Upper Trinity River Basin Feasibility Study
Clear and West Fork Interim Feasibility Study
Central City Interim Feasibility Study

Appendix I

Flood Damage Analyses

May 2005

PURPOSE

The purpose of this Economic Appendix is to: 1) evaluate flooding and related problems in the Clear Fork and West Fork of the Upper Trinity River watershed in the City of Fort Worth, TX; and 2) determine the National Economic Development (NED) benefits and costs associated with potential solutions.

STUDY AREA

Location

The study area is located along the Clear Fork and West Fork of the Trinity River, in Fort Worth, TX. The stretch of the Clear Fork under investigation is between its confluence with the West Fork upstream to the I-30 crossing. The section of the West Fork being studied begins upstream about one-half mile above the University Drive Bridge downstream to Riverside Drive. (See Figures 1 -3 and 3 - 1 of the main report)

Problems & Opportunities

Flooding

Flood flows along the Clear Fork and West Fork through the Study Area that result from frequent flooding events are generally contained within the channel banks. However, during less frequent events, such as the 0.2% ACE and the **S**tandard **P**roject **F**lood—roughly a 0.1% ACE, H & H analyses indicate that under existing conditions, there is a potential for significant flood damages. During these low-probability events, flood flows may overtop the channel banks and existing levees, inundating many residential, commercial, and public facilities.

WITHOUT PROJECT CONDITIONS

Without project conditions are those projected to prevail over the 50-year period of analysis, and form the basis for comparison to determine the benefits of identified alternatives. Thus, without project conditions must first be calculated in order to ascertain the *potential* benefits resulting from implementing alternatives.

Flood Damages

Flood Profiles & Reach Delineations

Two sets of water surface profiles—the first based on H & H existing conditions and the second on future stream conditions—were developed for this study. Specifically, the following events were modeled for this particular study area: 50%, 20%, 10%, 4%, 2%, 1%,

0.2%, and 0.1% Annual Chance Exceedance (ACE). These profiles were used to delineate the floodplain limits and determine both the stage-damage and frequency-damage (also referred to as single-occurrence damages) functions.

Data Collection & Adjustments

In summer of 2003, an inventory was made of the floodplain lands along the Clear and West Forks of the Trinity River adjacent to the study area to identify existing floodplain development. The inventory included enumeration, classification, and value estimation of the numbers and types of structures within the PMF (**P**robable **M**aximum **F**lood, the flood event resulting from the theoretical greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of year). Existing damageable properties were classified into four major damage categories, as shown in Table 1. This inventory was field-checked to update and verify values, location, and first floor elevations.

A determination of the value of floodplain investment (structures and contents) for each major damage category was based on data provided by the Tarrant County **T**ax **A**ppraisal **D**istrict. These data were then compared to **M**arshall & **S**wift Valuation Service tables. Structures had been assigned a classification code by TAD, based upon the condition and other physical attributes of each structure. Using the descriptors provided for these codes (construction material, roof type, etc.) and the square footage provided by TAD for the structures, M & S tables were used to calculate a second value for comparison purposes (nearly all of the residential structures and a representative sample of commercial/industrial). Averages were taken for both sets of values and compared. The M & S average was approximately 22% higher than the tax appraisal values (as expected, since citizens tend to protest appraisal values as too high in order to lower tax burdens). Based upon this analysis, the final values used in this analysis were the TAD values (to account for variability resulting from periodic inspections by county appraisers) increased by 22% to account for the apparent under-valuation resulting from M & S.

The value of existing residential contents was modeled at 100 percent of the structure value, per guidance and generic residential depth-damage curves issued by the Institute of Water Resources (IWR) in 2001. The values of contents for the other damage categories were based on information from the TAD website (www.tad.org) and/or direct field observation, interviews with property owners, and the relationship between structure and content values observed in prior studies within Tarrant County.

Table 1
Major Damage Categories

Damage Category	*Activity Description*
Residential	Single and multifamily dwellings
Commercial & Industrial	Retail and wholesale businesses
Public	Public and quasi-public structures
POV	Personal occupancy vehicles

Reach Determination

The area surveyed included all properties lying within the PMF floodplain along the Clear and West Forks of the Trinity River just to the west, north and east of downtown Fort Worth. Specifically, the stretch of the Clear Fork under consideration for this study extends from its confluence with the West Fork upstream approximately 2.5 miles. The section of the West Fork examined started downstream at its juncture with Riverside Drive and continued upstream approximately five miles. The area was divided into twelve reaches based on economic, hydrologic, and plan formulation considerations. Table 2 provides a description of the reach locations, stationing and index points used in this investigation, while a map of the study area with reach designations is shown in Figure 3 - 1 of main report.

Table 2
Central City Feasibility Study Area
Reach Descriptions and Stationing

Stream Name	Damage Reach Name	Beginning/ Downstream Station	Ending/Upstream Station	Bank	Index Location Station	Description
Clear Fork	CF East-Lower	0	4600	Right	2249	WF/CF confluence to 10th St.
Clear Fork	CF East-Water Works	4600	8189	Right	6258	10th St. to Tarantula RR
Clear Fork	CF West-Upper	8189	12020	Left	10906	Upstream end of CF Levee loop to IH-30
Clear Fork	CF East-Upper	8189	12020	Right	10906	Tarantula RR to IH-30
West Fork	WF South	222947	254500	Right	225658	Riverside Dr. to WF/CF confluence
West Fork	WF North-Riverside	222947	228095	Left	226962	Riverside Dr. to IH-35
West Fork	WF North-Middle	228095	235534	Left	232217	TRE RR to IH-35
West Fork	WF North-Upper	235534	242340	Left	239744	IH-35 to Samuels Ave.
West Fork	WF North-Main Marine Crk.	242340	242500	Left	242451	Samuels Ave to Marine Crk.
West Fork	WF North-Main Levee Loop	242500	258300	Left	253302	Downstream end of levee to Tarrant RR
West Fork	WF Cultural Dist. Levee	254500	265818	Right	257654	WF/CF confluence to Rockwood Pk.
West Fork	WF North-Main Jacksboro	258300	265500	Left	261002	Upstream of Tarr. RR to Rockwood Pk.

Table 3 displays the number of structures at inventoried by type and reach. Field investigations identified 2301 damageable structures within the PMF floodplain. These

structures have a total estimated investment value of $1.3 billion, based on July 2003 prices and level of development.

Around 42% percent of the inventoried structures are residential dwellings. Residential structures, contents and vehicles comprise about $54 million of the investment value of the PMF floodplain. Most of these are one or two-story detached residences, which have an average structure value of about $31,000.

Table 3
Enumeration of Inventoried Structures
By Reach and Type

Reach	Residential	Comm. & Ind.	Public
CF East-Lower	6	10	0
CF East-Water Works	11	31	2
CF West-Upper	2	43	10
CF East-Upper	5	38	2
WF South	243	100	16
WF North-Riverside	125	44	4
WF North-Middle	25	12	2
WF North-Upper	23	26	2
WF North-Main Marine Crk.	133	125	10
WF North-Main Levee Loop	42	178	4
WF Cultural Dist. Levee	339	631	23
WF North-Main Jacksboro	14	18	2
Total	**968**	**1256**	**77**

Without Project Structure & Content Damages

Methodology

Overview of Methodology

Methodology employed for this economic analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the Planning Guidance Notebook – ER 1105-2-100. Damages, benefits, and costs are computed at 2003 price levels using the Federal Discount rate of 5 5/8 percent. The period of analysis is 50 years. The Base Year for economic computations is 2008. Future damage calculations results from expected changes in Hydrologic & Hydraulic conditions; development (i.e., the structure inventory) is held constant at 2003 conditions. Finally, throughout this appendix, flood events will be expressed in probabilistic terms rather than the classic "x-yr" event. For example, the 100-yr event will be called a 1% Annual Chance Event (equivalent to the HEC-FDA term Annual Exceedance Probability Event). Other equivalent probabilities can be obtained by dividing 1 by the year occurrence interval; the 500-yr event is 1/500 = 0.2% ACE, and so forth.

A risk-based analysis (RBA) procedure has been used to evaluate without project flood damages in the study area. Guidance for conducting RBA is included in Corps Engineering Regulation 1105-2-101, *Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability and Economics in Flood Damage Reduction Studies (1 March 1996).*

The guidance specifies that the derivation of expected annual flood damage must take into account the uncertainty in hydrologic, hydraulic and economic factors. Risk and uncertainty are intrinsic in water resource planning and design. They arise from measurement errors and the inherent variability of complex physical, social and economic situations. Best estimates of key variables, factors, parameters and data components are developed, but are often based on short periods of record, small sample sizes, measurements subject to error, and innate residual variability in estimating methods. RBA explicitly analytically incorporates these uncertainties by defining key variables in terms of probability distributions, rather than single-point estimates. The focus of RBA is to concentrate on the uncertainties of variables having the largest impact on study conclusions.

The following are the primary sources of uncertainty for flood damage analysis studies:

Discharge/Probability: For a flood or storm event with a given probability of occurrence, there is uncertainty regarding what the resulting discharge will be at a specific location along the stream or river. The reliability of discharge/probability estimates is directly linked to the historical record of stream gauge data available. In cases where records are small or incomplete, the associated uncertainty increases. To address this uncertainty, an analytical or graphical method is typically used to determine statistical distributions of discharge for a range of probabilities at locations throughout the floodplain. For this study,

discharge/probability uncertainty has been estimated for each reach using the graphical method, based upon an equivalent record length of **50 years**.

Stage/Discharge: For a given discharge, there is uncertainty regarding what the resulting water surface elevation will be at a given location. Factors contributing to this uncertainty include bed forms, water temperatures, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, changes in channel shape during or as a result of flood events, as well as other factors. To address this uncertainty, standard deviation estimates are developed for stages associated with a range of discharges at locations throughout the floodplain. For this study, H&H provided the standard deviation of error 0.5 foot for the 1% ACE stage and higher; the HEC-FDA program automatically calculated appropriately smaller stage errors for all smaller (i.e., more frequent) events based upon the 0.5 ft @ the 1% ACE figure.

Geo-technical Features: When there are improvements such as levees along a river or stream, there is uncertainty regarding how effective they will be in containing a given flood event. Specifically, there is uncertainty regarding what combination of discharge and stage will result in levee failure. To address this uncertainty, probable failure and non-failure points (elevations) for levees are determined at various locations along the levee's length.

Levees do exist levees along the Clear Fork and West Fork in the Central City study area. Specifically, the CF East Water Works, WF South, WF North Riverside, WF North Main Levee Loop, and CF Cultural District Levee reaches have been modeled incorporating levees. None of these levees has been assigned failure curves as described above, since they meet Corps geo-technical criteria and have been properly maintained. Levee "failures" in these reaches refers only to the situations when river stages overtop the levee.

Reach	Levee Crest Elevation	Annual Exceedance Event Equivalent
CF East Water Works Levee	555.2	0.1% ACE + 2.1'
West Fork South Levee	533.6	0.1% ACE + 2.3'
WF North Riverside Levee	518.0	4% ACE + 0.5'
WF North Main Levee Loop	544.5	0.2% ACE + 4.7'
WF Cultural District Levee	550.7	0.2% ACE + 5.5'

Structure Elevation: A structure's susceptibility to being inundated is a function of its location within the floodplain and its elevation. There are two sources of potential error in determining elevation. The first is the topographic ground elevation of the structure. This uncertainty is a function of the data source used to derive the elevation estimate. The other source of uncertainty is associated with estimates of first floor elevations above ground level (or foundation height). This variable is key, as a structure built on fill or with a large crawl space, for example, may sustain only minor or no damages, even though the surrounding ground is underwater. First floor elevation estimate errors also vary with the methods used to derive them, ranging from best-guess estimates from windshield surveys to professional

surveys. Statistical uncertainty in elevation is typically determined by referencing the standard deviation estimates contained in Corp Engineering Manual 1110-2-1619 – *Risk Based Analysis for Flood Damage Reduction Studies (1 August 1996).* This publication presents standard deviation estimates for a wide range of measurement methods.

For this study, ground elevations for each structure were derived from a 2-foot interval digital elevation model in GIS format. First floor elevations above ground level were estimated during a field survey. Based upon the Engineering Manual cited above, the error associated with first floor elevation estimates is assumed to be normal, with a standard deviation of 0.5 feet.

Structure Values: Structure values have been determined based upon Marshall & Swift multiplication factors applied to square footage estimates and assessor's values. Square footage estimates were primarily obtained from county assessor's data (TAD) and are claimed to be accurate by 10% per the website. The primary source of potential error results from misclassification of a given structure in terms of its construction quality and condition. The errors associated with structure value estimates are assumed to be normal, with a standard deviation of 10%, per the TAD accuracy of the square footage measurements.

Inundation Depth/Percent Damage: There is considerable uncertainty regarding the percentage of damage to structures and contents given a certain level of flooding. The National Flood Insurance Program of FEMA collects damage data following flood disasters and publishes depth/damage functions. These functions are used to derive estimates of damages to non-residential structures. For residential structures, depth-damage functions and associated standard error estimates have been developed by the Institute for Water Resources based upon a statistical analysis of actual flood damages that have occurred throughout the United States. Damage percentages for both structures and contents are based upon corresponding structure values. These functions were used for this analysis.

The Corps of Engineers Hydrologic Engineering Center has developed software specifically designed for conducting RBA, referred to as the HEC-FDA Program (Version 1.1.01, January 2000, Special Version for CESWF created 01/27/2000 used for this analysis—developed and used for Dallas area studies where existing levees provides protection for extremely infrequent events, as is the case for the Central City area. This version does not treat extremely large events as statistical outliers, and includes damages created by such rare events into all calculations.). This program applies a Monte Carlo simulation process, whereby the expected value of damages is determined explicitly through a numerical integration technique accounting for uncertainty in the basic parameters described above. Data requirements for the program include:

- Structure data, including structure I.D., category (single or multi family residential, commercial, industrial, public), stream location, ground and/or first floor elevation, structure value and content value. This data was developed in a Microsoft Excel spreadsheet and imported into the HEC-FDA program.

- Hydrologic and hydraulic data, including water surface profiles, frequency/discharge relationships, and stage/discharge relationships. For this study, water surface profiles were developed using the HEC-RAS program. These functions were imported into the HEC-FDA program.

- Depth/Damage functions. Functions for residential and non-residential structures were obtained from the Institute for Water Resources and FEMA's National Flood Insurance Program.

- Risk & Uncertainty Parameters, as described in detail previously, were also entered into the program.

Table 4 on the following page describes the damages in each damage area categorized by specific flood events; expected annual damages are derived form these frequency-damage curves. Generally under without project conditions, significant damages begin with a 1% ACE discharge or higher. The exceptions are the West Fork Riverside reach and Jacksboro reaches, where significant damages appear prior to the 4% ACE discharge. Keeping in mind that most of these reaches lie behind existing levees (modeled with no failure scenarios, only overtopping), it is estimated that a 0.2-percent ACE (500 year) event could cause direct structure and content damages of approximately $14.2 million based on July 2003 prices and level of development. The 1-percent ACE (100 year) event could produce losses of about $4.0 million, and the 4 % ACE (25-yr) event—the smallest flood projected to cause damages in the hundreds of thousands—would cause damages of approximately $448 thousand.

Table 4
Frequency-Damage Relationships
Without-Project (Existing) Condition - Base Year (2005)
(July 2003 price level; $000)

Reach	50%	20%	10%	4%	2%	1%	0.4%	0.2%	0.1%
CF East-Lower	-	-	-	-	-	-	-	28.1	157.4
CF East-Water Works	-	-	-	-	-	-	-	-	-
CF West-	-	-	-	-	-	-	2,375.5	3,523.6	92,469.3
CF East-Upper	-	-	-	-	-	-	-	129.4	369.5
WF South	-	-	-	-	-	-	-	-	-
WF North-Riverside	-	-	-	231.5	1,904.6	3,496.2	5,781.2	7,708.3	9,302.0
WF North-Middle	-	-	-	-	-	-	9.7	26.3	51.3
WF North-Upper	-	-	-	-	-	-	-	41.6	997.2
WF North-Main Marine Crk.	-	-	-	-	-	-	-	1,167.3	11,168.6
WF North-Main Levee Loop	-	-	-	-	-	-	-	-	24,199.1
WF Cultural Dist. Levee	-	-	-	-	-	-	-	-	-
WF North-Main Jacksboro	1.1	1.8	2.9	216.7	402.9	528.2	720.0	1,555.8	1,789.8

Note: the damage figures above have been copied directly from the Exceedance Probability-Damage Functions output table in the HEC-FDA program for Base Year 2005. For three of the reaches, (all three protected by existing levees modeled only to be overtopped, thus not to geo-technically fail) the Exc. Prob.-Damage functions show $0 across all events, but in the Expected Annual Damage table below, these reaches have been assigned EAD. The damage figures above appear to be based upon computed means of the frequency-flow-stage-damages. With uncertainty parameters included, however, the EAD captures the damages that would occur for the most extreme upper bound values for the most extreme modeled event (e.g., two or three standard deviations above the largest calculated event; in this case up to 1.5 feet above the 0.1% (1000-yr) event). Any other explanation for these results should be referred to HEC-FDA support staff in Davis, CA.

Existing Condition Expected Annual Damages

Estimates of expected annual damages (EAD) under existing conditions were calculated, using the risk and uncertainty model, through integration of frequency-damage data. The expected annual flood losses in the study area totaled nearly $334.0 thousand based on July 2003 prices, of which 77 percent is associated with residential development. A breakdown of existing average annual damages by property type and reach is presented in Table 5.

Table 5
Expected Annual Damages
Without-Project (Existing) Condition - Base Year 2005
(July 2003 price level; $000)

Reach	Commercial	Industrial	Public	POV	Residential		Total EAD
					Multi-Family	Single Family	
CF East-Lower	0.3	-	-	-	0.1	-	0.4
CF East-Water Works	-	-	-	-	-	-	-
CF West-Upper	2.4	-	17.7	-	-	-	20.1
CF East-Upper	0.6	-	-	-	-	0.1	0.7
CF Total	3.3	-	17.7	-	0.1	0.1	21.2
WF South	-	-	-	-	-	-	-
WF North-Riverside	96.3	-	7.6	0.7	0.6	1.4	106.6
WF North-Middle	-	-	-	0.1	-	0.1	0.2
WF North-Upper	1.9	-	0.1	-	-	-	2.0
WF North-Main Marine Crk.	19.1	-	-	-	-	-	19.1
WF North-Main Levee Loop	28.4	2.6	0.3	0.1	-	0.2	31.6
WF-Cultural District Levee	109.5	2.1	7.1	1.0	5.5	3.9	129.1
WF North Main Jacksboro	2.3	-	21.9	-	-	-	24.2
WF Total	257.5	4.7	37.0	1.9	6.1	5.6	312.8
GRAND TOTAL	260.8	4.7	54.7	1.9	6.2	5.7	334.0

Results – Future Conditions

Hydrologic and hydraulic analyses were conducted for future without project conditions to determine the impacts of processes such as sedimentation and channel degradation and the resulting impacts on potential flooding. Updated water surface profiles and stage/discharge uncertainty data were used to recomputed expected annual damages under future conditions. Table 6 summarizes these results. Per guidance in the HEC-FDA manual, the most likely future year planning horizon has been set for 25 years from the base year of 2005.

Table 6
Expected Annual Damages
Without-Project (Future) Condition – Most Likely Future Year 2030
(July 2003 price level; $000)

Reach	Commercial	Industrial	Public	POV	Residential		Total EAD
					Multi-Family	Single Family	
CF East-Lower	0.3	-	-	-	0.2	-	0.5
CF East-Water Works	-	-	-	-	-	-	-
CF West-Upper	2.6	-	17.8	-	-	-	20.4
CF East-Upper	0.8	-	-	0.1	-	0.1	1.0
CF Total	3.7	-	17.8	0.1	0.2	0.1	21.9
WF South	-	-	-	-	-	-	-
WF North-Riverside	114.7	-	9.0	0.8	0.7	1.7	126.9
WF North-Middle	-	-	-	0.1	-	0.1	0.2
WF North-Upper	2.5	0.1	0.1	-	-	-	2.7
WF North-Main Marine Crk.	21.6	0.1	-	-	-	0.1	21.8
WF North-Main Levee Loop	32.8	3.4	0.3	0.1	-	0.2	36.8
WF-Cultural District Levee	223.5	4.3	14.9	2.0	12.1	8.0	264.8
WF North Main Jacksboro	2.6	-	22.4	-	-	-	25.0
WF Total	397.7	7.9	46.7	3.0	12.8	10.1	478.2
GRAND TOTAL	401.4	7.9	64.5	3.1	13.0	10.2	500.1

Table 7 displays the Equivalent Annual Damages for the various reaches. Equivalent Annual Damages are the summation of the base year (2005) expected annual damages plus the discounted value of the most likely future year (2030) expected annual damages. The future expected annual damages shown here are discounted over the project life of 50 years at the FY ’03 Federal discount rate of 5 5/8%.

Table 7
Equivalent Annual Damages
Analysis Period: 50 Years; Discount Rate 5 5/8%
(July 2003 price level; $000)

Reach	Commercial	Industrial	Multi-Family	Public	POV	Single Family	Total EAD
CF East-Lower	0.3	-	0.1	-	-	-	0.4
CF East-Water Works	-	-	-	-	-	-	-
CF West-Upper	2.5	-	-	17.7	-	-	20.2
CF East-Upper	0.7	-	-	-	-	0.2	0.9
CF Total	3.5	-	0.1	17.7	-	0.2	21.5
WF South	-	-	-	-	-	-	-
WF North-Riverside	105.3	-	0.6	8.3	0.8	1.5	116.5
WF North-Middle	-	-	-	-	0.1	0.1	0.2
WF North-Upper	2.2	0.1	-	0.1	-	-	2.4
WF North-Main Marine Crk.	20.3	0.1	-	-	-	-	20.4
WF North-Main Levee Loop	30.5	3.0	-	0.3	0.1	0.2	34.1
WF-Cultural District Levee	170.5	7.9	8.7	28.6	1.5	6.2	223.4
WF North Main Jacksboro	2.4	-	-	22.2	-	-	24.6
WF Total	331.2	11.1	9.3	59.5	2.5	8.0	421.6
GRAND TOTAL	334.7	11.1	9.4	77.2	2.5	8.2	443.1

Sump Damages Analysis
Without Project Damages

Methodology

H & H provided frequency-stage information regarding interior drainage flooding for the Cultural District and North Main Levee Loop damage areas to for economic damage analysis. The Cultural District sumps are referred to as Sump 14W/15W. The sump within the North Main Levee Loop damage area is referenced as Sump 26.

To calculate these interior damages, the structure inventories for both of these damage areas were copied into new HEC-FDA files. Interior flooding has characteristics of "pooling", i.e., flooding within the damage area is not dependent upon stream stationing. Therefore, all structures within each reach were assigned a proxy stream station, and this proxy was identified as the index point for aggregate damage and expected annual damage calculations.

Finally, the frequency-stage curves computed by H & H reflect stages that result from a flooding event with the sumps operating at capacity. Originally, these sumps were designed to protect the damage areas up to a 50-yr event.

Cultural District Results (Sumps 14W/15W)

This reach encompasses the area behind the Clear Fork Levee Loop. It is used primarily for commercial land uses, although there are also residential neighborhoods in the northeast sector of the damage area (e.g., Linwood and Monticello).

The following table displays the frequency-stage-damages resulting from insufficient sump capacity for this area:

Frequency Event	Pool Elev. (ft. NGVD)	Damages ($000s)
2-yr	528.0	$0
5-yr	531.0	$0
10-yr	533.0	$0
25-yr	535.4	$378.5
50-yr	536.7	$4,369.3
100-yr	537.5	$9,070.3
250-yr	537.9	$15,588.8
500-yr	538.2	$20,763.3
Expected Annual Damage		$259.5

North Main Levee Loop (Sump 26)

This reach encompasses the area behind the North Main Levee Loop. It is used primarily for industrial land uses. This area is the primary transportation connection between downtown Fort Worth and the Stockyards, one of the area's most popular family entertainment and tourist destinations. LaGrave Field, home to the Fort Worth Cats minor league baseball team is also situated within this damage area.

The following table displays the frequency-stage-damages resulting from existing sump capacity for this area:

Frequency Event	Pool Elev. (ft. NGVD)	Damages ($000s)
2-yr	526.0	$0
5-yr	528.0	$0
10-yr	528.4	$0
25-yr	529.0	$0
50-yr	529.5	$0
100-yr	530.0	$0
250-yr	530.5	$15.3
500-yr	530.9	$34.5
Expected Annual Damage		$0.2

Description of Federal Alternatives

Total without project for the Clear Fork reaches totaled only $21.5 thousand (see Table 7 above). As for the West Fork reaches, the Riverside reach has been investigated in the Upper Trinity River – Clear Fork and West Fork Interim Feasibility Study in 2001. That unpublished document reported that there is a non-federal levee in the area built by the Tarrant Regional Water District. The current analysis incorporated this levee. The levee does not appear to "fail" as a result of overtopping. Rather, the area behind this levee suffers flooding as a result of large events backing up from downstream outside of the study area.

Most of the other reaches had rather small Without Project EAD calculations. Thus, the only two reaches included in the following paragraphs and tables are the Cultural District Levee and the North Main Levee reaches. These two reaches are adjacent and have been determined to be hydraulically interdependent.

In order to meet the new design levels of flood control along the existing levees of the Cultural District Levee and North Main Levee reaches, certain portions of the levees will have to be raised. In addition to some levee raises, a flood wall that is located under the Main Street bridge adjacent to an existing TXU plant and substation will have to be modified in order to meet the new design flood protection criteria. The two levels of protection which have been reviewed will require improvements to match a levee design of SPF + 0 ft and SPF + 1 ft. The following descriptions are of the proposed improvements.

SPF + 0

The existing Floodwall under the Main Street Bridge along the Left Bank of the West Fork Trinity River will have to be raised. In order to minimize cost and provide an effective solution, the wall will be removed and replaced with an earthen levee.

The Tarantula Railroad has a bridge crossing the West Fork Trinity River approximately 2880 feet upstream of the confluence of the West Fork and the Clear Fork Trinity Rivers. Because the breach of the current authorized level of protection is so minor, the final model elevations would have to be field verified. Therefore, the use of sand bags would be proposed across this bridge crossing for developing a plan of action and cost comparison.

SPF + 1

The existing Floodwall under the Main Street Bridge will have to be raised as well. Likewise to minimize cost and provide an effective solution, this wall will be removed and replaced with an earthen levee. The fill material will be obtained from an off-site commercial borrow source and hauled to the project site.

The Tarantula Railroad Bridge will also have a breach of the current level of protection that is less than 1 foot. In order to correct this deficiency the final model elevations would have to be field verified. Therefore, the use of sand bags would be proposed across this bridge crossing for developing a plan of action and cost comparison.

The levee loop that provides protection along the Right Bank of the West Fork Trinity River and the Left bank of the Clear Fork Trinity River, will require improvement in three locations. The improvements will consist of raising three sections of the levee with earthen material hauled in from a commercial borrow site.

Residual Damages & Benefits

The study team has completed a preliminary analysis for five alternatives. The study authority stipulates that investigations should be made to determine the feasibility of restoring the originally authorized 'level of protection" to the study area. The original level of protection was SPF + 4' of freeboard. Thus, the study team decided to look at various levee raises, starting with simply raising levees back to the original SPF stage, and then proceeding in one-foot increments. The Without Project equivalent annual damages were relatively small for the North Main Levee Loop damage reach; so only one scenario—raising the levee back to its SPF elevation—was examined. Table 4 shows the reduction in flood damages for the North Main levee raise. Table 5 displays the same information for the Cultural District, albeit for levee raises of one through four feet above the SPF elevation. The following tables summarize the residual damages and expected annual benefits for each size of the levee raise alternative.

Central City Federal Alternatives

Structure & Content and Autos Damages

Tables 8 and 9 show Residual Expected Annual Damages and Damages Reduced (Benefits), respectively, for each Alternative.

Table 8
With Project Conditions
Equivalent Annual Damages (50 Years, 5 5/8%)
(In $1,000's)

Alternative: Levee Raise to SPF + 0'
(From elev. 544.5' to 546.15')

Reach	Equivalent Annual Damage		Flood Damage Reduction Benefits
	Total Without Project	Residual	-
WF North-Main Levee Loop	34.1	12.2	21.9

Note: Due to the relatively low value of the Without Project EAD, only one size of levee raise has been completed for the North Main Reach.

Table 9
With Project Conditions
Equivalent Annual Damages (50 Years, 5 5/8%)
(In $1,000's)

Alternative: Levee Raise to SPF + 0', 1', 2', 3', and 4'
(From elev. 550.7' to 551.4', 552.4', 553.4', 554.4', and 555.4')

Reach	Alternative	Equivalent Annual Damage		Flood Damage Reduction Benefits
		Total Without Project	Total With Project	-
WF Cultural District Levee	SPF + 0'	223.4	88.6	134.8
	SPF + 1'	223.4	3.9	219.5
	SPF + 2'& 4'	223.4	-	223.4

Table 8 shows that the levee raise alternatives will result in Expected Annual Benefits of $21.9 thousand for the North Main Levee damage area, cutting out approximately two-thirds of Without Project Existing Annual Damages. Table 9 shows that EAD in this reach would virtually be eliminated with a levee at elevation SPF + 2', and that just restoring the levee height to SPF would eliminate approximately two-thirds of the damages expected in the Cultural District Levee damage area.

Project Costs

Table 10 displays the project costs for the various levee raise alternatives described above.

Item	SPF +0'	SPF + 1' (1V3H)	SPF +1' (1V4H)	SPF + 2'	SPF + 4'
Construction Costs	$226.7	$428.1	$621.0	$2,086.1	$4,483.4
Contingency (25%)	$56.7	$106.7	$152.3	$505.3	$1,095.9
E & D	$28.3	$54.5	$77.3	$259.1	$557.8
S & A	$22.7	$43.6	$61.8	$207.3	$446.3
Total First Cost	$334.5	$642.8	$912.0	$3,057.8	$6,582.5
Int. Dur. Const.	-	-	-	-	-
Gross Investment	**$334.5**	**$642.8**	**$912.0**	**$3,057.8**	**$6,582.5**
Annualized(5.625%,50 yrs)	$20.4	$39.2	$55.6	$186.5	$401.4
Operation & Maintenance	-	-	-	-	-
Total Annual Cost	**$20.4**	**$39.2**	**$55.6**	**$186.5**	**$401.4**

Note: Here, Total Costs represent Construction Totals plus E & D plus S & A. Due to H & H interdependence, costs have been combined for both of the damage areas under consideration. Annualized costs based upon most current Federal Discount Rate of 5.625% and 50-yr Period of Analysis. Six-month construction period assumed for Interest During Construction calculations. Does not include any O & M figures.

BENEFIT/COST ANALYSIS

Table 11
Preliminary Net Benefits and

Benefit-Cost Analysis Estimates
(In $1,000's)

Alternative	Total Ann Benefits	Total Annual Costs	Net Benefits	B-C Ratio
SPF + 0’	(21.9 + 134.8) = 156.7	20.4	(156.7 – 20.4) = 136.3	7.7
SPF + 1’ (1V3H)	219.5	39.2	180.3	5.6
SPF + 1’ (1V4H)	219.5	55.6	163.9	3.9
SPF + 2’ (1V4H)	223.4	186.5	36.9	1.2
SPF + 4’ (1V4H)	223.4	401.4	(178.0)	0.6

Thus, the preliminary NED plan would be the alternative to raise the levee back to the originally authorized SPF + 1’.