	8000	9100	12600
J_TWN_11	1700	3900	5400	7000	8100	9300	12800
J_TWN_12	2100	4600	6300	8200	9500	11000	15100
J_TWN_13	2100	4600	6300	8200	9500	11000	15100
J_TWN_14	2100	4600	6300	8300	9600	11100	15300
J_TWN_15	2200	4700	6500	8500	9900	11500	15700
J_TWN_16	2400	4800	6500	8600	10000	11700	15900
J_TWN_17	2400	4800	6500	8600	10100	11700	16000
J_TWN_18	2500	5000	6700	8700	10200	11900	16200
J_TWN_19	2600	5200	7000	8800	10300	12100	16400
J_TWN_20	3100	6000	8100	10400	12000	13600	18000
J_TWN_21	3000	6000	8100	10400	12000	13600	18000
J_TWN_22	3100	6100	8200	10600	12300	13900	18200
J_TWN_23	3100	6000	8200	10500	12300	14000	18400
J_TWN_24	3100	6100	8300	10700	12500	14300	18600
J_TWN_25	3200	6100	8400	10700	12600	14300	18700
J_TWN_26	3500	6600	8900	11600	13800	16000	20700
J_TWN_27	3500	6600	9000	11700	13800	16100	21000
J_TWN_28	3500	6600	9000	11700	13800	16100	20800
J_TWN_29	3700	6800	9300	12000	14300	16900	21500
J_OUTLET	3400	6400	8700	11500	13600	15900	21500

The peak discharges from the CDC expansion Town Creek model were compared to the FRI model. It should be noted that comparison of these discharges includes two different hydrologic methods for determining storm water runoff. The FRI study used the SCS curve number loss and unit hydrograph methods, and the CDC expansion model used the USACE Fort Worth District

Urban Curves loss methods and modified Snyder unit hydrograph method. The difference in methodology will inherently result in different outcomes. In addition to the change in methodology, the CDC expansion model is based on the 2055 future land use conditions, while the FRI model was based on existing conditions. These hydrologic changes resulted in peak discharge increases throughout the watershed. The comparison of 100-year storm peak discharges between the two models is included in Table 6-2 below. There is an increase of 9% – 20% throughout the significant junctions.

Table 6-2. 100-year Peak Discharges (cfs) Comparison of FRI Existing and CDC Expansion 2055 Conditions

HEC-HMS Element Name	FRI Existing	CDC Expansion 2055	Difference	% Difference
J_TWN_03_04	8600	9400	800	9
J_TWN_05	7800	8700	1100	14
J_TWN_06	7800	8700	1100	14
J_TWN_07	7900	8800	1100	14
J_TWN_08	8000	8900	1100	14
J_TWN_09	8000	8900	1100	14
J_TWN_10	8200	9100	1200	15
J_TWN_11	8400	9300	1200	14
J_TWN_12	9700	11000	1500	15
J_TWN_13	9700	11000	1500	15
J_TWN_14	9800	11100	1500	15
J_TWN_15	10100	11500	1500	15
J_TWN_16	10200	11700	1500	15
J_TWN_17	10300	11700	1600	16
J_TWN_18	10400	11900	1600	15
J_TWN_19	10500	12100	1600	15
J_TWN_20	11800	13600	2100	18
J_TWN_21	11800	13600	2100	18
J_TWN_22	12000	13900	2300	19
J_TWN_23	11900	14000	2400	20
J_TWN_24	12000	14300	2500	21
J_TWN_25	12100	14300	2600	21
J_TWN_26	13800	16000	2200	16
J_TWN_27	13900	16100	2200	16
J_TWN_28	13900	16100	2200	16
J_TWN_29	14500	16900	2100	14
J_OUTLET	13600	15900	2100	15

7 HEC-RAS CDC Expansion Model Development

The HEC-RAS model from the FRI study was developed in version 5.0.3. The model was imported and updated to HEC-RAS version 6.6 with this pilot study. The geometry and cross-sections were already georeferenced in the FRI model, so no updates were made to the cross-section layout. Since the geometry was properly georeferenced, the geometry was reviewed in RAS Mapper with aerial imagery to determine if any significant stream crossings were constructed since the time of the FRI study. No new significant structures were observed. The geometry "TOWN_CREEK_WATERSHED" geometry from the FRI study was copied and renamed to "CDC: 50% to 0.2% AEP [TC]" to be consistent with the current CDC model naming convention (TC refers to Town Creek). No other changes were made to the geometry data.

The FRI hydraulic model was developed based on 2011 TNRIS LiDAR terrain data. This CDC expansion pilot study references the 2021 TWDB Seamless terrain file for hydrology updates and floodplain mapping. Within the cross-section editor of HEC-RAS, the FRI cross section geometry was compared to the 2021 TWDB terrain to identify any significant deviations. The FRI study cross section geometry generally conforms to the 2021 terrain data with only minor deviations in the overbanks, but more significant differences within the banks. The more significant differences within the banks are likely because the FRI model surveyed channel flow lines and interpolated between cross-sections, rather than extracting from LiDAR terrain data.

Due to budget and funding limitations, this pilot study did not update the cross-section geometry to the most current LiDAR terrain data. However, future CDC expansion efforts could include updating the modeling to the latest terrain data and survey verification, should funding be available. Updating modeling to the latest available terrain data would ensure the modeling and mapping are consistent and include the latest floodplain modifications, if any.

The steady flow file from the FRI study "TOWN_CREEK_MULTI PRO" was copied to create the flow file for the CDC expansion model called "CDC: 50% to 0.2% AEP [TC]". The downstream normal depth boundary condition was not changed from the FRI model with slope of 0.00261. The flow profiles were renamed from the recurrence interval years to the % AEP according to the CDC and USACE model standards and the 50% AEP storm profile was added. The flow outputs from the CDC expansion hydrology model were input at the corresponding junctions and cross-sections. The flow change locations were not revised from the FRI model. Table 7-1 shows the corresponding HEC-HMS junction and HEC-RAS cross section flow change locations.

Table 7-1. HEC-RAS Flow Change Locations and Corresponding HEC-HMS Junctions

HEC-HMS Element Name	HEC-RAS Cross-section
J_TWN_03_04	54847
J_TWN_05	47277
J_TWN_06	46534
J_TWN_07	45675
J_TWN_08	45457
J_TWN_09	43815
J_TWN_10	41121
J_TWN_11	39135
J_TWN_12	37248
J_TWN_13	36803
J_TWN_14	35470
J_TWN_15	31282
J_TWN_16	29344
J_TWN_17	28457
J_TWN_18	25926
J_TWN_19	25294
J_TWN_20	23730
J_TWN_21	21910
J_TWN_22	21442
J_TWN_23	15546
J_TWN_24	15011
J_TWN_25	14412
J_TWN_26	12898
J_TWN_27	10413
J_TWN_28	7958
J_TWN_29	7218
J_OUTLET	331

8 HEC-RAS CDC Expansion Results

The HEC-RAS model was run with the CDC future flows and the resulting water surface elevations were compared with the FRI existing condition results. Due to the increased CDC flows based on 2055 future land use conditions, the 100-year (1% AEP) water surface elevations were higher than the FRI existing conditions model. On average, there was 0.6 feet increase in the 100-year (1% AEP) water surface elevation. The areas of greatest increase in 100-year (1% AEP) water surface elevations were between the Town Creek Hike and Bike Trail Bridge (RS 15518) and the IH-20 bridge (RS 7912), where increases were approximately 1 to 2 feet. A comparison of the 100-year (1% AEP) results between RS 15518 and RS 7832 is included in Table 8-1 below for reference. A full hydraulic results comparison table is included in the Appendix.

Table 8-1. Hydraulic Results Comparison for the 100-year (1% AEP) storm

River Station	FRI Existing WSEL (ft)	CDC 2055 WSEL (ft)	Difference
15518	-	-	-
15496	961.49	962.61	1.12
15454	961.44	962.58	1.14
15289	961.25	962.38	1.13
15074	960.61	961.72	1.11
15011	960.14	961.17	1.03
14991	-	-	-
14974	959.17	960.4	1.23
14930	958.9	960.12	1.22
14749	957.91	959.14	1.23
14412	952.26	953.15	0.89
14258	952.69	953.6	0.91
14126	952.11	953	0.89
13752	950.23	950.86	0.63
13297	949.68	950.75	1.07
12898	949.38	950.5	1.12
12674	949.13	950.33	1.2
12383	948.33	949.86	1.53
12014	947.65	949.53	1.88
11787	947.34	949.38	2.04
11786	-	-	-
11549	947.3	949.33	2.03
11272	947.2	949.26	2.06
11039	947.05	949.17	2.12
10854	946.93	949.1	2.17
10532	946.48	948.78	2.3
10413	946.4	948.73	2.33
10382	-	-	-
10335	939.82	940.43	0.61
10166	941.15	942.15	1
9976	940.92	941.97	1.05
9537	940.36	941.6	1.24
9244	940.23	941.5	1.27
8980	940.15	941.45	1.3
8830	940.13	941.43	1.3
8540	940.08	941.39	1.31
8270	940.01	941.33	1.32
8116	939.54	940.89	1.35
8005	939.36	940.7	1.34
7958	937.61	938.74	1.13
7912	-	-	-

Due to the revised hydrologic methods, the 500-year (0.2% AEP) storm resulted in increases and decreases in discharge through the model. The changes in discharges resulted in water surface elevation changes with an average 0.2 feet of increase for the 500-year (0.2% AEP) storm event. However, the CDC program only evaluates the 100-year (1% AEP) and SPF flood plain impacts, so the 500-year (0.2% AEP) changes are only provided for reference.

The increases in the 100-year (1% AEP) water surface elevations also resulted in a larger flood inundation area. Figure 8-1 below shows the increased flood inundation in red for the CDC expansion 2055 flows compared to the FRI existing condition in blue.

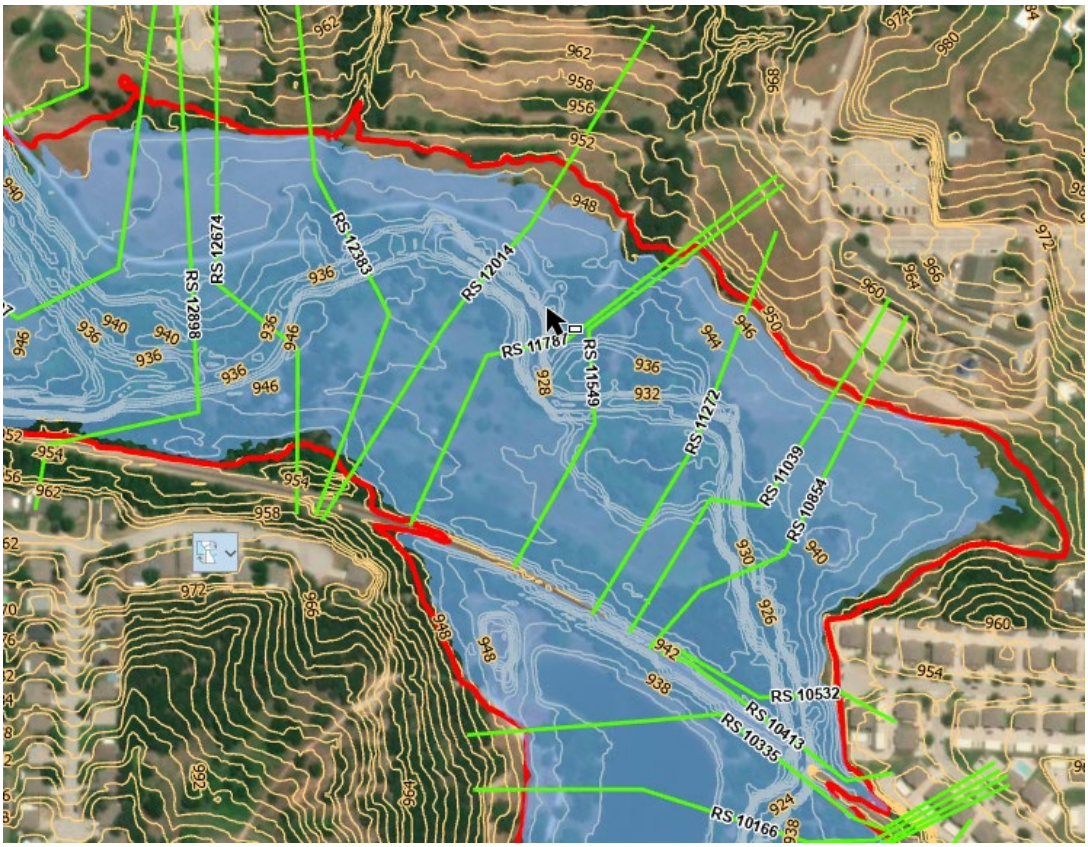


Figure 8-1. Flood Inundation Comparison FRI Existing (blue) vs. CDC Expansion 2055 (red)

9 CDC Expansion Model Consolidation

One of the benefits of the CDC Consolidated Model is the ability to have the FEMA plans and the CDC plans all within one common HEC-RAS project file. This improves efficiency by maintaining all the best available models in one project file for model maintenance and distribution. Additionally, this allows for quick comparison between cross section geometry and model results.

For the CDC expansion pilot study, the Town Creek reach drains to the Clear Fork Trinity River, but the hydraulic model is not directly connected to the Clear Fork CDC model geometry. Figure

9-1 below shows the cross-sections of the Town Creek model in relation to the cross-sections of the current CDC models. Connecting the CDC expansion model to the main CDC model downstream would require the development of significant lengths of hydraulic modeling. Alternatively, the separate Town Creek CDC expansion plans can be imported into the same HEC-RAS project file as the current CDC model. While the models will not be hydraulically connected in one geometry file, the consolidation of the CDC expansion plans into the current CDC model will ensure that all the CDC models can be tracked and shared in one HEC-RAS project file. For future CDC expansion efforts, additional reaches can be imported as separate plans into the one consolidated model.



Figure 9-1. Town Creek sections (yellow), Current CDC sections (green), Stream centerline (blue)

Figure 9-2 below shows the plan selection interface in HEC-RAS which includes the list of current FEMA and CDC plans and the added Town Creek FEMA and CDC plans. The plan names include the FEMA or CDC geometry used, storms modeled (1% AEP, etc.), and the stream name (CF=Clear Fork, WF=West Fork, EF=Elm Fork, TRMS=Trinity River Main Stem, and TC=Town Creek).

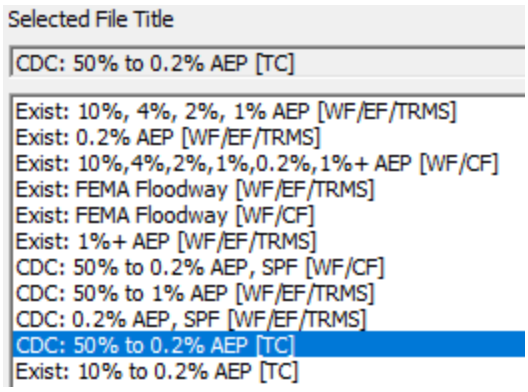


Figure 9-2. CDC Expansion Consolidated model HEC-RAS plans

10 CDC Expansion for Other Communities

This report has documented the steps taken to convert an existing FEMA hydraulic and hydrologic model to CDC modeling in Weatherford. However, the intent of this report is to be used for future replication for other communities within the TSI project area that may be interested in expanding the CDC program to their community. This section will address the steps needed to develop CDC modeling in other communities, based on the models available to that community. The following model availability scenarios are considered:

1. Existing FEMA 1D HEC-RAS model
2. Existing FEMA 2D HEC-RAS model
3. No existing FEMA models, but within BLE 1D HEC-RAS coverage
4. No existing FEMA models, but within BLE 2D HEC-RAS coverage
5. No existing FEMA models and no BLE models

10.1 Existing FEMA 1D HEC-RAS model

For communities with an existing FEMA 1D HEC-RAS model, the same steps performed in the pilot study can be followed to develop CDC models. If there is an associated HEC-HMS model available, the model and drainage divides can be leveraged to develop the CDC hydrology similar to this pilot study. However, if there is no hydrologic model available, the CDC hydrology model can be developed from scratch for the watershed using the HEC-HMS watershed delineation tools mentioned in this report. In this case, the step to enforce existing drainage divides would be skipped. Alternatively, the Trinity River WHA model can be requested from the Interagency Flood Risk Management (InFRM) website and used as a reference to develop the CDC expansion hydrology. The WHA model includes the entire Trinity River basin, so significant portions of the model would need to be removed, or the model could be used for starting parameters when preparing a new hydrology model from scratch. The WHA model subbasins are also likely too large to provide the definition needed to model a local watershed, so further subdivisions of the subbasins would be required using the HEC-HMS GIS tools. The TSI HEC-HMS SOP provides guidance for subdividing a watershed and parameterizing the HEC-HMS model such that the results are consistent with WHA results.

10.2 Existing FEMA 2D HEC-RAS model

For communities with an existing FEMA 2D HEC-RAS model, the CDC modeling could still be performed, but the inundation modeling and mapping would be in 2D. If there is an associated HEC-HMS model, the pilot study steps can be followed to develop the CDC hydrology. Depending on how the flows are entered into the 2D HEC-RAS model, the CDC flows can be applied to determine the CDC floodplain. If the 2D HEC-RAS model is set up with inflow hydrograph boundary conditions, the DSS paths would need to be revised to reference the CDC hydrology output. If the 2D HEC-RAS model is set up with gridded precipitation, the excess precipitation from the CDC hydrology model can be extracted and applied through a DSS file link. Additional loss parameters in the 2D HEC-RAS model should not be used if the excess precipitation is applied from the CDC hydrology model.

The current CDC Common Regional Criteria are based on 1D modeling. For example, no increases in the 100-year (1% AEP) water surface elevations are allowed (within 0.04-feet) and no significant increases in the SPF water surface elevations are allowed. HEC-RAS 2D models are more complex since a whole hydraulic mesh is modeled, rather than simple cross-sections. It can be more challenging to eliminate all increases in water surface elevations in a 2D HEC-RAS model. Therefore, if a community with existing FEMA 2D HEC-RAS models is interested in participating in the CDC program, the Steering Committee and Flood Management Task Force would need to discuss and adopt changes to the Common Regional Criteria that would be more applicable to 2D HEC-RAS modeling scenarios.

10.3 No existing FEMA models, but within BLE 1D HEC-RAS coverage

For communities that are interested in participating in the CDC program, but do not have existing FEMA models to use as a base, the FEMA Base Level Engineering (BLE) 1D HEC-RAS models may be available in the Upper West Fork Trinity (UWFT) Basin. The models can be downloaded here: https://webapps.usgs.gov/infrm/estBFE/. Not all tributaries are modeled within the BLE data, but the website can be reviewed to determine if a 1D HEC-RAS model is available for the watershed of interest. If the 1D HEC-RAS model is available, it will be a good base model to use, rather than starting from scratch. A standard operating procedure (SOP) document was developed as a part of TSI to enhance 1D HEC-RAS BLE models. It is recommended that the BLE model first be reviewed and enhanced per the SOP to include structures, revise reach lengths, and update flows, prior to use for CDC expansion modeling.

The BLE hydrologic modeling used in the UWFT basin was initially developed using USGS regression equations but ultimately referenced the USGS InFRM WHA model results for the flow discharges. The WHA hydrologic modeling was enhanced for the TSI region, so the enhanced TSI modeling could be used as a basis to develop the CDC hydrologic modeling for CDC expansion in the UWFT basin. Communities can coordinate with NCTCOG and USACE for access to the TSI enhanced modeling.

10.4 No existing FEMA models, but within BLE 2D HEC-RAS coverage

For communities that are interested in participating in the CDC program, but do not have existing FEMA models to use as a base, BLE 2D HEC-RAS models may be available in the Lower West Fork Trinity Basin. The models are not yet available for public download at the

USGS website; however, the preliminary models can be provided by FEMA upon request. Generally, the 2D HEC-RAS models cover large areas with multiple watersheds and jurisdictions. If a community is interested in joining the CDC program and needs to develop the CDC modeling along a particular creek in their community, the 2D models should be reviewed to determine if the creek is within one of the larger models. The 2D HEC-RAS model will require substantial refinement within the watershed of interest, including adding structures, reducing mesh cell sizes with refinement regions, adding break lines, and more. The remainder of the 2D model outside of the watershed of interested should be removed. However, the watershed of interest may be located toward the interior of the 2D area, so it may be more work to remove the remainder of the model, than it would be to develop a new hydraulic model from scratch.

The 2D BLE modeling typically uses rain on grid modeling, based on overall hydrologic models for the basin. It would not be feasible to cut out the watershed of interest from the BLE hydrologic model, so the CDC hydrology for the watershed of interest would need to be developed from scratch using the steps provided in this pilot study.

10.5 No existing FEMA model or BLE models

For communities that are interested in joining the CDC program but do not have existing FEMA models and the BLE modeling is not available for the watershed of interest, the CDC H&H models will need to be developed from scratch. The hydrologic model can be developed relatively quickly using the watershed processing tools previously mentioned, however developing the hydraulic model will not be as simple since HEC-RAS does not have the automated processes to develop models like HEC-HMS does. The BLE models use the WISE software to automate the 1D HEC-RAS model parameters, but ArcGIS tools are needed to review and modify cross section layouts. Alternatively, a 2D HEC-RAS model could be developed from scratch, which would require less cross section layout and modification. The TWDB seamless LiDAR terrain could be leveraged to generate a 2D HEC-RAS model of the watershed of interest and the modeler would need to follow similar steps as the TSI hydraulic SOP to add structures and refine the 2D mesh. Internal boundary conditions could be added to input flow hydrographs from the DSS output file generated by the CDC hydrology model developed. As previously mentioned, if 2D hydraulic modeling is used for CDC expansion models, the Steering Committee would need to discuss and adopt updated criteria.

10.6 Modeling Assistance and Funding

Communities interested in joining the CDC program and developing CDC modeling for their watershed(s) of interest will need to invest resources into the development of the models. It is possible that the communities will not have the modeling expertise available within city/county staff, so subcontractors may be needed to assist the model development. Alternatively, the communities could apply for federal funding and USACE technical assistance through the Floodplain Management Services (FPMS) program. A template application and funding request form has been prepared as a reference and guide for communities interested in applying for this federal assistance. The template application is included in the Appendix.

11 CDC Expansion Program Management

In addition to the modeling efforts, communities interested in joining the CDC program will require program management efforts to fully adopt the process and become a participating community. The CDC program recognizes and affirms local community authority over floodplain management, so a community interested in joining the program will need to take a leading coordination role in the process. The program management efforts will include the following elements: flood ordinance changes, coordination of the CDC applications, participation in the COMMON VISION committees, and financial commitments. Additional information about the CDC program can be obtained through the CDC website (https://www.nctcog.org/envir/watershed-management/corridor-development-certificate-program) or by contacting the NCTCOG (Environment and Development Department) directly at 817-695-9210, or at EandD@nctcog.org.

11.1 Flood Ordinance Changes

Since the floodplain management authority ultimately resides with the local government, the community interested in joining the CDC program will need to adopt changes to their flood damage prevention ordinances mandating participation in the CDC program. The Common Regional Criteria of the CDC program will also need to be adopted into the ordinances. All the current CDC member communities have revised their flood ordinances to include the CDC requirements, and their flood ordinance documents can be used as a reference. The current CDC member communities include Arlington, Carrollton, Coppell, Dallas, Dallas County, Farmers Branch, Fort Worth, Grand Prairie, Irving, Lewisville, Seagoville, and Tarrant County. Revising the flood damage prevention ordinances will likely involve public engagement and/or council approval, so the community should be able to effectively communicate the benefits of the CDC program to ensure approval of the ordinance changes.

11.2 CDC Application Coordination

The community in which the CDC application is located is the coordination lead through the process. A community that is interested in joining the CDC program will need to become familiar with the application process and submittal requirements. The applicant first submits the CDC application to the community and then the community is responsible for reviewing the application to ensure it is complete and contains all required materials. The community is also responsible for determining if the application is eligible for an exemption according to the CDC manual section 1.6. Once the community determines if the application is complete, the community is responsible for establishing a CDC case number, uploading the application materials to the NCTCOG portal for regional review, and requesting technical review by USACE.

Once the technical review letter is issued by USACE and the regional review comments have been received, the community will make the final determination for the CDC application approval. Communities interested in joining the CDC program should understand that even though regional review and technical USACE review are provided by the program, the final decision authority remains with the community. Once the CDC review process is complete, the community issues the final CDC action letter.

Once the CDC application is approved, the community will be responsible to provide annual status reports to NCTCOG regarding construction of the project and re-evaluate the CDC in the event of significant changes in the project. For more detailed explanation of the CDC program and application process, the latest edition of the CDC Manual is available at the NCTCOG website at https://www.nctcog.org/envir/watershed-management/corridor-development-certificate-program.

It should be noted that the CDC program is not a replacement of the National Flood Insurance Program requirements with FEMA. The community as the floodplain administrator is still responsible for processing any FEMA Flood Insurance Rate Map (FIRM) changes through the standard Letter of Map Revision (LOMR) processes, including Conditional Letter of Map Revisions (CLOMR). This assumes that the community is already a participant in the NFIP.

11.3 Participation in the COMMON VISION

Joining the CDC program would include participating in the Trinity River COMMON VISION regional initiative which strives to make the Trinity River and its tributaries safe, clean, enjoyable, natural, and diverse. Participation would include becoming a member of the Steering Committee which is comprised of elected officials from CDC communities and provides policy guidance for the CDC program. Additionally, staff from the community would be able to join the Flood Management Task Force which provides the technical support and coordination for the CDC program.

The Steering Committee meets annually and member communities which provide funding support for the program have voting representatives, while other members are non-voting. The Steering Committee discusses program updates, related Trinity River activities, and voting on action items such as changes to the work program and budget. The Steering Committee would also vote on adding new communities and adopting new models into the CDC consolidated model. The Flood Management Task Force meets quarterly and has a more technical focus. During the meetings, technical presentations are made, and progress is discussed for the various work plan tasks. Communities interested in joining the CDC program would have the benefit of better regional planning and coordination through these committees.

The CDC process also includes regional review by other member communities. When a new CDC application is submitted, the application is sent to all other participating communities for review and comment, since ultimately all communities along the Trinity River are impacted by upstream development along the river. Comments from participating communities, if any, are provided to the permitting community and should be considered in the final CDC action determination. The permitting community can choose to address comments from other communities or not. However, having this regional review provides the permitting community with more regional impact feedback. There are typically no significant comments from the regional review and usually only the adjacent communities provide comments.

11.4 Financial Commitments

As mentioned previously, the Steering Committee has both funding members with voting rights and non-funding members. The CDC program is funded by the participating communities and new communities interested in joining the program should understand that a cost participation

may be required. There is a minimum $1,000 annual contribution and the contribution amount is typically based on the relative acreage of the SPF floodplain in the community. For new communities with disconnected watersheds, this methodology may no longer be applicable, so the Steering Committee will need to determine a new policy for funding requirements.

Additionally, there is a CDC application review fee that covers the cost of USACE technical review and NCTCOG coordination of the application. The application fee is paid by the CDC applicant, which can either be the private developer, or the community itself in the case of a public project. The permitting community is responsible for coordinating the payment from the applicant to the NCTCOG. Upon receipt of payment, NCTCOG forwards a portion of the payment to USACE for the technical review. The fee is $6,000 for projects in the effective flow areas, and $4,000 in the ineffective flow areas. The community can coordinate with USACE to determine if a project resides in the ineffective flow areas of the model, however for new communities with separate watershed models, it is likely that the review fee will generally be $6,000.

12 Conclusion

This report documents the TSI pilot study modeling procedures and lessons learned from converting the Town Creek existing models in Weatherford, TX, into CDC expansion modeling. This report and the modeling processes are intended to be a replicable guide for communities with similar existing models to create CDC modeling for their community. Additionally, this report addresses the programmatic implications of expanding the CDC program into the TSI region.

The CDC program has demonstrated the benefit of higher floodplain regulatory standards by stabilizing flooding risks and maintaining floodplain storage. Expanding the CDC program to communities in the TSI project area would expand the benefits of the program to new communities and the entire Trinity River system downstream of those communities. Expanding the CDC program would also provide communities with technical review assistance from USACE and would improve regional flood planning efforts. However, if communities are interested in adopting the higher standards, but not officially participating in the program, the current CDC manual and this guidance document can be used as technical references to better understand the modeling and impact requirements to enforce the Common Regional Criteria. While there may be obstacles to expanding the program to separate communities and separate watershed models, the communities in the TSI region could consider adopting the Common Regional Criteria into their flood damage prevention ordinances, as a minimum effort to reduce flooding impacts as the TSI region develops.

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