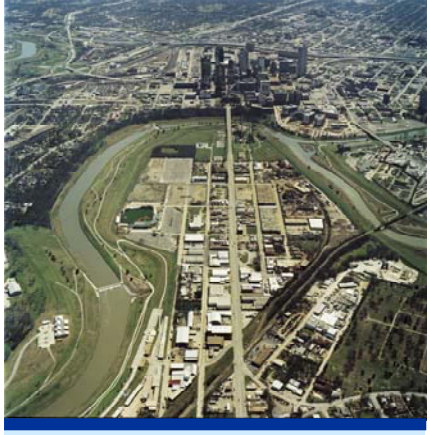
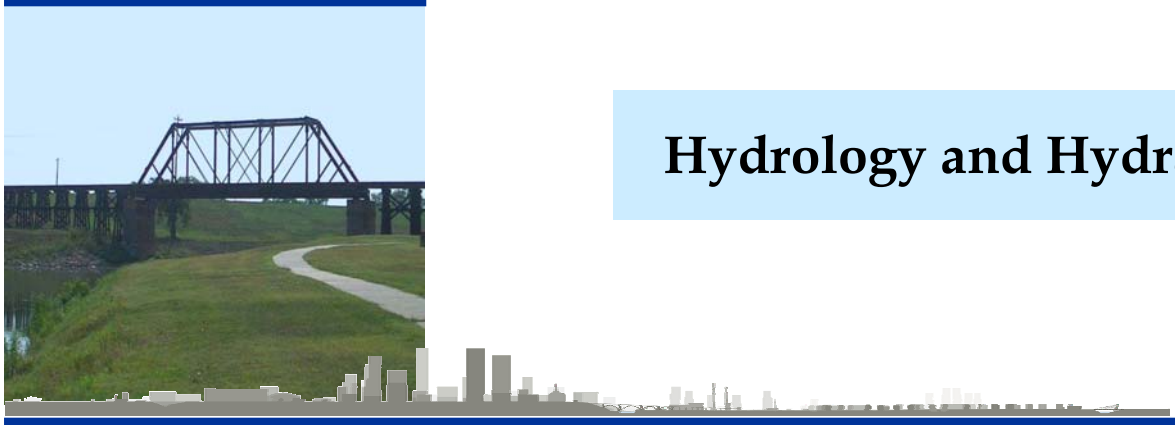


Fort Worth Central City Preliminary Design



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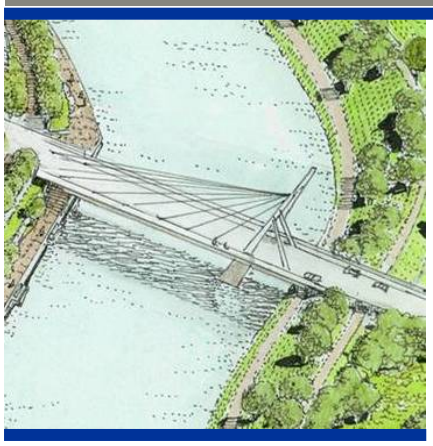

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Appendix A

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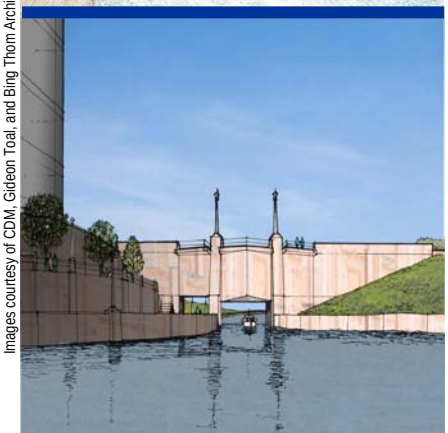

Images courtesy of CDM, Gideon Toal, and Bing Thom Architects

Fort Worth Central City Preliminary Design

Hydrology and Hydraulics

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Appendix A

May 2005

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Section 1
Introduction

1.1 Project Description

The Fort Worth Central City (FWCC) Project consists of a bypass channel, levee system and associated improvements to divert flood flows around a segment of the existing Trinity River adjacent to downtown Fort Worth. The proposed bypass channel is approximately 8,400 feet long and approximately 300 feet wide between the top of levees. The bypass channel would be approximately 30 feet below existing grade. Design level of protection of the project is SPF plus four feet. The essential components of the project are shown in Figures 1-1 through 1-3.

Water levels in the bypass channel would be controlled by a dam with crest gates. The dam is proposed on the West Fork of the Trinity River just east of the Samuels Avenue bridge and would be designed to maintain normal water level of approximately 525 feet above sea level in the bypass channel and interior area. Flood isolation gates would be incorporated into the levee system to protect the interior area, otherwise known as Trinity Uptown. The gates are located upstream at the confluence of the bypass channel and the Clear Fork (Clear Fork Gate), at the midpoint of the bypass channel and the West Fork confluence (Trinity Point Gate), and downstream at the confluence of the bypass channel and the West Fork (TRWD Gate).

Construction of the bypass channel, dam and isolation gates would create an approximately two-mile segment of the existing West Fork Trinity River as a controlled, quiescent watercourse. A water feature or urban lake, approximately 2900 feet long, is proposed for the interior area (Trinity Uptown). The water feature would extend from the bypass channel southeast to the existing West Fork and Clear Fork confluence of the Trinity River.

Six bridges are proposed for the project, including four vehicular bridges and two pedestrian bridges. Vehicular bridges are proposed over the bypass channel at North Main Street, over the bypass channel and Fort Worth and Western Railroad (FW&W Railroad) at Henderson Street and White Settlement Road, and on the White Settlement Road extension over the urban lake. Two pedestrian bridges are also proposed, across the bypass channel downstream of Henderson Street, and across the West Fork, approximately 500 feet upstream of the existing FW&W Railroad Bridge.

The project also includes proposed modifications to University Drive, which would effectively raise the roadway approximately 10 feet from existing grade and out of the 100 year floodplain. The proposed modifications begin north of the existing bridge over the West Fork extending to Jacksboro Highway (State Highway 199).

Without mitigation, the project would result in a loss of floodplain or valley storage due to the fact that the bypass channel is shorter and contains less volume than the existing river channel. To mitigate for this potential loss of storage, valley storage mitigation sites are included in the preliminary design. A wide range of valley storage mitigation alternatives were considered. Valley storage mitigation sites would be provided in three areas, along the West Fork of the Trinity River upstream of the project area, in the vicinity of the Samuels Avenue Dam, and slightly downstream of the dam in proximity to Riverside Park. Construction of the bypass channel and associated valley storage sites would not increase downstream water surface elevations or downstream flows.

1.2 Purpose and Scope

This appendix to the Draft Environmental Impact Statement summarizes the existing hydrologic, hydraulic, and associated regulatory conditions within the project area (Section 1). This document also outlines the development of the hydrologic and hydraulic models and associated hydrologic and hydraulic analyses for the FWCC Project (Sections 2 and 3). Operational and maintenance consideration are detailed in Section 4. Summary and conclusions are presented in Section 5 and references in Section 6.

These analyses were completed by CDM on behalf of the Tarrant Regional Water District (TRWD) in collaboration with the U.S. Army Corps of Engineers (USACE), and the City of Fort Worth The objective of the analyses is to demonstrate a viable configuration of the Project that maintains flood protection with regard to the relevant design criteria (discussed in Section 1.3), while being consistent with other project objectives, including environmental enhancement, recreation, and urban revitalization The hydraulic analyses include modeling a bypass channel to divert flood flows from the West Fork and Clear Fork of the Trinity River near downtown Fort Worth, and include four structures to control water flow (one dam and three isolation gates).

1.3 Regulatory Considerations

In the mid-1980's, USACE prepared a regional programmatic Environmental Impact Statement (EIS) to establish a floodplain development permitting strategy for the Upper Trinity River and its tributaries. USACE issued a Record of Decision in April 1988 specifying criteria the USACE would use to evaluate Section 404 permit applications in the Upper Trinity River Corridor. As a result, the cities and counties in the Upper Trinity River Corridor formed the Trinity River Steering Committee, facilitated by the North Central Texas Council of Governments. The Steering Committee developed and is responsible for implementing the Corridor Development Certificate (CDC) process to meet the 1988 Record of Decision.

The CDC program and accompanying CDC Manual affirm local government authority for local floodplain management while establishing a set of common permit criteria and procedures for development within the Upper Trinity River Corridor. The Trinity River Steering Committee, consisting of local elected official from jurisdictions

in the Upper Trinity River Corridor, approved the first edition of the CDC manual May 23, 1991. Within the next two years, the participating communities (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, Lewisville) officially amended their floodplain ordinances to adopt the CDC common permitting criteria and process. In the CDC process, the CDC model (a HEC-RAS model developed and maintained by USACE) is considered the baseline design model for proposed development projects in the Upper Trinity River Corridor.

1.4 Existing Conditions

The Upper Trinity River has been considerably urbanized over the past century as a part of the Dallas /Fort Worth (DFW) metropolitan area, otherwise known as the Metroplex. In 2000, the population of the ten county Metroplex was just over five million and covered a land area of over 7,200 square miles (NCTCOG 2003). The 2030 projected population for the region indicates an increase of an additional four million people.

The waterways of the Upper Trinity River basin are currently and will continue to be heavily influenced by urban hydrology. Waterways are further influenced by discharges from surrounding man-made reservoirs. The combined effects of urban development and flood control activities within the basin have permanently altered the natural-state hydroperiod and hydraulic regime.

The Central City study area shown on Figure 1-1, encompasses the confluence of the Clear Fork and West Fork of the Trinity River within the developed metropolitan area of Fort Worth. Several flood control projects dating back to the 1920's were constructed within the study area and the area is currently an active Federal floodway operated and maintained by the Tarrant Regional Water District. Water supply and flood control reservoirs exist upstream on both the Clear Fork (Benbrook Lake) and the West Fork (Lake Worth and Eagle Mountain Lake).

The study area is part of the Upper Trinity River system, which is covered by two major floodplain management policies, the 1988 Record-of-Decision associated with the USACE's Upper Trinity River Feasibility Study and the resulting CDC Program. The CDC hydrologic and hydraulic models, as the foundation to the CDC Program, are used for analysis of proposed floodplain development projects within the Upper Trinity River Corridor.

The baseline condition hydraulic model used for this study is the current CDC model which was developed and is maintained by the USACE. The CDC model was originally developed using the backwater program HEC-2 Water Surface Profiles. The model was subsequently converted to HEC-RAS River Analysis System version 3.0, but has most recently been used in version 3.1.2. The West Fork Trinity River CDC model limits are the confluence of the West Fork and the Elm Fork in Dallas County on the downstream side and the confluence to Lake Worth Dam on the upstream side, a distance of 58.08 miles.

The original CDC West Fork hydraulic models were developed by extensive use of digitized 2-foot contour interval topography. The topographic data was developed from February/March 1991 aerial photography. The majority of the cross-section data were supplied by the surveying contractor and generated from the topographic data, with cross sections locations developed by the USACE. Additional cross sections were developed from the topographic files and included in the models as necessary. Other information used in the development of the CDC models originated from bridge plans, bridge surveys, field reconnaissance, and levee surveys. Channel data originated from 1975 field surveys. Aerial photographs and field reconnaissance were used to determine roughness coefficients.

The Federal Emergency Management Agency (FEMA) maintains maps of local floodplains as a part of its administration of the National Flood Insurance Program. For the Central City Project area, Figure 1-4 illustrates the existing 100-yr and 500-yr floodplains as defined by FEMA.

1.5 Relevant Design Criteria

Several hydrologic and hydraulic criteria are applicable to proposed projects within the Upper Trinity River floodplain and include criteria associated with USACE regulations and the regional CDC Program.

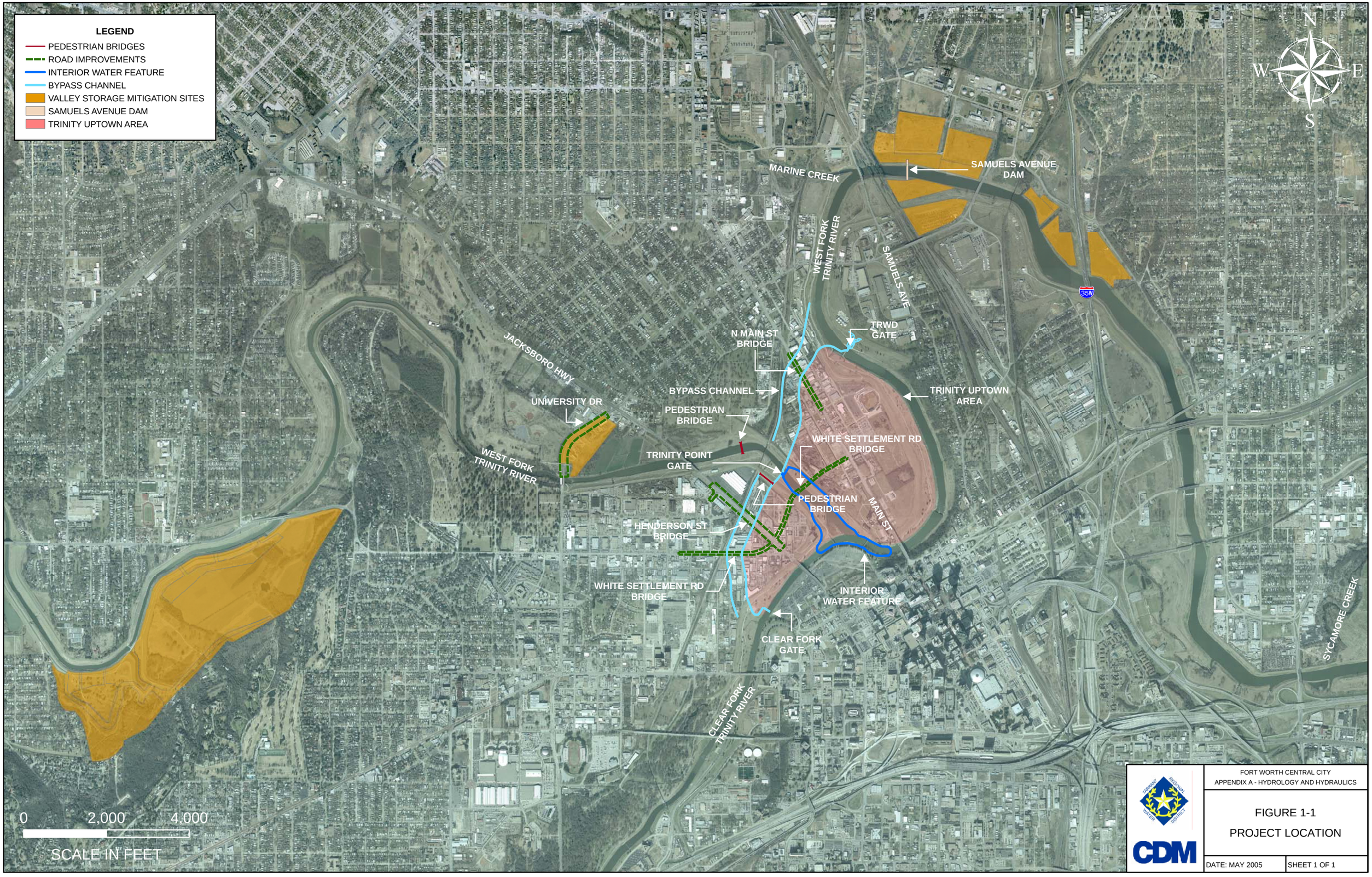
In consultation with the USACE, it was determined that if the hydrologic and hydraulic analysis of the Central City Project met the standard criteria set forth by the regional CDC guidelines, then all regulatory criteria would be met. The specifics of the CDC criteria are:

- No increase in 100-year and SPF water surface elevations outside the project limits;
- No increase in 100-year flood or effective increases in SPF water surface elevations within the project limits unless appropriate flood protection is provided;
- No decrease in valley storage for 100-year flows; and
- No more than five percent decrease in valley storage for SPF flows.

In addition to the CDC criteria, the design will be subject to the following hydraulic performance requirements:

- No increase in the SPF water surface elevation as this is the Record of Decision Criteria for the Upper Trinity planning area and base USACE criteria for construction within a Federal flood control project;
- Discharges will not be increased downstream of the project limits;
- Increases in the base flood elevation (BFE) will be mitigated with appropriate flood protection measures;

- Velocities will not be increased above erosive levels outside the project limits;
- Manageable flow velocities will be maintained throughout the range of return periods such that infrastructure, earthen structures, habitats, and the like will not be damaged; and
- Levee freeboard above the SPF water surface elevation will be provided consistent with the existing level of protection. USACE preference is for "SPF plus four feet," which will be provided for all new levees.

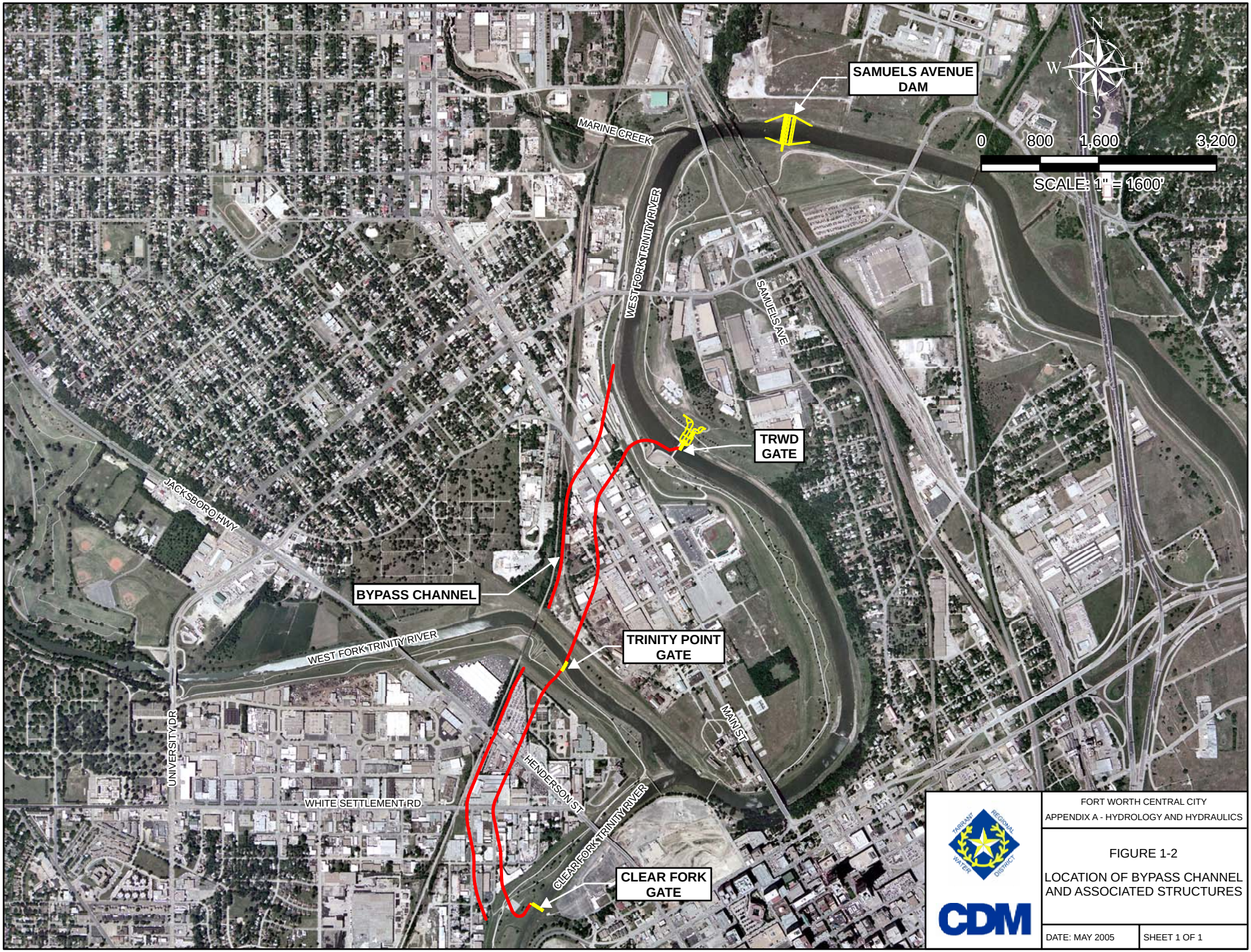


FORT WORTH CENTRAL CITY
APPENDIX A - HYDROLOGY AND HYDRAULICS

FIGURE 1-1
PROJECT LOCATION

DATE: MAY 2005

SHEET 1 OF 1



FORT WORTH CENTRAL CITY

APPENDIX A - HYDROLOGY AND HYDRAULICS

FIGURE 1-2

LOCATION OF BYPASS CHANNEL AND ASSOCIATED STRUCTURES

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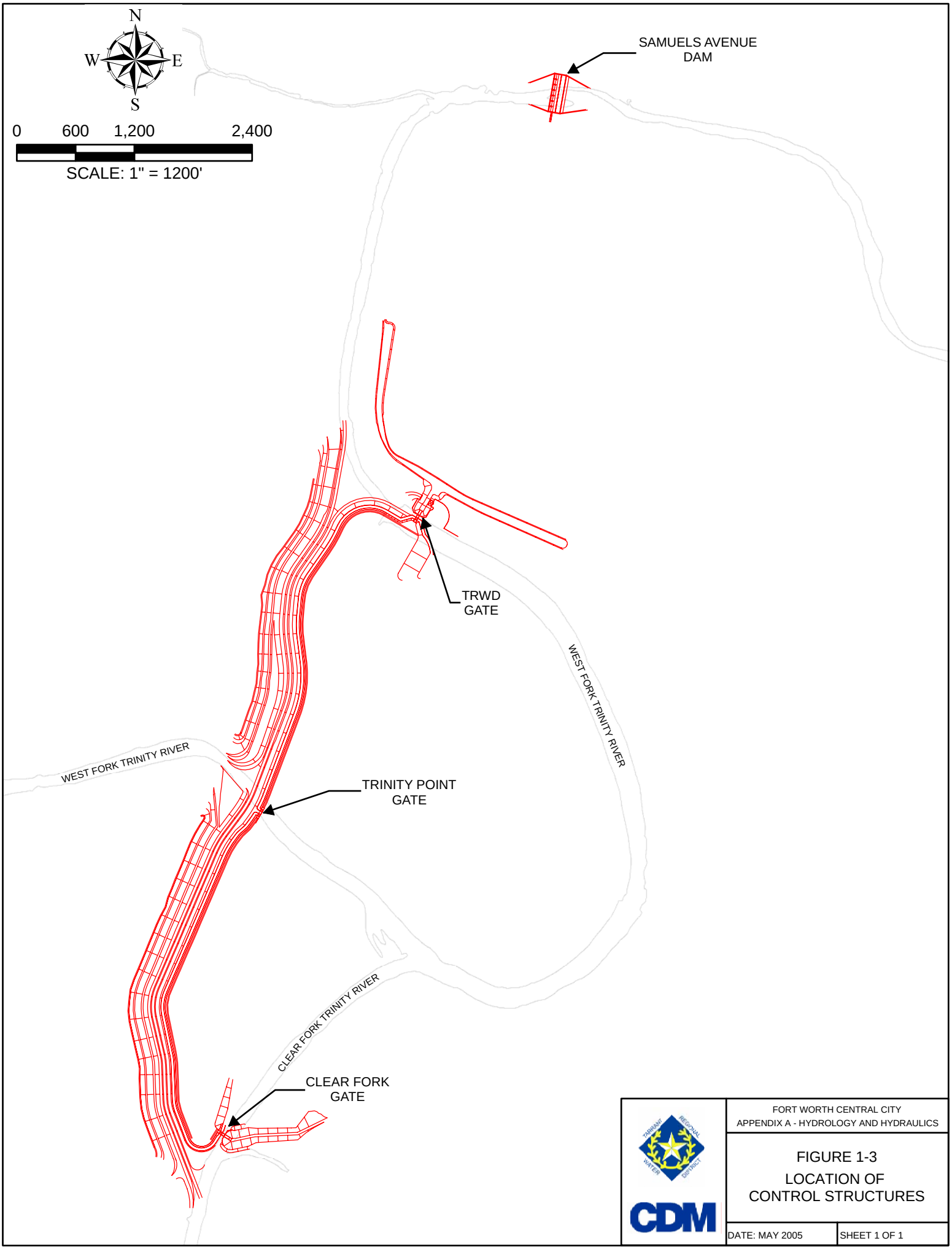
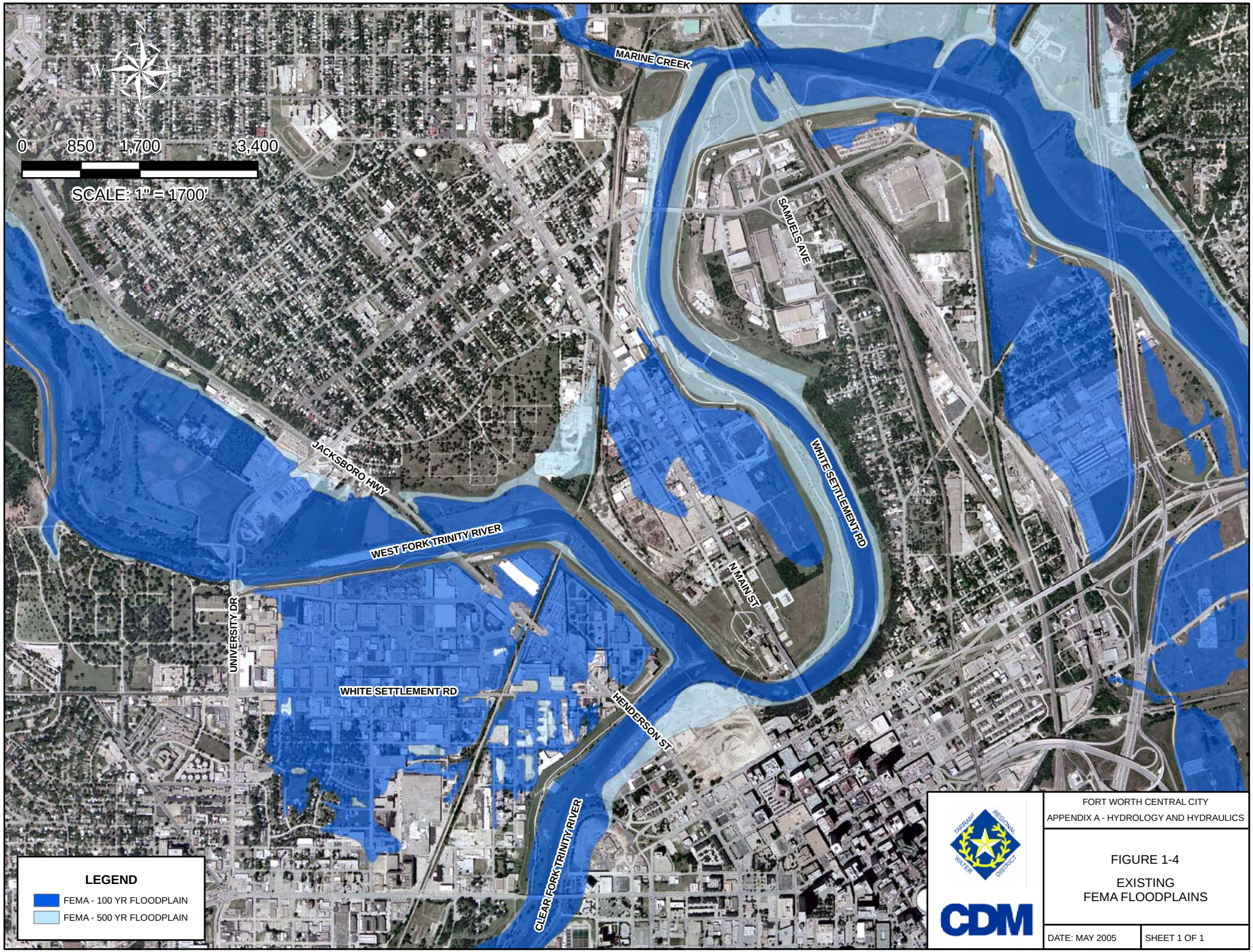


FORT WORTH CENTRAL CITY
APPENDIX A - HYDROLOGY AND HYDRAULICS

FIGURE 1-3
LOCATION OF CONTROL STRUCTURES

DATE: MAY 2005

SHEET 1 OF 1



FORT WORTH CENTRAL CITY

APPENDIX A - HYDROLOGY AND HYDRAULICS

FIGURE 1-4

EXISTING
FEMA FLOODPLAINS

DATE: MAY 2005

SHEET 1 OF 1

Section 2
Hydrologic Analysis

2.1 Baseline Model

The starting point for the hydrologic analysis of the Central City Project was a HEC-1 model of the Upper Trinity River system provided by the USACE. The model was developed for the regional CDC process and is maintained by the USACE Fort Worth District. In order for this model to serve as a baseline model for this assessment, modifications to the model were required after consultation with USACE.

For the analyses associated with the Central City Project, the baseline HEC-1 model was developed from the CDC HEC-1 model to provide the best available representation of Year 2050 flows in the existing configuration of the floodway. This required updating of the routing reach storage and outflow data in the project area so that the modeled storage for each reach conformed to the most current channel geometry in the Upper Trinity HEC-RAS model. CDM and USACE prepared the updated hydrologic model during July and August of 2004. Nine HEC-1 routing reaches were modified during this process. These reaches are listed in Table 2-1.

The updated model produces the baseline condition flows listed in Table 2-2. The updated baseline HEC-1 model flow outputs were then assigned to locations in the HEC-RAS model indicated in Table 2-2. This includes all flow values except the Standard Project Flood (SPF) flow values for the Clear Fork, which are shown in Table 2-3 and were provided by USACE staff based on spills from Benbrook Lake and a separate evaluation, previously established, SPF pool elevation. At the direction of the USACE, these flows for the Clear Fork were used throughout the analysis for SPF conditions.

2.1.1 Addressing Uncertainty in Sizing of the Project

Per the design criteria described in Section 1.5, the project must provide protection for all flood flows up to and including the SPF. In areas where levees are used for protection, USACE requirements per the 1988 Record of Decision are that four feet of freeboard must be provided.

USACE also employed coincident events and critical pool elevations to develop the SPF flows for the baseline model. This included defining a one-half PMP storm center over each tributary watershed and assuming full pools in key reservoirs. The defined condition has been developed addressing potential uncertainty in the sizing of elements as the design flows are well above the 0.2 percent chance of exceedence flows.

The consensus with USACE is that these two approaches adequately address uncertainty in project sizing.

2.2 Proposed Conditions Flows

Although a proposed conditions hydrologic model was developed, the baseline flows were used in evaluating the project. This was done in consensus with USACE and was found to be a conservative assumption. It is also consistent with previous applications of the CDC process. For reference purposes, proposed conditions flows are included in the discharge results provided in Section 2.2.2.

2.2.1 Discharge Frequency Relationships

Baseline conditions discharges were computed as discussed in Section 2.1. A proposed conditions model was developed by modifying the routing reaches that would be changed by the proposed project. These modifications include storage losses in reaches LWORCF, FWHWF and FWOMAR. Mitigation storage was incorporated into LWORCF and MARSYC. Some of these reaches were redefined for proposed conditions. Notably, FWHWF was cut off at station 3590 and includes the upper bypass. LWORCF is cut off at 257426 and FWOMAR is cut off at its upstream end at 245866, but would include the lower bypass.

The baseline and proposed conditions HEC-1 models were run for a range of storm frequencies. Discharge results are provided in Table 2-4. Comparison of baseline and proposed flows show decreases in flows from upstream of the confluence through the bypass to Marine Creek. The system experiences slight increases in flow in some locations downstream of Marine Creek although there is no overall increase in 100-year or SPF flow downstream of the project. As previously indicated, these flow decreases were not used to evaluate the project.

2.2.2 Project Induced Changes Obligating Mitigation

The primary activity that would affect the nature of flood flows in the project area is the re-routing of flood flow through the proposed bypass channel rather than the existing reaches of the Clear and West Forks of the river. As the bypass channel shortens an existing meander in the river, there would be a net loss of reach storage. The reduced storage values were determined by conducting a multiple profile analysis on a proposed conditions HEC-RAS model that included a likely bypass channel configuration and ancillary structures. The bypass channel results directly in storage losses in the following HEC-1 reaches: LWORCF (Lower), FWHWF, and FWOMAR.

These reaches are most affected by the fact that the bypass channel reduces the length of conveyance channel in the system. Since valley storage is calculated based on a water surface elevation, losses in valley storage were also caused by lowered water surface elevations resulting from the proposed project. Observed reductions in water surface elevations in the proposed configuration of the bypass channel occur because the bypass channel: 1) presents less resistance to flow than the current channel; and 2) has a greater slope than the current channel. The greater slope occurs because the routing of the river through the bypass channel would now result in the same grade

change over a much shorter distance. This combines to reduce valley storage through a "draw down" effect on water surface elevations in the both the Clear Fork and West Fork upstream of their confluence with the proposed bypass channel.

The construction of the proposed bypass channel is estimated to cause a net loss of approximately 2,850 acre feet of valley storage under SPF conditions. An additional estimated 2,400 acre feet of valley storage would be lost due to drawdown under SPF conditions, if no action is taken to reduce drawdown. In the proposed project, the aggregate lost valley storage (5,250 acre feet) would be mitigated using in-line and off-line storage and an additional structure to reduce water surface draw down.

An analysis was performed to determine the expected effect on flows by incorporating the proposed changes into the HEC-1 model. The proposed valley storage in each reach was determined using HEC-RAS, except for the off-line storage at Riverbend, which was calculated using Microstation. The HEC-1 model was run with mitigation storage in place to determine the expected 100-year and SPF flows under proposed conditions. These flows are included in Table 2-2. Although the proposed conditions flows accurately depict projected flows, they are not used to evaluate CDC compliance.

2.2.3 SPF Flooding

There are areas within the Upper Trinity River Basin that are currently subject to flooding under SPF flow conditions. The project would reduce SPF flooding within the project area due to resulting lower water levels on the West Fork upstream of the proposed confluence and increased levee protection levels associated with the bypass channel. The project would not exacerbate SPF flooding at any location outside the project area.

2.2.4 Stage-Discharge Relationships

The hydraulic model employs a stage-discharge relationship that is defined at the model limit at cross-section 206218. This stage-discharge relationship was provided by USACE. No additional stage-discharge relationships were developed for this analysis.

2.2.5 Flow Duration

Figures 2-1 and 2-2 show computed hydrographs upstream and downstream of the project area for existing and proposed conditions. The hydrographs illustrate several important points: the effect of the mitigation storage on the shape of the hydrograph and the reduction of the second flood peak and the change in controlling peak flows upstream and downstream of Marine Creek. In upstream areas and through the bypass, the second peak has higher peak flow. The maximum flow shifts to the first peak downstream of Marine Creek. In either case, there are no changes in the duration of flooding.

2.2.6 Reservoir Yields/Discharges

The upstream project analysis limits are Benbrook Lake on the Clear Fork and Lake Worth on the West Fork. The storage-discharge behaviors of these two reservoirs were incorporated into the HEC-1 models by the USACE.

2.3 Residual and Induced Flooding

An additional benefit of the project is that some portion of the existing floodplain would be eliminated or reduced in extent. The project would reduce residual flooding in some locations because of lower water levels, lesser peak flows, and increased levee level protection. Residual flooding would not be increased at any location within the project area. There is also no induced flooding associated with this project during either construction or post-construction project conditions. Any water elevation increases would occur in protected areas within the limits of the project. Anticipated changes to the FEMA 100-yr and 500-yr floodplains as a result of the project are shown in Figure 2-3.

As shown, overbank flooding would be eliminated within the interior drainage basin. This would be accomplished through levee construction along with the interior drainage pump station. Drainage improvements and levee construction would also eliminate flooding in the Northwest basin as shown on Figure 2-3.

The project is expected to reduce the 100-yr water surface profile by up to 4 feet on the West Fork between the bypass channel and University Drive. This reduction in water level could reduce the extent of the overbank flooding north of the West Fork and in the 14W/15W drainage basin. The extent of the floodplain reduction in these areas would be determined in analyses to be conducted during 2005 in association with the development of a Conditional Letter of Map Revision (CLOMR) for the project. A LOMR is part of the formal process to have the FEMA floodplain maps revised once the project is constructed.

Table 2-1
HEC-1 Reaches in the Central City Area

Reach ID	HEC-RAS River Reach	HEC-RAS Station Upstream	HEC-RAS Station Downstream
LWORCF	WF4	306246	269743
LWORCF	WF4	269743	254346
MRYFWH	CF	41045	11918
FWHWF	CF	11918	477
FWOMAR	WF3	254346	242451
MARSYC	WF3	242451	219536
SYCBFL	WF3	219536	206314

Table 2-2
Flow Results for Baseline and Proposed Conditions

Location		*100-yr Flow (cfs)*		*SPF Flow (cfs)*	
		Baseline	**Proposed**	**Baseline**	**Proposed**
***Clear Fork*[1]**	CFBMRY	27600	27600	54400	54400
	FWHT2	32300	32300	63100	63100
	CFAWF	32100	32200	62100	62300
West Fork 4	FLWT2	35400	35400	56400	56400
	WFACF	35400	33000	59800	56400
West Fork 3	FWOT2	48400	46900	119000	115200
	WFAMAR	48100	47000	118900	115100
	WFBMAR	50300	50100	122400	121200
	WFASYC	51000	51000	127300	127800
	WFBSYC	73000	73600	156400	156900
	WFABFL	63400	63200	147800	146600

[1] The Clear Fork flows computed in HEC-1 are not used directly in HEC-RAS. They are listed here for information only.

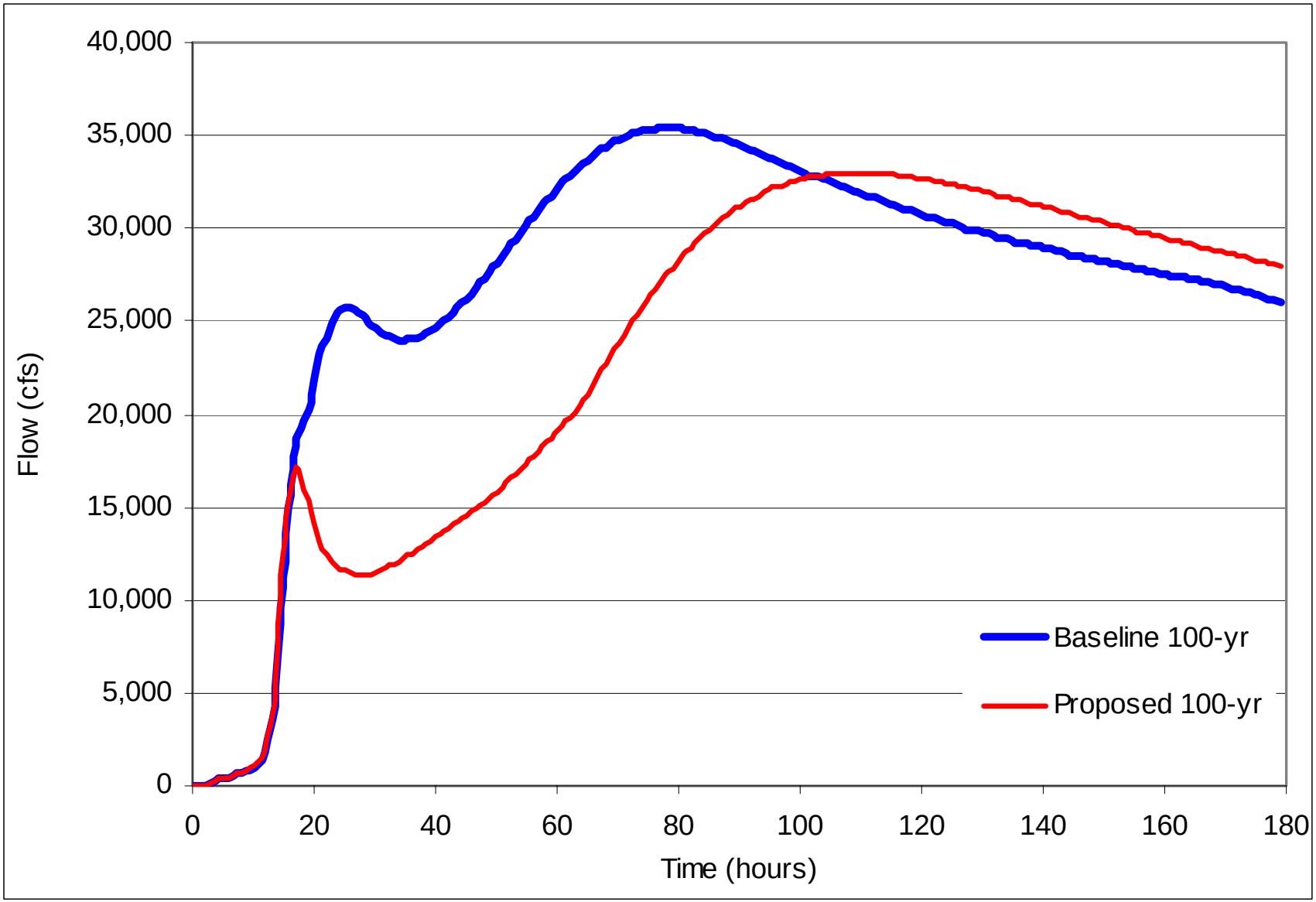
Table 2-3
Clear Fork Baseline SPF Flows

Location	Flow
CFBMRY	71800 cfs
FWHT2	81300 cfs
CFAWF	77800 cfs

Table 2-4
Frequency Discharges for Baseline and Proposed Conditions

Location		***Baseline Flow (cfs)***			
		2-yr	**5-yr**	**10-yr**	**25-yr**
Clear Fork	CFBMRY	5000	10600	14800	19000
	FWHT2	6800	12200	17100	22200
	CFAWF	7200	13000	17700	22700
West Fork 4	FLWT2	13600	18900	22200	26500
	WFACF	13600	18900	22200	26500
West Fork 3	FWOT2	13600	18900	24400	32300
	WFAMAR	13600	18900	24100	32500
	WFBMAR	13700	19500	26100	33700
	WFASYC	13700	19500	26200	34200
	WFBSYC	21200	34200	42200	51800
	WFABFL	15900	24700	31900	40700

Location		***Proposed Flow (cfs)***			
		2-yr	**5-yr**	**10-yr**	**25-yr**
Clear Fork	CFBMRY	5000	10600	14800	19000
	FWHT2	6800	12200	17100	22300
	CFAWF	7000	13000	17700	22800
West Fork 4	FLWT2	13600	18900	22200	26500
	WFACF	12700	16400	20000	24400
West Fork 3	FWOT2	12700	17100	24500	31800
	WFAMAR	12700	17100	24400	32000
	WFBMAR	12700	20500	27300	34500
	WFASYC	12700	19600	26800	34900
	WFBSYC	21500	34300	42300	51900
	WFABFL	16200	25000	32300	40900

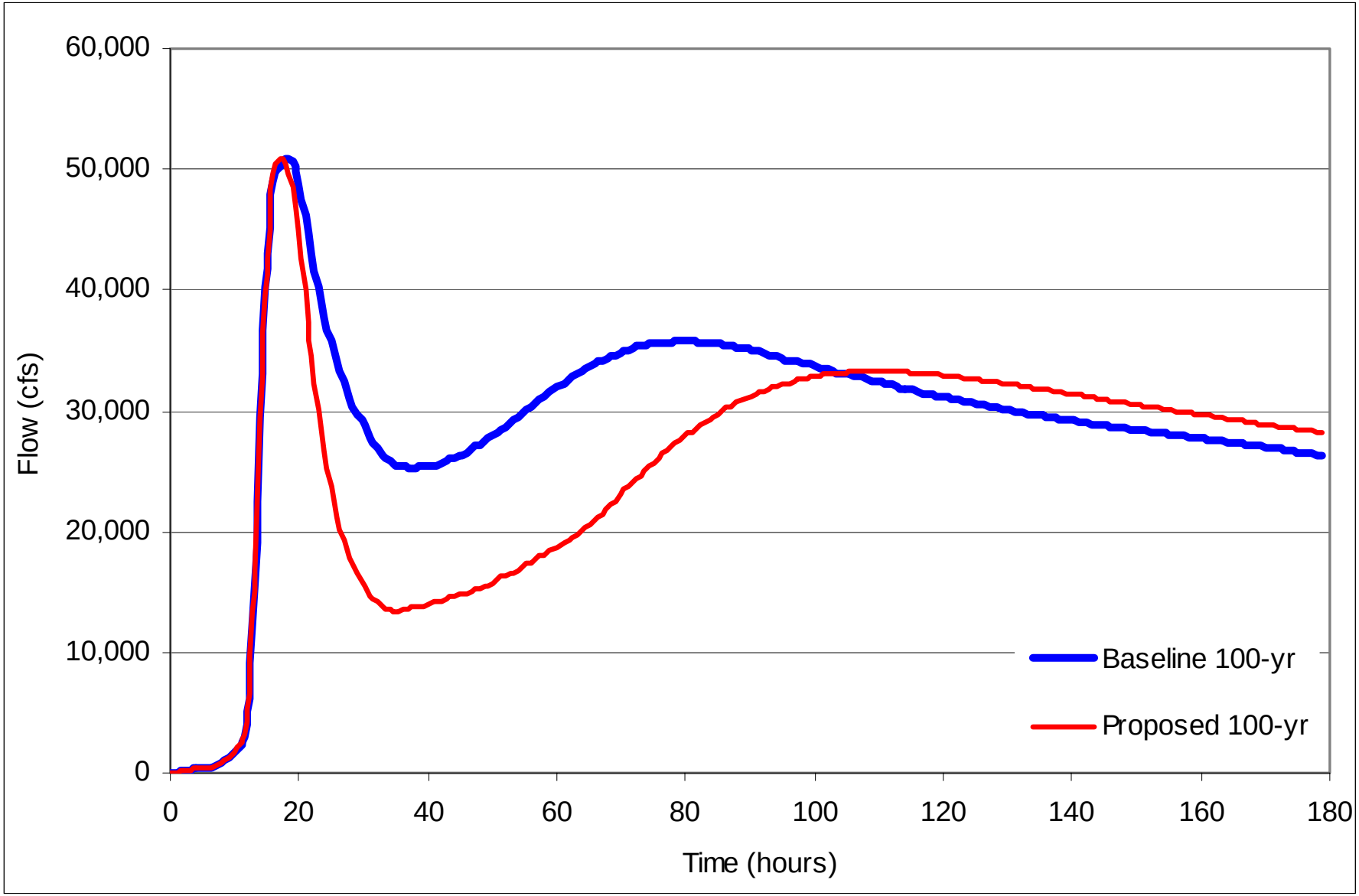


FORT WORTH CENTRAL CITY
APPENDIX A – HYDROLOGY AND HYDRAULICS

FIGURE 2-1
BASELINE AND PROPOSED 100-YR FLOOD HYDROGRAPHS ON THE WEST FORK ABOVE THE CLEAR FORK

DATE: MAY 2005

SHEET 1 OF 1

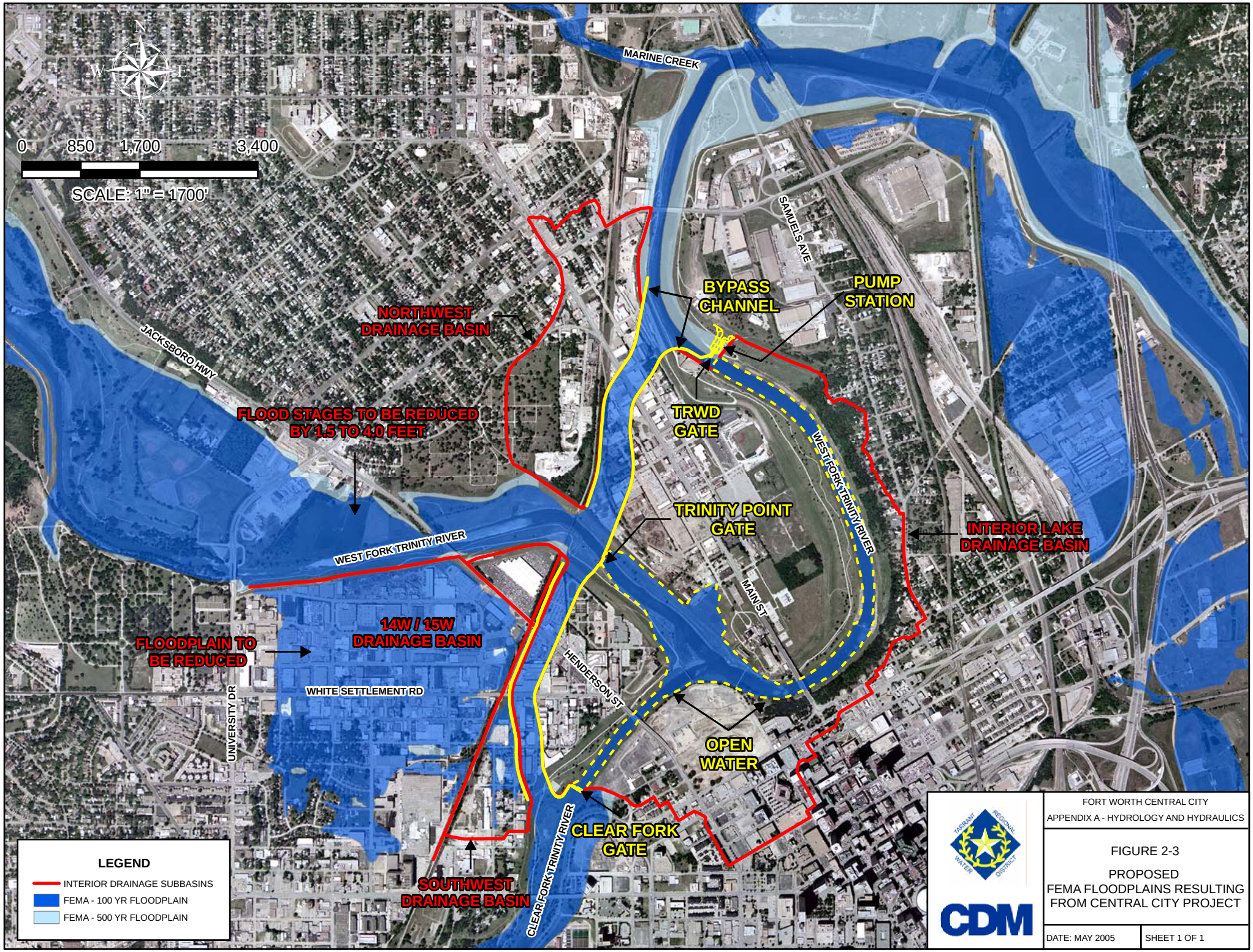


FORT WORTH CENTRAL CITY
APPENDIX A – HYDROLOGY AND HYDRAULICS

FIGURE 2-2
BASELINE AND PROPOSED 100-YR FLOOD HYDROGRAPHS ON THE WEST FORK ABOVE SYCAMORE CREEK

DATE: MAY 2005

SHEET 1 OF 1



FORT WORTH CENTRAL CITY

APPENDIX A - HYDROLOGY AND HYDRAULICS

FIGURE 2-3

PROPOSED
FEMA FLOODPLAINS RESULTING
FROM CENTRAL CITY PROJECT

DATE: MAY 2005

SHEET 1 OF 1

Section 3
Hydraulic Analysis

3.1 Approach

The hydraulic evaluation of the proposed bypass channel alignment for the Fort Worth Central City (FWCC) Project was performed using the U.S. Army Corps of Engineers (USACE) HEC-RAS version 3.1.2. HEC-RAS is a hydraulic step-backwater software program which calculates water surface elevations and computes resulting river reach storage (usually referred to as valley storage) and flow velocities. In order to demonstrate compliance with the CDC criteria described in Section 1, the steady-flow capabilities of HEC-RAS were employed. Flow inputs were obtained from the HEC-1 hydrologic analysis described in Section 2.

Unsteady flow analyses will be needed to facilitate design of the operable features of the project including the control gates and dam. The unsteady flow analyses of the project will be conducted prior to final design.

3.2 Hydraulic Assessments

3.2.1 Baseline Condition

CDM obtained an updated regional hydraulic model of the Upper Trinity River system from the USACE Fort Worth District. The model, referred to as the Corridor Development Certificate or CDC model, is maintained by the USACE as a part of their ongoing work with other entities in the region. A subset of the larger Upper Trinity CDC model sufficient to evaluate the project was provided to CDM by the USACE. This subset of the Upper Trinity CDC model, referred to as the Central City model, is the baseline hydraulic model for this analysis. The modeled area extends from Benbrook Lake on the Clear Fork and Lake Worth on the West Fork downstream past the confluence to East First Street on the West Fork.

3.2.2 Proposed Condition

The major hydraulic elements of the proposed project were incorporated into the baseline model to create the proposed conditions model. This included the addition of the proposed bypass channel, three isolation gates, Samuels Avenue Dam and the proposed valley storage mitigation sites. In addition, three roadway bridges and two pedestrian bridges were incorporated into the proposed conditions model.

3.2.2.1 Structural Sizing Needed to Meet Design Capacities

The proposed improvements were incorporated into the proposed conditions model as described below. Each improvement was adjusted until the size and configuration of each element was adequate to fulfill the project design criteria outlined in Section 1.

3.2.2.2 Bypass Channel

The bypass channel extends from the Clear Fork downstream of West Seventh Street to the West Fork, intersecting the West Fork approximately 2,600 feet upstream of the existing confluence with the Clear Fork. The bypass channel continues to the northeast and rejoins the West Fork 8,500 feet downstream of the existing confluence with the Clear Fork. The overall length of the bypass channel is approximately 8,400 feet. The proposed Bypass Channel Plan is provided in Figures 3-1, 3-2 and 3-3. These figures show model cross-section locations.

The bypass channel has upper and lower segments. The upper segment carries flow diverted from the Clear Fork and the lower bypass carries flow from both the Clear and West Forks. Manning 'n' values were determined based on channel and floodplain 'n' values assigned to nearby areas of the West Fork in the baseline model. These values are n = 0.035 in the channel and n = 0.055 in the overbank areas. The pedestrian walkway element of cross-section was assigned an 'n' value of 0.025. The bottom profile of the bypass channel was set to match invert elevations at each intersection with an existing stream. To reduce excavation quantities and potential tractive forces, a grade control structure is located at Station 9+80. A profile of the proposed bypass channel is shown in Figure 3-4.

3.2.2.3 Isolation Gates

The project would include three isolation gates designed to protect the interior area east of the bypass channel from water entry during flood events. The gates were not explicitly represented in this steady flow model, as it was not necessary for these analyses. The steady flow model represents a "snap shot" during the peak of a flood event and, therefore, the gates are assumed to already be in the closed position and the interior area is sealed off. As the operation of the system is modeled in detail, an unsteady, dynamic model of the project will be developed to simulate the movement of the isolation gates during storm events.

3.2.2.4 Samuels Avenue Dam

Water levels with in the project area would be controlled by a dam with adjustable gates located approximately 1,200 feet downstream of Samuels Avenue. The crest is at 524.3 feet, and the dam is designed to maintain normal water levels in the project area from 524.3 feet to 525.0 feet. The dam is an overflow type with gates designed to open downward lowering the crest to allow major flood events to pass. The maximum gate opening is 17.5 feet deep; thus, the crest elevation is of the fully opened dam is 507 feet. In the proposed conditions model, the dam was modeled assuming the gates were in the fully open position for both the 100-year and the SPF flood events. During the detailed design phase, operation of the gates will be modeled dynamically using an unsteady flow model.

3.2.2.5 Bridges

Five bridges were added to the model. Three roadways would cross the bypass: White Settlement Road, Main Street and Henderson Road. These bridges would be built with bridge decks above the levee crest. Therefore only the proposed piers would interact with the modeled flow. Two pedestrian bridges are also proposed. The pedestrian bridges would be designed to pass the 100-year flow through the opening while the SPF would pass over the deck. One bridge would be located at Station 44+26 on the upper bypass. A cross-section view of this bridge is provided in Figure 3-5. The second pedestrian bridge would be located at Station 2579+95 on the West Fork. A cross-section view is shown in Figure 3-6 and a plan showing the location of this bridge is in Figure 3-7.

3.2.2.6 Mitigation Storage

The project would mitigate valley storage that is displaced or lost due to construction of the bypass channel. With no corrective action, as much as 5,250 acre feet of valley storage could be lost. The project would replace this storage in several ways. Figure 3-8 is a general overview, while Figure 3-9 is a more detailed overview, of these mitigation sites, which include:

- Off-line valley storage mitigation site upstream on the West Fork in the Riverbend area;
- Approximately six in-line, overbank sites around and downstream of Samuels Avenue; and
- Drawdown mitigation by raising University Drive.

The Riverbend off-line valley storage mitigate site is located adjacent to the West Fork approximately 4 miles upstream of the existing confluence of the Clear and West Forks, between Stations 2768+53 and 2834+00 in the HEC-RAS model. A plan of the proposed Riverbend site is shown in Figures 3-10 to 3-13. The Riverbend valley storage mitigation site would be constructed by cutting "notches" in the existing levee and allowing flow to occupy the low-lying area behind the levee. The inverts of the notches are set below the 2-year flood but well above the normal water level of the channel. Depending on the final configuration of the site, a back levee may be constructed to prevent flooding of any private property. Calculations provided in Attachment A indicate that this site would provide 1,594 acre feet of storage in the 100-year flood and 3,246 acre feet in the SPF.

Downstream of Samuels Avenue, six storage areas would be developed by excavating overbank areas between Station 2417+08 and 2355+22. Preliminary plans for these sites are provided in Figures 3-14 to 3-17. These sites were incorporated into the model cross-sections because portions of the facilities can both convey and store flow.

The SPF storage volume they provide was calculated in HEC-RAS and is approximately 607 acre feet.

More than 2,000 acre feet of valley storage could be lost along the West Fork due to the drawdown effect of the bypass channel. To recover a portion of this storage, the project would raise University Drive at Station 2625+48 on the West Fork. This proposed modification would return 100-year and SPF water levels upstream of University Drive to near the levels of baseline conditions.

The proposed site layout for raising University Drive is provided in Figures 3-18, 19 and 20. Figure 3-21 shows how ineffective flow areas were defined in the HEC-RAS model to reflect the changes in flow pattern caused by raising University Drive.

3.2.2.7 Hydraulic Roughness Coeffecients

Manning roughness coefficient ('n') values were selected for the bypass channel and for proposed in-line storage areas in consensus with USACE. The construction and morphology of the bypass channel should mimic the existing channel to the extent possible. As a result, the selected Manning roughness coefficient values are similar to those employed in the baseline model of the West and Clear Forks. Throughout the project area, the baseline model from USACE uses the following values.

- All main channels, n=0.035
- Clear Fork overbank areas, n=0.060
- West Fork overbank areas, n=0.055

As a result, the bypass channel generally was assigned n=0.035 in the main channel and n=0.055 in the overbank areas. Exceptions to these values are the areas proposed to be hard surface. These fall into two classifications:

- Smooth paved surfaces with few appurtenances or attached features were assigned an n value of 0.015 ; and
- Paved surfaces with attached features and/or architectural elements were assigned an n value of 0.025.

The proposed in-line storage areas that were incorporated into the model are also mostly assigned to n=0.035 in the channel and n=0.055 in the overbanks. However, a few overbank storage areas that are proposed to be highly maintained lawns and completely free of trees or obstructions have been assigned n=0.035.

3.2.2.8 Criteria for Facility and Utility Relocations

Utility relocation criteria and requirements are discussed in Appendix C – Civil/Structural.

3.2.2.9 Interior Drainage

The project will require appropriate interior drainage storage and conveyance facilities to prevent flooding in interior areas. The analysis and design of these facilities are described in Attachment B.

3.3 Results of Analyses and Compliance with CDC Criteria

3.3.1 Valley Storage

Computed valley storage for baseline and proposed conditions for both the 100-year and SPF events is summarized in Table 3-1. All valley storage volumes were obtained from the HEC-RAS model except for the Riverbend site. As the Riverbend site operates as off-line storage, it was not directly included in the model such that valley storage amounts could be computed in HEC-RAS. Volume calculations for Riverbend were performed using CAD and are described in Attachment A. As indicated in Table 3-1, the valley storage in the 100-year flood is mitigated well over 100%. The net loss of valley storage in SPF is less than 40 acre feet. Project limits are defined as the area between the start of the bypass channel and Samuels Avenue Dam, so this loss is less than one half of one percent – effectively zero for regulatory considerations.

The local sponsor established a goal of mitigating 100 percent of the project's valley storage reductions, which is beyond the requirements of the CDC process. In addition, the valley storage calculations do not account for the substantial additional storage that is provided in the interior area. The capacity of this interior area is approximately 270 acre feet during a 100-yr event at which time there is an estimated 100 acre feet of valley storage. The storage volume of this interior area will be included in final calculations.

3.3.2 Water Surface Elevations

Steady-flow baseline and proposed conditions water surface elevations for both 100 year and SPF events are shown in Table 3-2. The project decreases or maintains baseline water levels at all locations with just a few minor exceptions. Water levels increase for the SPF at seven cross-sections, and at five cross-section for 100-year event. The maximum water level increases are 0.07 feet (less than 1-inch) in the 100-year flood and 0. 12 feet (1.5 inches) in the SPF.

There are slight increases in the immediate project area upstream and downstream of Samuels Avenue Dam and within the proposed storage mitigation sites between Samuels Avenue Dam and I-35. Increased in water levels occur because of expansions and contractions of flow introduced by the widening of overbank areas in the valley storage mitigation sites. The increases are confined to areas that would be purchased and maintained by TRWD, thus would have no impact on private property if the

increases actually occur. As new levees are constructed in the immediate project area, additional levee protection can easily be provided to compensate.

3.3.3 Head Loss

Construction of the bypass channel effectively shortens the West Fork by approximately 7,000 feet. This results in a reduction in head loss that must be partly restored in order to prevent significant additional loss of valley storage. Head loss would be returned to the system through modification or addition of structures. These include raising University Drive upstream on the West Fork, restrictive bypass channel sections, building Samuels Avenue Dam and two pedestrian bridges.

3.3.4 Average Channel Velocities

The agreed-upon CDC criteria for the proposed project include important provisions regarding channel velocities. Table 3-3 shows average channel velocity at selected locations for both baseline and proposed conditions. The table shows that velocity increases are generally less than 1 foot per second. Modeling analyses to date indicate exceptions to these increases may exist at the entrance to the bypass channel and at University Drive. Further analyses, using a physical model or additional modeling, would be undertaken prior to final design to evaluate appropriate armoring that may be necessary to prevent erosion or scour. Table 3-4 list velocities in the bypass channel. Designing the bypass to handle these flow velocities has been determined to be feasible with common engineering practices.

3.3.5 Existing and Post-Project Sedimentation

A sediment transport analysis of the proposed project is necessary to support several aspects of the project including:,

- Prediction of significant erosion and/or depositional impacts to existing infrastructure or ecosystems;
- Input to design considerations for improvements associated with the project;
- Definition of operation and maintenance needs of the floodway after project implementation; and
- Support of the environmental impact assessment associated with the project.

The objectives of the sediment transport analysis include the assessment of the sediment transport characteristics of the proposed system during years with significant flows and development of recommendations regarding subsequent analyses, data collection, project design considerations and project operation and maintenance based on sediment transport assessments. Figures 3-22 and 3-23 show results of this analysis. A more detailed description of the sediment transport analyses and the results are included in Attachment C. The analyses indicates that the

construction of Samuels Avenue Dam is required to maintain the channel without severe sediment aggradation or degradation after construction of the bypass channel.

3.3.6 Energy Dissipation/Erosion Control Features

Energy dissipation features are included in the design of Samuels Avenue Dam in order to protect the dam's structure during releases. Refer to the Civil/Structural Appendix (Appendix C) of this Draft Environmental Impact Statement for more information on Samuels Avenue Dam. Additional energy dissipation downstream of the dam is not anticipated, but would be confirmed during final design. As Tables 3-3 and 3-4 and the sedimentation analysis indicate, there appear to be no need for erosion control other than standard practices typically associated with structures such as bridges (e.g., aprons, pier protection, etc.).

However, additional investigations relative to erosion and deposition would be undertaken and the project's design would be adjusted accordingly should additional protections be warranted.

3.3.7 Control of Water and Project Sequence

Sequencing of the bypass channel construction and other elements will be critical to protect the environment and maintain comparable flood protection levels. Care will be taken in planning the construction activities to minimize any potential negative impacts on the river. Separate erosion and water control plans would be prepared for various construction contracts and elements of the project. The plans would include requirements and guidelines for contractor staging and equipment maintenance areas.

Mass excavation and grading would be planned and sequenced to minimize in-channel and bank excavation. Where in-channel or swale excavation is required, the excavation would be scheduled from downstream to upstream and major equipment and supplies removed from the floodway each day. Dewatering discharges from excavations would not be allowed to discharge directly to the river or storm sewer. Discharges would be directed to sedimentation basins outside of the existing floodway, prior to discharge to the river.

Buffer zones and barriers would be provided in excavation and fill areas to minimize erosion and siltation to water courses and/or the storm sewer system. Seeding of new levees would be completed as soon as possible to produce rapid establishment and maturity of cover. Temporary biodegradable erosion control blankets would be used in selected areas to help minimize erosion and facilitate the growth of vegetative cover.

Consideration was given, during the development of the sequence of work, to minimizing construction impacts to waterways. A preliminary sequence of construction has been established based on assumptions that environmental assessments, land acquisition, permitting, and funding activities would not adversely

impact the schedule. Key issues and objectives considered and factored into the development of this preliminary sequence include:

- Minimizing the duration of construction activities within or directly connected to the River channel;
- Maintaining a comparable level of flood protection during construction;
- Phasing of improvements to have valley storage mitigation areas on-line at the appropriate time; and
- Maximizing construction opportunities under dry conditions.

For discussion purposes, the construction sequence can be described in eight basic segments. Actual contract packages, construction contract size, and specific timing would be developed in more detail as the project detailed design progresses. The overall sequencing requirements and constraints are shown by the following construction segment overview:

- ***Construction Segment No. 1: Roadway Bridges:*** Construct temporary roadway bypasses at Henderson, Main St., and White Settlement. Construct bridge piers, bridges, and roadway approaches at all three locations. Complete roadway improvements and tie-in to new bridges. This would allow for the construction of the bridges and roadways "in the dry" without the need for temporary bridgeworks.
- ***Construction Segment No. 2: Interior Bypass Channel:*** Construct the interior portions of the upper and lower bypass channels without breaching the existing levees to the river. Complete excavation, utility relocations, new levee construction, and interior retaining walls. This would allow for a major portion of the channel to be constructed "in the dry" condition, except for potential groundwater.
- ***Construction Segment No. 3: Riverbend Mitigation:*** Complete the Riverbend mitigation site grading, ecosystem restoration and levee modifications. This would provide additional valley storage to compensate for the drawdown when the bypass channel is initially opened.
- ***Construction Segment No. 4: Bypass Channel Tie-ins:*** Construct the remaining reaches of the upper and lower bypass channel excavation, levee, and retaining walls. Breach levees and tie-in new bypass channel beginning from lower to upper channel connections. This would minimize the amount of construction within the existing channel and reduce the amount of coffer dam construction.

- ***Construction Segment No. 5: Construct University Drive Mitigation:*** Reconstruction of University Dr. to raise it out of the 100 year flood elevation and to provide for valley storage mitigation would closely follow the completion of the bypass channel. This component is required to partially restore the 100-year and SPF flood elevations from the drawdown effect of the bypass channel on the West Fork. Construction would be deferred until the bypass channel is complete so there would not be an increase in flood elevations during construction.

- ***Construction Segment No. 6: Construct Isolation Gates:*** After the completion of the bypass channel and "upstream" valley storage mitigation the existing West Fork interior channel can be taken out of service for major flow events. This would allow for the construction of the isolation gates for the interior area. Coffer dam construction is envisioned to segregate the construction area and provide protected working conditions from river flows. This segment would include the construction of all three isolation gates, tie-ins to the bypass channel retaining walls, levees, and the stormwater pump station at the TRWD gate.

- ***Construction Segment No. 7 Samuels Avenue Dam:*** Construction of the Samuels Avenue Dam would also include the remaining downstream valley storage mitigation sites. Construction of these improvements would be concurrent with the construction of the isolation gates thus providing the remaining valley storage when the interior area is completely isolated.

- ***Construction Segment No. 8 Interior Water Feature and Connector:*** Completion of the isolation gates and valley storage sites would enable the re-routing of flows from the interior area to the new bypass channel. This would allow for the construction of the interior water feature and the completion of the White Settlement Connector.

Table 3-1: Valley Storage Calculations for Proposed and Baseline Conditions

Reach	Reach limits D/S Station	Reach limits U/S Station	100-yr Baseline (ac ft)	100-yr Proposed (ac ft)	100-yr Gain or Loss (ac ft)	SPF Baseline (ac ft)	SPF Proposed (ac ft)	SPF Gain or Loss (ac ft)
East First to Riverside Drive	206218	222998	9721.3	9721.3	0.0	17838.0	17838.0	0.0
Riverside Drive to Highway 121	222998	231100	2877.5	2877.5	-0.1	5343.6	5343.6	0.0
Highway 121 to U/S Samuels Dam	231100	241255	2982.3	3733.1	750.8	5393.6	6262.6	869.0
U/S Samuels Dam to Bypass Outlet	241255	245866	823.7	850.2	26.5	1834.8	1891.9	57.1
Bypass Rejoin to Confluence	245866	254346	1377.9	Interior	-1377.9	2871.4	Interior	-2871.4
Current Confluence to New Confluence	254346	257026	402.2	Interior	-402.2	876.6	Interior	-876.6
New Confluence to FWRR	257026	257557	78.2	52.6	-25.6	165.7	150.6	-15.2
FWRR to University Drive	257557	262497	942.6	794.4	-148.2	2413.4	1827.8	-585.6
Univeristy Drive to Above Riverbend	262497	283400	4707.5	4633.6	-73.9	9541.4	8898.6	-642.8
Riverbend/Rivercrest mitigation area			Not there	1718.0	1718.0	Not there	3246.0	3246.0
Upper West Fork above Riverbend	283400	306246	3435.2	3434.2	-1.0	6460.0	6386.7	-73.3
Clear Fork below Bypass	0	3465	442.8	Interior	-442.8	1238.6	Interior	-1238.6
Clear Fork above start of Bypass	3465	65616	5957.4	5854.6	-102.8	22590.0	22549.0	-41.0
Lower Bypass	0	3656	Not there	539.8	539.8	Not there	1001.6	1001.6
Upper Bypass	3656	8421	Not there	504.0	504.0	Not there	1132.2	1132.2
Total			33748.6	34713.1	964.5	76567.1	76528.6	-38.5

Baseline = Fort Worth Central City Model
Proposed = Proposed Project