HARRIS COUNTY FLOOD CONTROL DISTRICT

US Army Corps of Engineers
Galveston District

HARRIS COUNTY FLOOD CONTROL DISTRICT
September 2013 (Revised February 2014)

MAIN REPORT AND ENVIRONMENTAL ASSESSMENT

GENERAL REEVALUATION REPORT

Appendix B – Economic Analysis

WHITE OAK BAYOU, TEXAS

FEDERAL FLOOD DAMAGE REDUCTION PROJECT

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1.0 INTRODUCTION

This report provides a description of the investigations, procedures, and analyses conducted for the economic analysis for the General Reevaluation Report (GRR) for the development of a flood control plan for White Oak Bayou. The scope of this report includes economic analysis of both existing and future With and Without Project Conditions.

White Oak Bayou originates in the northwest quadrant of Harris County and extends southeast to its confluence with Buffalo Bayou near the Houston Central Business District (CBD). White Oak Bayou is comprised of approximately 110 square miles or a total of approximately 70,000 acres. Numerous flood events have occurred along White Oak Bayou resulting in significant property damage to residences and businesses in the watershed. Several projects have been constructed along White Oak Bayou to reduce the flooding and are listed in **Section 2.0 Prior Studies**.

2.0 PRIOR STUDIES

Since the first Federal interest in flood control measures for Buffalo Bayou and tributaries was established by the Rivers and Harbors Act of 1938, several studies and projects have been undertaken for White Oak Bayou. The flood control act of September 1954 provided for clearing, straightening, enlarging, and improving White Oak Bayou up to 8.6 miles from its mouth. The report, *Buffalo Bayou & Tributaries, Texas, Feasibility Report (Flood Damage Prevention)* (Reference 1), May 1988, citing a 1961 General Design Memorandum, reports that the US Army Corps of Engineers (USACE) in January 1964 recommended an additional 2.1 miles of channel modifications to extend the project upstream to its confluence with Cole Creek. The channel modifications were authorized for construction by the Flood Control Act of October 1965 and construction of the 10.7 miles of modifications were completed in 1975. The upper reaches of White Oak Bayou were later studied as documented in an interim feasibility report, *Buffalo Bayou & Tributaries, Texas Interim Report on Upper White Oak Bayou Feasibility Report (Flood Damage Prevention)*, (Reference 2), April 1976. In the report, the USACE recommended 9.2 miles of channel enlargement, modification, and partial paving of the main stem upstream of Cole Creek. Also recommended was floodplain zoning and regulation of development within the 1 percent exceedance probability floodplain along the 5.6-mile most upstream reach of the bayou. The upper White Oak Bayou recommended plan was authorized for construction by the Water Resources Development Act of 1986. Another report, *Buffalo Bayou & Tributaries, Texas (Flood Damage Prevention) General Reevaluation Report on Upper White Oak Bayou*, (Reference 3), October 1987, presented a modified recommended plan which took into account work already done by local interests that had accomplished much of the authorized project. Features of the recommended plan included channel enlargement, modification, and partial paving of 5.8 miles of the main stem and nonstructural floodplain management of suburban developments along the main stem to prevent future damageable developments within the 1 percent exceedance probability floodplain.

3.0 GENERAL REEVALUATION

A General Reevaluation Report (GRR) study has been authorized for White Oak Bayou main stem under Section 211(f) of the Water Resources Development Act of 1996 (WRDA-96). The primary objectives of the GRR study are to assess the existing flooding problems, to evaluate alternative plans to mitigate the effects of the flood damages, to investigate the potential environmental impacts of the alternative plans, and to recommend a cost effective plan of improvement that contributes to National Economic Development (NED). The recommended plan of improvement must comply with existing laws, regulations and ordinances, and must be acceptable to the local sponsor (HCFCD) and the United States Army Corps of Engineers (USACE).

4.0 PERIOD OF ANALYSIS, INTEREST RATE AND PRICE LEVEL

For planning purposes, the period of analysis represents the time horizon to attain the project benefits and should be the same for all alternative plans. A uniform period of analysis is required to incorporate the time value of money for plan comparison. The period of analysis for comparing costs and benefits following project implementation begins in 2016 and extends 50 years in the future to 2066, in accordance with ER 1105-2-100 (Reference 4). A base year of 2016 was initially chosen as it is the year in which the project is anticipated to be completed and benefits are expected to begin to fully accrue. All the Plan Formulation steps were performed using 2009 as the base year. The final results of this study are presented in April 2011 price levels, with a base year of 2016. There are no changes in the hydrologic conditions throughout the project life. Therefore there are no changes resulting from changing the base year. A discussion of the hydrologic conditions is presented in Appendix A. Field surveys and data collections were conducted between 1998 and 2003 and initially reported at 2002 price levels. Structure values and unit costs were updated to 2009 price levels and then again to 2011 price levels (Attachment 5) for use in the analysis of the Without Project condition and in the selection of the Tentatively Recommended Plan and the Recommended Plan.

USACE Guidance ER 1105-2-100 (Reference 4) requires that all project benefits be reported as average annual equivalent values (AAE). The computational procedure involves calculating damages over the entire period of analysis, discounting them to the base year, and then amortizing them over the project life using the stated interest rate to produce AAE values. A federal interest rate is specified by the USACE annually for the formulation and evaluation of water and related land resources planning studies. The federal interest rate is 4.125 percent for fiscal year 2011, which extends over the period of October 1, 2010 through and including September 30, 2011 (Reference 5). As is discussed later in this report, the Base Year and Future Year conditions are the same. The benefits are presented in the Expected Annual Damages (EAD) tables. Since the Base Year and Future Year Conditions are the same, the EAD and AAE damages are identical.

5.0 ECONOMIC ANALYSIS AREA

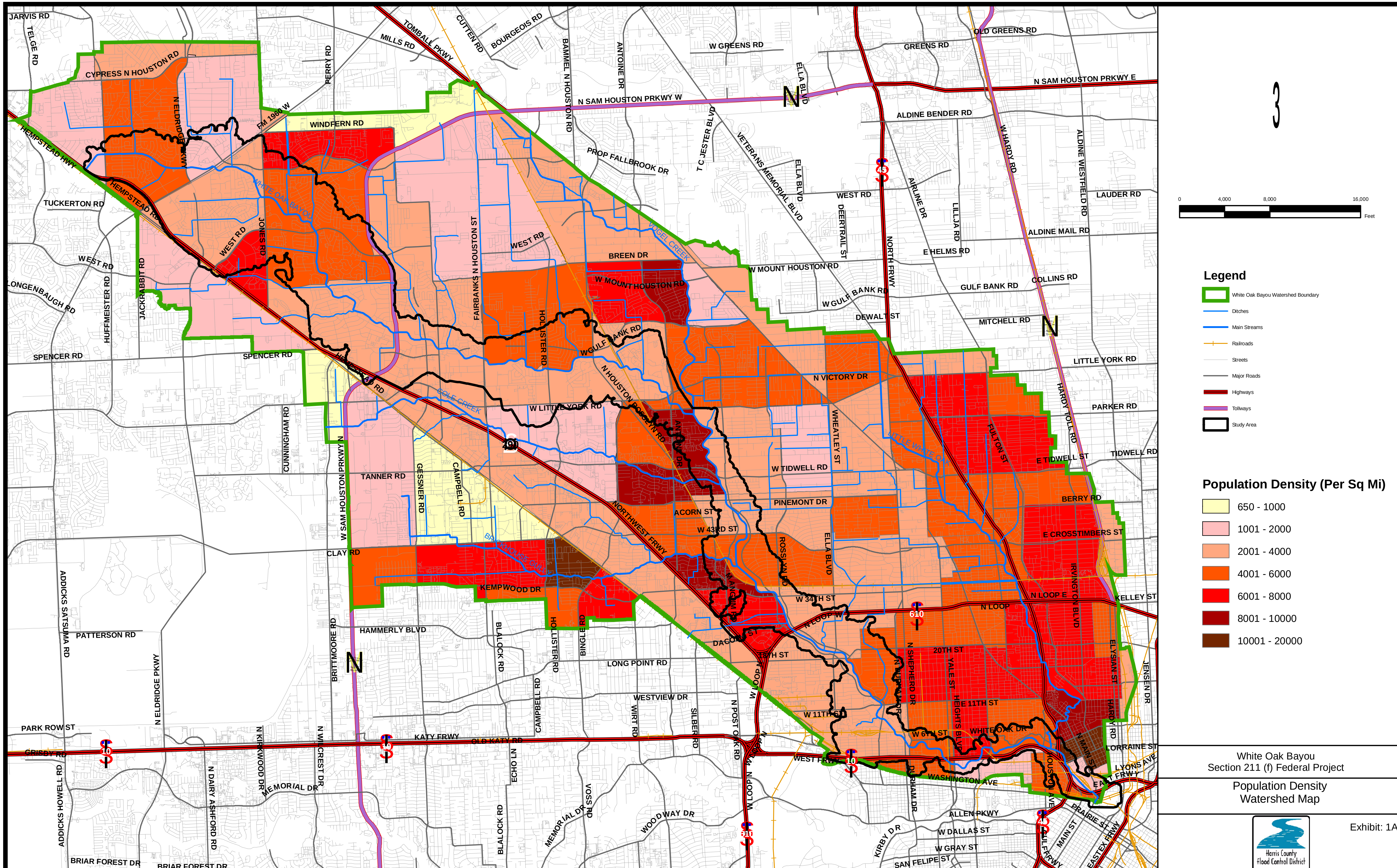
The economic analysis area defined for the economic analysis is the area along the main stem of White Oak Bayou based on the 0.2 percent chance exceedance floodplain plus the 500-foot buffer as determined using the latest TSARP hydrologic and hydraulic models for the base year 2016 condition. In the aftermath of Tropical Storm Allison, the Federal Emergency Management Agency (FEMA) and HCFCD began an initiative called Tropical Storm Allison Recovery Project (TSARP) that comprehensively assessed the flood risks within Harris County. As a result, new FEMA Flood Insurance Rate Maps are being developed.

White Oak Bayou is a tributary of Buffalo Bayou. It originates in northwest Harris County and flows southeast for approximately 25 miles to the confluence with Buffalo Bayou at downtown Houston, as shown in **Exhibits 1a and 1b**. The approximate 0.2 percent floodplain, watershed boundary, and economic reaches are also shown in **Exhibit 1b**. The structure inventory for the study area includes development along the full length of the stream from Station 0+00 to Station 1350+06 within the 0.2 percent floodplain. It excludes development along the tributaries of White Oak Bayou.

5.1 Population at Risk

According to the 2000 U.S. Census (Reference 6), the White Oak Bayou watershed has an estimated population of 515,528. The study area defined as the 0.2 percent exceedance probability floodplain has an estimated population of 183,571 and is comprised of approximately 24 of the White Oak Bayou Watershed's 110 square miles. With 7,649 people per square mile, the study area has a relatively higher density than the 3,860 people per square mile seen in the rest of the watershed. The population densities within the watershed are shown in **Exhibit 1a**. The higher population density within the study area signifies a concentration of flood risk to a relatively significant number of lives and property. The relatively high population exposure in the study area can also be seen in the context of a county-wide population density of 1,967 people per square mile. According to published US Census Bureau, Census 2000 Land Area and Population Density tables, Texas and the United States each record a population density average of 79.6 people per square mile.

The average median household income in the study area is $44,365, which is higher than the average for the entire White Oak Bayou watershed ($38,480), the state average ($39,927), and the national average ($42,148). This study area average is also significantly higher than the median household income of $36,616 for the Houston metropolitan area. However, it is closer to the average for U.S. metropolitan areas with populations of 1,000,000 or more, which was $48,079 for the year 2000. The study area's relatively high population density and high median household income make it susceptible to relatively high dollar damage due to flooding.


Legend
White Oak Bayou Watershed Boundary
Ditches
Main Streams
Railroads
Streets
Major Roads
Highways
Tollways
Study Area
Population Density (Per Sq Mi)
650 - 1000
1001 - 2000
2001 - 4000
4001 - 6000
6001 - 8000
8001 - 10000
10001 - 20000
0
4,000
8,000
16,000
Feet
White Oak Bayou
Section 211 (f) Federal Project
Population Density
Watershed Map
Harris County
Flood Control District
Exhibit: 1A

6.0 ECONOMIC REACHES

Properties surveyed within the 0.2 percent annual exceedance probability flood event were assigned to the nearest stream cross-section between Station 0+00 and Station 1350+06. Each property was associated with the left or right bank of the stream. The stream was divided into 26 planning reaches with representative index stations for modeling purposes. The areas which were identified as potential levee locations in the alternatives analysis to be performed later were isolated as separate reaches. Those structures which might be located in the levee area were assigned to that levee reach. The potential levee reaches are Hidden Lake Town Homes (WOB-4a(L)), Arbor Oaks (WOB-8a(L)), Inwood Forest (WOB-8b(L)), Woodland Trails North (WOB-10a(L)), and Woodland Trails West (WOB-10b(R)).

The economic reaches are presented in **Table 1** and are shown in **Exhibit 1b**.

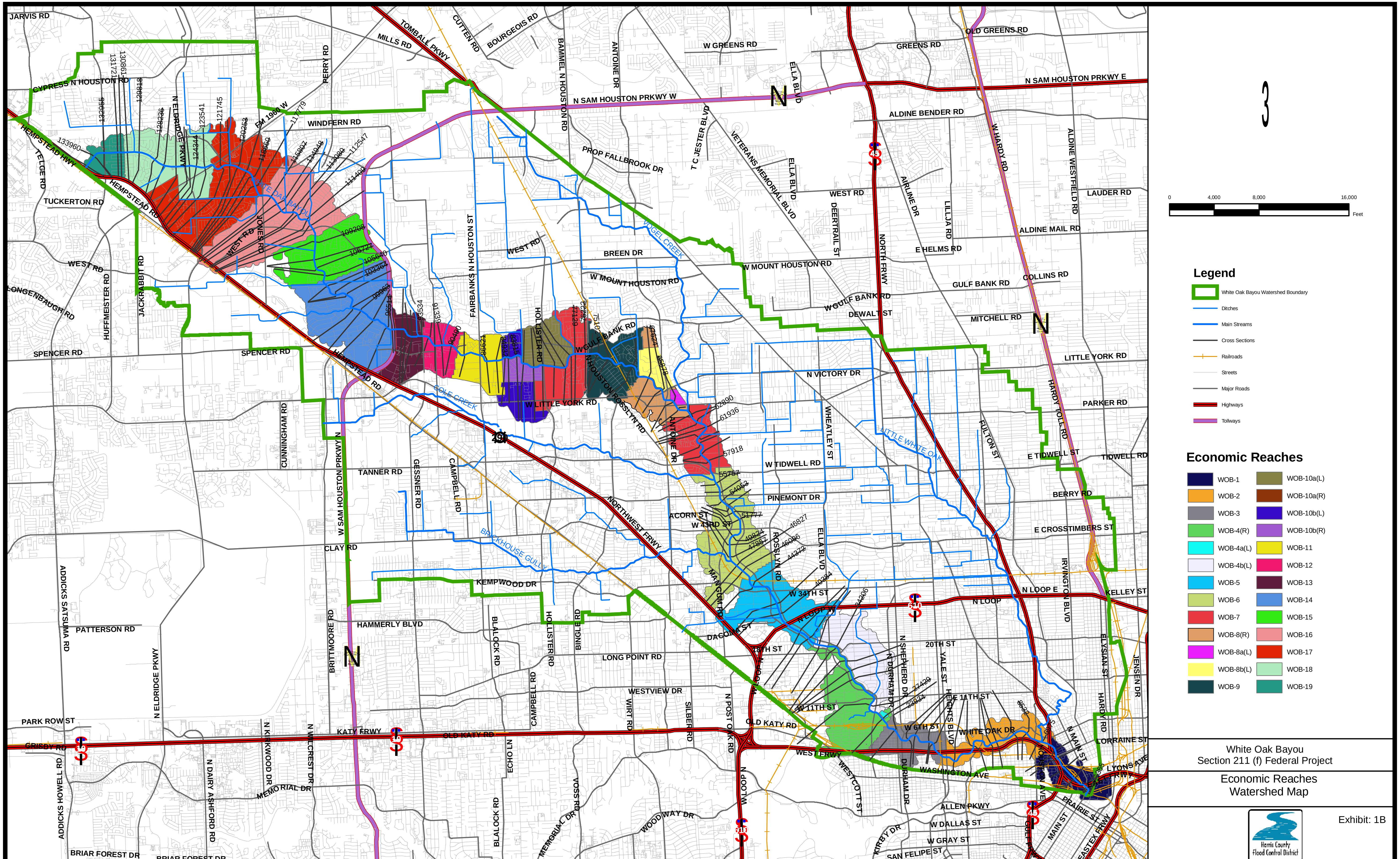
The main principles of reach delineation adhered to the following:

- Beginning and ending stations for each reach were defined such that each reach had relatively consistent hydrology.

- Each reach had similar flows at every cross-section with relatively small variations in the water surface profiles.

- Index locations, the point to which all damages in a reach would be aggregated, were located at a cross-section with the most significant concentration of structures in the reach.

- Unprotected structures sharing the same bank as proposed ring levee structures were relocated to the unprotected bank.



3
0
4,000
8,000
16,000
Feet
Legend
White Oak Bayou Watershed Boundary
Ditches
Main Streams
Cross Sections
Railroads
Streets
Major Roads
Highways
Tollways
Economic Reaches
WOB-1
WOB-2
WOB-3
WOB-4(R)
WOB-4a(L)
WOB-4b(L)
WOB-5
WOB-6
WOB-7
WOB-8(R)
WOB-8a(L)
WOB-8b(L)
WOB-9
WOB-10a(L)
WOB-10a(R)
WOB-10b(L)
WOB-10b(R)
WOB-11
WOB-12
WOB-13
WOB-14
WOB-15
WOB-16
WOB-17
WOB-18
WOB-19
White Oak Bayou
Section 211 (f) Federal Project
Economic Reaches
Watershed Map
Harris County Flood Control District
Exhibit: 1B

Table 1
Economic Reaches for White Oak Bayou Study Area

Stream Name	Damage Reach Name	Beginning Station	Ending Station	Bank	Index Location Station	Description
E100-00-00	WOB-1	0	5525	Both	4687	Mouth to I-45
E100-00-00	WOB-2	5525	18176	Both	9779	IH-45 to Yale St.
E100-00-00	WOB-3	18176	23934	Both	23934	Yale St. to D/S Hidden Lake
E100-00-00	WOB-4a(L)	23934	25536	Left	25536	D/S Hidden Lake Town Homes to U/S Hidden Lake Town Homes
E100-00-00	WOB-4(R)	23934	35718	Right	30779	D/S Hidden Lake Town Homes to Ella Blvd.
E100-00-00	WOB-4b(L)	25536	35718	Left	32570	U/S Hidden Lake Town Homes to Ella Blvd.
E100-00-00	WOB-5	35718	44983	Both	41337	Ella Blvd. to Burlington Northern RR.
E100-00-00	WOB-6	44983	56811	Both	48942	Burlington Northern RR. to W. Tidwell Rd.
E100-00-00	WOB-7	56811	63780	Both	57918	W. Tidwell Rd. to W. Little York Rd.
E100-00-00	WOB-8a(L)	63780	65878	Left	65878	W. Little York Rd. to Antoine Dr.
E100-00-00	WOB-8(R)	63780	70347	Right	67624	W. Little York Rd. to Alabonson Rd.
E100-00-00	WOB-8b(L)	65878	70347	Left	69408	Antoine Dr. to Alabonson Rd.
E100-00-00	WOB-9	70347	76222	Both	74115	Alabonson Rd. to N. Houston Rosslyn Rd.
E100-00-00	WOB-10a(R)	76222	79748	Right	77625	N. Houston Rosslyn Rd. to Hollister Rd.
E100-00-00	WOB-10a(L)	76222	82633	Left	77625	N. Houston Rosslyn Rd. to HCFCD Ditch Unit E124-00-00
E100-00-00	WOB-10b(R)	79748	84932	Right	82633	Hollister Rd. to Woodland West Dr.
E100-00-00	WOB-10b(L)	82633	84932	Left	83815	HCFCD Ditch Unit E124-00-00 to Woodland West Dr.

Stream Name	Damage Reach Name	Beginning Station	Ending Station	Bank	Index Location Station	Description
E100-00-00	WOB-11	84932	88972	Both	88972	Woodland West Dr. to W. Gulf Bank Rd.
E100-00-00	WOB-12	88972	92851	Both	90490	W. Gulf Bank Rd. to N. Gessner Rd.
E100-00-00	WOB-13	92851	96514	Both	95013	N. Gessner Rd. to Sam Houston Pkwy.
E100-00-00	WOB-14	96514	104527	Both	100723	Sam Houston Pkwy. to Wyndham Village Dr.
E100-00-00	WOB-15	104527	110346	Both	107598	Wyndham Village Dr. to West Rd.
E100-00-00	WOB-16	110346	116549	Both	112547	West Rd. to Jones Rd.
E100-00-00	WOB-17	116549	122498	Both	119390	Jones Rd. to FM 1960 W.
E100-00-00	WOB-18	122498	130861	Both	127300	FM 1960 W to Oak Acres Dr.
E100-00-00	WOB-19	130861	135006	Both	131721	Oak Acres Dr. to US 290

7.0 LAND USES

The White Oak Bayou economic study area, as defined by the 0.2 percent exceedance probability floodplain with Year 2016 Hydraulics and Hydrology, plus a 500-foot buffer, encompasses approximately 25 square miles in central and northwest Harris County. Based on an extensive analysis of the White Oak Bayou study area, the study area is approximately 90 percent developed with residential, commercial, industrial, and public land uses. Due to this high percent of developed land, the implementation of the HCFCD detention policy for new development, and the Harris County building regulation requiring that all new structures have their finish floor elevations at least 18 inches above the base flood elevation (BFE), the inclusion of future development in the Economic Analysis was deemed unnecessary. These policies are described in Appendix A Hydrology & Hydraulics. The policies require that no increases in water surface elevations are permitted in the future. In our analysis of with project benefits, Base Year and Future Year conditions are the same. This is discussed further in **Section 11.2** of this report.

The land uses within the economic study area (0.2 percent annual exceedance probability floodplain) were determined from parcel data obtained from the 2002 Harris County Appraisal District (HCAD) real property records with some changes made to the data after visual verification from field surveys and photogrammetry. The 2002 land use distribution in the economic study area is presented in **Table 2.**

Table 2
2002 Land Use Distribution for
White Oak Bayou Economic Study Area

Land Use	Area (Acres)	Percent of Total Developed Area
Residential	5,219	33.8%
Commercial	1,954	12.6%
Public	492	3.2%
Roads	3,232	20.9%
R.O.W.	1,925	12.5%
No Damage	1,028	6.7%
Vacant (Undeveloped)	1,584	10.3%
Total	**15,434**	**100.0%**

Source: Harris County Appraisal District Real Property Data, June 2002.

The largest land use category in the economic study area is residential at 33.8 percent. “No Damage” properties include auxiliary improvements, unsound structures, parking areas, and downtown R.O.W. areas. R.O.W. includes channel and detention right-of-way. All land uses shown in the table except “Vacant” constitute areas that are no longer available for development.

8.0 DATA COLLECTION AND ANALYSIS PROCEDURES

The economic analysis was performed to determine the project benefits in accordance with the methodology and requirements set forth in the most current guidance notebook, ER 1105-2-100, dated 22 April 2000, (Reference 4). The economic procedures were also consistent with the *National Economic Procedures Manual – Urban Flood Damage*, March 1988 (Reference 7). Damages for the Without Project Conditions are based on inundation damages to structures, contents, vehicles, utilities, roads, and other costs sustained by individuals following flood events such as temporary relocation and reoccupation costs.

A Geographic Information System (GIS) was used for the White Oak Bayou watershed to assist in the data collection, processing, and evaluation procedures. The ArcGIS geodatabases employed contain HCAD year 2002 parcel shapes with an associated HCAD property database.

8.1 Survey of Existing Development

The structure inventory of existing development along White Oak Bayou was identified for properties subject to flooding within the 0.2 percent annual exceedance probability (500-year) floodplain. The 0.2 percent annual exceedance probability floodplain for the study area was identified from hydrologic and hydraulic modeling based on current TSARP models. Topographic mapping was based on Light Detecting and Ranging (LIDAR) data obtained from the TSARP project. Other mapping and data sources used included January 2002 1-foot resolution digital aerial ortho photos, parcel maps, and associated 2002 property database from HCAD, City of Houston Monumentation and Mapping Program (HMMP), and Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) Line Files for Harris County. Current detailed roadmap and stream shape files were obtained from the HCFCD.

Economic work base maps were developed for the study area, which included the HCAD parcel data mapped on the HMMP grid system. The parcel maps were indexed and plotted to the same horizontal reference system and scale (1"=100') used for the project. The parcel work maps included parcel identification, stream cross-section stations, and the limits of the 0.2 percent annual exceedance probability floodplain. All mapping during this study was carried out using the North American Datum (NAD) 83 Texas South Central coordinate system.

The parcel map shape attributes and associated 2002 HCAD tax assessment records provided the basis for inventory of each individual parcel within the study area. Structure inventory characteristics taken from the tax records included structure value, number of stories, foundation type, structure type, street address and land use category (occupancy type). The parcel maps and property data were associated by HCAD account number and subsequently given a unique numerical identification (structure name) for each parcel. Each parcel's total structure value was divided by the number of structures when represented in the HEC-FDA model. The total number of structures was specified for each parcel in the model so that each structure within a parcel could be treated as one of identical individual structures subject to sampling during Monte Carlo simulations.

The economic work maps were used to identify each parcel by structure identification, nearest stream station, left or right bank, map panel number and number of structures. Ground elevations were assigned from LIDAR data at the centroid of the parcel using GIS spatial queries. Land parcels that exhibited significantly high range of elevations were subject to manual LIDAR extraction at the location of the building footprint as determined from aerial photography. The vertical datum used for the assignment of ground elevations was the North

American Vertical Datum (NAVD) of 1988, 2000 adjustment, which is the same datum used in the hydraulic analysis for White Oak Bayou.

A field survey was performed to determine a first floor correction for each structure in the study area. The first floor correction factor was measured as the difference between the ground elevation and the finished floor elevation at each structure. The field survey was also used to identify unknown properties, fill in HCAD data gaps, and obtain pertinent structure data including land use and the number of structures.

8.2 Property Values

Estimated values for residential, commercial and public properties identified in the structure inventory were originally based on the 2002 HCAD assessed values for the improvements, and the use of content-to-structure value ratios (CSVR) to determine the content values and were later updated to 2011 price levels for analysis of the Without Project Condition and the Tentatively Recommended Plan (RF-30 LA NSB1) and the Recommended Plan (RF-31). Refer to **Attachment 3** and **Attachment 5** for a description of how this data was updated.

Structure values do not include land value, as land is assumed to be undamaged by flood inundation. The 2009 price level update was used to update the structure values to reflect market changes which may have occurred since 2002. Real estate and economic theory generally attributes location value (both positive and negative) to the land and not to the depreciated value of the structures (improvements). The replacement cost new less depreciation (RCNLD) value of structures is a function of the cost of construction, as depreciated, and is not a reflection of the market perception of value due to flooding. Relative values of structures in different reaches may have changed since 2002. However, a comparison was made of 21,525 properties in the study area comparing the 2002 structure values and 2009 assessor values. This analysis indicated that less than 3% of the properties declined in value, suggesting that there would be minimal changes in relative values by reach within the study area. An additional price update was performed to update values to 2011 levels. In the Main Report for the Recommended Plan, the prices were escalated to FY 2013 levels.

A 100 percent Residential CSVR for one- and two-story homes was used based on the generic depth-damage curves in the HEC-FDA model. The 100 percent CSVR is a HEC-FDA modeling requirement for the correct application of the IWR generic depth-percent content damage curves in the estimation of content damage as reported in *Economic Guidance Memorandum 01-03, Generic Depth-Damage Relationships*, USACE, December 4, 2000 (Reference 8). A 100 percent CSVR for single-family homes does not necessarily reflect true content value. The current guidance notebook (ER1105-2-100, 22 April 2000, Appendix E-109) states: “When generic depth-damage curves are used no valuation of contents is required. Districts are therefore not required to collect or report content valuations for flood damages analyzed through the use of generic curves". These generic depth-damage functions were provided by USACE for single-family structures as part of their objective to provide planners with standardized depth damage data based on actual losses from flood events and to reduce the need for separate depth damage studies in the local project. All other residential, commercial and public CSVRs were taken from the USACE New Orleans District (NOD) study entitled *Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-To-Structure Value Ratios in Support of the Jefferson and Orleans Flood Control Feasibility Studies*, prepared by GEC, Inc., June 1996 (Reference 9).

The NOD study was deemed applicable to this study due to the relative proximity of the White Oak Bayou study area to the New Orleans study area and their close similarities in construction type and characteristics of flooding. The NOD study conducted for Jefferson and Orleans parishes classifies construction types for multi-family residential and nonresidential structures as metal frame, masonry bearing, or wood or steel frame. These construction types are applicable to the White Oak Bayou study area as all such structures in the multi-family and nonresidential occupancy types can be correctly grouped according to the NOD study's construction type classification. In addition, similar commercial services of comparable quality and similar content can be found in the two study areas. Based on these factors the nonresidential occupancy type classifications and CSVR's for the NOD study are adequate and can be correctly applied to the White Oak Bayou study area.

Current guidance (ER1105-2-100, 22 April 2000, Appendix E-100) states: "When depth-damage curves are used, the correct measure of structure value, consistent with cost-benefit concepts, is replacement cost less depreciation to the existing (pre-flood) structure." ER1105-2-100 also states: "When real estate appraisals are used as a source of basic data, the appraisal process shall be documented." ER1105-2-100 requires that when structure value data is obtained from sources other than direct estimation of cost of physical replacement less depreciation, the data should be verified as being reasonable estimates of replacement cost less depreciation. This can be done using a sampling procedure to select a relatively small number of structures for direct estimation of replacement cost less depreciation. The results can be used to compare to, and if appropriate, adjust the data obtained from other sources.

HCAD property data for residential properties was developed using a cost approach consistent with the Corps requirements. The cost approach is the backbone of the property tax appraisal system for HCAD, which assesses the improvement value using estimates on what it would cost to replace the improvements (buildings) and then subtracting an amount for accrued depreciation. The cost approach provides a structure value consistent with the replacement cost less depreciation. Sampling was performed to validate the use of the secondary data (HCAD) using the Marshall & Swift Residential Cost Estimator Program. The sampling procedures and results are discussed in the following section. Based on the results of the sampling, no adjustments were made to the residential property values.

For nonresidential structures, HCAD uses a number of different valuation methods including the Cost Approach, Income Approach and Market Approach. Unlike the cost approach, which is primarily based on information about construction costs and widely used in valuing residential property for tax purposes, the market approach uses sales information based on comparable properties while the income approach values property based on income and expense information. The income approach is used for properties that currently or could potentially produce income and is the recommended method of appraisal by HCAD for typical commercial use property.

Sampling was also performed to validate the use of the secondary data (HCAD) using the Marshall & Swift Commercial Cost Estimator Program. The sampling procedures and results are discussed in the following section.

The Marshall and Swift cost approach as applied to this study is based on the Marshall and Swift construction cost model with depreciated replacement cost obtained by using the following formula.

Depreciated Replacement Cost = Size X Unit Construction Cost X (1 - % Depreciation)

A reasonable estimate of percent depreciation is determined from the effective age or estimated remaining life of the structure.

In order to achieve higher accuracy, a field survey form and/or Commercial Estimator Worksheet was prepared for each of the surveyed properties. The size of each structure was obtained from the field survey. Building class was also established based upon the Marshall and Swift cost groups depending on type of framing wall, floor and roof structure, and fireproofing. This information was used to obtain a unit cost for the structure. The basic cost estimate was refined according to the quality of construction by qualifying the level of workmanship, quality of materials and quantity of components relative to a typical structure in its class. A replacement cost for the structure was estimated from the unit cost and building size. The effective age or remaining life of the structure was then estimated to determine percent depreciation based on a straight-line depreciation method. Replacement Cost Less Depreciation was obtained by subtracting the depreciated value from the replacement cost.

All appraisals were performed by a Certified and Licensed State of Texas appraiser.

8.3 Sampling

In accordance with ER 1105-2-100, a stratified sample of properties in the study area was surveyed to validate the property values obtained from HCAD. The use of sampling also provided a quantifiable measure of the uncertainty in the estimated values.

The sample design was based on the inventory of structures by structure type and by the total number of structures in each reach. A stratified pilot sample of 115 structures was randomly selected for the appraisals using the Marshall and Swift Estimator Programs. The sample distribution included 30 residential structures and 85 commercial structures. Since there is more similarity between residential structures than commercial structures, a smaller sample size for residential structures was considered reasonable. Relatively small samples sizes such as those used in this study are consistent with those used in other studies and yield statistically reliable results. A statistical evaluation of the pilot sample and HCAD property values was performed to determine the level of precision based on 90 percent confidence interval, and to test the mean relationship between the sample and HCAD structure values.

Statistical comparisons were made between the HCAD values and the sample values obtained using Marshall and Swift. The ratio of depreciated replacement cost value to HCAD value for each structure was computed and collectively used as inputs to the statistical analysis.

The residential sample was determined to have a level of precision of 7 percent of the mean ratio for a 90 percent confidence level. The mean ratio of depreciated replacement cost values to HCAD values was computed as 1.03. The residential sample was analyzed (see **Attachment 1A**) to examine if the direct use of the HCAD values would yield structure values similar to the depreciated replacement cost method. Assuming a normal distribution, a Student t-test applied to the data supported acceptance of the null hypothesis that at 10 percent level of significance, the mean ratio of depreciated replacement cost values to HCAD values is likely to be 1.0. These results appear reasonable since HCAD uses the Cost Approach and reports depreciated replacement cost values. No adjustment was made to the HCAD residential structure values.

The commercial sample was determined to have a level of precision of 8 percent of the mean ratio using a 90 percent confidence level. The mean ratio of depreciated replacement cost values to HCAD values was computed as 1.05. The Student t-test applied supported acceptance of the null hypothesis that at 10 percent significance level, the mean ratio of depreciated replacement cost values to HCAD values was likely to be 1.0. This gave an indication that the direct use of commercial HCAD values as proxy replacement cost less depreciation values would be acceptable. No adjustment was made to the HCAD commercial structure values. **Attachment 1B** shows sampled properties and statistical computations performed.

The use of sampling in the comparison of structure values also provided a quantifiable measure of the uncertainty in the estimated values. The standard deviation used in the economic model was 17 percent for the residential sample and 37 percent for the non-residential sample with the normal distribution assumed. These error values, as shown in **Attachments 1C and 1D**, were the standard deviations of the percent differences between the Marshall & Swift values and HCAD values for the respective samples expressed as a percentage of structure value.

A topographic survey was performed to verify first floor elevations by precision instrument surveying for the sampled properties. Statistical tests showed that the mean of the differences between the estimated first floor elevations and the precision surveyed first floor elevations was 0.12 feet with the approximate methods producing generally higher first floor elevations. The standard deviation of the differences between approximate elevations and elevation by instrument survey for all the surveyed structures was 1.23 feet. This standard deviation was used in the HEC-FDA model to generate a normal probability density function to describe the uncertainty in estimating first floor elevations for structures in the commercial, public and residential categories. It was assumed that errors in first floor elevation would be randomly distributed within the range of ±2.46 feet with 95.4 percent confidence limits. The sampled structures and statistical calculations performed can be seen in **Attachment 1E** of this economic appendix.

8.4 Analytical Tools

The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) computer program, Version 1.2, March 2000, was used in the economic analysis. HEC-FDA utilizes the structure inventory data including the ground and first floor elevations, structure types and values, and content-to-structure value ratio (CSVR) to compute damages by depth of inundation and their aggregates by reach. The procedure combines the discharge-exceedance probability relationship, stage-discharge relationship, and the stage-damage relationship to determine the damage-exceedance probability relationship at each aggregated index location along the economic reaches.

8.5 Risk and Uncertainty

ER1105-2-100 (Reference 4) requires that all flood damage reduction studies adopt risk-based analysis for feasibility studies, general design memorandums, and general reevaluation reports. ER1105-2-101 (Reference 10) in conjunction with EM1110-2-1619 (Reference 11) details procedures for carrying out risk-based analysis. Risk-based analysis involves consideration of risk and uncertainty in key planning and design variables.

Risk and uncertainty are intrinsic in water resources planning and design. All measured or estimated values in project planning and design are inaccurate to various degrees. Best estimates were used for key variables, factors, parameters, and data components in estimating expected damages and damages reduced. As indicated in **Tables 3a** and **3b**, data inputs are all subject to uncertainty error. HEC-FDA embodies risk-based analysis procedures to quantify uncertainty in discharge-exceedance probability, stage-discharge and stage-damage functions. The Monte Carlo simulation in HEC-FDA incorporates the measures of uncertainty in plan evaluation and then describes the results through the Expected Annual Damages (EAD). Damage values are presented as a single most likely value. However, since uncertainty exists in the variables, there is actually a range of potential values. An understanding of risk and uncertainty is necessary in order to compare competing options.

The determination of expected annual damages for a flood risk management study must take into account the complex relationships between the key hydrologic, hydraulic and economic information:

- Hydrologic – The discharge exceedance probability function describes the probability a given flood will occur. Variables with uncertainties accounted for in the analysis include gage records that are often too short or do not exist, precipitation-runoff computational methods that are not precisely known, and imprecise knowledge of the effectiveness of flow regulating structures. Using graphical probability functions, HEC-FDA calculates error bands based on the input frequency-discharge curve and the equivalent gage period of record.

- Hydraulic – The stage-discharge function describes the water surface elevation for a given rate of flow. Uncertainty arises from the use of simplified models to describe complex hydraulic relationships, including simplified geometric data, effects of hydraulic structures, and errors in estimates of slopes and roughness factors. HEC-FDA calculates error bands to the stage-discharge curve based on a provided error distribution.

- Economic – The stage-damage functions describe the amount of damage that may occur for a given flood elevation. Uncertainties include depth/damage relationships, structure and content values, structure locations, first floor elevations, flood duration, flood warning time and the response of floodplain inhabitants.

These inter-related functions make up the conceptual risk approach utilized by the Corps on all flood risk management projects. HEC-FDA performs a Monte Carlo simulation of discharge-probability, stage-discharge, and stage-damage relationships incorporating their associated uncertainties, to compute a damage-probability function. Expected annual damages, an estimate of annual damages for a given condition and year of analysis are calculated by integrating the damage-probability function. HEC-FDA uses a Monte Carlo routine to perform numerous model realizations by randomly selecting values within the specified uncertainty limits of each function.

At a minimum, the following variables must be explicitly incorporated in the risk-based analysis: the stage-damage function for economic studies (with special emphasis on structure first floor elevation, depth-percent damage relationships, and content and structure values for urban studies); discharge associated with exceedance frequency for hydrologic studies; and conveyance roughness and cross section geometry for hydraulic studies.

Uncertainty in the depth-percent damage relationships and CSVR was based on the USACE/IWR study (Reference 8) and the NOD study (Reference 9) except CSVR for residential single-family properties. One- and two-story single-family homes were assigned CSVRs of 100 percent based on the application of generic content depth-damage curves (for residential structures with no basements) published in the USACE Economic Guidance Manual EGM 01-03 (Reference 8). Due to the high water table in Harris County, residences with basements are exceedingly rare and none were noted in the study area. Economic uncertainty in structure values, and first floor elevations were quantified based on survey results. The survey statistics for first floor elevations and residential and commercial structure values can be seen in **Attachments 1C, 1D and 1E.**

Hydrologic and Hydraulic (H & H) uncertainty was incorporated into the HEC-FDA program for the water surface profiles. Discharge-Exceedance probability functions were constructed by analytical means by fitting a Log Pearson III distribution to the data using a 34-year record length to describe the uncertainty. The resulting theoretical curves modeled the eight discharges and extended predictions to the 99.9 percent and 0.1 percent exceedance probabilities. These curves were computed for the 5, 25, 75, and 95 percent confidence levels. The median curve was used as the primary data with other curves used to incorporate uncertainty. Stage-Discharge functions with uncertainty were also computed for each reach. A full discussion of the hydrologic and hydraulic uncertainty can be found in the **Appendix A - Hydrology and Hydraulics.**

Uncertainty values and the probability distribution function types used in this study for key variables are summarized in **Table 3a** and **Table 3b.** **Table 3a** illustrates the economic uncertainty associated with the depth-damage functions, structure values, CSVR, and the first floor stage elevations. **Table 3b** illustrates the hydrologic and hydraulic uncertainty associated with the discharge-exceedance probability function and stage-discharge function. The same uncertainty values were used throughout the study.

The HEC-FDA White Oak Bayou Flood Control Project model calculates uncertainty for the following key variables.

1. H&H Discharge-Exceedance Probability
2. H&H Stage Discharge
3. Depth-Damage Function
4. Structure Value
5. Content-To-Structure Value
6. First Floor Stage

A sensitivity analysis was performed to determine the relative impact of these uncertainty variables. This analysis was performed by preparing test HEC-FDA models to omit uncertainty for each of the above variables and comparing the differences in damage results. Based on this analysis, uncertainty related to Stage-Discharge and First Floor Elevation are the largest contributors to uncertainty in the HEC-FDA model, both contributing in the range of approximately 15 to 20 percent of the total uncertainty. The upper and middle reaches starting with WOB-10 experience the largest variations in expected annual damages due to uncertainty.

Expected damage values were computed using Monte Carlo sampling techniques within the HEC-FDA program to produce a risk based annual value for each reach. In the construction of aggregate depth-damage functions, the number of Monte Carlo simulations was increased from the default 100 to 400 to eliminate errors of decreasing damage with increasing depth occurring in some reaches. These errors arose where profiles between two exceedance probability events were relatively close together and/or unparallel and required more structure sampling at the ordinates in between to ensure that model convergence resulted in increasing dollar damages at each higher ordinate. Expected Annual Damages (EAD) Monte Carlo Iterations ranged between 75,000 and 160,000 in number required to converge to a mean expected annual value for each reach with corresponding mean standard error. Risk based computations with uncertainty were carried out for Without Project conditions and similarly for all With Project conditions.

Table 3a
Section 211(f) - White Oak Bayou
Economic Uncertainty Error Types and Values for Key Variables

	Depth-Damage Function Error Type		Structure Value		CSVR	CSVR	First Floor Stage	
	Structure	Content	Error Type	St. Dev. (%)	Mean (%)	St. Dev. (%)	Error Type	St. Dev. (feet)
1-Story Single Family	Normal	Normal	Normal	17.0	100.0	0.0	Normal	1.23
2-Story Single-Family	Normal	Normal	Normal	17.0	100.0	0.0	Normal	1.23
Mobile Home	Triangular	Triangular	Normal	17.0	60.0	24.1	Normal	1.23
Multi-Family Residences	Triangular	Triangular	Normal	17.0	37.0	14.3	Normal	1.23
Eating & Recreation	Triangular	Triangular	Normal	37.0	114.0	48.2	Normal	1.23
Groceries & Gas Stations	Triangular	Triangular	Normal	37.0	127.0	48.2	Normal	1.23
Professional Businesses	Triangular	Triangular	Normal	37.0	43.0	13.8	Normal	1.23
Public & Semi Public	Triangular	Triangular	Normal	37.0	114.0	71.5	Normal	1.23
Repairs & Home Use	Triangular	Triangular	Normal	37.0	206.0	102.0	Normal	1.23
Retail & Personal Services	Triangular	Triangular	Normal	37.0	142.0	93.2	Normal	1.23
Warehouse & Contractor Services	Triangular	Triangular	Normal	37.0	168.0	98.3	Normal	1.23
Vehicles*	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Utility*	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post Disaster Costs*	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Roads*	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Direct Depth-Dollar Damage functions used.

Table 3b
Section 211(f) - White Oak Bayou
Hydrologic and Hydraulic Uncertainty Error Types and Values for Key Variables

	Discharge-Exceedance Probability Function		Stage-Discharge Function			
Reach	Error Type	Record Length Years	Error Type	St. Dev. (feet)	Min. Error (feet)	Max. Error (feet)
WOB-1	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-2	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-3	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-4	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-5	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-6	Log Pearson III	34	Triangular	N/A	5.00	3.00
WOB-7	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-8	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-9	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-10	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-11	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-12	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-13	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-14	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-15	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-16	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-17	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-18	Log Pearson III	34	Normal	1.44	N/A	N/A
WOB-19	Log Pearson III	34	Normal	1.44	N/A	N/A

9.0 DAMAGE CATEGORIES

Damage categories and occupancy types used to estimate inundation damages to structures and contents were based on the damage categories established in the NOD study (Reference 9). Apart from USACE developed generic curves used for residential single-family structures, depth-percent damage relationships established in the NOD study (Reference 9) were applied to the White Oak Bayou study due to similarities in structure type and construction practices in New Orleans and Houston as discussed in **Section 8.2.** Unit costs applied for "non-physical" damages were generally based upon previous studies in Harris County. A study undertaken by GEC in October 1998 to establish vehicle, utility and road damage unit values was referenced. Public agencies including government agencies at all levels, commercial, and non-profit organizations were contacted regarding historical flooding events in the Houston area. The GEC study determined that due to sparse data, the figures from previous USACE studies in Harris County, updated to 2011 price levels, were the best estimates available. A summary report on the GEC study can be seen in **Attachment 2**.

Structures that were dissimilar from the typical structures used to develop the depth-damage curves (e.g. multi-story buildings) and had significant impact on the analysis underwent a scale down appraisal to provide an equivalent two-story value on which the relevant depth-percent damage function was applied.

The damage categories used for this study are discussed in more detail as follows.

9.1 Residential

Residential structure damages include inundation losses for single-family dwellings classified as one-story on pier or slab; two-story on pier or slab; mobile home; and for multi-family residences classified as metal frame structure, masonry bearing wall structures, or wood or steel frame structure. Separate structure and content depth-percent damage relationships based on the USACE EGM 01-03 *Generic Depth-Damage Relationships* (Reference 8), were applied to the residential single-family inventory based on the classification of each structure by story height. The generic depth-damage functions are being provided by the USACE as part of their objective to provide planners with standardized depth-damage data based on actual losses from flood events and to reduce the need for separate depth-damage studies in the project locale. The generic curves were applied to this study for single-family homes using a 100 percent CSVR (since the USACE generic content depth-damage functions were directly estimated and divided by structure value) for the With and Without Project conditions. Depth-damage relationships from the NOD study were applied to residential mobile homes and multi-family residences. The NOD study (Reference 9) was referred to in the absence of recent local studies or generic data for depth-damage functions and CSVR with uncertainty applicable to the White Oak Bayou study area. The suitability of the NOD study data used in this study was discussed in **Section 8.2.**

9.2 Commercial

Commercial damages include losses to properties used in commerce, industry, business trade, servicing or entertainment. Separate depth-damage relationships were used to assess inundation damages to commercial structures and contents based on depth-percent damage relationships derived in the NOD study (Reference 9). Commercial structures were classified into three different structure types with separate depth-percent damage relationships. The three structure types are metal frame walls, masonry walls, and wood or steel frame. Contents for commercial properties were classified into six separate damage categories with separate depth-percent damage relationships. The six commercial content categories include eating and recreation, groceries and gas stations, professional businesses, repairs and home use, retail and personal services, and warehouse and contractor services. Content values were estimated using the mean CSVR's derived in the NOD study (Reference 9).

9.3 Public

Public damages include damages to public facilities such as public buildings, parks, and other facilities, including equipment and furnishings owned or operated by Federal, State, County, and local governmental entities. Since most public structures are tax exempt entities HCAD did not report structure values for several public properties. All those properties were field inspected and a Marshall & Swift cost estimate performed. Separate depth-percent damage relationships were used to assess inundation damages to public structures and contents. The damage relationships and CSVR's were derived from the NOD study (Reference 9). The Harris County Jail and the University of Houston were two public structures that warranted special attention because of their unique nature and their significant damage potential. These structures were scaled down in value in order to properly apply available depth-percent damage curves.

9.4 Vehicles

The nature of development within Harris County is such that streets are graded lower than the surrounding land in order to function as tertiary drainage from the surrounding urban development. Due to the dual function of roadways for transportation and drainage, vehicles are especially vulnerable to damage from flooding. The method for calculating vehicle damages changed after plan optimization. Prior to the last added analysis in **Section 15.3**, vehicle damages were calculated using data from the 1989 IWR Houston Damage Survey. The final last added analysis was performed using *Economic Guidance Memorandum*

(EGM), 09-04. The U.S. Army Corps of Engineers has published *EGM, 09-04, Generic Depth-Damage Relationship for Residential Vehicles* dated June 22, 2009. The purpose of the guidance memorandum is to release and provide guidance for the use of generic residential vehicle depth-damage curves for USACE Flood Damage Reduction Studies. This methodology was considered to be applicable to estimate vehicle damages for the economic analysis area. The EGM 09-04, as well as a description of the methodology used to estimate damages, can be seen in **Attachment 4**.

The survey results in EGM 09-04 provided depth-damage relationships for five classes of vehicles: Sedans, Pickups, SUV's, Sports, and Mini Vans. The guidance states that damage to residential vehicles is dependent on the average number of vehicles per household, the approximate percentage breakdown of type of vehicles, the average value of vehicle based on the make, model, and age, and the percentage of vehicles that are likely to be at the residence at the time when flood waters reached the property or otherwise be subject to flood damage because of the inability to safely evacuate the vehicle. The guidance indicates the number of vehicles can be estimated using the American FactFinder section of the U.S. Census website by inputting the zip code and looking under household characteristics. Information for determining the appropriate distribution of class of vehicle was obtained from R.L. Polk & Co. Average values, for the five vehicle classes, were obtained from the Autotrader.com.

The EGM also notes the length of potential warning time and the access to a safe evacuation route to a flood-free location should be considered in estimating the percentage of vehicles that would likely remain in the flood prone location. The guidance provides results on the percentages from a post-flood data collection of respondents that moved vehicles to higher ground and the length of the respondents' warning time. A warning time of 6 hours or less was used in the vehicle damage estimate. Harris County Flood Control District operates a flood alert system to advise residents of potential flooding along the bayous during storm events. Flood warning times are generally less than 6 hours in Harris County. Harris County experiences widespread flooding from tropical storms and hurricane events, heavy rainfall events, and has extensive floodplains throughout the area. Harris County has a very large population that limits evacuation in extreme events. During Tropical Storm Allison in 2001, Harris County received over 28 inches of rainfall during a 12-hour period that damaged over 95,000 vehicles, 73,000 residences, and caused over $5 billion in property damage.

9.5 Utilities

Utility damages include losses to electrical transformers and transmission lines, telephone company lines and switch boxes, and water and gas pipelines. Damage figures developed by IWR following the July 1979 Tropical Storm

Claudette, which flooded Harris and Galveston Counties, were estimated at $77 per flooded structure. This average damage value per structure flooded was updated to a 2011 value of $241 by applying the relative percentage increase in the CPI over that time period. Utility stage-dollar damages curves were calculated outside the FDA program using the distribution of flooded structures by reach within the eight annual exceedance probability floodplains and applying the unit damage value of $241 as shown in **Attachment 2.**

9.6 Roads

Road damages include repair costs for roads, bridges, street signals, and street lighting. Stage-percent damage relationships for roads were based on the April 1979 Montgomery County storm and the July 1979 Tropical Storm Claudette flood data collected from FEMA. From the FEMA data, the average experienced repair cost per mile of inundated asphalt, concrete and dirt roads was updated to a 2011 value of $13,071 per mile by applying the relative percentage increase in the CPI. Miles of roads by reach within the various annual exceedance probability floodplains were measured from an enhanced modification of the 2000 US Census Topologically Integrated Geographic Encoding and Referencing (TIGER) Line files for Harris County. Stage-dollar damage relationships for roads were developed by calculating the number of road miles per exceedance probability floodplain multiplied by the unit damage of $13,071 per mile. Further details on the computation of road damage from unit costs can be seen in **Attachment 2.**

9.7 Post Disaster Costs

IWR's 1990 survey of flood victims within the Cypress Creek and Greens Bayou watersheds in Harris County revealed other costs associated with flooding that were not otherwise quantified. These costs included lodging, travel, food, vandalism, looting and medical costs, costs of clean up, and costs of moving and storing furniture all associated directly with the flood experience. On average these types of costs exceeded $5,700 as reported by surveyed households. This average cost incurred per flooded household was adjusted to a 2011 value of $9,939 using the CPI. The distribution of residences by flood elevation was used with the unit damage value to assess the post disaster costs associated with flooding. Further details on determination of costs for the Post Disaster damage category can be seen in **Attachment 2.**

10.0 DETERMINATION OF EXISTING CAPITAL INVESTMENT WITHIN THE EXISTING 0.2 PERCENT ANNUAL EXCEEDANCE PROBABILITY FLOODPLAIN

The structure inventory and the distribution of capital investment within the eight existing annual exceedance probability floodplains of White Oak Bayou based on first floor elevations is presented in **Table 4**. It is estimated that over 92 percent of the total structures in the estimated 0.2 percent annual probability floodplain are residential, which accounts for approximately $752 million of structure value. Total structure value in the 0.2 percent floodplain is approximately $1.1 billion. The two structures located in the 50% exceedance probability floodplain are located in Reaches 4a(L) and 12. Structures in the 20% exceedance probability event are concentrated in the middle reaches (4 and 5 and 9 through 14). Reaches 4 and 5 are located near Hwy 290 and I-610, and Reaches 9 through 14 extend from Alabonson Rd. to Wyndham Village Dr. Structures located in the less frequent exceedance probability events are located throughout the study area.

11.0 DETERMINATION OF FLOOD DAMAGES FOR WITHOUT PROJECT CONDITION

Flood damages were estimated for all properties within the 0.2 percent annual exceedance probability floodplain of White Oak Bayou for the Without Project condition. Damages from inundation are based on data obtained from the previously described field inventory of existing development. Damage estimates were computed for structures and contents of the various types of physical properties classified as residential, commercial, and public. Damages were estimated for vehicles, utilities, roads, and other costs associated with flooding. Intangible damages were not evaluated.

11.1 Single Occurrence Damages

Damages expected to accrue from the various annual exceedance probability events for the Without Project condition are displayed in **Tables 5a** and **5b**. These values represent damages expected for individual events under the Without Project hydrologic conditions and include structure and content values. Damages begin to accrue when the flood stage reaches within one foot of the finished floor elevation. Therefore damages shown in **Table 5a** may accrue to more structures than those summarized in **Table 4**. Similarly, later in this appendix, the numbers of structures damaged are those for which damages begin to accrue based on the stage being within one foot of the finished floor elevation.

As an example of the results shown in **Table 5a**, total one-time damages expected during a 1 percent annual exceedance probability event is approximately $423 million. The one-time damages expected during a 0.2 percent exceedance probability event are approximately $857 million.

As seen in **Table 5a**, vehicle damage represents a relatively small percentage of total damages under the 50 percent annual exceedance probability event, but a much higher percentage under all other events. This is due to the fact that vehicle damage is a function of residential units flooding above first floor elevation. The 50 percent exceedance probability event has only two residential units inundated above slab. However, the larger events produce above slab inundation of significantly more residential structures including eight multi-family residences during the 20 percent exceedance probability event. The presence of multi-family residences with several residential units during a flooding event can result in significant vehicle damages compared to where no multi-family residences are inundated.

11.2 Expected Annual Damages

Expected Annual Damages (EAD) were calculated for Without Project conditions. A manual integration (traditional EAD calculation method) by computing the area under the Exceedance Probability versus Damage curve derived from **Table 5a** produced an estimated EAD of approximately $34.2 million as shown in **Table 6**. The derivation of single occurrence damages from the HEC-FDA model shown in **Table 5a** is based on the Median Exceedance Probability versus Discharge function. The EAD was then recomputed within the HEC-FDA program without consideration of uncertainty. This produced a value of approximately $34.5 million as shown in **Table 6**. The model differed from manual computations because the Median Exceedance Probability versus Discharge function computed for each reach is automatically adjusted by the model to account for Expected Probability in accordance with Bulletin 17B (Reference 12). The HEC-FDA model calculates the EAD using the Expected Probability versus Discharge function rather than the Median Exceedance Probability versus Discharge function. This indicates that although the without uncertainty option is computed, a measure of uncertainty is introduced from the hydrology that results in a higher EAD value than the manual computation. However, the values are close because of the relatively low level of uncertainty in the discharge-exceedance probability functions. In addition, a relatively good fit to the Log-Pearson III distribution resulted in the expected probability functions closely approximating the median probability curve. EAD Computations in the HEC-FDA model with consideration of uncertainty resulted in EAD values of $60 million for years 2014 and 2064 as shown in **Table 6**. Damages are highest in Reach 10a and 10b because this area is characterized by flat topography, a wide floodplain, and a large concentration of single-family residential structures. This reach contains approximately 70 percent of the single-family residences within the 10 percent exceedance probability flood plain for the study reach, and approximately 50 percent for the 4 percent flood plain.

As was discussed in **Section 7.0** the economic study area is 90% developed with residential, commercial, industrial and public land uses. Due to the high percent of developed land, the implementation of the HCFCD detention policy for new development, and the Harris County building regulation requiring that all new structures have their finish floor elevations at least 18 inches above the base flood elevation (BFE), the inclusion of future development in the Economic Analysis was deemed unnecessary. These policies are described in Appendix A -Hydrology & Hydraulics. These policies do not permit increases in water surface elevations and thus support the exclusion of future development. A previous analysis was performed to evaluate if any significant change in damages would occur if control of excess runoff due to increased imperviousness was not provided for the small area remaining to be developed. FDA results showed only a six percent increase in Future EAD damages and a two percent increase in average annual damages over the project life. Based on these small hypothetical increases and the existing regulatory controls, the Base Year and Future Year EAD used in this analysis are identical.

Expected annual damages for the without project condition are shown in **Table 6**. Damages are higher with consideration of uncertainty than without uncertainty. All of the reaches, with the exception of WOB-1 and WOB-2, show higher damages when calculated with uncertainty compared to the damage without uncertainty calculation. HEC-FDA performs a Monte Carlo simulation of discharge-probability, stage-discharge, and stage-damage relationships incorporating their associated uncertainties, to compute a damage-probability function. Expected annual damages, an estimate of annual damages for a given condition and year of analysis, are calculated by integrating the damage-probability function. HEC-FDA uses a Monte Carlo routine to perform numerous model realizations by randomly selecting values within the specified uncertainty limits of each function. Uncertainty related to the Stage-Discharge function and the First Floor Elevation are the greatest contributors to uncertainty in the damage estimates. The impact of this uncertainty is most pronounced in the upper and middle reaches of the study area.

11.3 Average Annual Equivalent Damages

Average Annual Equivalent (AAE) Damages are computed over the 50-year project life and accounts for changes in the development between the Base and Future Years. Since Base Year and Future Year conditions will be the same over the 50-year project life EAD and AAE damages are equivalent.

Table 4
Section 211(f) - Federal Project - White Oak Bayou
Distribution of Capital Investment within Annual Exceedance Probability Flood Plains
Cummulative Totals based on First-Floor Elevations and Without Project Hydrology and Hydraulics
Dollar Values in $1,000's, April 2011 Price Levels

	Exceedance Probability Events								
Damage Category	Bank to 50% Flood Plain "2-Year"	Bank to 20% Flood Plain "5-Year"	Bank to 10% Flood Plain "10-Year"	Bank to 4% Flood Plain "25-Year"	Bank to 2% Flood Plain "50-Year"	Bank to 1% Flood Plain "100-Year"	Bank to 0.4% Flood Plain "250-Year"	Bank to 0.2% Flood Plain "500-Year"	NIFP*
Residential Property									
Number of Structures	2	568	1,277	2,517	4,289	5,633	7,793	9,610	15,141
Single-Family	2	559	1,266	2,450	3,942	5,189	7,212	8,843	14,157
Multi-Family	0	8	8	63	89	173	234	412	906
Mobile Homes	0	1	3	4	258	271	347	355	78
Distribution	0.0%	5.9%	13.3%	26.2%	44.6%	58.6%	81.1%	100.0%	N/A
Structure Value	$153	$47,516	$101,988	$200,583	$305,822	$419,482	$582,822	$751,913	$1,733,745
Content Value**	$153	$46,669	$101,134	$193,384	$296,567	$394,180	$542,742	$677,227	$1,554,308
Total Value	$305	$94,185	$203,122	$393,967	$602,390	$813,662	$1,125,564	$1,429,139	$3,288,053
Commercial Property									
Number of Structures	0	23	54	142	273	419	633	828	1,032
Distribution	0.0%	2.8%	6.5%	17.1%	33.0%	50.6%	76.4%	100.0%	N/A
Structure Value	$0	$3,782	$13,590	$54,625	$99,713	$141,905	$188,116	$247,236	$527,194
Content Value	$0	$6,137	$22,654	$77,852	$140,647	$202,385	$266,806	$343,928	$630,184
Total Value	$0	$9,919	$36,244	$132,477	$240,360	$344,290	$454,922	$591,164	$1,157,378
Public Property									
Number of Structures	0	1	2	6	12	22	49	57	60
Distribution	0.0%	1.8%	3.5%	10.5%	21.1%	38.6%	86.0%	100.0%	N/A
Structure Value	$0	$0	$183	$37,850	$58,438	$88,008	$136,611	$139,774	$120,441
Content Value	$0	$0	$208	$43,148	$66,619	$100,328	$155,735	$159,341	$137,303
Total Value	$0	$0	$391	$80,997	$125,058	$188,336	$292,346	$299,115	$257,744
Total Property									
Number of Structures	2	592	1,333	2,665	4,574	6,074	8,475	10,495	16,233
Distribution	0.0%	5.6%	12.7%	25.4%	43.6%	57.9%	80.8%	100.0%	N/A
Structure Value	$153	$51,298	$115,761	$293,058	$463,973	$649,395	$907,549	$1,138,923	$2,381,380
Content Value	$153	$52,806	$123,996	$314,384	$503,833	$696,893	$965,283	$1,180,496	$2,321,795
Total Value	$304	$104,104	$239,757	$607,442	$967,807	$1,346,288	$1,872,832	$2,319,419	$4,703,175
Total Roads									
Roadway Lengths (Miles)	13	51	90	149	184	215	252	283	N/A
Distribution	4.8%	17.9%	31.9%	52.6%	65.0%	76.2%	89.0%	100.0%	N/A

* Not in Flood Plain (these structures were inventoried as part of the study area within the 0.2% exceedance probability floodplain extents, but they have first floor elevations above the floodplain).

** Residential Single Family Content Values displayed are based on a 100 percent content-to-structure value ratio (CSVR).

Table 5a
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event
Without Project Hydrology and Hydraulics
April 2011 Values in $1,000's

	Annual Exceedance Probability Events							
	50%	20%	10%	4%	2%	1%	0.40%	0.20%
	"2-Year"	"5-Year"	"10-Year"	"25-Year"	"50-Year"	"100-Year"	"250-Year"	"500-Year"
Damage Category								
Residential Property	$1,190	$23,482	$42,803	$88,382	$132,667	$180,095	$264,292	$343,266
Commercial Property	$5	$1,410	$5,495	$22,317	$46,447	$70,209	$115,044	$161,285
Public Property	$0	$0	$2	$3,434	$22,091	$36,701	$61,467	$84,516
Total Damages to Structures and Contents	$1,195	$24,892	$48,300	$114,133	$201,206	$287,004	$440,803	$589,067
Post Disaster Costs	$20	$6,705	$17,641	$35,201	$54,387	$75,226	$102,836	$141,410
Road Damages	$176	$661	$1,178	$1,943	$2,403	$2,815	$3,289	$3,695
Utility Damages	$0	$163	$428	$853	$1,318	$1,824	$2,493	$3,429
Vehicle Damages	$5	$5,372	$11,520	$26,404	$40,395	$55,825	$87,948	$118,929
Total by Event	$1,397	$37,793	$79,067	$178,535	$299,708	$422,693	$637,368	$856,529
Percent Distribution								
Residential Property	85.20%	62.13%	54.14%	49.50%	44.27%	42.61%	41.47%	40.08%
Commercial Property	0.38%	3.73%	6.95%	12.50%	15.50%	16.61%	18.05%	18.83%
Public Property	0.00%	0.00%	0.00%	1.92%	7.37%	8.68%	9.64%	9.87%
Post Disaster Costs	1.42%	17.74%	22.31%	19.72%	18.15%	17.80%	16.13%	16.51%
Road Damages	12.61%	1.75%	1.49%	1.09%	0.80%	0.67%	0.52%	0.43%
Utility Damages	0.03%	0.43%	0.54%	0.48%	0.44%	0.43%	0.39%	0.40%
Vehicle Damages	0.35%	14.22%	14.57%	14.79%	13.48%	13.21%	13.80%	13.88%
Total by Event	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 5b
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event and Reach
Without Project Hydrology and Hydraulics
April 2011 Values in $1,000's

		Annual Exceedance Probability Events							
	Damage Category	50% "2-Year"	20% "5-Year"	10% "10-Year"	4% "25-Year"	2% "50-Year"	1% "100-Year"	0.40% "250-Year"	0.20% "500-Year"
WOB-1	**Structures and Contents**	$0	$0	$3	$3,993	$22,894	$34,694	$60,329	$81,884
	Other Damages	$17	$40	$85	$127	$194	$359	$1,781	$3,297
	Total	**$17**	**$40**	**$88**	**$4,120**	**$23,088**	**$35,053**	**$62,111**	**$85,181**
WOB-2	**Structures and Contents**	$0	$0	$8	$614	$826	$1,106	$4,482	$12,305
	Other Damages	$13	$27	$49	$1,681	$1,979	$2,509	$7,821	$15,176
	Total	**$13**	**$27**	**$57**	**$2,295**	**$2,805**	**$3,615**	**$12,304**	**$27,481**
WOB-3	**Structures and Contents**	$0	$0	$0	$472	$664	$1,151	$5,564	$10,450
	Other Damages	$3	$32	$34	$100	$154	$250	$1,199	$2,086
	Total	**$3**	**$32**	**$34**	**$572**	**$818**	**$1,401**	**$6,763**	**$12,536**
WOB-4a(L)	**Structures and Contents**	$17	$407	$861	$1,758	$2,229	$2,508	$3,132	$3,467
	Other Damages	$10	$216	$460	$1,098	$1,258	$1,337	$1,475	$1,517
	Total	**$27**	**$623**	**$1,321**	**$2,857**	**$3,487**	**$3,845**	**$4,608**	**$4,984**
WOB-4(R)	**Structures and Contents**	$0	$14	$167	$678	$2,080	$4,473	$15,443	$24,640
	Other Damages	$17	$25	$107	$264	$1,491	$2,700	$7,440	$13,083
	Total	**$17**	**$40**	**$274**	**$942**	**$3,571**	**$7,173**	**$22,883**	**$37,723**
WOB-4b(L)	**Structures and Contents**	$1	$60	$255	$4,125	$9,801	$14,785	$29,393	$38,803
	Other Damages	$1	$77	$137	$1,208	$4,753	$8,285	$16,913	$20,630
	Total	**$3**	**$136**	**$392**	**$5,333**	**$14,555**	**$23,070**	**$46,306**	**$59,433**
WOB-5	**Structures and Contents**	$0	$332	$2,803	$13,305	$23,955	$33,268	$47,133	$60,052
	Other Damages	$4	$1,059	$1,534	$8,626	$14,076	$20,373	$30,266	$35,356
	Total	**$4**	**$1,391**	**$4,336**	**$21,931**	**$38,031**	**$53,641**	**$77,399**	**$95,408**
WOB-6	**Structures and Contents**	$0	$0	$109	$6,945	$13,236	$18,969	$28,822	$42,108
	Other Damages	$5	$7	$5,460	$12,364	$18,661	$23,676	$29,551	$42,246
	Total	**$5**	**$7**	**$5,568**	**$19,308**	**$31,897**	**$42,646**	**$58,373**	**$84,354**
WOB-7	**Structures and Contents**	$0	$0	$116	$2,647	$6,751	$14,691	$22,035	$29,330
	Other Damages	$2	$7	$26	$581	$2,755	$9,905	$12,533	$16,348
	Total	**$2**	**$7**	**$142**	**$3,228**	**$9,505**	**$24,596**	**$34,567**	**$45,678**
WOB-8a(L)	**Structures and Contents**	$0	$0	$2	$83	$263	$406	$576	$673
	Other Damages	$0	$2	$4	$15	$157	$315	$389	$426
	Total	**$0**	**$2**	**$7**	**$99**	**$420**	**$720**	**$965**	**$1,099**
WOB-8(R)	**Structures and Contents**	$0	$210	$676	$2,580	$5,559	$7,987	$11,379	$14,195
	Other Damages	$2	$9	$331	$1,112	$1,813	$2,315	$3,597	$4,296
	Total	**$2**	**$219**	**$1,008**	**$3,693**	**$7,373**	**$10,302**	**$14,976**	**$18,491**
WOB-8b(L)	**Structures and Contents**	$0	$146	$977	$3,951	$8,910	$10,526	$13,097	$15,025
	Other Damages	$0	$10	$258	$2,572	$4,522	$5,320	$6,453	$7,183
	Total	**$0**	**$156**	**$1,235**	**$6,523**	**$13,432**	**$15,847**	**$19,550**	**$22,208**
WOB-9	**Structures and Contents**	$8	$1,302	$4,320	$8,888	$12,555	$15,494	$21,765	$27,628
	Other Damages	$1	$310	$1,619	$3,715	$5,479	$7,106	$11,043	$19,632
	Total	**$9**	**$1,612**	**$5,939**	**$12,603**	**$18,034**	**$22,599**	**$32,808**	**$47,260**
WOB-10a(R)	**Structures and Contents**	$0	$208	$1,038	$3,875	$7,843	$12,850	$20,860	$24,520
	Other Damages	$0	$508	$613	$1,766	$3,723	$6,397	$9,675	$11,220
	Total	**$0**	**$716**	**$1,652**	**$5,641**	**$11,565**	**$19,247**	**$30,535**	**$35,740**
WOB-10a(L)	**Structures and Contents**	$222	$7,113	$11,944	$16,773	$20,450	$24,158	$28,838	$31,429
	Other Damages	$20	$2,972	$7,628	$10,778	$12,934	$15,287	$18,366	$19,821
	Total	**$242**	**$10,085**	**$19,572**	**$27,552**	**$33,384**	**$39,445**	**$47,204**	**$51,250**
WOB-10b(R)	**Structures and Contents**	$293	$4,870	$6,617	$8,152	$9,061	$9,922	$10,956	$11,703
	Other Damages	$29	$1,616	$2,884	$4,499	$5,096	$5,607	$6,141	$6,451
	Total	**$322**	**$6,486**	**$9,501**	**$12,650**	**$14,157**	**$15,530**	**$17,097**	**$18,154**
WOB-10b(L)	**Structures and Contents**	$520	$4,380	$5,455	$6,377	$7,138	$7,942	$8,975	$10,835
	Other Damages	$17	$4,146	$4,987	$5,690	$6,002	$6,430	$7,041	$11,628
	Total	**$537**	**$8,526**	**$10,442**	**$12,068**	**$13,141**	**$14,373**	**$16,016**	**$22,463**
WOB-11	**Structures and Contents**	$46	$1,681	$2,273	$3,101	$3,878	$5,083	$6,845	$7,844
	Other Damages	$23	$710	$1,302	$1,706	$1,876	$2,047	$2,289	$2,473
	Total	**$69**	**$2,392**	**$3,575**	**$4,807**	**$5,755**	**$7,130**	**$9,134**	**$10,318**
WOB-12	**Structures and Contents**	$86	$913	$2,678	$7,126	$9,706	$12,026	$14,349	$16,820
	Other Damages	$23	$451	$900	$1,982	$4,764	$5,173	$5,587	$5,939
	Total	**$110**	**$1,364**	**$3,578**	**$9,108**	**$14,470**	**$17,199**	**$19,936**	**$22,759**
WOB-13	**Structures and Contents**	$0	$0	$0	$355	$4,350	$7,934	$11,746	$16,171
	Other Damages	$1	$6	$17	$31	$45	$49	$83	$242
	Total	**$1**	**$6**	**$17**	**$385**	**$4,395**	**$7,983**	**$11,829**	**$16,412**
WOB-14	**Structures and Contents**	$2	$3,233	$7,397	$14,469	$20,123	$28,798	$37,973	$52,738
	Other Damages	$7	$601	$2,116	$4,030	$5,650	$7,102	$9,024	$11,794
	Total	**$9**	**$3,834**	**$9,512**	**$18,499**	**$25,773**	**$35,901**	**$46,997**	**$64,532**
WOB-15	**Structures and Contents**	$0	$0	$68	$444	$972	$1,798	$3,368	$5,664
	Other Damages	$0	$1	$11	$31	$48	$83	$240	$639
	Total	**$0**	**$1**	**$79**	**$475**	**$1,020**	**$1,880**	**$3,607**	**$6,303**
WOB-16	**Structures and Contents**	$0	$21	$262	$1,367	$3,434	$7,620	$15,345	$22,131
	Other Damages	$2	$33	$84	$195	$404	$1,529	$4,501	$8,774
	Total	**$2**	**$54**	**$345**	**$1,562**	**$3,838**	**$9,150**	**$19,846**	**$30,906**
WOB-17	**Structures and Contents**	$0	$1	$269	$2,044	$4,414	$8,413	$16,696	$24,702
	Other Damages	$1	$35	$119	$204	$611	$1,425	$2,881	$6,748
	Total	**$1**	**$36**	**$389**	**$2,248**	**$5,025**	**$9,839**	**$19,578**	**$31,450**
WOB-18	**Structures and Contents**	$0	$0	$0	$10	$96	$318	$1,201	$2,851
	Other Damages	$1	$1	$2	$24	$54	$101	$190	$330
	Total	**$1**	**$1**	**$2**	**$34**	**$151**	**$419**	**$1,391**	**$3,182**
WOB-19	**Structures and Contents**	$0	$0	$0	$0	$18	$84	$501	$1,099
	Other Damages	$0	$0	$0	$2	$3	$9	$83	$126
	Total	**$0**	**$0**	**$0**	**$2**	**$21**	**$93**	**$584**	**$1,226**
All Reaches	**Total**	**$1,397**	**$37,793**	**$79,066**	**$178,535**	**$299,708**	**$422,693**	**$637,368**	**$856,529**

Table 6
Distribution of Expected Annual Damages (EAD) by Reach
Base Year 2014 and Future Year 2064 Without Project and April 2011 Values
in $1000's

Reach Name	Reach Description	Without Uncertainty	With Uncertainty
WOB-1	Mouth to I-45	$1,453.33	$1,415.01
WOB-2	IH-45 to Yale St.	271.07	260.67
WOB-3	Yale St. to D/S Hidden Lake	102.48	142.42
WOB-4a(L)	D/S Hidden Lake Town Homes to U/S Hidden Lake Town Homes	460.06	425.65
WOB-4(R)	D/S Hidden Lake Town Homes to Ella Blvd.	374.94	443.42
WOB-4b(L)	U/S Hidden Lake Town Homes to Ella Blvd.	1,090.60	1,163.96
WOB-5	Ella Blvd. to Burlington Northern RR.	3,260.47	3,331.81
WOB-6	Burlington Northern RR. to W. Tidwell Rd.	2,764.03	2,660.17
WOB-7	W. Tidwell Rd. to W. Little York Rd.	892.86	1,344.66
WOB-8a(L)	W. Little York Rd. to Antoine Dr.	27.39	39.56
WOB-8(R)	W. Little York Rd. to Alabonson Rd.	604.94	1,033.82
WOB-8b(L)	Antoine Dr. to Alabonson Rd.	879.84	1,396.63
WOB-9	Alabonson Rd. to N. Houston Rosslyn Rd.	2,003.93	3,145.52
WOB-10a(R)	N. Houston Rosslyn Rd. to Hollister Rd.	1,135.32	2,145.76
WOB-10a(L)	N. Houston Rosslyn Rd. to HCFCD Ditch Unit E124-00-00	5,436.89	6,942.29
WOB-10b(R)	Hollister Rd. to Woodland West Dr.	2,828.07	4,046.37
WOB-10b(L)	HCFCD Ditch Unit E124-00-00 to Woodland West Dr.	3,370.37	7,062.18
WOB-11	Woodland West Dr. to W. Gulf Bank Rd.	1,152.89	2,281.11
WOB-12	W. Gulf Bank Rd. to N. Gessner Rd.	1,528.80	4,002.98
WOB-13	N. Gessner Rd. to Sam Houston Pkwy.	357.09	1,613.48
WOB-14	Sam Houston Pkwy. to Wyndham Village Dr.	3,210.26	6,640.11
WOB-15	Wyndham Village Dr. to West Rd.	114.54	1,073.25
WOB-16	West Rd. to Jones Rd.	534.59	2,985.41
WOB-17	Jones Rd. to FM 1960 W.	653.32	3,828.07
WOB-18	FM 1960 W to Oak Acres Dr.	35.86	468.83
WOB-19	Oak Acres Dr. to US 290	9.83	126.26
	Totals	**$34,553.77**	**$60,019.40**
	Total Traditional EAD	**$34,231.15**	

Note: Base Year 2014 and Future Year 2064 conditions are the same. Therefore EAD and AAED are the same.

12.0 DETERMINATION OF ALTERNATIVE “WITH-PROJECT” DAMAGES

Various structural solutions to flooding were considered to reduce flooding in the study area. These included construction of detention basins, channel modifications, bridge replacements, levees, and several combinations of the aforementioned. Non-structural solutions evaluated as individual measures and in combination with structural measures included buyouts and the elevation of floodplain structures.

Each alternative project condition was analyzed with risk and uncertainty using the HEC-FDA program in the same manner as the Without Project condition. Economic benefits, based on reduction in 2010 Without Project EAD values for each project, were computed and compared for each alternative. Particular attention was given to flood risk management benefits in each individual economic reach. This was to identify areas that conflict with Harris County Flood Control District’s criterion that negative economic benefits, that is, increased flooding, in any reach would be unacceptable. The aim of the economic analysis of alternatives was to select a plan that maximized net benefits and produced no adverse impacts along the bayou. If a plan in its final configuration produces adverse impacts and has the highest net EA benefits, mitigation for those impacts must be considered.

Alternatives were formulated by incrementally adding structural and non-structural components until further increments failed to yield added net benefits. Damage values computed for plan formulation and alternative analysis are Expected Annual Damages (EAD) values. Once each alternative was formulated a Last Added analysis was conducted to ensure that each component provided a positive contribution to the net benefits of the plan. A refinement of each plan was conducted during which its constituting components were further optimized where necessary to maximize net benefits of the plan.

All economic benefit computations for each alternative during the plan formulation phase were based on a 50-year period with FY2008 discount rate of 4.875 percent and at February 2002 price levels. A construction period of seven years was assumed when determining annualized costs. Damage reduction was computed as the difference between the Without Project condition and the with project condition EAD values. These benefits were computed using the same uncertainty parameters and are thus directly comparable with each other at each step of the plan formulation and alternative analysis. NED net economic benefits were then computed by deducting the annual costs for each project from the flood risk management benefits. The annual costs are based on the construction and the operation and maintenance costs discussed in **Appendix C.** Savings in National Flood Insurance Program Benefits were accounted for by adding the savings to the inundation reduction benefits for the NED plan.

12.1 Component Analysis

The initial step in the component analysis was to identify all of the possible alternative components that might fit into a flood risk management plan. Components that maximize net benefits were favored as the anchor or primary components for plan formulation. Fourteen potential structural components were evaluated individually using the HEC-FDA program. Structural elements include channel modification with and without bypass channelization, detention, bridge modification and ring levees. Variations in the size and scope of these components were analyzed to see which variation provides the optimal net benefits. Descriptions of these components can be found in **Table 7.** The results from the economic analysis for each component are summarized in **Table 8**. Discussions of the alternative economic results for the structural solutions considered are presented in succeeding sections of this appendix.

The component analysis was conducted using a preliminary HEC-FDA model. At the conclusion of the component analysis, a final HEC-FDA model was available and was used for verification of the component analysis. Verification was performed to ensure that the changes in the model were insufficient to cause any significant changes in the outcome of the component analysis conducted. The results of this verification process can be seen in **Table 9**.

12.2 Channel Modification

The main stem of the White Oak Bayou was divided into three reaches for the component analysis. No modifications were considered for the lower reach. Two were considered for the middle reach - TG (modifications from the existing Cole Creek to the confluence with the existing HCFCD drainage channel E200-00-00 in Jersey Village) and GE200 (modifications from Gessner Road to HCFCD unit E200-00-00). One channel modification was considered for the upper reach – E200H (modifications from HCFCD unit E200-00-00 to Huffmeister Road). These three components were then optimized by evaluating the net economic benefits for various sizes of the channel modifications. From these analyses, it was concluded that a variation of Channel TG would be the anchor on which to base successive applications of a first-added analysis. Option TG.8 (a concrete lined channel) provided the largest net EA benefits ($19.2 million) and is the optimized size for this component. TG.2 (an earthen lined channel with net EA benefits of $9.4 million) was also considered due to potential environmental and social constraints of TG.8 and other concrete-lined channels. The two other channel modifications considered (GE200 and E200H) provided nominal to negative net expected annual benefits and were reevaluated as part of the first-added incremental analysis.

12.3 Detention

Seven detention sites were identified and optimized during this step. Five detention basins are located in middle reach – TWLY (located near Tidwell Road and West Little York Road), NHR (located at North-Houston Rosslyn Road and Gulf Bank Road), HOL (located at Hollister Road), FNH (located at Fairbanks-North Houston Road), and GBW (located at Gessner Road and Beltway 8). Two detention basins are located in the upper reach – RG (located at Rio Grande Road) and JR (located at Jones Road). The optimal sizes at each of the detention sites provide positive net EA benefits, but the most effective sites are NHR.3, HOL.2, FNH.3 and JR.4 which produce net EA benefits of $1.8 million, $2.0 million, $4.4 million, and $4.0 million, respectively.

12.4 Ring Levees

Two sites were identified for possible levee construction. The potential levees evaluated were LIA (located at the Inwood Forest and Arbor Oaks subdivisions) and LWT (located at the Woodland Trails West subdivision). Both the height of the levees and the internal drainage systems were analyzed during the optimization process. Only the Levee at Woodland Trails (LWT) produced positive net economic benefits, and the highest net benefits were obtained with the 0.2 percent levee height and 1 percent pumping capacity (LWT5.4) for total net EA benefits of $1.28 million.

12.5 Non-structural Buyout

An evaluation of non-structural measures was performed for White Oak Bayou as part of the component screening process. Non-structural measures were evaluated to present an alternative to or to be used in conjunction with structural measures. The main objectives of non-structural measures are to remove damageable properties from flood prone areas and to manage development in the floodplain in a manner that will minimize flood damage. Out of all potential non-structural measures considered, buyout and elevation of structures in the floodplain were the non-structural measures evaluated.

Potential buyouts were considered for all structures in the 50, 20, 10, 4, and 2 percent annual exceedance probability floodplains. Structures were assessed for buyout if they experienced more than zero depth of flooding for each of the specified events. In accordance with WRDA 1999, the benefits of removing the structures from the floodplain were computed in a manner similar to the computation of benefits for structural projects. The HEC-FDA model was used to compute losses avoided by isolating the buyout structures in each floodplain and computing the expected annual damages to those structures and their associated non-physical costs. Non-physical damages considered were vehicle damage, utility damage, and post-disaster costs. These damages are discussed in detail in **Sections 9.0 – 9.5**. Road damage was not deemed a benefit since the relocation of structures from the floodplain is performed in the form of a checkerboard, leaving other structures to utilize the roads. The computed damages to the buyout structures will be the damages avoided if they are all relocated.

In accordance with USACE guidance, non-structural benefits were computed as the reduction of externalized costs of floodplain occupancy. Annualized residual value of the vacated land was not applied, and it was assumed that the land would remain vacant. The costs of buyout were computed according to guidelines provided by the HCFCD Buyout Section. The costs used in the calculations are outlined below:

- Demolition/removal costs - $4.40 per square foot.
- Right of way costs - equal to the land value.
- Building fair market value - 1.5 times the HCAD improvement value.
- Administrative fees - $1,500 for single-family residences and $8,000 for other types of buildings.
- Relocation costs - $20,000 for single-family residences, $3,500 per apartment, and $3.50 per square foot for all other types of buildings.
- Contingency costs - equal to 20 percent of demolition/removal and relocation costs plus 25 percent of the land value, fair market value, and administrative costs.

As seen in **Table 8**, the optimization of buyouts indicates that the maximum benefits were obtained with the buyout of 13 structures in the 50 percent exceedance probability floodplain. This is the only buyout plan that produced positive net benefits, with net EA benefits of $125,000 and a BCR of 1.29. The other buyout plans had negative net benefits and were economically infeasible as lone components. The benefit and cost analysis can be seen in **Table 10**.

12.6 Structure-Raising

The same structures that were evaluated for buyout were also evaluated for flood proofing by structure elevation. The first floor elevation for each structure in the 50, 20, 10, 4 and 2 percent exceedance probability floodplains was raised to 1.5 feet above the 1 percent exceedance probability water surface elevation in the HEC-FDA model. Elevation to 1.5 feet above the 1 percent exceedance probability floodplain was used based on current Harris County guidelines that require all new construction or substantial improvement of a structure to have the top of the slab of the lowest habitable floor elevated to at least 18 inches above the floodplain base. However, the amount of elevation was limited to 8 feet, when essentially another story is added to the structure. It was assumed that all structures were structurally sound. Resulting damages to these properties and associated non-physical damages were computed in the HEC-FDA model.

Structure-raise projects were assumed to have no effect on vehicle damages due to the fact that only the structures, and not garages or driveways, were raised. The damage reduction as a result of elevating the structures is the difference between pre-raise EAD and elevated property (post-raise) EAD.

The average raise performed on 4,934 structures in the 2% exceedance probability floodplain was 3.19 feet with 45 of those structures requiring raises up to 8 feet. The average raise performed on 674 structures in the 20% exceedance probability floodplain was 3.35 feet, with 32 of the 674 structures raised up to 8 feet. The majority of the structures in the White Oak Bayou study area are slab-on-grade properties. For example, less than 2% of structures in the 20% exceedance probability floodplain and 2.5% in the 2% exceedance probability floodplain have pier and beam foundations.

The benefits associated with elevating structures were determined by the reduction in damages associated with flooding for flood-prone property in the watershed. The costs associated with structure rising were estimated in accordance with the methodology outlined in the USACE document *Flood Proofing, How to Evaluate Your Options* (Reference 28). The costs used in the calculations are outlined below:

- Pier and Beam Structures elevation cost - $32.50 per square foot.
- Slab on Grade Structures elevation cost - $67.50 per square foot.
- Fill (including hauling and compaction) - $12.50 per cubic yard.
- Landscaping (no trees, bushes, or flowers) - $6.50 per square yard.
- Contractor's profit - 10 percent of total cost.

The optimization of this component shows that none of the plans had positive net benefits. The net benefits decreased incrementally under each successive plan, as more structures were included. The break-down of benefits and costs can be seen in **Table 11**.

12.7 Component Optimization

As stated in **Section 12.2**, two channel modification components were selected as anchor components for a first-added analysis due to their high NED benefits and acceptability. A detention basin anchor plan was also used as a base in the plan formulation process, but its net benefits were significantly lower than those of the channel modification plans. The detention anchor was considered in this analysis primarily because of the public interest, the interest of environmental groups, and HCFCD's desire to determine if a detention anchor plan with additional components would perform as well as channel anchor plans.

As stated in **Section 12.2**, TG.8 yielded the highest net economic benefits, and will be considered in the plan formulation. TG.8 is a concrete lined channel that produces significant adverse downstream impacts. Concrete channels are not looked upon favorably by public interest groups, and any induced damages would require mitigation. TG.2, on the other hand, is an earthen lined channel, which is generally more acceptable to the public. Compared to other earthen lined channels, TG.2 performs relatively well in terms of damage reduction and net economic benefits and requires a minimal amount of right-of-way acquisition. Therefore, TG.2 will also be considered in the formulation of alternatives evaluated for the National Economic Development (NED) objective. The combination of detention basins FNH.3 and JR.4 was used as the anchor for the detention base plan formulation. These two components ranked as the second and third best performing components of all components evaluated.

Table 7
Component Descriptions

Identification	Location	Length (ft)	Bottom Width (ft)	Classification	Description
CHANNEL MODIFICATION					
Lower Reach: Houston to Tidwell (HT)					
Reference previous analysis results.					
Middle Reach: Tidwell to Gessner (TG)					
TG.1	Sta. 56231 to Sta. 77129	20,898	50	earthen	Channelization of White Oak Bayou within existing ROW to convey 20% probability flood.
	Sta. 77129 to Sta. 93534	17,700	45		
TG.2	Sta. 56231 to Sta. 77129	20,898	60		Channelization of White Oak Bayou with 15 ft. ROW acquisition to convey 10% probability flood.
	Sta. 77129 to Sta. 93534	17,700	50		
TG.3	Sta. 56231 to Sta. 77129	20,898	80		Channelization of White Oak Bayou with 35 ft. ROW acquisition to convey 4% probability flood.
	Sta. 77129 to Sta. 93534	17,700	60		
TG.4	Sta. 56231 to Sta. 77129	20,898	100		Channelization of White Oak Bayou with 55 ft. ROW acquisition to convey 2% probability flood.
	Sta. 77129 to Sta. 93534	17,700	80		
TG.5	Sta. 56231 to Sta. 77129	20,898	120		Channelization of White Oak Bayou with 75 ft. ROW acquisition to convey 1% probability flood.
	Sta. 77129 to Sta. 93534	17,700	100		
TG.6	Sta. 55239 to Sta. 93534	39,040	200		Channelization of White Oak Bayou with 145 ft. ROW acquisition to convey 0.2% probability flood.
TG.7	Sta. 56231 to Sta. 77129	20,898	50	concrete	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 3:1 side slopes. Conveys 0.2% probability flood.
	Sta. 77129 to Sta. 93534	17,700	45		
TG.8	Sta. 56231 to Sta. 77129	20,898	90		Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2:1 side slopes. Conveys greater than 0.2% probability flood.
	Sta. 77129 to Sta. 93534	17,700	80		
TG.9	Sta. 56231 to Sta. 77129	20,898	50	concrete/earthen	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2:1 side slopes from flowline to 10 ft height. Earthen channel with benches (10 ft wide) and 3:1 SS to top of banks. Conveys 4% probability flood.
	Sta. 77129 to Sta. 93534	17,700	45		
TG.10	Sta. 56231 to Sta. 77129	20,898	70	concrete	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2.5:1 side slopes. Conveys 0.2% probability flood.
	Sta. 77129 to Sta. 93534	17,700	60		
TG.11	Sta. 56231 to Sta. 77129	20,898	120		Channelization of White Oak Bayou. ROW acquisition required (~35 ft). Concrete-lined channel with 2:1 side slopes. Conveys greater than 0.2% probability flood.
	Sta. 77129 to Sta. 93534	17,700	100		

Table 7 cont.
Component Descriptions

Identification	Location	Length (ft)	Bottom Width (ft)	Classification	Description
Middle Reach: Gessner to E200-00-00 (GE200)					
GE200.0	E100-00-00: Sta. 97052 - 101269	4,200	30	earthen	Channelization of E100-00-00 within ROW. Conveys 10% probability flood.
GE200.1	E200-00-00: remove berm	500	40		Remove berm area at E200-00-00 and E141-00-00 confluences. Conveys 4% probability flood.
GE200.2	E200-00-00: Sta. 150 - 2000	1,850	50		Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower bypass flowline by ~ 5-10 ft. Conveys 2% probability flood.
	E200-00-00: Sta. 2000 - 7500	5,500	80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.3	E200-00-00: Sta. 150-2500	2,350	50		Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower bypass flowline by ~7-15 ft. Conveys 1% probability flood.
	E200-00-00: Sta. 2500 - 7500	5,000	60 - 80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.4	E200-00-00: remove berm	500	40		Channelization of E100-00-00 within ROW. Remove berm area within E200-00-00; channelization of White Oak Bayou within existing ROW. Conveys 2% probability flood.
	E100-00-00: Sta. 97052 - 101269	4,200	30		
GE200.5	E100-00-00: Sta. 97052 - 101269	4,200	30		Channelization of E100-00-00 within ROW. Channelization of E200-00-00 within existing ROW. Limited channelization within E141-00-00. Lower bypass flowline by ~ 5-10 ft. Conveys 1% probability flood.
	E200-00-00: Sta. 150 - 2000	1,850	50		
	E200-00-00: Sta. 2000 - 7500	5,500	80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.6	E100-00-00: Sta. 97052 - 101269	4,200	30		Channelization of E100-00-00 within ROW. Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower flowline by ~7-15 ft. Conveys 0.4% probability flood.
	E200-00-00: Sta. 150-2500	2,350	50		
	E200-00-00: Sta. 2500 - 7500	5,000	60 - 80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
Upper Reach: E200-00-00 to Huffmeister (E200H)					
E200H.1	Sta. 105000 - 115000	10,000	60	earthen	Channelization of White Oak Bayou within ROW. Conveys 10% probability flood.
	Sta. 115000 - 125000	10,000	40		
E200H.2	Sta. 105000 - 115000	10,000	80		Channelization of White Oak Bayou within ROW. Conveys 4% probability flood.
	Sta. 115000 - 125000	10,000	50		
E200H.3	Sta. 105000 - 115000	10,000	100		Channelization of White Oak Bayou within ROW. Conveys 1% probability flood.
	Sta. 115000 - 125000	10,000	60		

Table 7 cont.
Component Descriptions

Identification	Location	Area (ac)	Volume (ac-ft)	Description
DETENTION				
Detention at Tidwell - W. Little York (TWLY)				
TWLY.0	Tidwell/T.C. Jester/W. Little York; Sta. 57990-65400	18	160	Modification of E500-05-00
TWLY.2		45	516	Expansion of E500-05-00
TWLY.3		69	1032	Expansion of E500-05-00; off-line facility
TWLY.5		123	1658	Expansion of E500-05-00 to the north.
Detention at North Houston-Rosslyn Road (NHR)				
NHR.1	North Houston-Rosslyn Road; Sta. 75800	33	595	Modification and expansion of E500-04-00; off-line facility
NHR.2		62	811	Expansion of E500-04-00; off-line facility
NHR.3		83	1069	Expansion of E500-04-00; off-line facility
NHR.4		139	1211	Expansion of E500-04-00 and expansion to the east
Detention at Hollister Road (HOL)				
HOL.1	Hollister Rd.; Sta. 80200	57	444	Excavation north of pipeline
HOL.2		94	522	New facility E500-03-00; expansion south of pipeline
HOL.3		136	730	Expansion of facility to the west
Detention at Fairbanks-North Houston (FNH)				
FNH.1	Fairbanks-North Houston; Sta. 87150 - 87489	86	843	Expansion of E500-01-00; off-line facility
FNH.2		143	1271	Expansion of E500-01-00 & new facility E500-02-00 south of bayou
FNH.3		184	1717	Expansion of E500-01-00, new facility E500-02-00 south of bayou, & new facility west of Fairbanks-North Houston
FNH.4		222	2111	Expansion of E500-01-00, new facility E500-02-00 south of bayou, & new facility west of Fairbanks-North Houston
Detention at Gessner-Beltway 8 (GBW)				
GBW.1	Gessner / Beltway 8; Sta. 94856	21	229	In-line facility north of bayou
GBW.2		45	427	New facility (E500-10-00) located north and south of bayou.
GBW.3		56	519	New facility located north and south of bayou, with expansion of facility to the south.
Detention at Rio Grande (RG)				
RG.1	Rio Grande; E135-00-00 Sta. 3000	45	277	Off-line facility north of E135-00-00
RG.2		45	399	Expansion of facility north of E135-00-00
RG.3		117	882	Expansion of facility south of E135-00-00
RG.4		45	277	RG.1 and channelization of E135-00-00
Detention at Jones Road (JR)				
JR.1	Jones Road; Sta. 114940 - 118000	23	134	Off-line facility; south of pipeline easement and east of Jones Rd.
JR.2		39	220	Expansion of facility north of pipeline easement, east of Jones Rd.
JR.3		53	295	Expansion of facility west of Jones Rd.
JR.4		69	420	Expansion on additional land west of Jones Rd.
JR.5		74	470	Expansion on additional land west of Jones Rd.

Table 7 cont.
Component Descriptions

Identification	Location	Maximum Height (Feet)	Interior Volume	Description
LEVEE				
Levee at Inwood Forest / Arbor Oaks (LIA)				
LIA	Sta. 65500 - 70270	Protection to Inwood Forest and Arbor Oaks		
LIA1.1		6.8	minimum	Optimize height for 1% flood
LIA2.1		6.5		Optimize height for 2% flood
LIA3.1		5.0		Optimize height for 4% flood
LIA4.1		7.0		Optimize height for 0.4% flood
LIA5.1		7.5		Optimize height for 0.2% flood
Levee at Woodland Trails (LWT)				
LWT	Sta. 77100 - 85000	Protection to Woodland Trails North and Woodland Trails West		
LWT1.1		7.4	minimum	Optimize height for 1% flood
LWT1.2			20% capacity	Optimize interior volume, 20% pumping capacity
LWT1.3			4% capacity	Optimize interior volume, 4% pumping capacity
LWT1.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT1.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT1.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT1.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT2.1		6.8	minimum	Optimize height for 20% flood
LWT2.2			20% capacity	Optimize interior volume, 20% pumping capacity
LWT2.3			4% capacity	Optimize interior volume, 4% pumping capacity
LWT2.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT2.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT2.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT2.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT3.1		7.0	minimum	Optimize height for 4% flood
LWT3.2			20% capacity	Optimize interior volume, 20% pumping capacity
LWT3.3			4% capacity	Optimize interior volume, 4% pumping capacity
LWT3.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT3.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT3.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT3.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT4.1		8.0	minimum	Optimize height for 0.4% flood
LWT4.2			20% capacity	Optimize interior volume, 20% detention capacity
LWT4.3			20% capacity	Optimize interior volume, 20% pumping capacity
LWT4.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT5.1		8.2	minimum	Optimize height for 0.2% flood
LWT5.2			20% capacity	Optimize interior volume, 20% detention capacity
LWT5.3			20% capacity	Optimize interior volume, 20% pumping capacity
LWT5.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT5.5			0.4% capacity	Optimize interior volume, 0.4% pumping capacity
LWT5.6			0.2% capacity	Optimize interior volume, 0.2% pumping capacity

NON-STRUCTURAL

Identification	Location	Classification	Description
Buyouts			
NSB-50%	throughout watershed	13 structures within 50% floodplain	Removal of structures within 50% floodplain
NSB-20%		674 structures within 20% floodplain	Removal of structures within 20% floodplain
NSB-10%		1277 structures within 10% floodplain	Removal of structures within 10% floodplain
NSB-4%		3277 structures within 4% floodplain	Removal of structures within 4% floodplain
NSB-2%		4934 structures within 2% floodplain	Removal of structures within 2% floodplain
Elevating Structures			
ELEV-50%	throughout watershed	13 structures within 50% floodplain	Elevating structures within 50% floodplain
ELEV-20%		674 structures within 20% floodplain	Elevating structures within 20% floodplain
ELEV-10%		1277 structures within 10% floodplain	Elevating structures within 10% floodplain
ELEV-4%		3277 structures within 4% floodplain	Elevating structures within 4% floodplain
ELEV-2%		4934 structures within 2% floodplain	Elevating structures within 2% floodplain

Table 8
Component Net EA Benefit Summary
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
TG: Channel Modification from Tidwell to Gessner							
TG.1	$51,459	$7,977	$15,374	$18,620	$1,120	7.12	$6,857
TG.2	$47,529	$11,907	$33,779	$40,910	$2,461	4.84	$9,447
TG.3	$45,619	$13,817	$65,249	$79,023	$4,753	2.91	$9,064
TG.4	$41,556	$17,880	$115,914	$140,384	$8,444	2.12	$9,437
TG.5	$39,235	$20,202	$136,838	$165,726	$9,968	2.03	$10,233
TG.6	$33,707	$25,730	$238,478	$288,823	$17,372	1.48	$8,357
TG.7	$43,503	$15,933	$62,245	$75,385	$4,534	3.51	$11,399
TG.8	$35,037	$24,399	$71,309	$86,363	$5,195	4.70	$19,205
TG.9	$47,486	$11,950	$35,487	$42,979	$2,585	4.62	$9,365
TG.10	$35,637	$23,800	$64,869	$78,563	$4,725	5.04	$19,074
TG.11	$36,265	$23,171	$117,943	$142,842	$8,592	2.70	$14,579
GE200: Channel Modification from Gessner to E200-00-00							
GE200.0	$59,018	$418	$1,470	$1,780	$107	3.90	$311
GE200.1	$62,971	-$3,535	$493	$597	$36	N/A	N/A
GE200.2	$61,857	-$2,421	$7,445	$9,017	$542	N/A	N/A
GE200.3	$59,460	-$23	$22,091	$26,754	$1,609	N/A	N/A
GE200.4	$61,827	-$2,391	$1,922	$2,328	$140	N/A	N/A
GE200.5	$61,170	-$1,734	$8,875	$10,748	$646	N/A	N/A
GE200.6	$59,150	$286	$23,520	$28,485	$1,713	0.17	-$1,427
E200H: Channel Modification from E200-00-00 to Huffmeister							
E200H.1	$64,582	-$5,146	$7,827	$9,480	$570	N/A	N/A
E200H.2	$65,421	-$5,985	$11,107	$13,451	$809	N/A	N/A
E200H.3	$62,516	-$3,080	$16,376	$19,833	$1,193	N/A	N/A
TWLY: Detention at Tidwell / West Little York							
TWLY.2	$58,933	$503	$9,340	$11,312	$680	0.74	-$177
TWLY.3	$57,557	$1,880	$22,834	$27,655	$1,663	1.13	$216
TWLY.5	$56,749	$2,687	$52,629	$63,740	$3,834	0.70	-$1,147
NHR: Detention at North Houston-Rosslyn Road							
NHR.1	$58,697	$740	$7,956	$9,635	$580	1.28	$160
NHR.2	$58,368	$1,069	$14,527	$17,593	$1,058	1.01	$10
NHR.3	$56,083	$3,353	$21,721	$26,306	$1,582	2.12	$1,771
NHR.4	$56,349	$3,088	$46,276	$56,045	$3,371	0.92	-$283
HOL: Detention at Hollister Road							
HOL.1	$56,564	$2,872	$15,102	$18,290	$1,100	2.61	$1,772
HOL.2	$56,032	$3,404	$18,816	$22,788	$1,371	2.48	$2,033
HOL.3	$55,797	$3,640	$28,533	$34,557	$2,079	1.75	$1,561
FNH: Detention at Fairbanks-North Houston							
FNH.1	$56,846	$2,590	$15,096	$18,283	$1,100	2.36	$1,490
FNH.2	$54,004	$5,432	$29,438	$35,653	$2,144	2.53	$3,288
FNH.3	$51,698	$7,738	$45,188	$54,727	$3,292	2.35	$4,446
FNH.4	$50,761	$8,676	$58,684	$71,073	$4,275	2.03	$4,401
GBW8: Detention at Gessner-Beltway 8							
GBW.1	$58,797	$639	$5,066	$6,135	$369	1.73	$270
GBW.2	$57,335	$2,101	$12,741	$15,431	$928	2.26	$1,173
GBW.3	$57,227	$2,209	$18,271	$22,129	$1,331	1.66	$878
RG: Detention at Rio Grande							
RG.1	$58,371	$1,066	$9,900	$11,990	$721	1.48	$344
RG.2	$57,872	$1,564	$14,529	$17,597	$1,058	1.48	$505
RG.3	$57,368	$2,069	$44,883	$54,358	$3,270	0.63	-$1,201
RG.4	$64,718	-$5,282	$10,607	$12,846	$773	N/A	N/A
JR: Detention at Jones Road							
JR.1	$57,461	$1,975	$5,252	$6,361	$383	5.16	$1,593
JR.2	$56,603	$2,833	$8,829	$10,693	$643	4.41	$2,190
JR.3	$55,525	$3,911	$12,422	$15,044	$905	4.32	$3,006
JR.4	$54,187	$5,249	$17,247	$20,888	$1,256	4.18	$3,993
JR.5	$53,806	$5,630	$29,386	$35,589	$2,141	2.63	$3,489

Table 8 cont.
Component Net EA Benefit Summary
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
LIA: Levee at Inwood Forest and Arbor Oaks							
LIA3.1	$59,797	-$361	$9,153	$11,086	$667	N/A	N/A
LIA2.1	$59,741	-$305	$10,497	$12,713	$765	N/A	N/A
LIA1.1	$59,489	-$53	$11,186	$13,548	$815	N/A	N/A
LIA4.1	$59,820	-$383	$13,236	$16,030	$964	N/A	N/A
LIA5.1	$59,648	-$212	$14,620	$17,707	$1,065	N/A	N/A
LWT: Levee at Woodland Trails							
LWT2.1	$66,689	-$7,253	$8,117	$9,831	$591	N/A	N/A
LWT2.2	$58,192	$1,244	$57,014	$69,050	$4,153	0.30	-$2,909
LWT2.3	$56,848	$2,588	$65,919	$79,835	$4,802	0.54	-$2,214
LWT2.4	$56,782	$2,654	$74,519	$90,251	$5,428	0.49	-$2,774
LWT2.5	$59,207	$230	$47,827	$57,924	$3,484	0.07	-$3,254
LWT2.6	$57,889	$1,547	$63,423	$76,813	$4,620	0.33	-$3,073
LWT2.7	$56,997	$2,440	$84,785	$102,683	$6,176	0.40	-$3,737
LWT3.1	$69,656	-$10,220	$11,239	$13,612	$819	N/A	N/A
LWT3.2	$58,579	$857	$60,136	$72,831	$4,381	0.20	-$3,524
LWT3.3	$55,631	$3,805	$69,041	$83,616	$5,029	0.76	-$1,224
LWT3.4	$55,201	$4,235	$77,641	$94,032	$5,656	0.75	-$1,421
LWT3.5	$60,499	-$1,063	$50,949	$61,705	$3,711	N/A	N/A
LWT3.6	$58,360	$1,077	$66,545	$80,594	$4,848	0.22	-$3,771
LWT3.7	$55,845	$3,591	$87,907	$106,464	$6,404	0.56	-$2,813
LWT1.1	$69,655	-$10,219	$13,031	$15,782	$949	N/A	N/A
LWT1.2	$57,725	$1,711	$61,928	$75,002	$4,511	0.38	-$2,800
LWT1.3	$54,537	$4,900	$70,833	$85,787	$5,160	0.95	-$260
LWT1.4	$53,745	$5,691	$79,433	$96,203	$5,786	0.98	-$95
LWT1.5	$59,934	-$498	$52,741	$63,875	$3,842	N/A	N/A
LWT1.6	$57,685	$1,751	$68,338	$82,764	$4,978	0.35	-$3,227
LWT1.7	$55,305	$4,131	$89,699	$108,635	$6,534	0.63	-$2,403
LWT4.1	$70,321	-$10,885	$15,677	$18,986	$1,142	N/A	N/A
LWT4.3	$57,478	$1,958	$64,573	$78,206	$4,704	0.42	-$2,745
LWT4.2	$59,944	-$507	$55,386	$67,079	$4,035	N/A	N/A
LWT4.4	$53,278	$6,159	$82,079	$99,407	$5,979	1.03	$179
LWT5.1	$70,109	-$10,673	$16,623	$20,133	$1,211	N/A	N/A
LWT5.3	$56,588	$2,848	$65,520	$79,352	$4,773	0.60	-$1,925
LWT5.2	$59,482	-$46	$56,333	$68,225	$4,104	N/A	N/A
LWT5.4	$52,109	$7,327	$83,025	$100,553	$6,048	1.21	$1,279
LWT5.5	$51,834	$7,602	$87,219	$105,632	$6,354	1.20	$1,249
LWT5.6	$51,598	$7,839	$93,537	$113,283	$6,814	1.15	$1,025
Non-structural buyouts							
NSB-50%	$58,881	$555	$5,898	$7,143	$430	1.29	$125
NSB-20%	$48,394	$11,042	$157,773	$191,080	$11,493	0.96	-$451
NSB-10%	$40,731	$18,705	$321,071	$388,852	$23,389	0.80	-$4,684
NSB-4%	$30,247	$29,189	$833,410	$1,009,351	$60,711	0.48	-$31,522
NSB-2%	$21,844	$37,592	$1,378,881	$1,669,977	$100,446	0.37	-$62,854
Elevating Structures							
ELEV-50%	$58,961	$475	$12,953	$15,687	$944	0.50	-$469
ELEV-20%	$51,538	$7,898	$117,878	$142,763	$8,587	0.92	-$689
ELEV-10%	$46,162	$13,274	$291,068	$352,515	$21,203	0.63	-$7,929
ELEV-4%	$38,627	$20,809	$687,174	$832,244	$50,058	0.42	-$29,249
ELEV-2%	$32,365	$27,071	$1,077,628	$1,305,126	$78,501	0.34	-$51,430

Table 9
Component Verification Results
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
TG.1	$48,686	$4,337	$15,374	$18,620	$1,120	3.87	$3,217
TG.2	$43,972	$9,052	$33,779	$40,910	$2,461	3.68	$6,591
TG.5	$34,723	$18,300	$136,838	$165,726	$9,968	1.84	$8,332
TG.6	$30,286	$22,737	$238,478	$288,823	$17,372	1.31	$5,365
TG.8	$33,749	$19,275	$71,309	$86,363	$5,195	3.71	$14,080
TG.10	$35,408	$17,615	$64,869	$78,563	$4,725	3.73	$12,890
TG.11	$33,550	$19,474	$117,943	$142,842	$8,592	2.27	$10,882
FNH.2	$45,934	$7,089	$29,438	$35,653	$2,144	3.31	$4,945
FNH.3	$43,331	$9,692	$45,188	$54,727	$3,292	2.94	$6,400
FNH.4	$44,047	$8,977	$58,684	$71,073	$4,275	2.10	$4,702
JR.4	$47,647	$5,376	$17,247	$20,888	$1,256	4.28	$4,120
BR-NHR	$53,937	$43	$2,098	$2,541	$153	0.28	-$109

Table 10
Results of Economic Analysis for Non-Structural (Buyout) Options
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

	Exceedance Probability Events				
	Bank to 50% Flood Plain "2-Year"	Bank to 20% Flood Plain "5-Year"	Bank to 10% Flood Plain "10-Year"	Bank to 4% Flood Plain "25-Year"	Bank to 2% Flood Plain "50-Year"
Number of Structures	**13**	**674**	**1277**	**3277**	**4934**
Damage Reduced by Category					
Commercial	$421	$1,138	$2,372	$4,493	$6,196
Emergency	$28	$1,664	$2,870	$3,820	$4,810
Public	$0	$0	$0	$59	$1,835
Residential	$67	$5,887	$9,410	$15,347	$18,281
Roads	$0	$0	$0	$0	$0
Utilities	$1	$43	$70	$453	$136
Vehicles	$39	$2,310	$3,984	$5,017	$6,694
Total Damage Reduced	**$555**	**$11,042**	**$18,705**	**$29,189**	**$37,952**
Total Costs by Category					
Demolition/Removal	$52	$460	$1,119	$2,533	$4,119
Right of Way	$22	$1,357	$3,136	$9,398	$13,815
Fair Market Value	$224	$6,257	$12,331	$31,198	$54,180
Administrative Fees	$3	$151	$296	$795	$1,263
Relocation	$46	$1,030	$1,951	$4,945	$7,442
Contingency	$82	$2,239	$4,555	$11,843	$19,627
Total Costs	**$430**	**$11,493**	**$23,389**	**$60,711**	**$100,446**
Net Economic Benefits	**$125**	**-$451**	**-$4,684**	**-$31,522**	**-$62,494**
Benefit to Cost Ratio	**1.29**	**0.96**	**0.80**	**0.48**	**0.38**

Table 11
Results of Economic Analysis for Non-Structural (Elevation) Options
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

	Exceedance Probability Events				
	Bank to 50% Flood Plain "2-Year"	Bank to 20% Flood Plain "5-Year"	Bank to 10% Flood Plain "10-Year"	Bank to 4% Flood Plain "25-Year"	Bank to 2% Flood Plain "50-Year"
Number of Structures	**13**	**674**	**1277**	**3277**	**4934**
Damage Reduced by Category					
Commercial	$389	$1,134	$2,210	$3,537	$5,448
Emergency	$28	$1,660	$2,850	$3,762	$4,717
Public	$0	$0	$0	$55	$1,404
Residential	$59	$5,063	$8,145	$13,008	$15,369
Roads	$0	$0	$0	$0	$0
Utilities	$1	$41	$69	$447	$133
Vehicles	$0	$0	$0	$0	$0
Total Damage Reduced	**$476**	**$7,898**	**$13,274**	**$20,809**	**$27,071**
Total Costs by Category					
Structure Elevation	$828	$7,233	$17,933	$42,367	$67,046
Fill (includes hauling and compaction)	$27	$449	$1,099	$2,519	$3,476
Basic Landscaping	$2	$124	$243	$622	$842
Contractor's Profit and Contingencies	$86	$781	$1,928	$4,551	$7,136
Total Costs	**$944**	**$8,587**	**$21,203**	**$50,058**	**$78,501**
Net Economic Benefits	**-$468**	**-$689**	**-$7,929**	**-$29,249**	**-$51,430**
Benefit to Cost Ratio	**0.50**	**0.92**	**0.63**	**0.42**	**0.34**

13.0 PLAN FORMULATION

Alternative plans were formulated using incremental first-added analysis. Once anchor components were established, remaining components were added individually to determine if they were incrementally justified as next-added components. The component that produced the largest positive incremental benefit became part of the formulated plan. The then formulated plan was then used as the base for the next step and other components were added individually. The optimal combination of components (with the highest net EA benefits) was then used as the base plan in the next step. This process continued until the optimal combination of components was found and no more components could be added that increase net annual benefits. A detailed discussion of the Plan Formulation process is presented in **Chapter 4** of the General Reevaluation Report.

A re-optimization stage was performed on the remaining components after two components were added to the alternatives. This was done because as components are added to the group, changes occur in flows, water surface elevations, and resulting economic damages and the component configuration that performed the best in a previous iteration may not be the configuration that performs best in a subsequent iteration.

The following subsections and **Table 12** present a summary of the results for the incremental addition of components.

Table 12
Plan Formulation Summary
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Incremental EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Incremental EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incremental Net EA Benefits ($1,000)
Base Conditions												
Base Without Project Condition		$53,981										
Summary of Plan Formulation Steps with Channel Anchor TG.8												
TG8	TG.8	$34,462	$19,519		36.16%	$71,309	$86,363	$5,195		3.76	$14,324	
TG8_1.32	TG.8+JR.4	$30,766	$23,214	$3,696	43.00%	$88,556	$107,251	$6,451	$1,256	3.6	$16,763	$2,439
TG8_2.7	TG.8+JR.4+GBW.2	$28,774	$25,206	$1,992	46.69%	$101,297	$122,682	$7,379	$928	3.42	$17,827	$1,064
TG8_3.2	TG.8+JR.4+GBW.2+E200H.3	$25,966	$28,015	$2,808	51.90%	$117,673	$142,515	$8,572	$1,193	3.27	$19,443	$1,615
TG8_4.8	TG.8+JR.4+GBW.2+E200H.3+TWLY.3	$22,455	$31,526	$3,511	58.40%	$140,507	$170,170	$10,235	$1,663	3.08	$21,291	$1,848
TG8_5.1	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1	$20,942	$33,038	$1,512	61.20%	$155,603	$188,452	$11,335	$1,100	2.91	$21,703	$413
TG8_6.4	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+ GE200.0	$20,465	$33,515	$477	62.09%	$157,073	$190,232	$11,442	$107	2.93	$22,073	$370
TG8_7.11	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+ GE200.0+ NSB_20%	$19,494	$34,487	$972	63.89%	$165,357	$200,265	$12,046	$603	2.86	$22,441	$368
TG8_8.1	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+ GE200.0+ NSB_20%+ NHR.1	$18,758	$35,223	$736	65.25%	$173,313	$209,900	$12,625	$580	2.79	$22,597	$156
TG8_9.2	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+ GE200.0+ NSB_20%+ NHR.1+ RG.0	$18,465	$35,515	$293	65.79%	$177,024	$214,395	$12,896	$270	2.75	$22,620	$22
Summary of Plan Formulation Steps with Channel Anchor TG.2												
TG2	TG.2	$43,789	$10,192		18.88%	$33,779	$40,910	$2,461		4.14	$7,731	
TG2_1.30	TG.2+JR.4	$38,507	$15,473	$5,282	28.66%	$51,027	$61,799	$3,717	$1,256	4.16	$11,756	$4,025
TG2_2.5	TG.2+JR.4+HOL.3	$33,771	$20,209	$4,736	37.44%	$79,560	$96,356	$5,796	$2,079	3.49	$14,414	$2,657
TG2_3.6	TG.2+JR.4+HOL.3+GBW.2	$30,996	$22,985	$2,776	42.58%	$92,301	$111,787	$6,724	$928	3.42	$16,261	$1,847
TG2_4.18	TG.2+JR.4+HOL.3+GBW.2+FNH.1	$28,610	$25,371	$2,386	47.00%	$107,397	$130,070	$7,823	$1,100	3.24	$17,547	$1,286
TG2_5.5	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2	$26,880	$27,101	$1,730	50.20%	$121,927	$147,666	$8,882	$1,058	3.05	$18,219	$672
TG2_6.2	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+ E200H.2	$25,871	$28,109	$1,008	52.07%	$133,033	$161,118	$9,691	$809	2.9	$18,418	$199
TG2_7.1	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+ E200H.2+GE200.0	$24,895	$29,085	$334	53.88%	$134,503	$162,897	$9,798	$107	2.97	$19,287	$227
TG2_8.1	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+ E200H.2+GE200.0+ TWLY.2	$24,063	$29,917	$832	55.42%	$143,843	$174,210	$10,478	$680	2.86	$19,439	$151
Summary of Plan Formulation Steps with Detention Anchor: FNH.3 + JR.4												
DA_1	FNH.3+JR.4	$39,090	$14,891		27.59%	$62,435	$75,616	$4,548		3.27	$10,343	
DA_1.18	FNH.3+JR.4+GBW.3	$35,007	$18,974	$4,083	35.15%	$80,706	$97,744	$5,879	$1,331	3.23	$13,095	$2,752
DA_2.4	FNH.3+JR.4+GBW.3+HOL.3	$32,309	$21,672	$3,235	40.15%	$109,240	$132,301	$7,958	$2,079	2.72	$13,714	$1,156
DA_3.1	FNH.3+JR.4+GBW.3+HOL.3+GE200.2	$30,721	$23,260	$1,588	43.09%	$116,685	$141,318	$8,500	$542	2.74	$14,760	$1,046
DA_4.8	FNH.3+JR.4+GBW.3+HOL.3+GE200.2+ RG.1	$29,689	$24,292	$1,032	45.00%	$126,585	$153,308	$9,221	$721	2.63	$15,071	$311

13.1 TG.8 Plan Formulation

In Step 1 of the TG.8 channel plan formulation process, the TG.8 channel anchor was combined with the other potential channel modifications, each of the potential detention basin options, and non-structural buyout and structure raise plans for the 50, 20, 10, 4, and 2 percent probability exceedance floodplains in order to arrive at the optimal combination that would be used in the next step of the formulation process. A summary of the TG.8 economic results is shown in **Table 12**. A comparison of each TG.8 plan next added component with the without project conditions can be seen in the economic damage profiles shown in **Exhibit 2**. It was found that the addition of detention basin JR.4 produced the largest incremental benefits, with total net annual benefits of $16.8 million.

These two components were used as the anchor for Step 2, and were combined with the remaining best performing components from Step 1. Adding the mid reach GBW.2 detention basin yielded the highest net annual benefits with $17.8 million, and this combination of components was used as the anchor for Step 3. In Step 3, each of the remaining best performing components from each component type was added separately to the Step 2 plan. Adding the E200H.3 channel modifications in the upstream reaches yielded the best performing plan with net EA benefits of $19.4 million.

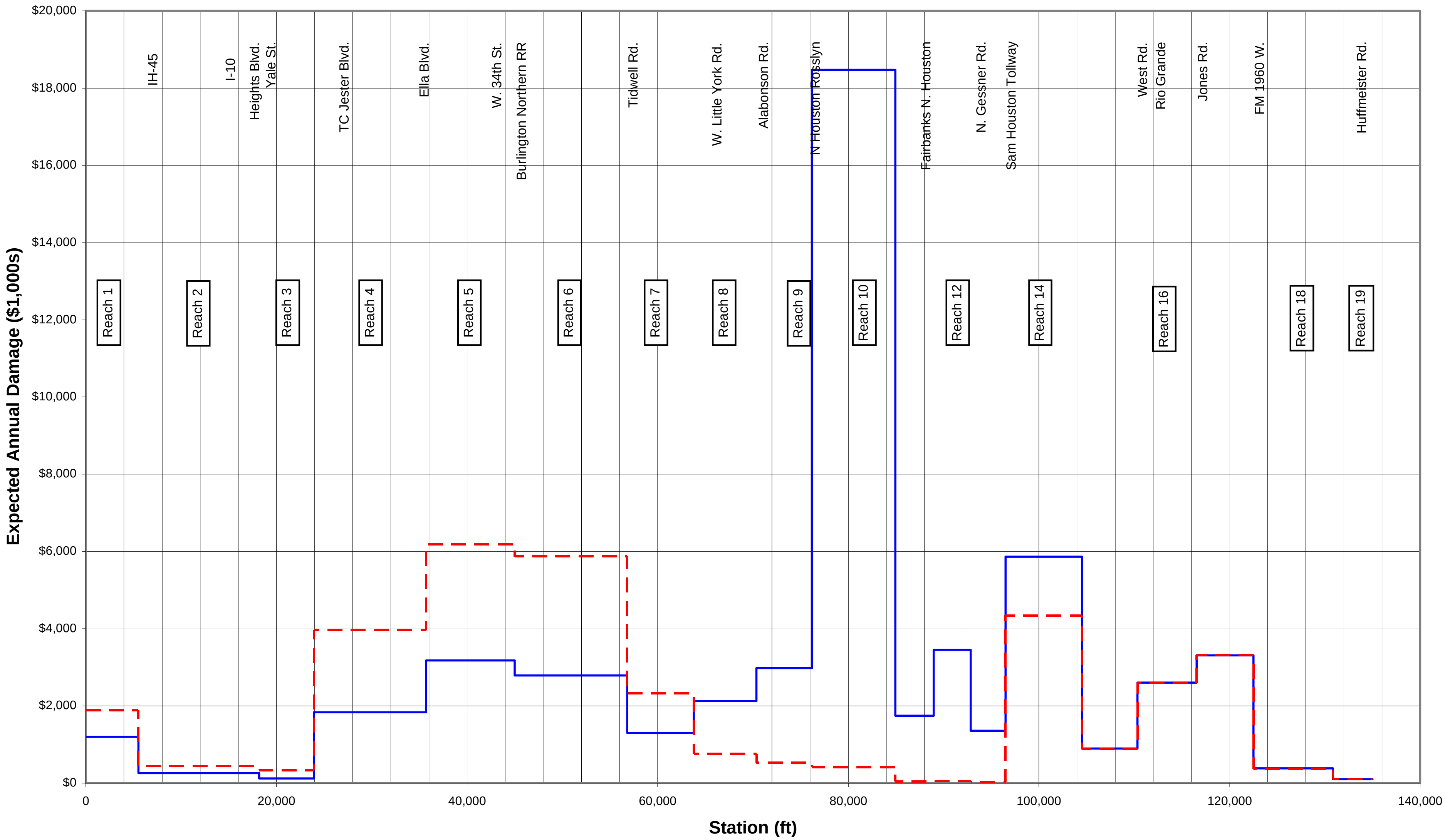
In Step 4, a sufficient number of components were added individually to ensure that the next added component was the optimized version. The levee and structure raise components were not carried forward to this re-optimization step because it was determined that none of these components would have the possibility of producing positive incremental net benefits of any significance. In the initial analysis, only one of the levee components showed any positive net economic benefits. The analysis indicated that the channel and detention anchors provide a significant decrease in the water surface elevations, thereby further reducing the potential benefits of a levee or structure raise. During this re-optimization step, the TG.8 anchor from Step 3 was combined with a total of twenty-six possible components, with the highest net annual benefits ($21.3 million) occurring with the addition of the TWLY.3 detention basin. This component set was used as the starting point for the Step 5 analysis.

In Step 5, the Step 4 plan was combined with the six remaining best performing components (one from each component type). The addition of FNH.1 yielded the highest net benefits for this step with $21.7 million. This plan was combined with the five remaining best-performing components in Step 6. Adding the GE200.0 channel modifications proved to be the best alternative with net EA benefits of $22.1 million.

In Step 7, a re-optimization of the remaining components was again performed to ensure that the best-performing components were carried through to the additional steps. This step had highest net benefits ($22.4 million) with the inclusion of a non-structural buyout plan for the residual 20 percent exceedance probability floodplain. This plan results in the removal of 34 structures from the floodplain.

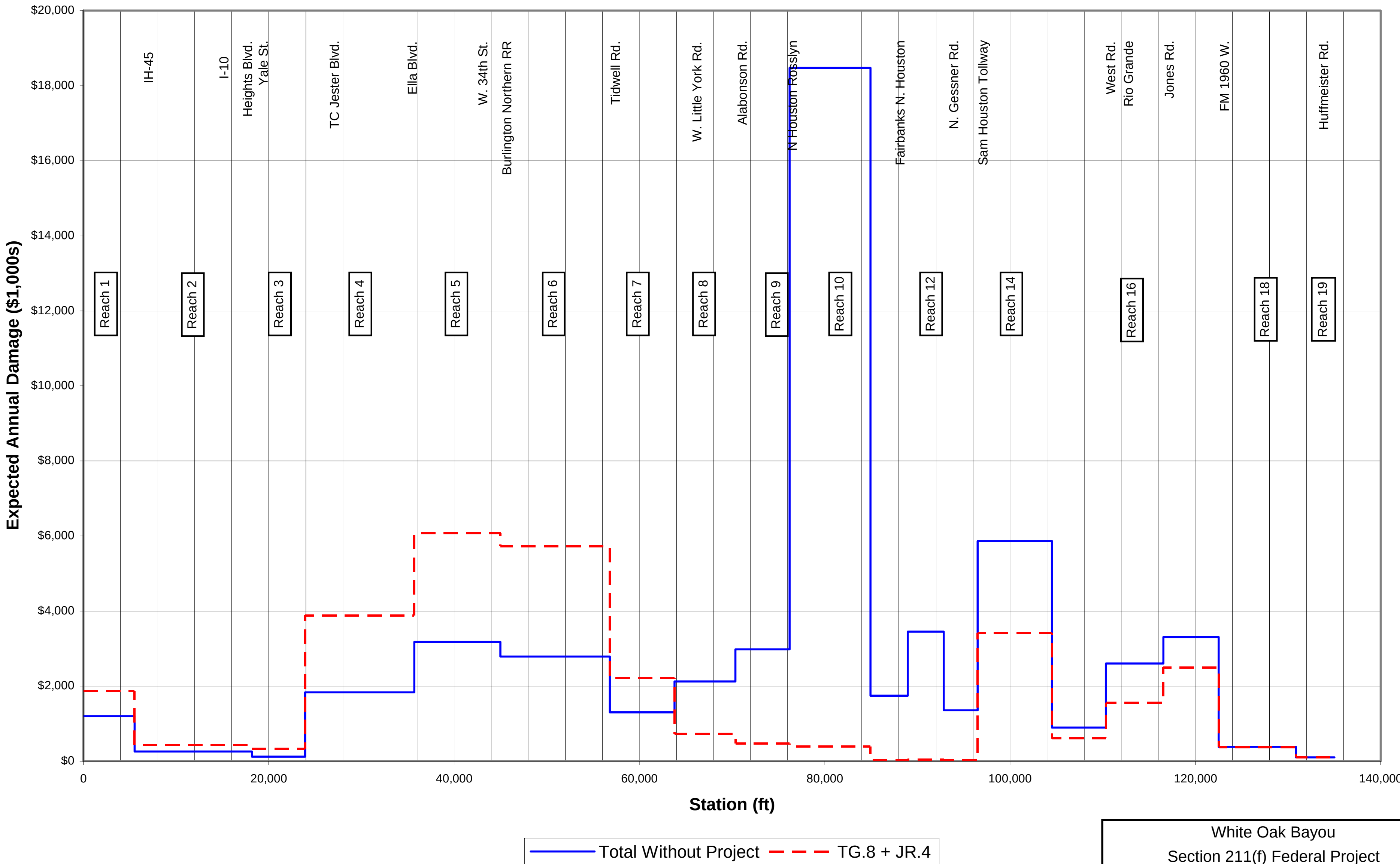
In Step 8, the three remaining best performing components were combined with the Step 7 plan. Adding the NHR.1 detention basin produced the highest incremental net benefits with total net annual benefits of $22.6 million. The two remaining best performing components were combined individually with this plan in Step 9. Adding the RG.0 detention basin adds $22,000 in net annual benefits to the formulated plan, with total net annual benefits of $22.6 million. The other component, the HOL.2 detention basin, resulted in decreased net benefits, so no further steps were needed. The resulting alternative plan, TG8_9.2, was comprised of the TG.8 channel modifications in the upper reach, the E200H.3 channel modifications in the upper reach, detention basins GBW.2, TWLY.3, FNH.1, NHR.1, RG.0, and the buyout of 34 properties that were previously in the 20 percent floodplain.

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor with HEC-FDA Model WOB801

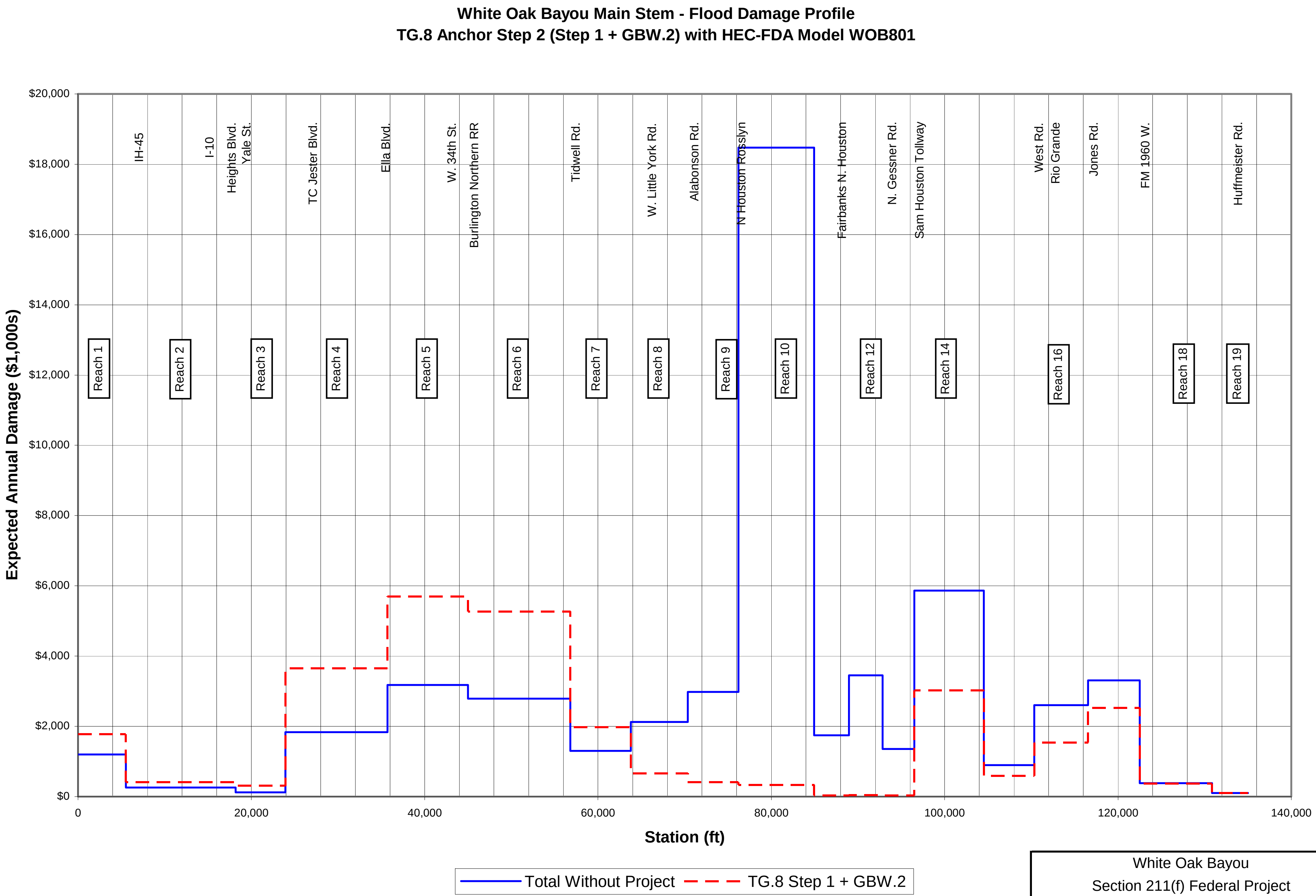


White Oak Bayou Section 211(f) Federal Project	
Flood Damage Profile TG8 Anchor	
Harris County Flood Control District	Exhibit: 2A

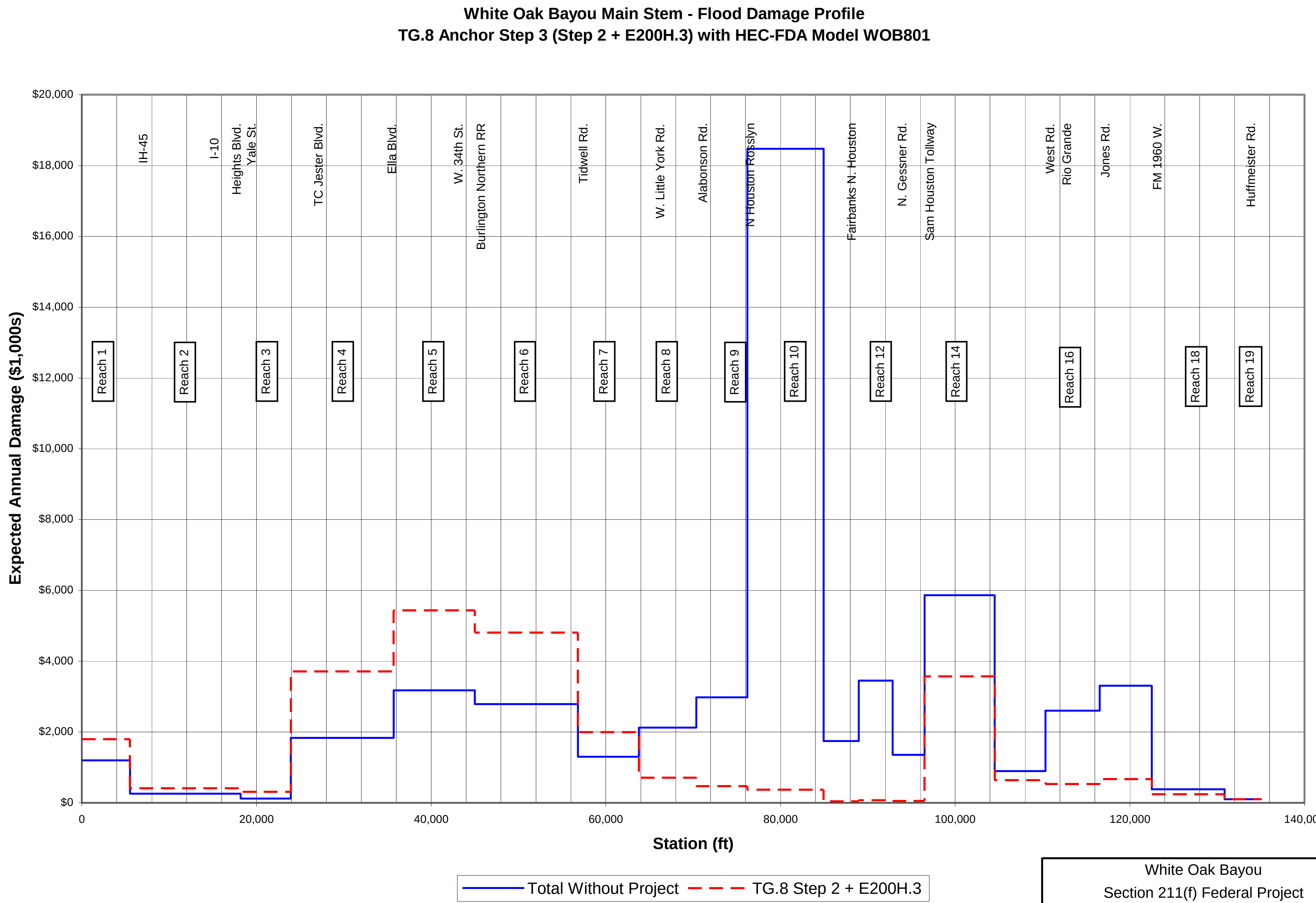
White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 1 (TG.8 + JR.4) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 1
Harris County Flood Control District — Exhibit: 2B



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 2
Harris County Flood Control District — Exhibit: 2C

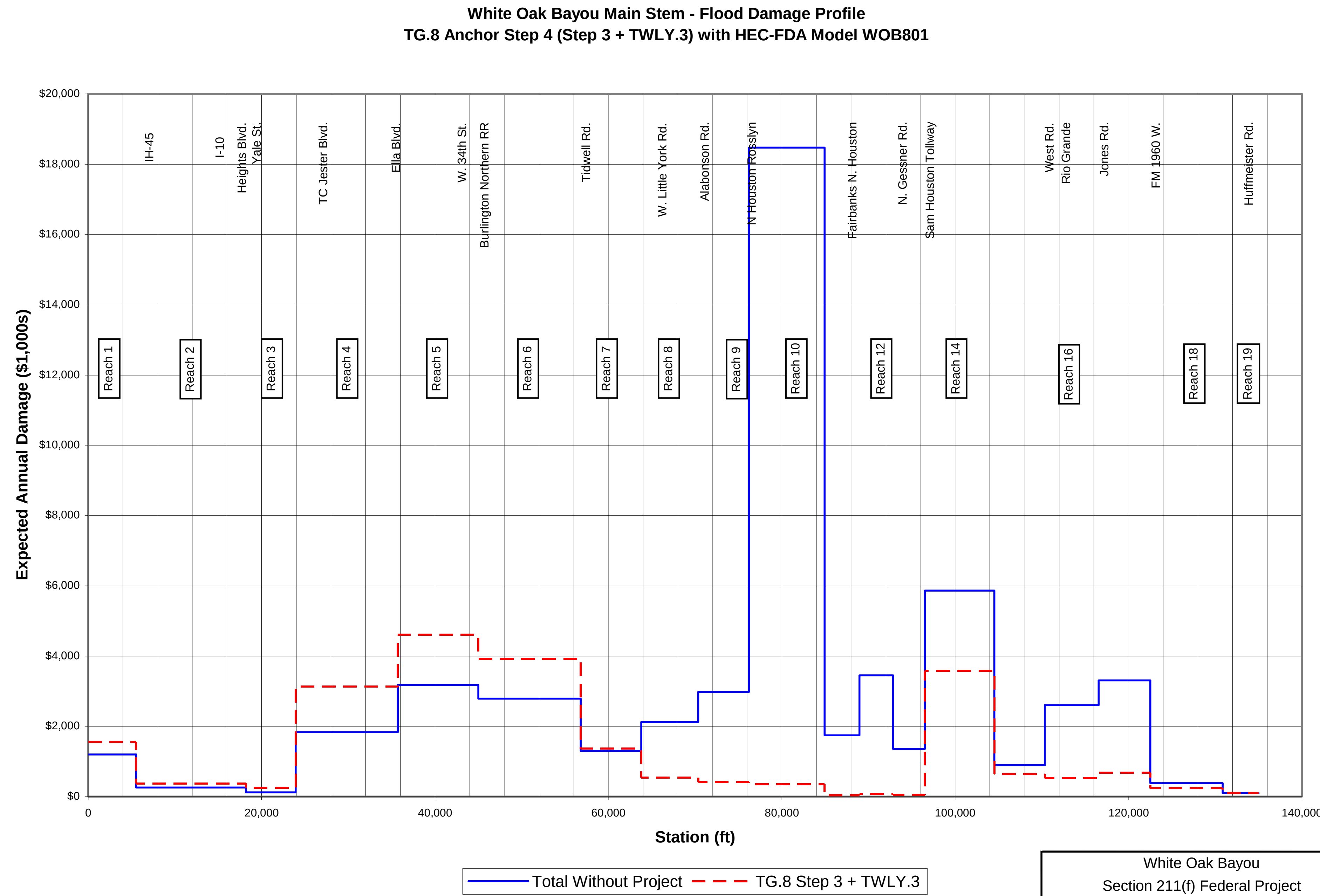


White Oak Bayou
Section 211(f) Federal Project

Flood Damage Profile
TG8 Anchor Step 3

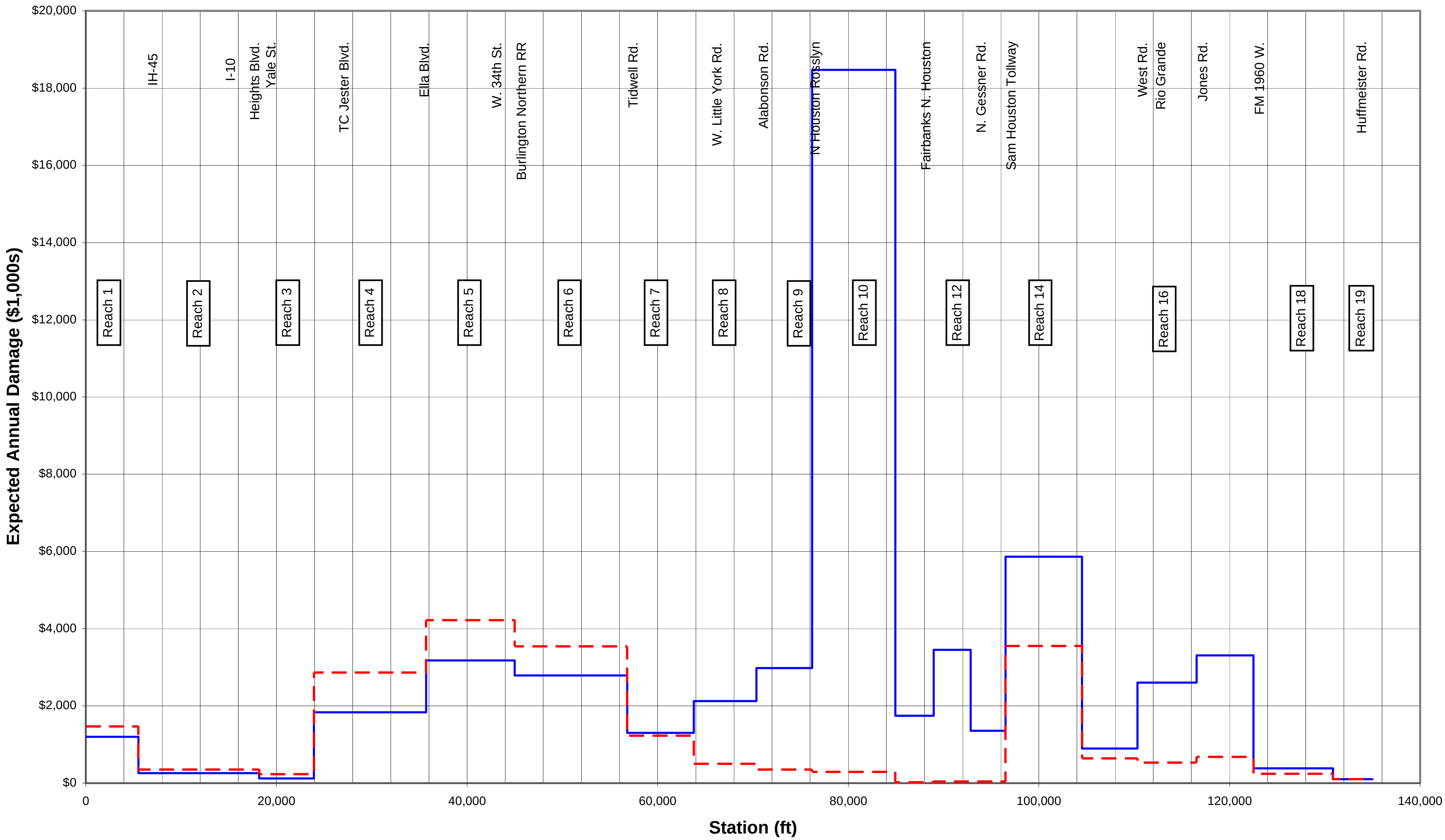
Exhibit: 2D

Harris County Flood Control District



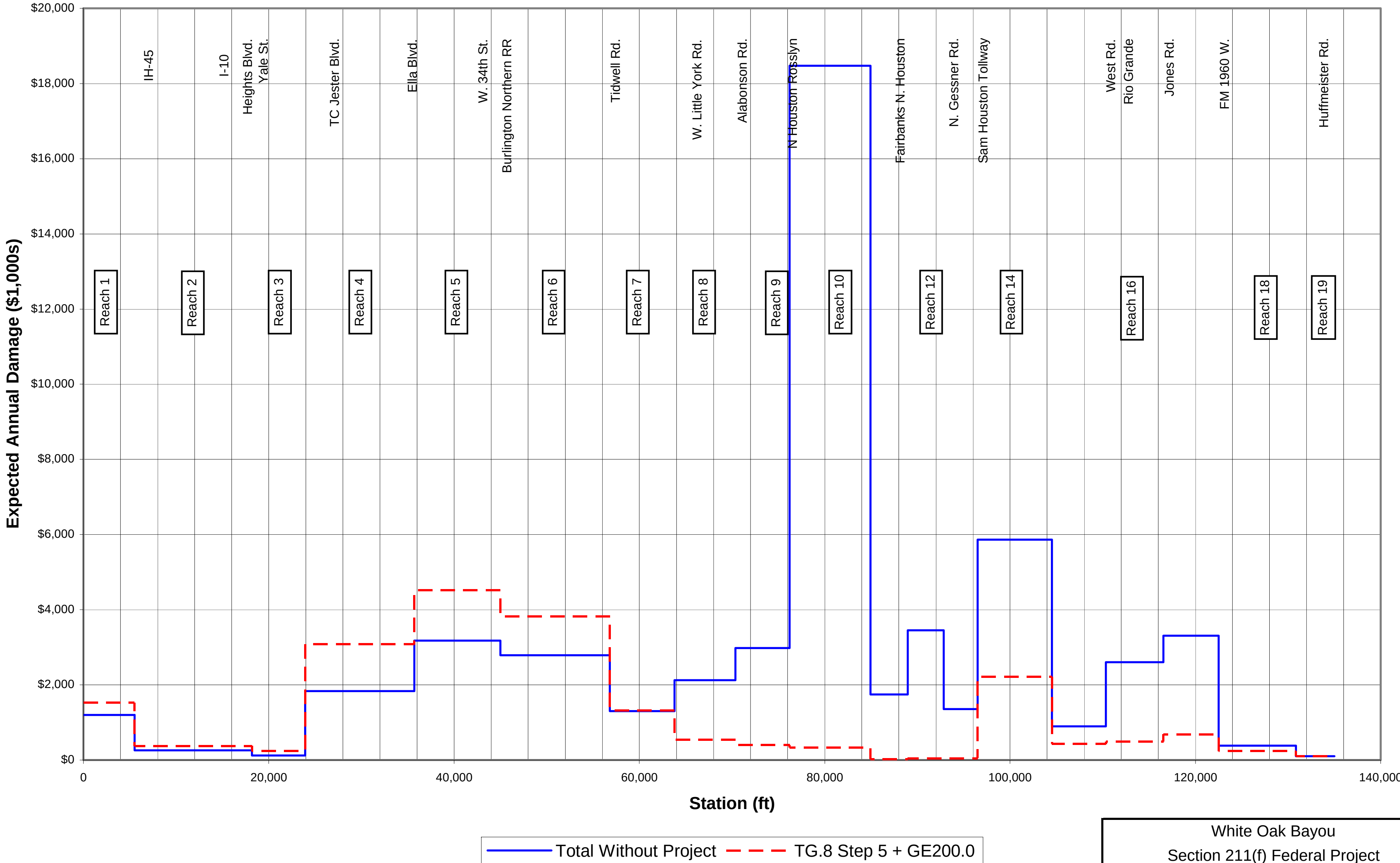
White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 4
Harris County Flood Control District · Exhibit: 2E

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 5 (Step 4 + FNH.1) with HEC-FDA Model WOB801



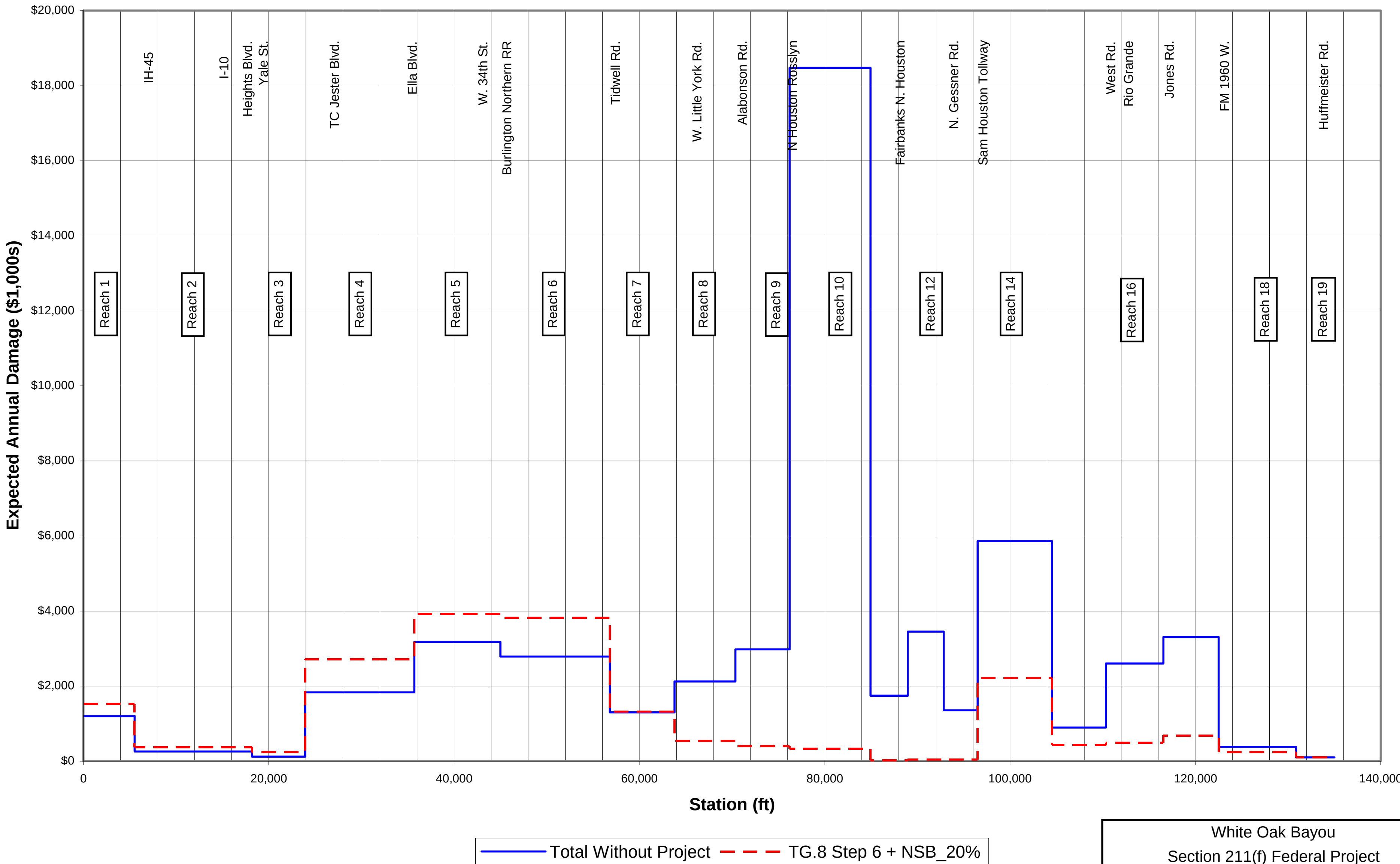
White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 5
Harris County Flood Control District — Exhibit: 2F

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 6 (Step 5 + GE200.0) with HEC-FDA Model WOB801



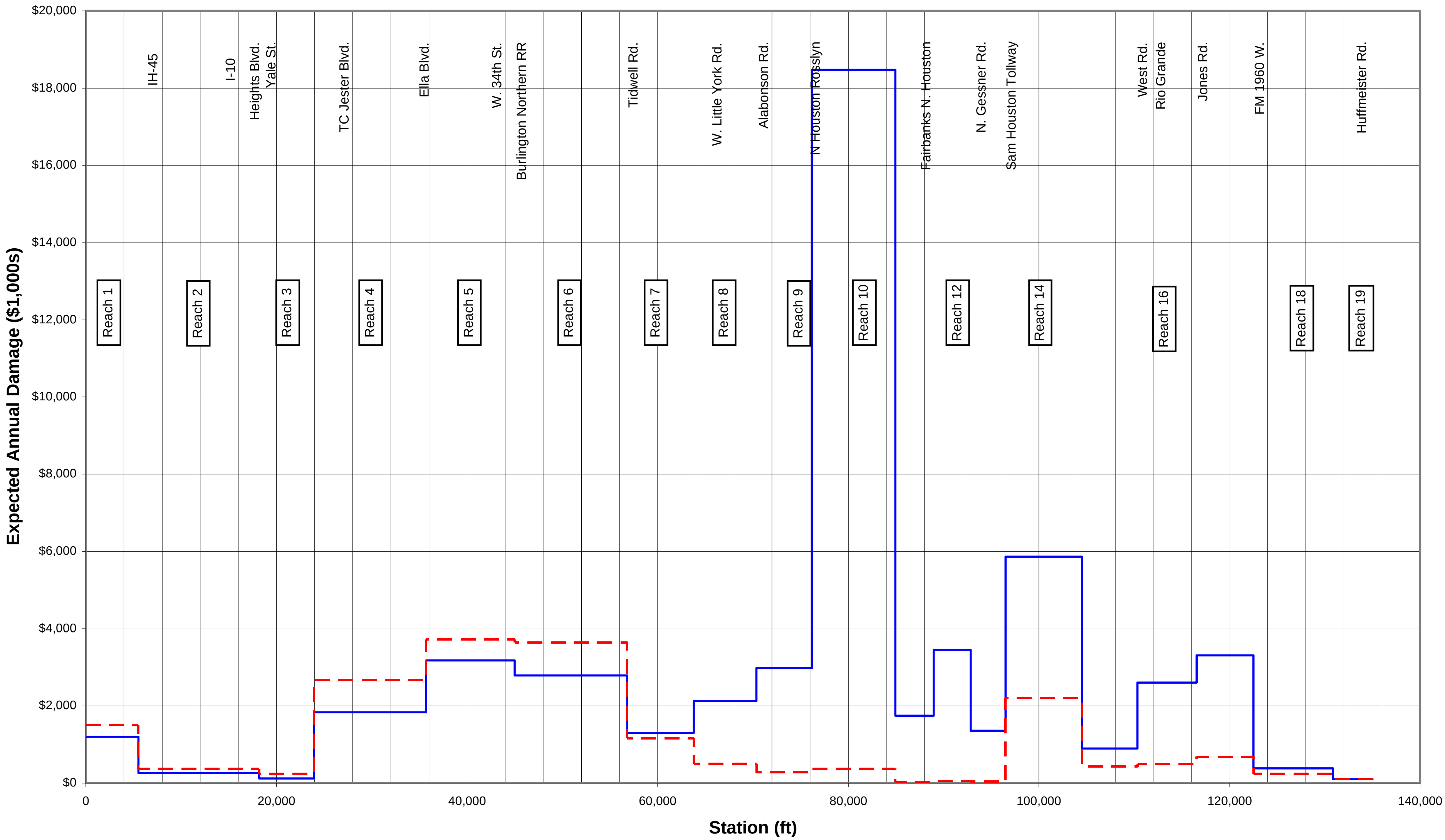
White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 6
Harris County Flood Control District — Exhibit: 2G

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 7 (Step 6 + NSB_20%) with HEC-FDA Model WOB801



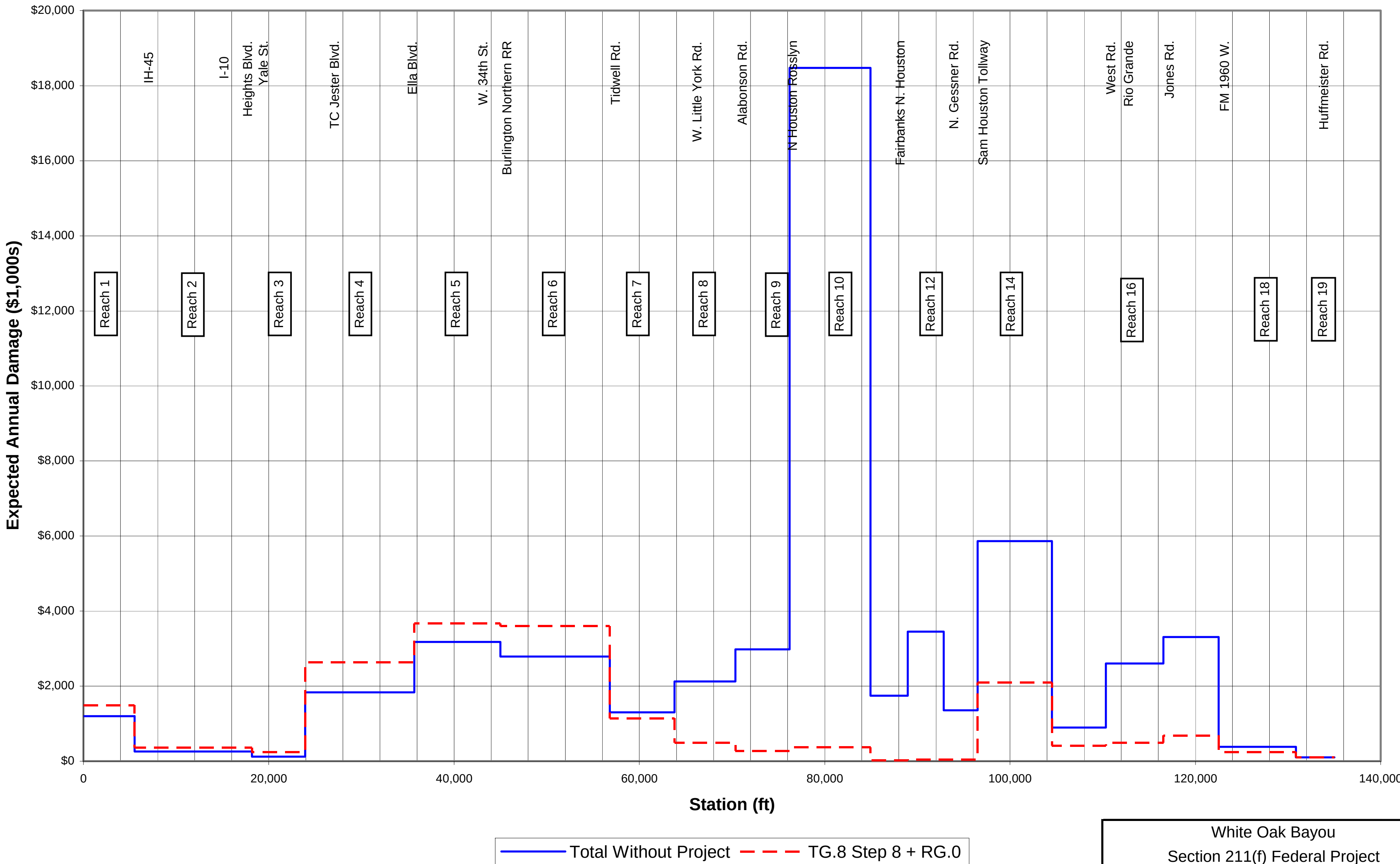
White Oak Bayou Section 211(f) Federal Project	
Flood Damage Profile TG8 Anchor Step 7	
Harris County Flood Control District	Exhibit: 2H

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 8 (Step 7 + NHR.1) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 8
Harris County Flood Control District — Exhibit: 2I

White Oak Bayou Main Stem - Flood Damage Profile
TG.8 Anchor Step 9 (Step 8 + RG.0) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG8 Anchor Step 9
Harris County Flood Control District — Exhibit: 2J

13.2 TG.2 Plan Formulation

A summary of the TG.2 plan formulation results can be seen in **Table 12**. A comparison of each TG.2 plan next added component with the without project conditions can be seen in the economic damage profiles shown in **Exhibit 3**. In Step 1 of the TG.2 channel plan formulation process, the TG.2 component was combined with each of the other proposed channel modifications, detention basins, and non-structural measures in order to arrive at an optimal combination with which to proceed to the next step in the formulation process. The addition of the proposed detention basin JR.4 resulted in the highest total annual net benefits of $11.8 million, and this was used as the anchor plan for Step 2.

In Step 2, the Step 1 top performing components for each component type were combined with the Step 1 formulated plan. Non-structural components were not evaluated further because it was evident that they could not produce incremental benefits on the same scale as the structural measures. Unlike TG.8 where induced damage occurred and allowed for the addition of a non-structural component in later stages, the induced damage produced by TG.2 was reduced and subsequently eliminated in the early stages by the addition of structural components. Step 2 showed that adding the HOL.3 detention basin results in the best performing plan and had the highest annual net benefits of $14.4 million. In Step 3, each of the remaining best performing components (from the Step 1 and Step 2 analyses) was added separately to the best-performing Step 2 plan. The detention component GBW.2 added the most benefits, with total annual net benefits of $16.3 million for the resulting plan.

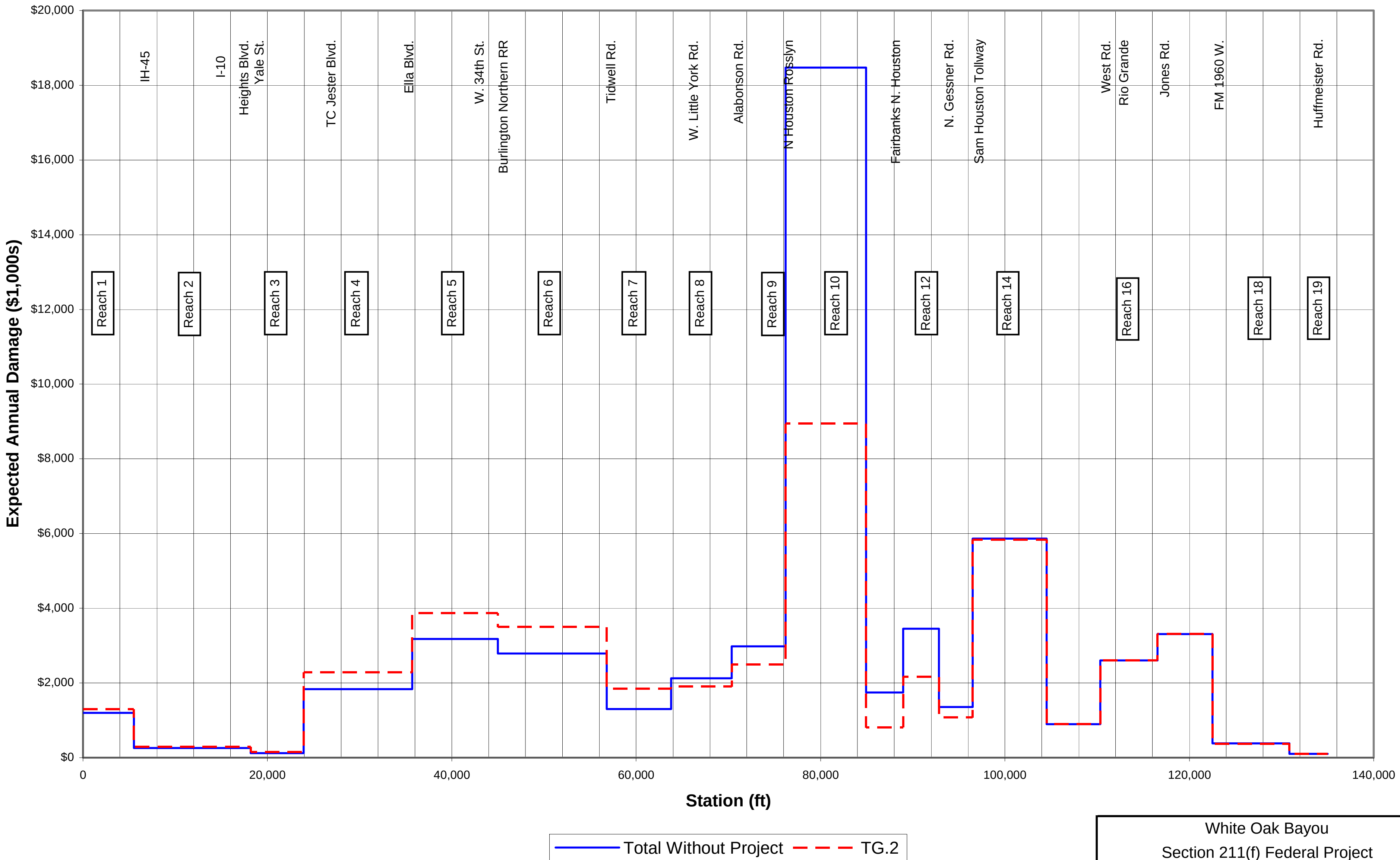
As with the TG.8 formulation, re-optimization was conducted in Step 4 of the TG.2 formulation to ensure the addition of optimized versions of the components. Once again, the levee components were not carried forward in this step because it was determined that none would have the possibility of producing positive net economic benefits. During this step, the Step 3 formulated plan was combined with twenty-three individual components. The addition of the FNH.1 detention basin yielded the highest total net EA benefits ($17.5 million) for this step.

In Step 5, the Step 4 plan was combined with the five remaining best performing components (from the Step 4 analysis). Adding the RG.2 detention basin yielded the highest annual net benefits with $18.2 million. In Step 6, the remaining four best performing components are individually added to this plan. The addition of the E200H.2 channel modifications had the highest net annual benefits for this step with $18.4 million.

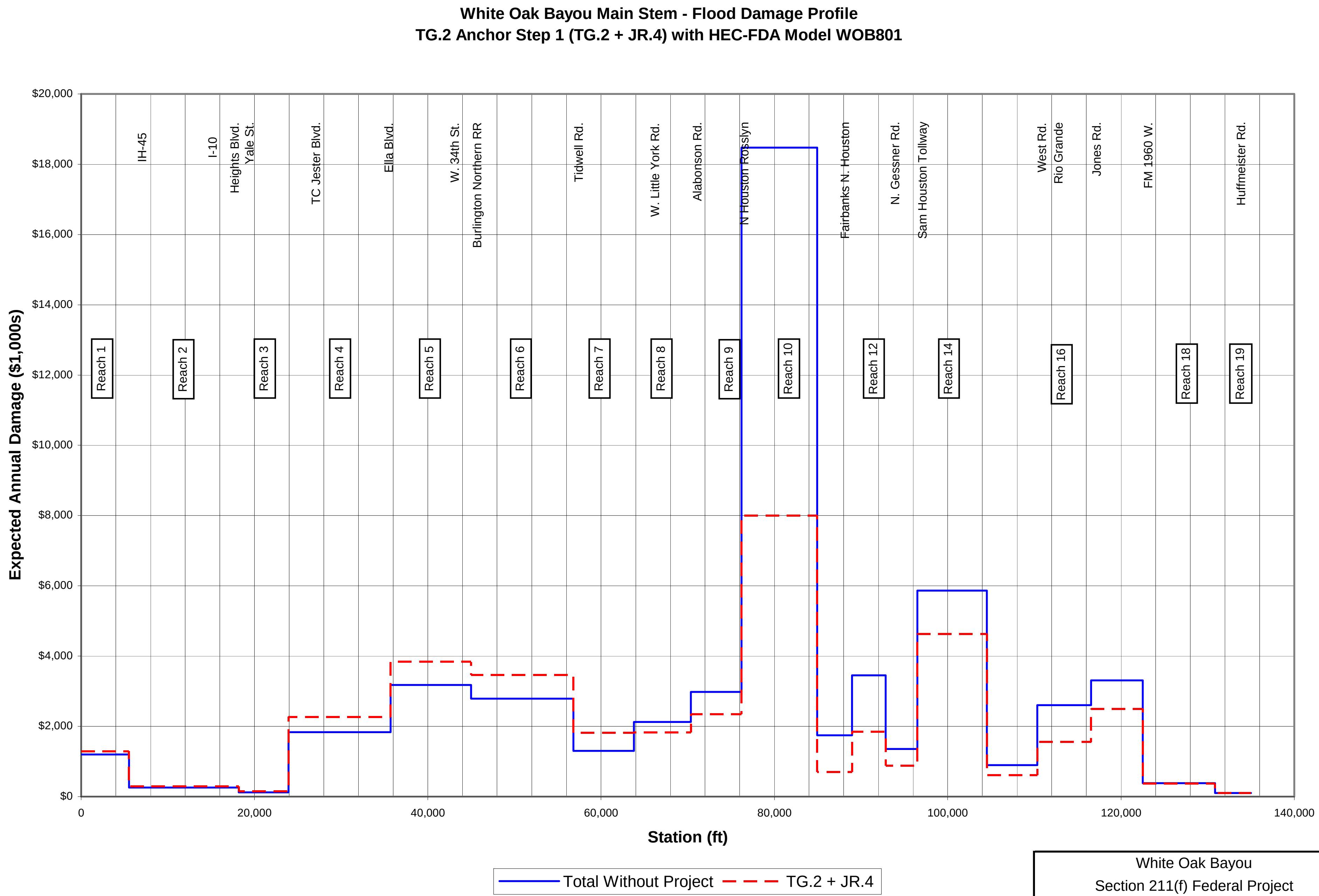
In Step 7, more individual components were added to the Step 6 plan. A re-optimization process was again conducted on these components in Step 7. The Step 6 formulated plan combined with the GE200.0 channel modifications was the best performing plan and had annual net benefits of $19.3 million.

Step 8 combined the best performing plan from Step 7 with the remaining best-performing components (as shown in the re-optimization in Step 7) to further increase the net project benefits. Adding the TWLY.2 detention basin had the greatest increase in net benefits, resulting in total annual net benefits of $19.4 million. The resulting plan (TG2_8.1) was then used as the base plan in the TG.2 optimization process.

White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor with HEC-FDA Model WOB801

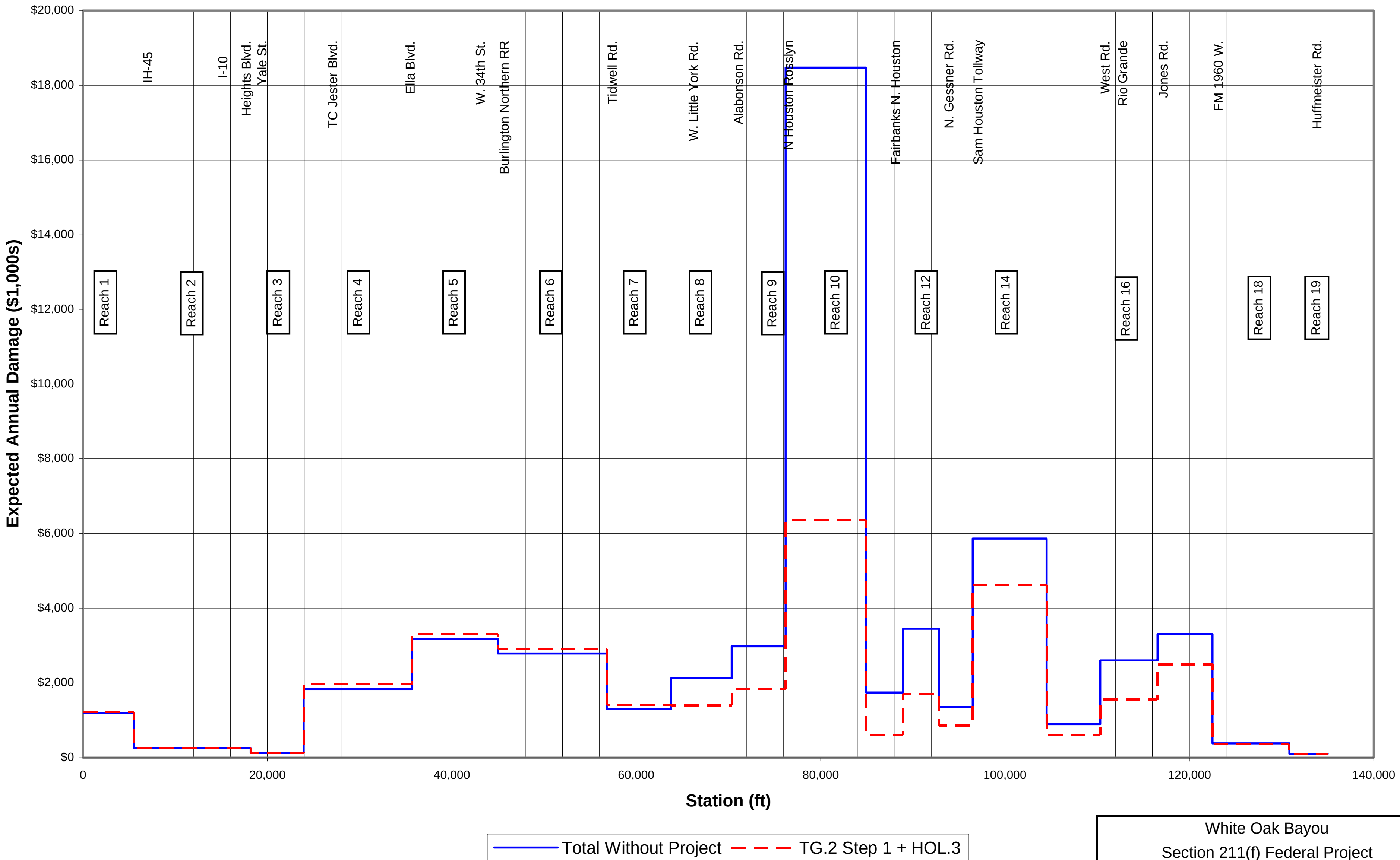


White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor
Harris County Flood Control District — Exhibit: 3A



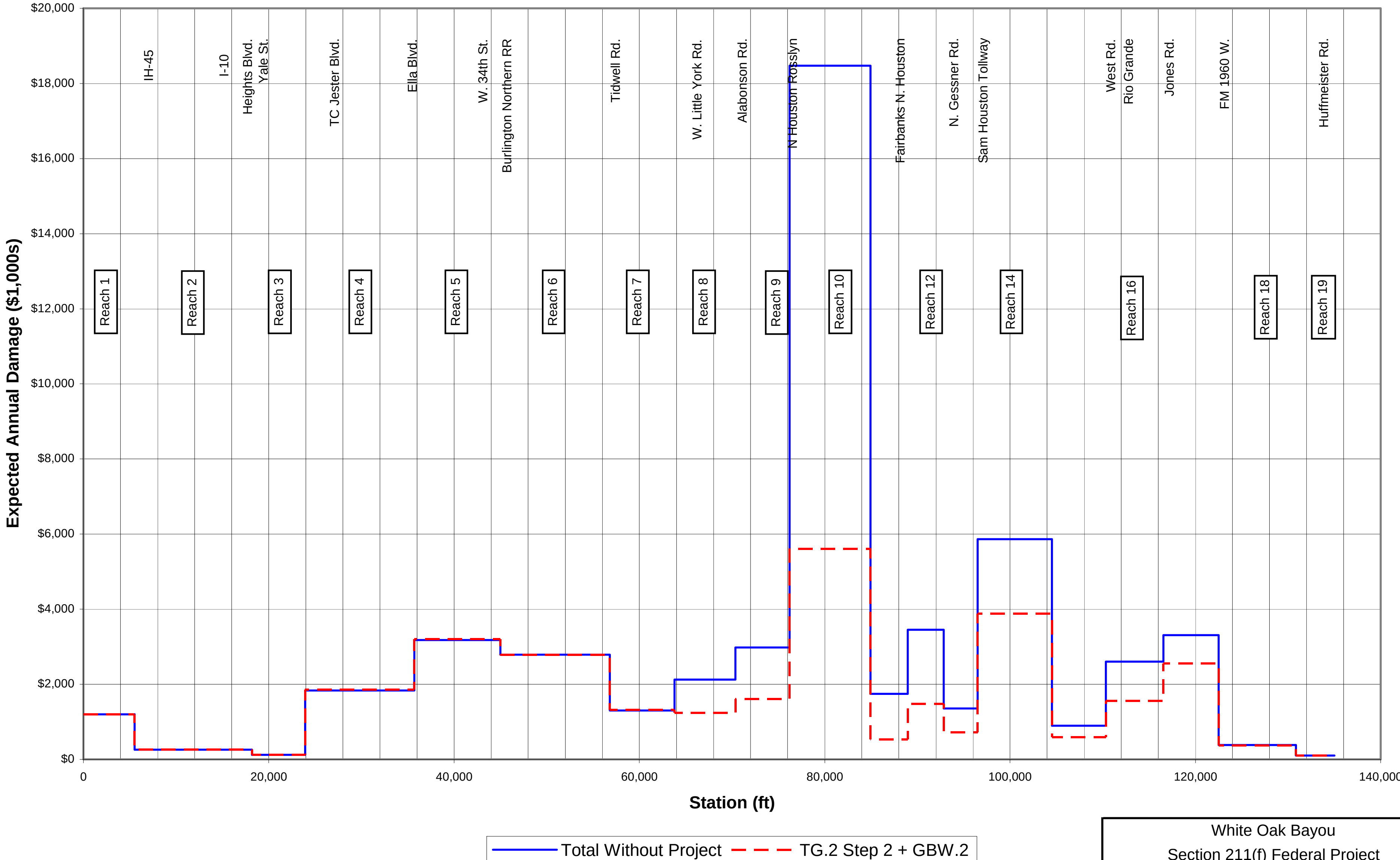
White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 1
Harris County Flood Control District — Exhibit: 3B

White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor Step 2 (Step 1 + HOL.3) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project	
Flood Damage Profile TG2 Anchor Step 2	
Harris County Flood Control District	Exhibit: 3C

White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor Step 3 (Step 2 + GBW.2) with HEC-FDA Model WOB801



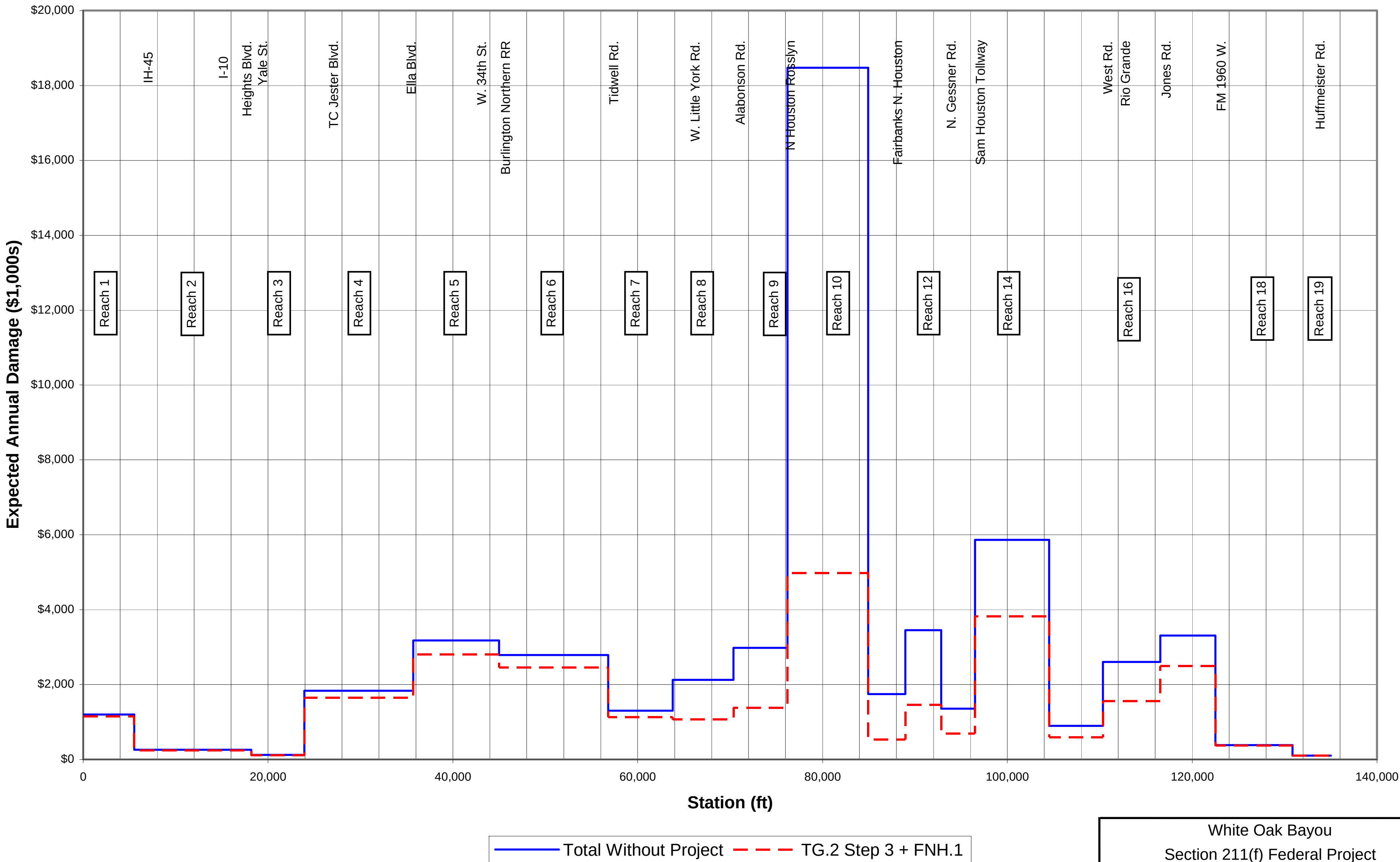
White Oak Bayou
Section 211(f) Federal Project

Flood Damage Profile
TG2 Anchor Step 3

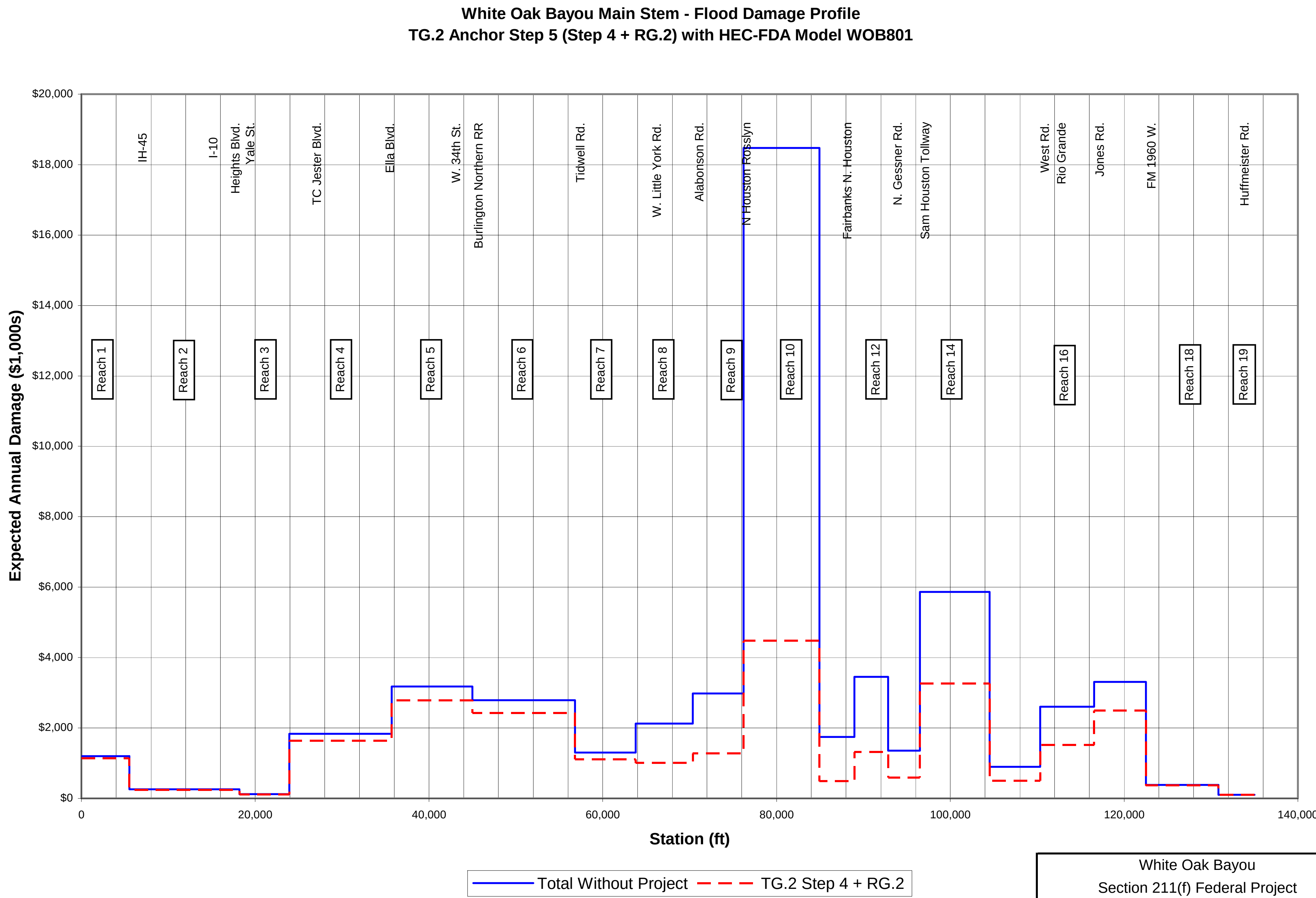
Harris County Flood Control District

Exhibit: 3D

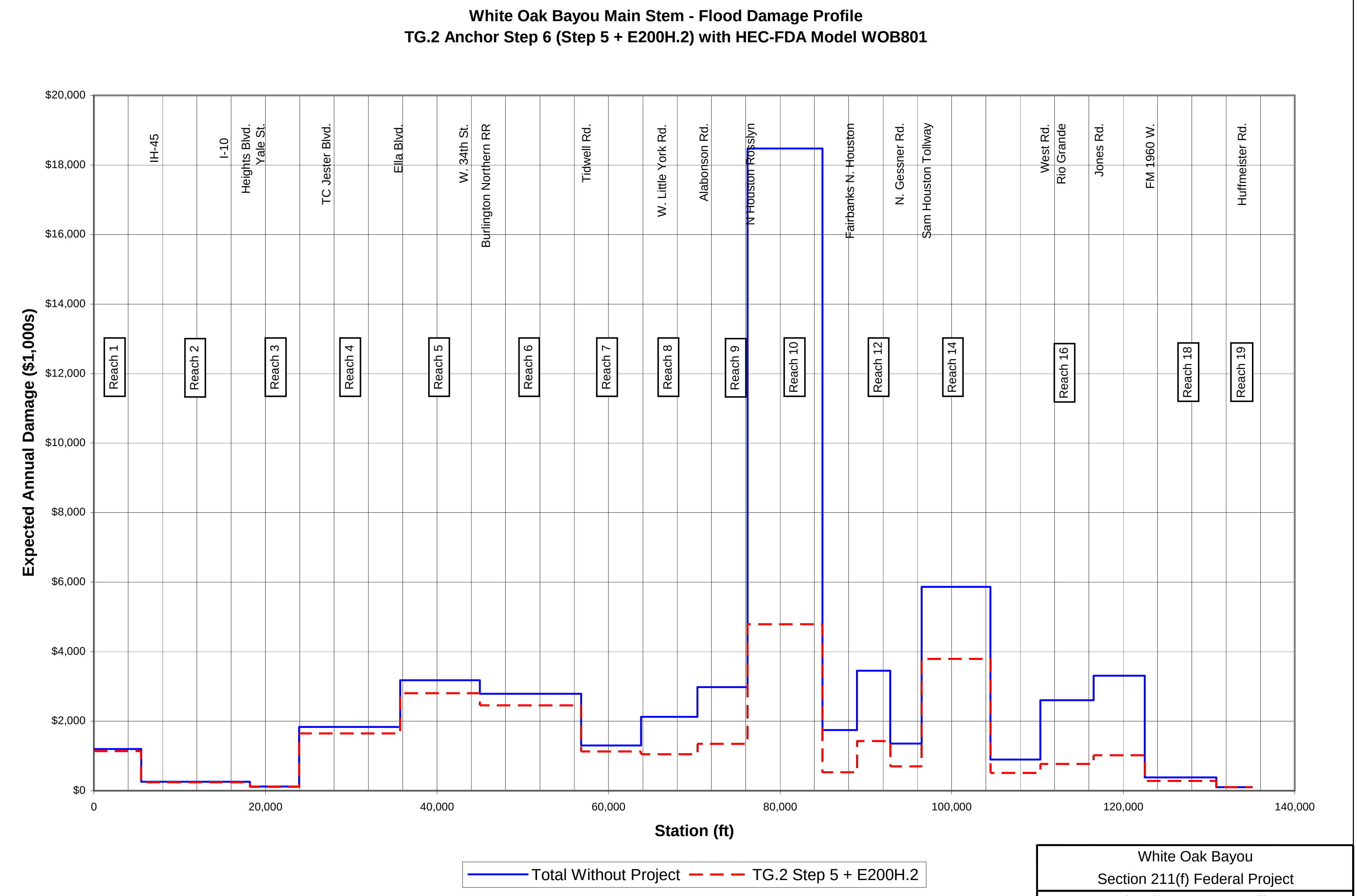
White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor Step 4 (Step 3 + FNH.1) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 4
Harris County Flood Control District — Exhibit: 3E

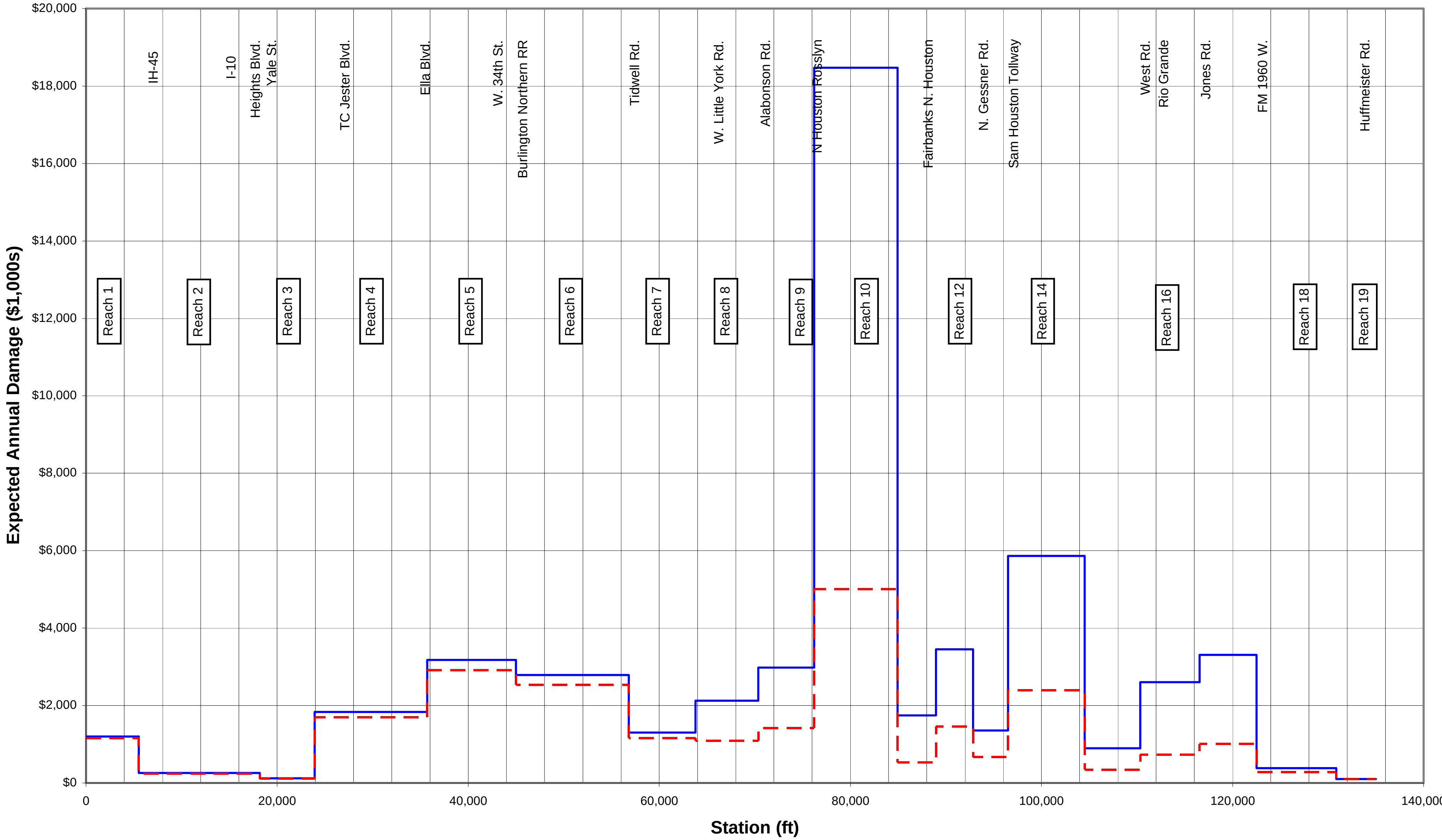


White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 5
Harris County Flood Control District — Exhibit: 3F



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 6
Harris County Flood Control District — Exhibit: 3G

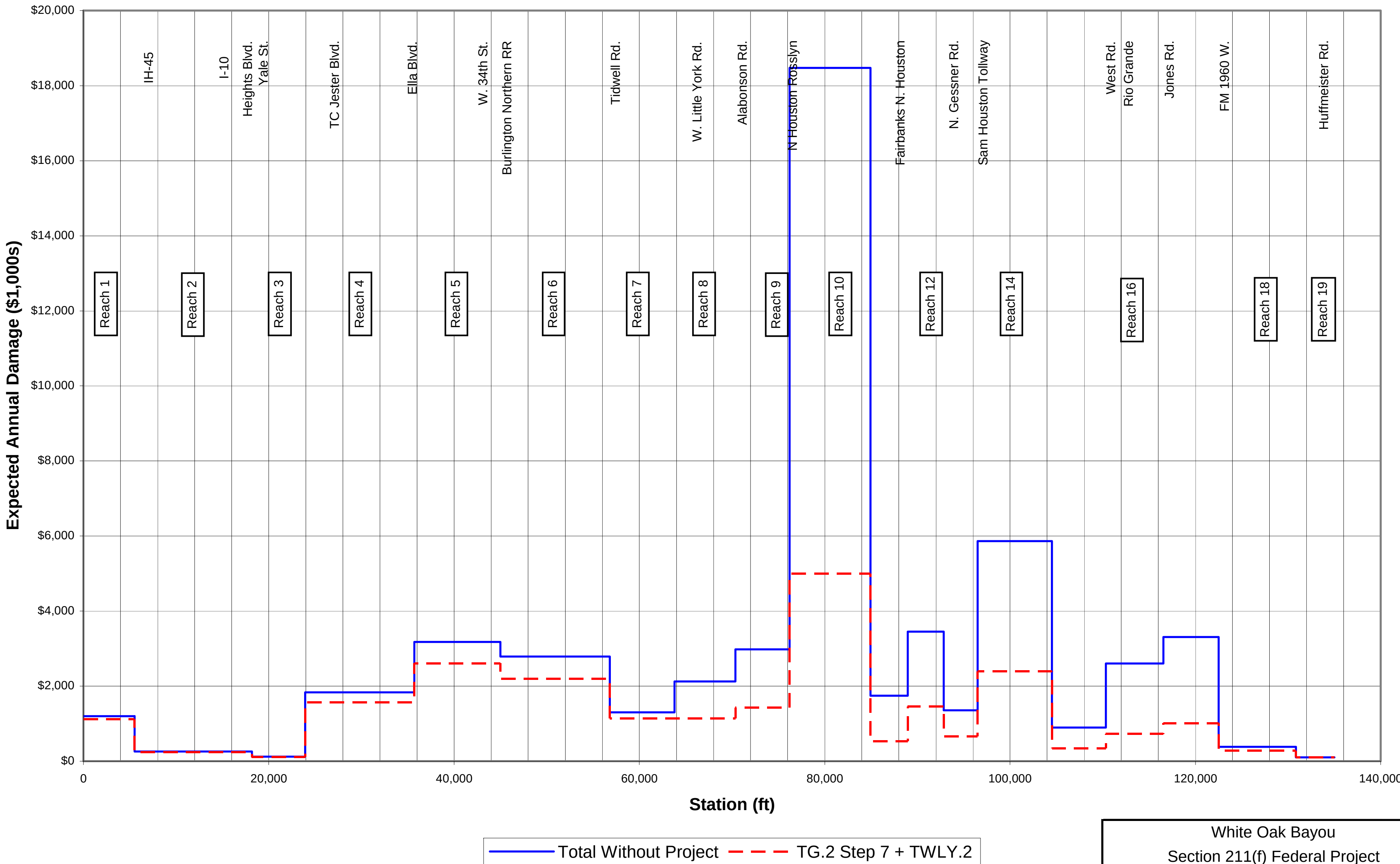
White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor Step 7 (Step 6 + GE200.0) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 7
Exhibit: 3H

Harris County Flood Control District

White Oak Bayou Main Stem - Flood Damage Profile
TG.2 Anchor Step 8 (Step 7 + TWLY.2) with HEC-FDA Model WOB801



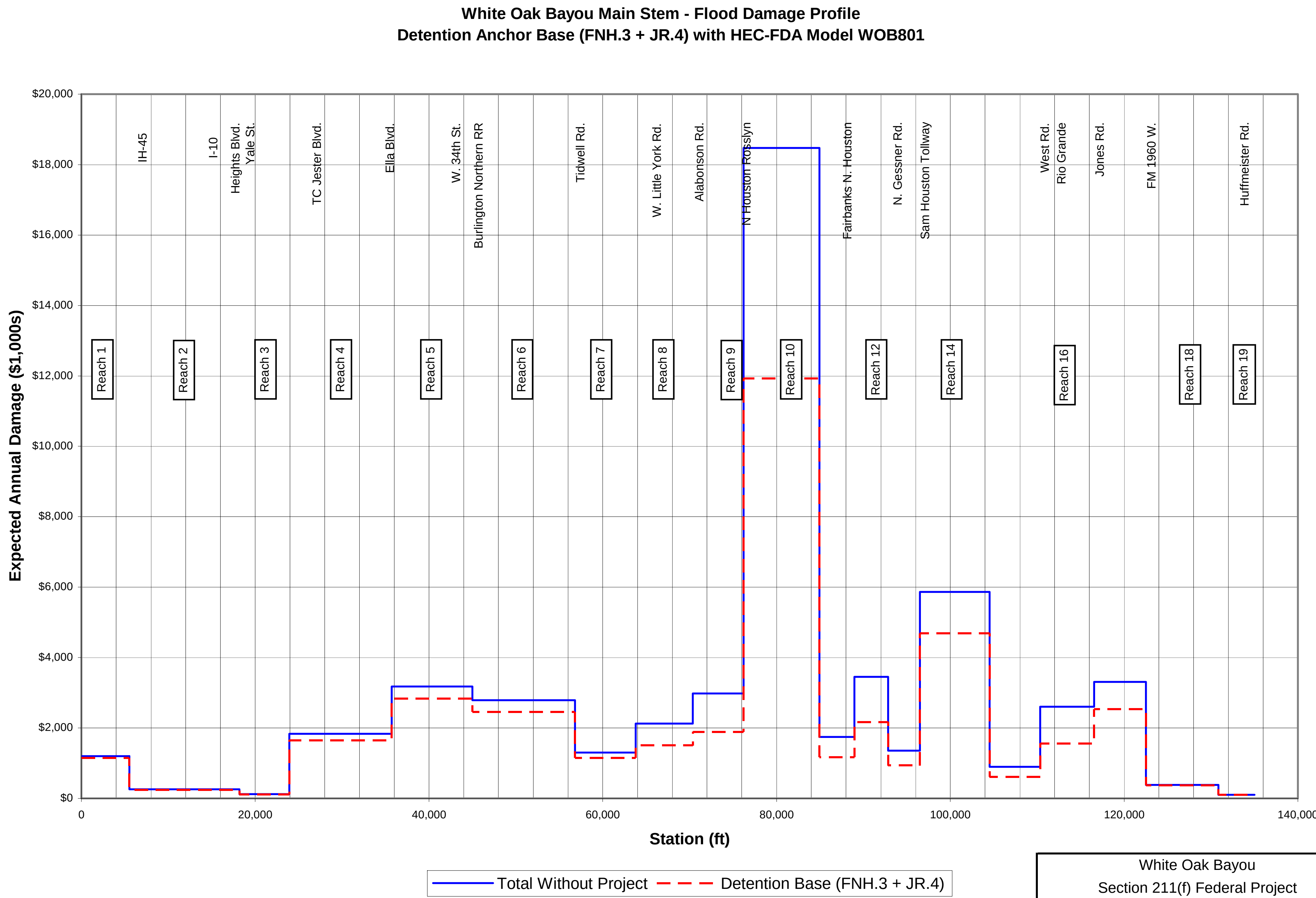
White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile TG2 Anchor Step 8
Harris County Flood Control District — Exhibit: 3I

13.3 Detention Plan Formulation

A plan was also considered that had detention basins at Fairbanks-North Houston (FNH.3) and Jones Road (JR.4) as anchors. As seen in **Table 12**, this plan was called DA_1. Detention plan formulation was conducted in a manner similar to the TG.2 and TG.8 plan formulation. Individual detention only components were added to the anchor and the highest net benefit plan was considered as the anchor in the next step. A detention only alternative was considered due to the popularity of detention basins in the study area. Four steps were completed in this analysis. A comparison of each Detention plan next added component with the without project conditions can be seen in the economic damage profiles shown in **Exhibit 4**.

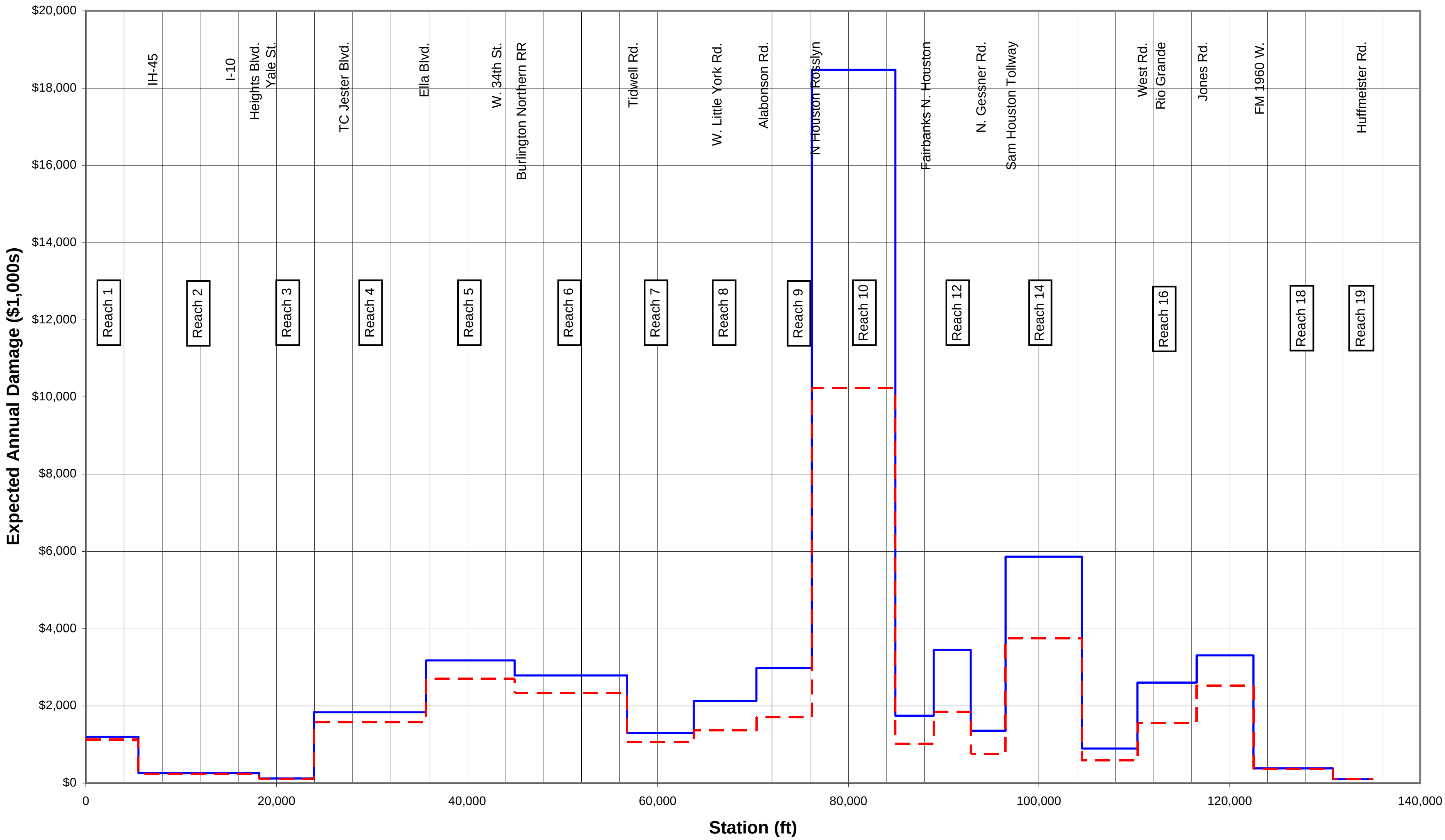
In Step 1, the base plan (DA_1) was combined separately with twenty-two potential detention component alternatives. The plan that yielded the highest net benefits was the addition of GBW.3 and the expected annual net benefits were $13.1 million. In Step 2, this plan was then combined with the five other highest performing alternatives (as shown in Step 1). Expected annual net benefits were maximized at $13.7 million, with the addition of the HOL.3 detention basin. This process was repeated in Step 3 with the four remaining highest performing alternatives. Net benefits for this step were maximized at $14.8 million with the addition of the GE200.2 channel modification.

In Step 4, a re-optimization was performed on the remaining components. The formulated plan from Step 3 was combined with three different sizes of each of the TWLY, NHR, and RG components. The plan that included the addition of RG.1 (DA_4.8) yielded expected net EA benefits of $15.1 million, which was the highest for this step.

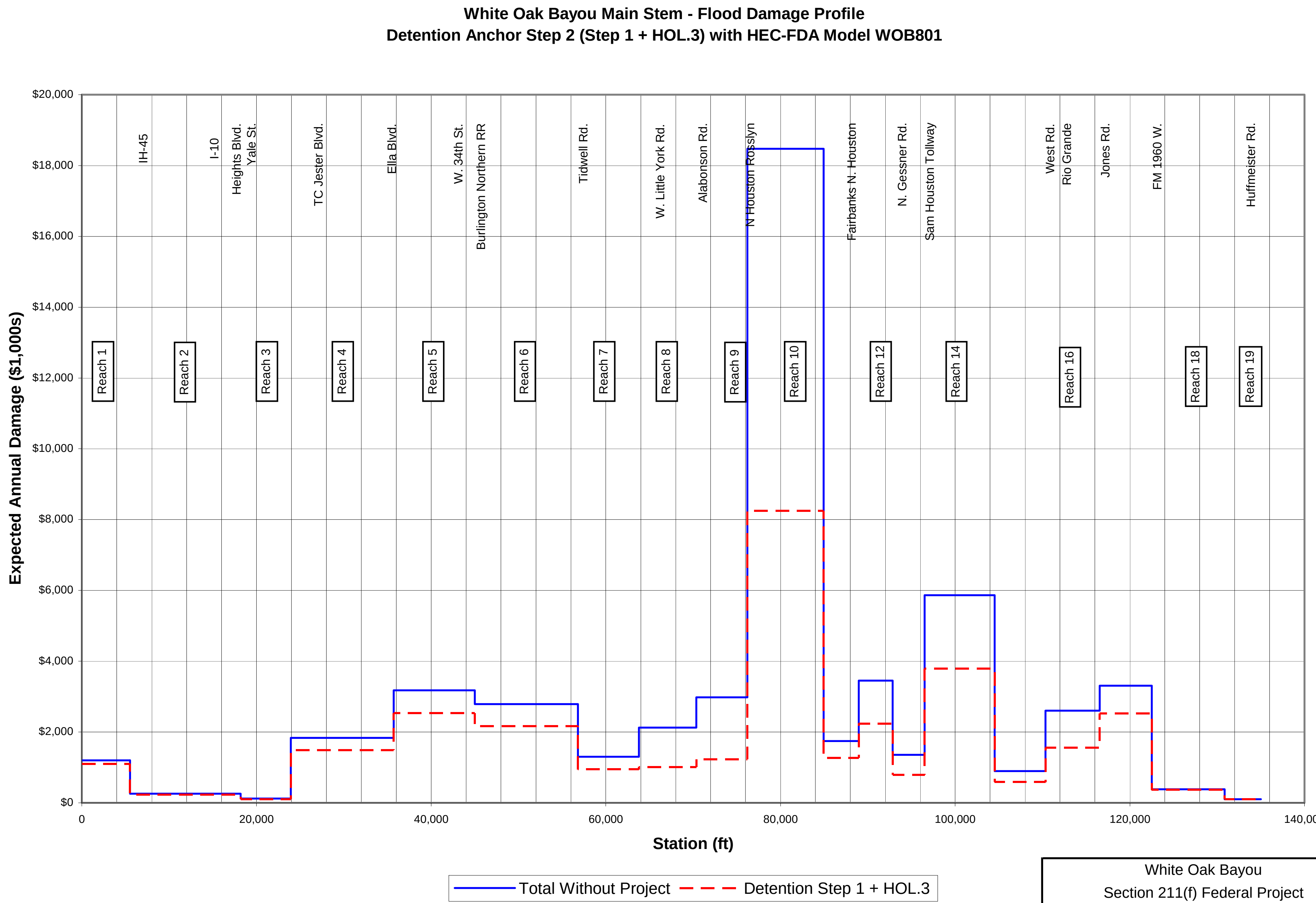


White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile Detention Anchor
Harris County Flood Control District — Exhibit: 4A

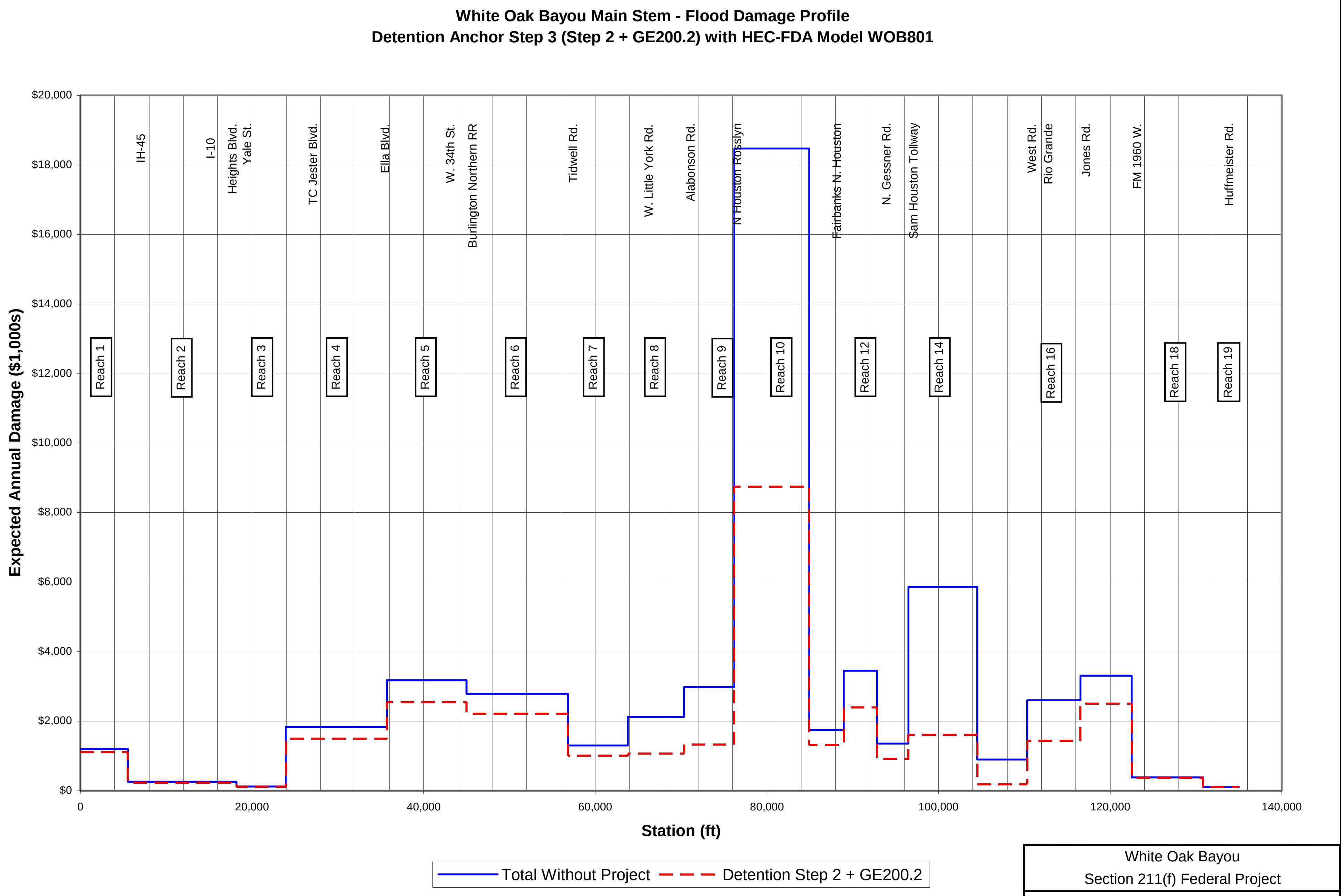
White Oak Bayou Main Stem - Flood Damage Profile
Detention Anchor Step 1 (Base + GBW.3) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project	
Flood Damage Profile Detention Anchor Step 1	
Harris County Flood Control District	Exhibit: 4B



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile Detention Anchor Step 2
Harris County Flood Control District — Exhibit: 4C



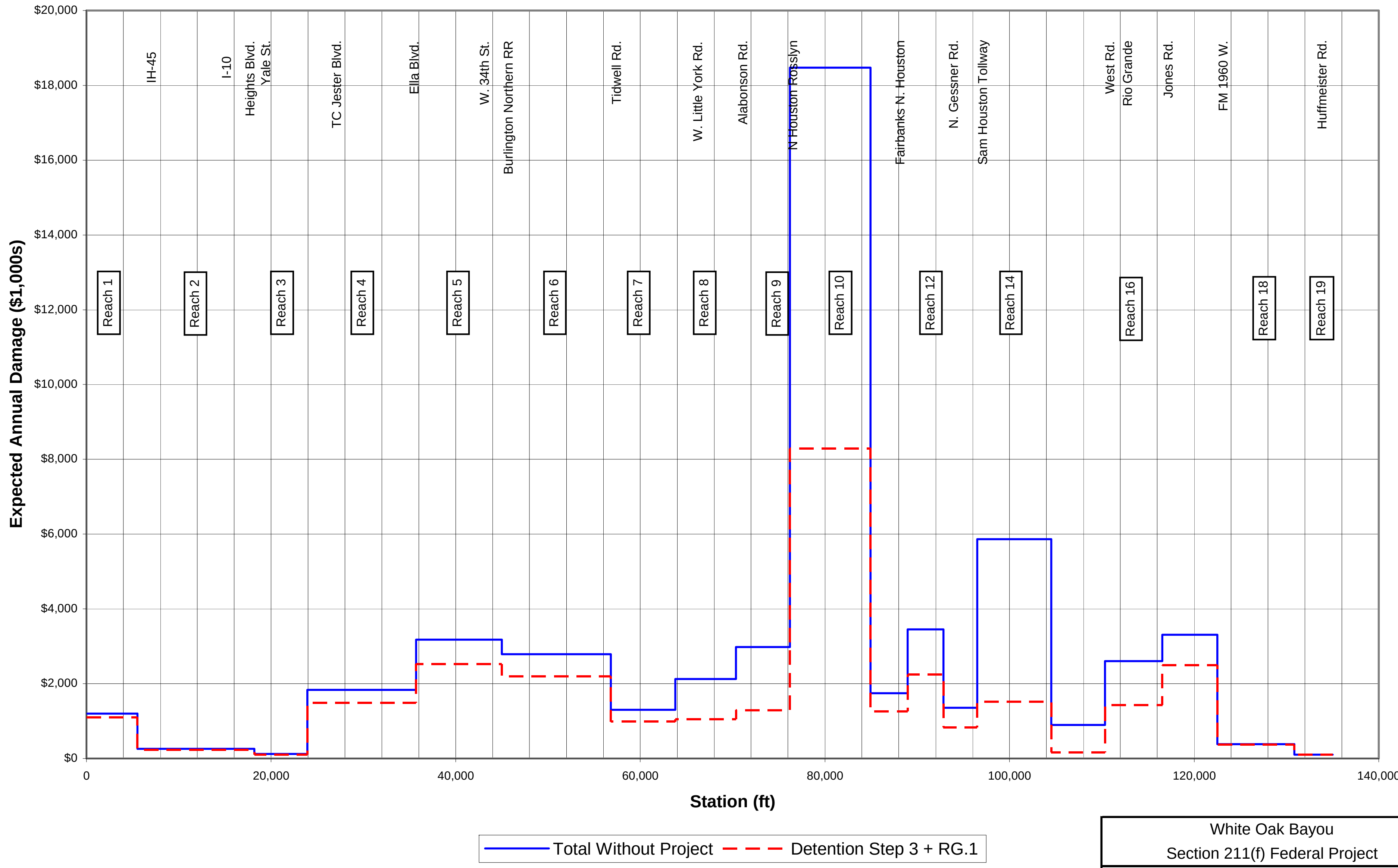
White Oak Bayou
Section 211(f) Federal Project

Flood Damage Profile
Detention Anchor Step 3

Exhibit: 4D

Harris County Flood Control District

White Oak Bayou Main Stem - Flood Damage Profile
Detention Anchor Step 4 (Step 3 + RG.1) with HEC-FDA Model WOB801



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile Detention Anchor Step 4
Harris County Flood Control District — Exhibit: 4E

13.4 Last Added Analysis

A last added analysis was performed to ensure that each individual component contributed an incremental net benefit with all of the other components in place. The best TG.8, TG.2, and Detention plans from the formulation process were analyzed with each constituent component removed separately. (The individual components were evaluated as if each one was the "last-added" in the formulation process.)

Nine last-added runs were performed on the formulated TG.8 plan. A new last-added run was not performed on RG.0 because it was the last added component in the incremental analysis. Eight last-added runs were performed with the formulated TG.2 plan as the starting point. A new last-added run was not performed on TWLY.2 because it was the last-added component in the incremental analysis. Five last-added runs were performed on the detention anchor formulated plan. A new last-added run was not performed on RG.1 because it was the last-added component in the incremental analysis. Each of the last-added runs in the TG.8, TG.2, and detention anchor plans resulted in a decrease in net EA benefits, showing that all of the components still warrant inclusion in the plans. The results of the last added analysis can be found in **Table 13**.

Table 13
Last Added Analysis
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Contributed EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Contributed EA Cost ($1,000)	Net EA Benefits ($1,000)	Incremental Net EA Benefits
Last Added Analysis of TG2 Based Formulated Plan											
	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+ E200H.2+GE200.0+TWLY.2	$24,063	$29,917		55.42%	$143,843	$174,210	$10,478		$19,439	
TG2_LA1	TG2 Formulated Plan - TG.2	$32,604	$21,377	$8,540	39.60%	$110,064	$133,299	$8,018	$2,461	$13,359	-$6,080
TG2_LA2	TG2 Formulated Plan - JR.4	$27,633	$26,348	$3,569	48.81%	$126,596	$153,321	$9,222	$1,256	$17,126	-$2,313
TG2_LA3	TG2 Formulated Plan - HOL.3	$27,168	$26,812	$3,105	49.67%	$115,310	$139,653	$8,400	$2,079	$18,413	-$1,026
TG2_LA4	TG2 Formulated Plan - GBW.2	$26,048	$27,933	$1,985	51.75%	$131,102	$158,779	$9,550	$928	$18,382	-$1,057
TG2_LA5	TG2 Formulated Plan - FNH.1	$26,207	$27,774	$2,144	51.45%	$128,747	$155,927	$9,379	$1,100	$18,395	-$1,044
TG2_LA6	TG2 Formulated Plan - RG.2	$25,740	$28,241	$1,677	52.32%	$129,314	$156,613	$9,420	$1,058	$18,821	-$618
TG2_LA7	TG2 Formulated Plan - E200H.2	$25,818	$28,163	$1,754	52.17%	$132,737	$160,759	$9,669	$809	$18,494	-$945
TG2_LA8	TG2 Formulated Plan - GE200.0	$24,448	$29,533	$385	54.71%	$142,374	$172,430	$10,371	$107	$19,161	-$278
TG2_LA9	TG2 Formulated Plan - TWLY.2	$24,895	$29,085	$832	53.88%	$134,503	$162,897	$9,798	$680	$19,287	-$151
Last Added Analysis of TG8 Based Formulated Plan											
	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH. 1+GE200.0+NHR.1+RG.0	$18,465	$35,515		65.79%	$177,024	$214,395	$12,896		$22,620	
TG8_LA1	TG8 Formulated Plan - TG.8	$32,846	$21,135	$14,381	39.15%	$105,715	$128,032	$7,701	$5,195	$13,434	-$9,186
TG8_LA2	TG8 Formulated Plan - JR.4	$20,435	$33,546	$1,969	62.14%	$159,776	$193,507	$11,639	$1,256	$21,907	-$713
TG8_LA3	TG8 Formulated Plan - GBW.2	$19,641	$34,339	$1,176	63.61%	$164,282	$198,964	$11,967	$928	$22,372	-$248
TG8_LA4	TG8 Formulated Plan - E200H.3	$20,642	$33,339	$2,176	61.76%	$160,648	$194,562	$11,703	$1,193	$21,636	-$984
TG8_LA5	TG8 Formulated Plan - TWLY.3	$21,659	$32,322	$3,194	59.88%	$154,189	$186,740	$11,232	$1,663	$21,090	-$1,530
TG8_LA6	TG8 Formulated Plan - FNH.1	$19,907	$34,074	$1,442	63.12%	$161,928	$196,112	$11,796	$1,100	$22,278	-$342
TG8_LA7	TG8 Formulated Plan - GE200.0	$19,220	$34,761	$754	64.40%	$175,554	$212,615	$12,788	$107	$21,973	-$647
TG8_LA8	TG8 Formulated Plan without 20% Buyout	$19,434	$34,547	$969	64.00%	$168,739	$204,362	$12,292	$603	$22,255	-$365
TG8_LA9	TG8 Formulated Plan - NHR.1	$19,152	$34,829	$686	64.52%	$169,068	$204,760	$12,316	$580	$22,513	-$107
TG8_LA10	TG8 Formulated Plan - RG.0	$18,758	$35,223	$293	65.25%	$173,313	$209,900	$12,625	$270	$22,597	-$23
Last Added Analysis of Detention Based Formulated Plan											
	FNH.3+JR.4+GBW.3+HOL.3+GE200.2 +RG.1	$29,689	$24,292		45.00%	$126,585	$153,308	$9,221		$15,071	
DA_LA1	Detention Formulated Plan - FNH.3	$36,356	$17,625	$6,667	32.65%	$81,397	$98,581	$5,930	$3,292	$11,696	-$3,375
DA_LA2	Detention Formulated Plan - JR.4	$33,998	$19,983	$4,309	37.02%	$109,338	$132,420	$7,965	$1,256	$12,018	-$3,053
DA_LA3	Detention Formulated Plan - GBW.3	$33,040	$20,941	$3,351	38.79%	$108,314	$131,180	$7,890	$1,331	$13,050	-$2,020
DA_LA4	Detention Formulated Plan - HOL.3	$32,977	$21,004	$3,288	38.91%	$98,052	$118,751	$7,143	$2,079	$13,861	-$1,209
DA_LA5	Detention Formulated Plan - GE200.2	$32,100	$21,881	$2,411	40.53%	$119,140	$144,291	$8,679	$542	$13,202	-$1,869
DA_LA6	Detention Formulated Plan - RG.1	$30,721	$23,260	$1,032	43.09%	$116,685	$141,318	$8,500	$721	$14,760	-$311

14.0 PLAN OPTIMIZATION

The results of the last-added analysis indicate that all components in the three formulated alternative plans are economically justified and contribute positive net economic benefits to the formulated plans. Each component of the formulated alternatives was subjected to a refinement/optimization analysis to see if costs of the alternative could be reduced. Basically, it was a further re-optimization of the component sizes. The plan formulation process showed that the detention based alternative produced significantly lower benefits than either of the channel anchor alternatives. The detention alternative was formulated primarily because of public interest in a detention plan. Although it produced substantial flood risk reduction, the net economic benefits were more than 20 percent lower than the TG.2 alternative and more than 30 percent lower than the TG.8 alternative. Because further re-optimization of the components for the detention anchor plan was unlikely to result in net benefits that exceed either channel anchor alternative, the detention anchor alternative was not considered in the plan refinement process.

At this stage in the analysis, an adjustment was made to the HEC-FDA model. The finished floor elevation of a 392-unit multi-family residence located on Watonga Boulevard was raised from 62.01 feet to 63.48 feet because it was decided that the mean LIDAR elevation would be more representative than the LIDAR elevation at the parcel centroid. The mean LiDAR elevation represents a computed average of the ground elevations for each structure within the parcel. This adjustment was used in all subsequent HEC-FDA runs.

14.1 TG.8 Refinement

The formulated TG.8 plan from Step 9 was used as the base in the final optimization process. A total of thirteen refinement steps were performed to see which combination of components produced the highest net EA benefits. These steps can be seen in detail in **Table 14**. Two of the components in the base plan were found to have more optimal configurations. Alternative TG8-RF7 incorporates these changes and is the best performing alternative. Shortening the upper reach channel component (E200H.3) by ending it at FM 1960 instead of Huffmeister Road added $181,000 in incremental net benefits. This new component was labeled E200H.3A. TG8-RF7 also had smaller detention facilities at Gessner Road and Beltway 8. Using the 147 ac-ft GBW.1 detention facility instead of the 345 ac-ft GBW.2 facility added $24,000 in incremental net benefits to the plan. This re-optimized TG.8 plan had total net EA benefits of $21.1 million.

Once this plan was found, a non-structural component analysis was performed on a property-by-property basis. Each structure that had residual flooding with the TG8-RF7 plan in place was analyzed for buyout and structure elevation.

Structures that are located downstream of IH-610 were not considered in this analysis as all structural and non-structural projects in this location are to be evaluated as part of the Buffalo Bayou project. Benefits were computed using a manual integration of the damages for each structure as determined from the structure detail output of the HEC-FDA model. Non-physical costs avoided (as discussed in **Sections 9.0-9.5**) were also added as benefits on a per flooded residential unit basis. Benefits were computed in accordance with WRDA 1999. A further explanation of benefit computation can be found in **Sections 12.5 and 12.6**.

Costs of each individual buyout were computed using the guidelines provided by the HCFCD Buyout Section. Costs of each individual structure raise were estimated in accordance with the USACE document *Flood Proofing, How to Evaluate Your Options* (Reference 28). The specific costs used for the capital cost estimations are outlined in **Sections 12.5 and 12.6**. Properties with BCRs of at least 1.1 for buyout or 1.05 for structure raising were included in the optimized plan. This was to account for uncertainty as the individual structure EADs resulted from a manual integration without risk. One property met this feasibility requirement under the TG8-RF7 plan – a group of apartments located on T.C. Jester Boulevard. These structures were removed from the HEC-FDA model and the structures from the 20 percent buyout plan were re-added. This was to see which buyout plan resulted in the greatest net EA benefits. The buyout of the apartment complex instead of the 34 structures in the 20 percent buyout plan resulted in incremental net EA benefits of $52,000, so it was determined to be the optimized size for the non-structural buyout component. The refined TG.8 plan (TG8-RF23) produced total net EA benefits of $21.0 million.

As the GE200 component in its present form in the project was deemed non-constructible due to the slop stability concerns identified from preliminary geotechnical investigations, an analysis was performed to see if other variations of this component were economically justified for inclusion in the optimized plan. GE200.7 was the modified component that was included in the plan. This reduced net EA benefits by $812,000. This formulated TG.8 plan has total net EA benefits of $20.2 million. The TWLY.3 component was also deemed non-constructible due to the discovery of hazardous material on the site and was subsequently removed from the formulated plan. This further reduced net EA benefits by $1.6 million. The resulting TG8 plan, RF25, has total net EA benefits of $18.6 million.

Table 14
TG.8 Formulated Plan Refinement Analysis
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Change in EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Change in EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Change in Net EA Benefits ($1,000)
	Base Without Project Condition	**$53,430**										
	TG.8+JR.4+GBW.2+E200H.3+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	**$17,872**	**$35,558**		**66.55%**	**$203,700**	**$246,704**	**$14,839**		**2.40**	**$20,719**	
Refinement Step 1: to optimize upstream channel												
TG8-RF1	TG.8+JR.4+GBW.2+**E200H.3A**+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	**$17,922**	**$35,508**	**-$50**	**66.46%**	**$200,537**	**$242,872**	**$14,608**	**-$230**	**2.43**	**$20,900**	**$181**
TG8-RF2	TG.8+JR.4+GBW.2+**E200H.3B**+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$18,826	$34,604	-$954	64.77%	$196,661	$238,178	$14,326	-$513	2.42	$20,278	-$441
Refinement Step 2: to optimize TG.8												
TG8-RF3	**TG.8A**+JR.4+GBW.2+E200H.3A+TWLY.3 + FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$19,697	$33,732	-$1,776	63.13%	$187,949	$227,627	$13,691	-$917	2.46	$20,041	-$859
TG8-RF4	**TG.8B**+JR.4+GBW.2+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$21,364	$32,066	-$3,443	60.01%	$166,279	$201,382	$12,113	-$2,496	2.65	$19,953	-$947
Refinement Step 3: to optimize Detention Facilities JR												
TG8-RF5	TG.8B+**JR.3**+GBW.2+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$18,444	$34,986	-$522	65.48%	$195,726	$237,046	$14,258	-$350	2.45	$20,728	-$172
TG8-RF6	TG.8B+**JR.5**+GBW.2+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$17,890	$35,540	$32	66.52%	$212,668	$257,564	$15,492	$884	2.29	$20,048	-$852
Refinement Step 4: to optimize Detention Facilities GBW												
TG8-RF7	TG.8B+JR.3+**GBW.1**+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	**$18,460**	**$34,970**	**-$538**	**65.45%**	**$192,823**	**$233,530**	**$14,046**	**-$562**	**2.49**	**$20,924**	**$24**
TG8-RF8	TG.8B+JR.3+**GBW.3**+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$17,903	$35,526	$18	66.49%	$206,066	$249,569	$15,011	$403	2.37	$20,515	-$384
TG8-RF9	TG.8B+JR.3+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$19,094	$34,335	-$1,173	64.26%	$186,029	$225,301	$13,552	-$1,057	2.53	$20,784	-$116
Refinement Step 5: to optimize Detention Facilities TWLY												
TG8-RF10	TG.8B+JR.3+GBW.1+E200H.3A+**TWLY.2.5**+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$18,885	$34,545	-$425	64.66%	$187,136	$226,643	$13,632	-$414	2.53	$20,913	-$11
TG8-RF11	TG.8B+JR.3+GBW.1+E200H.3A+**TWLY.3.5**+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$18,217	$35,213	$243	65.90%	$198,510	$240,418	$14,461	$414	2.44	$20,752	-$172
Refinement Step 6: to optimize Detention Facilities FNH												
TG8-RF12	TG.8B+JR.3+GBW.1+E200H.3A+TWLY.3+ **FNH.0** + GE200.0 + NSB_20% + NHR.1+ RG.0	$19,491	$33,939	-$1,031	63.52%	$181,943	$220,354	$13,254	-$793	2.56	$20,685	-$239
TG8-RF13	TG.8B+JR.3+GBW.1+E200H.3A+TWLY.3+ **FNH.2** + GE200.0 + NSB_20% + NHR.1+ RG.0	$17,985	$35,445	$475	66.34%	$207,128	$250,855	$15,089	$1,042	2.35	$20,356	-$567

Table 14 cont.
TG.8 Formulated Plan Refinement Analysis
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Change in EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Change in EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Change in Net EA Benefits ($1,000)
Refinement Step 7: to optimize Bypass Channel GE200												
TG8-RF14	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.1 + **GE200.2** + NSB_20% + NHR.1+ RG.0	$18,285	$35,145	$175	65.78%	$198,765	$240,726	$14,479	$433	2.43	$20,666	-$258
TG8-RF15	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.1 + **GE200.5** + NSB_20% + NHR.1+ RG.0	$18,496	$34,934	-$36	65.38%	$200,202	$242,467	$14,584	$538	2.40	$20,350	-$574
Refinement Step 8: to optimize Detention Facilities NHR												
TG8-RF16	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.0 + GE200.0 + NSB_20% + **NHR.0**+ RG.0	$19,138	$34,291	-$679	64.18%	$187,889	$227,554	$13,687	-$359	2.51	$20,604	-$319
TG8-RF17	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.0 + GE200.0 + NSB_20% + **NHR.2**+ RG.0	$18,191	$35,239	$269	65.95%	$199,373	$241,462	$14,524	$477	2.43	$20,715	-$208
Refinement Step 9: to optimize Detention Facilities RG												
TG8-RF18	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.0 + GE200.0 + NSB_20% + NHR.1+ **RG.1**	$18,016	$35,413	$443	66.28%	$198,991	$241,000	$14,496	$449	2.44	$20,917	-$6
TG8-RF19	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.0 + GE200.0 + NSB_20% + NHR.1	$19,059	$34,370	-$600	64.33%	$189,125	$229,051	$13,777	-$269	2.49	$20,593	-$330
Refinement Step 10: to optimize Detention Facilities TWLY.3												
TG8-RF20	TG.8+JR.4+GBW.1+E200H.3A+**TWLY.3B**+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$20,618	$32,812	-$2,158	61.41%	$178,782	$216,524	$13,024	-$1,023	2.52	$19,788	-$1,136
TG8-RF21	TG.8+JR.4+GBW.1+E200H.3A+**TWLY.3C**+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$20,582	$32,847	-$2,123	61.48%	$179,502	$217,396	$13,076	-$970	2.51	$19,771	-$1,152
TG8-RF22	TG.8+JR.4+GBW.1+E200H.3A+**TWLY.3D**+ FNH.1 + GE200.0 + NSB_20% + NHR.1+ RG.0	$20,567	$32,863	-$2,107	61.51%	$180,189	$218,228	$13,126	-$920	2.50	$19,736	-$1,187
Refinement Step 11: to optimize Non-structural Buyout												
TG8-RF23	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.1 + GE200.0 + NHR.1+ RG.0 + **NSB_1**	**$18,778**	**$34,652**	**-$318**	**64.86%**	**$187,747**	**$227,382**	**$13,677**	**-$370**	**2.53**	**$20,975**	**$52**
Refinement Step 12: to optimize Bypass Channel GE200												
TG8-RF24	TG.8+JR.4+GBW.1+E200H.3A+TWLY.3+ FNH.1 + **GE200.7** + NHR.1+ RG.0 + NSB_1	**$19,464**	**$33,966**	**-$686**	**63.57%**	**$189,478**	**$229,478**	**$13,803**	**$126**	**2.46**	**$20,163**	**-$812**
Refinement Step 13: Removing TWLY												
TG8-RF25	TG.8+JR.4+GBW.1+E200H.3A+ FNH.1 + GE200.7 + NHR.1+ RG.0 + NSB_1	**$22,679**	**$30,751**	**-$3,215**	**57.55%**	**$166,729**	**$201,928**	**$12,146**	**-$1,657**	**2.53**	**$18,605**	**-$1,558**

14.2 TG.2 Refinement

The formulated TG.2 plan from Step 8 of the plan formulation process was the base plan that was used in the final optimization. A total of eleven steps are completed that refine various components of the TG.2 formulated plan. These steps can be seen in detail in **Table 15**.

Using a 522 ac-ft facility at Hollister Road (HOL.2) instead of a 730 ac-ft facility (HOL.3) added a total of $1.8 million in incremental net benefits. Shortening the upstream channel component by ending it at FM 1960 instead of Huffmeister Road (E200H.2A instead of E200H.2) added $177,000 in net EA benefits. Optimizing the TG.2 channel component by ending it at Fairbanks-North Houston Road instead of Gessner Road (replacing TG.2 with TG.2A) increased net EA benefits by $140,000.

Increasing the size of the Gessner Road/Beltway 8 detention facility from 345 ac-ft (GBW.2) to 437 ac-ft (GBW.3) increased net EA benefits by $292,000. The detention facility at Fairbanks-North Houston Road was increased in size from 843 ac-ft (FNH.1) to 1,717 ac-ft (FNH.3) which added $1.8 million in incremental net EA benefits. Decreasing the size of the Rio Grande Road detention facility from 399 ac-ft (RG.2) to 277 ac-ft (RG.1) added incremental net benefits of $19,000. The Tidwell-West Little York detention facility was deemed non-constructible due to real project constraints and was subsequently removed from the formulated plan, which decreased net EA benefits by $107,000. The GE200.0 bypass channel was deemed non-constructible and was removed, which decreased net EA benefits by $1.4 million. It was then replaced with GE200.7 which added $869,000 in net EA benefits.

In the next step of the refinement, a non-structural component analysis was performed on a parcel-by-parcel basis. Each structure that had residual flooding with the TG.2 plan in place was analyzed for buyout and structure raising. Structures that are located downstream of IH-610 were not considered in this analysis as they will be analyzed at a later time as part of the Buffalo Bayou project. Benefits were computed using a manual integration of the damages for each structure as produced by the HEC-FDA model. Non-physical costs avoided (as discussed in **Sections 9.0-9.5**) were also added as benefits on a per flooded residential unit basis. A reduction in damages to vehicles was not considered for structure-raising as raising a structure does not include raising a garage or driveway, so vehicle damages would remain the same. Benefits were computed in accordance with WRDA 1999.

Costs of buyout were computed using the guidelines provided by the HCFCD Buyout Section. Costs of structure raising were estimated in accordance with the USACE document *Flood Proofing, How to Evaluate Your Options* (Reference 28). The specific costs used for the capital cost estimations are outlined in

Sections 12.5 and 12.6. To account for uncertainty, properties with BCRs of at least 1.1 for buyout or 1.05 for structure raising were included in the optimized plan. One property met all of these feasibility requirements – a group of apartments on T.C. Jester Boulevard. These apartments had greater net benefits under a buyout plan than under a structure raising plan. This project was incorporated into the HEC-FDA model, which resulted in $266,000 incremental net benefits. This increased the total net EA benefits to $21.4 million. The refined TG2 plan is labeled RF23.

A last-added analysis was performed to determine if all optimized components were economically justified for inclusion in the optimized TG2 plan. As all last-added run resulted in fewer net EA benefits than RF23, it was determined that all components were economically justified.

Following these steps, the Local Sponsor decided that additional modifications to components TG.2A, GE200.7 and HOL.2 would be evaluated for flood risk management and economic benefits, as potential Locally Preferred Plans (LPP's).

Modifications to these components consisted of the following:

(1) TG.2A – the channel cross-section was modified in the reach from Station 77625 near the Hollister (HOL) detention basin to Gessner Road and in an alternative smaller reach length.
(2) GE200.7 – the combined Jersey Village Channel and E141 were added to GE200.7.
(3) HOL.2 – the storage volume was initially increased to as much as 1,100 acre-feet within the land area for TG.2 The increased volume would be added by deepening the basin, without additional land acquisition.

Initially two alternative options were evaluated. These two are described as followed.

(1) TG2-RF24 – the same as TG2-RF23 except:
  - TG.2A was changed to TG.2A1, which has a revised cross-section from Station 77625 near the Hollister detention basin up to Station 86621 at Gessner Road.
  - GE200.7 was changed to GE200.7A which adds the Jersey Village Channel and the E141 connection to White Oak Bayou. HOL.2 was changed to HOL.5, which has a volume of 1,100 acre-feet within the land area of HOL.2.

(2) TG2-RF25 – the same as TG2-RF24 except the revised cross-section for TG2.A extends only from the upstream side of the Fairbanks – North Houston Road Bridge at Station 87025 upstream to Station 86621 at Gessner Road. This component was called TG.2A3.

The results of the analyses are presented in Table 4-24. They show that of these two alternatives, TG2-RF25 has the higher net benefits, $21,414,000. These results were compared to TG2-RF23, and they show that TG2-RF25 generates net benefits approximately $44,000 higher than TG2-RF23.

To check that all the different component changes made to TG2-RF23 as part of TG2-RF25 add net benefits, a last-added analysis of these components was performed. Each of the revised components, TG.2A3, GE200.7A, and HOL.5, were removed as last-added components. In the case of HOL.5, two last-added runs were made, one removing the entire Hollister basin, and the other reducing the volume to the same as HOL.2. The results presented in Table 4-24 show that all the components add net benefits to TG2-RF25. The results for the Hollister basin show that HOL. 2 adds more benefits than HOL.5. These results indicate that the Hollister basin size was not optimized for this set of components. To optimize the size of the basin, additional volumes of the basin were considered, including 444 acre-feet (HOL.1), 730 acre-feet (HOL.3) with additional land acquired, and 730 acre-feet without additional land (HOL.3B). The results in Table 4-24 show that TG2-RF28, which has the HOL.3B basin volume, generated net benefits of $21,726,000, approximately $356,000 more than TG2-RF23, and $312,000 more than TG2-RF25.

An additional plan (TG2-RF29) was then evaluated that was the same as TG2-RF28 except that the TG.2A1 channel modifications were substituted for the TG.2A3 channel modifications. The resulting net benefits of $21,897,000 for TG2-RF29, shown in Table 4-24, are approximately $527,000 more than TG2-RF23, and $171,000 more then TG2-RF28.

Based on the results of the additional evaluation TG2-RF29 is the optimum TG.2 plan.

Table 15
TG.2 Formulated Plan Refinement Analysis
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Change in EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Change in EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Change in Net EA Benefits ($1,000)
	Base Without Project Condition	$53,430										
	TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+E200H.2 +GE200.0+ TWLY.2	$23,604	$29,825		55.82%	$143,352	$173,615	$10,443			$19,383	
	TG.2+JR.4+**HOL.3**+GBW.2+FNH.1+RG.2+E200H.2+GE200 .0+ TWLY.2	$23,604	$29,825		55.82%	$169,591	$205,393	$12,354	$1,911	2.41	$17,471	-$1,911
Refinement Step 1: Updating Detention Facility HOL												
TG2-RF1	TG.2+JR.4+**HOL.2**+GBW.2+FNH.1+RG.2+ E200H.2+GE200.0+ TWLY.2	$24,325	$29,104	-$721	54.47%	$135,405	$163,990	$9,864	-$2,490	2.95	$19,240	$1,769
Refinement Step 2: Optimize upper limit of project												
TG2-RF2	TG.2+JR.4+HOL.2+GBW.2+FNH.1+RG.2+ **E200H.2A**+GE200.0+ TWLY.2	$24,314	$29,115	$11	54.49%	$133,135	$161,241	$9,698	-$165	3.00	$19,417	$177
TG2-RF3	TG.2+JR.4+HOL.2+GBW.2+FNH.1+RG.2+ **E200H.2B**+GE200.0+ TWLY.2	$25,019	$28,411	-$693	53.17%	$131,562	$159,335	$9,584	-$280	2.96	$18,827	-$413
Refinement Step 3: to optimize TG.2												
TG2-RF4	**TG.2A**+JR.4+HOL.2+GBW.2+FNH.1+RG.2+E200H .2A+GE200.0+ TWLY.2	$24,793	$28,637	-$479	53.60%	$124,634	$150,945	$9,079	-$619	3.15	$19,557	$140
TG2-RF5	**TG.2B**+JR.4+HOL.2+GBW.2+FNH.1+RG.2+E200H .2A+GE200.0+ TWLY.2	$30,079	$23,351	-$5,765	43.70%	$119,518	$144,750	$8,706	-$992	2.68	$14,644	-$4,773
TG2-RF6	**TG.2C**+JR.4+HOL.2+GBW.2+FNH.1+RG.2+E200H .2A+GE200.0+ TWLY.2	$33,526	$19,903	-$9,212	37.25%	$105,606	$127,900	$7,693	-$2,005	2.59	$12,210	-$7,207
Refinement Step 4: to optimize Detention Facilities (JR)												
TG2-RF7	TG.2A+**JR.3**+HOL.2+GBW.2+FNH.1+RG.2+E200H. 2A+GE200.0+ TWLY.2	$25,872	$27,557	-$1,079	51.58%	$119,823	$145,119	$8,729	-$350	3.16	$18,829	-$729
TG2-RF8	TG.2A+**JR.5**+HOL.2+GBW.2+FNH.1+RG.2+E200H. 2A+GE200.0+ TWLY.2	$24,324	$29,106	$469	54.47%	$136,765	$165,637	$9,963	$884	2.92	$19,143	-$414
Refinement Step 5: to optimize Detention Facilities (HOL)												
TG2-RF9	TG.2A+JR.4+**HOL.1**+GBW.2+FNH.1+RG.2+E200H .2A+GE200.0+ TWLY.2	$25,805	$27,624	-$1,012	51.70%	$120,836	$146,346	$8,802	-$277	3.14	$18,822	-$736
TG2-RF10	TG.2A+JR.4+**HOL.3**+GBW.2+FNH.1+RG.2+E200H .2A+GE200.0+ TWLY.2	$24,222	$29,208	$571	54.67%	$158,820	$192,349	$11,569	$2,490	2.52	$17,638	-$1,919
Refinement Step 6: to optimize Detention Facilities (GBW)												
TG2-RF11	TG.2A+JR.4+HOL.2+**GBW.3**+FNH.1+RG.2+E200H. 2A+GE200.0+ TWLY.2	$24,098	$29,332	$695	54.90%	$130,163	$157,642	$9,482	$403	3.09	$19,850	$292
TG2-RF12	TG.2A+JR.4+HOL.2+**GBW.4**+FNH.1+RG.2+E200H. 2A+GE200.0+ TWLY.2	$23,314	$30,116	$1,479	56.37%	$145,379	$176,070	$10,590	$1,511	2.84	$19,526	-$32
Refinement Step 7: to optimize Detention Facilities (FNH)												
TG2-RF13	TG.2A+JR.4+HOL.2+GBW.3+**FNH.0**+RG.2+E200H. 2A+GE200.0+ TWLY.2	$25,566	$27,864	-$1,468	52.15%	$119,283	$144,465	$8,689	-$793	3.21	$19,175	-$675
TG2-RF14	TG.2A+JR.4+HOL.2+GBW.3+**FNH.2**+RG.2+E200H. 2A+GE200.0+ TWLY.2	$22,030	$31,400	$2,068	58.77%	$144,468	$174,966	$10,524	$1,042	2.98	$20,876	$1,026
TG2-RF15	TG.2A+JR.4+HOL.2+GBW.3+**FNH.3**+RG.2+E200H. 2A+GE200.0+ TWLY.2	$20,065	$33,364	$4,033	62.45%	$160,288	$193,982	$11,676	$2,195	2.86	$21,688	$1,838
TG2-RF16	TG.2A+JR.4+HOL.2+GBW.3+**FNH.4**+RG.2+E200H. 2A+GE200.0+ TWLY.2	$20,035	$33,394	$4,063	62.50%	$173,711	$210,383	$12,654	$3,172	2.64	$20,740	$890

Table 15 cont.
TG.2 Formulated Plan Refinement Analysis
Values in $1,000s, February 2002 Price Levels With FY 2008 Interest Rate 4.875%

ID	Plan	EA Damages ($1,000)	EA Benefits ($1,000)	Change in EA Benefits ($1,000)	Percent Damage Reduced	Capital Cost ($1,000)	Base Year Equivalent Cost1 ($1,000)	EA Cost ($1,000)	Change in EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Change in Net EA Benefits ($1,000)
Refinement Step 8: to optimize Detention Facilities (RG)												
TG2-RF17	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+**RG.1**+E200H.2A+GE200.0+ TWLY.2	**$20,383**	**$33,047**	**-$317**	**61.85%**	**$155,673**	**$188,537**	**$11,340**	**-$336**	**2.91**	**$21,707**	**$19**
TG2-RF18	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+**RG.3**+E200H.2A+GE200.0+ TWLY.2	$19,394	$34,035	$671	63.70%	$190,582	$230,816	$13,883	$2,207	2.45	$20,152	-$1,536
TG2-RF19	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+**RG.0**+E200H.2A+GE200.0+ TWLY.2	$21,225	$32,205	-$1,159	60.28%	$149,506	$181,068	$10,891	-$785	2.96	$21,314	-$374
Refinement Step 9: removing TWLY.2												
TG2-RF20	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.0	**$21,167**	**$32,263**	**-$784**	**60.38%**	**$146,367**	**$177,267**	**$10,662**	**-$678**	**3.03**	**$21,600**	**-$107**
Refinement Step 10: Updating GE200												
TG2-RF21	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+ E200H.2A	**$22,639**	**$30,790**	**-$1,472**	**57.63%**	**$144,890**	**$175,477**	**$10,555**	**-$108**	**2.92**	**$20,236**	**-$1,365**
TG2-RF22	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+**GE200.7**	**$21,653**	**$31,777**	**$986**	**59.47%**	**$146,507**	**$177,436**	**$10,672**	**$118**	**2.98**	**$21,104**	**$869**
Refinement Step 11: Adding Non-Structurals												
TG2-RF23	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+**NSB_1**	**$21,153**	**$32,277**	**$500**	**62.35%**	**$149,715**	**$181,321**	**$10,906**	**$234**	**2.96**	**$21,370**	**$266**
Last Added Analysis												
TG2-RF23-LA1	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+GE200.7+NSB_1	$22,926	$30,504	-$1,773	57.14%	$140,755	$166,398	$10,009	-$897	3.05	$20,496	-$874
TG2-RF23-LA2	TG.2A+JR.4+HOL.2+GBW.3+RG.1+E200H.2A+GE200.7+NSB_1	$27,208	$26,222	-$6,055	49.13%	$104,490	$122,478	$7,367	-$3,539	3.56	$18,855	-$2,515
TG2-RF23-LA3	TG.2A+JR.4+HOL.2+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1	$23,062	$30,368	-$1,909	56.89%	$129,558	$152,837	$9,193	-$1,713	3.30	$21,175	-$195
TG2-RF23-LA4	TG.2A+JR.4+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1	$23,154	$30,276	-$2,001	56.71%	$130,748	$154,279	$9,280	-$1,626	3.26	$20,996	-$374
TG2-RF23-LA5	TG.2A+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1	$24,466	$28,964	-$3,313	54.26%	$132,402	$156,281	$9,400	-$1,506	3.08	$19,564	-$1,806
TG2-RF23-LA6	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+E200H.2A+GE200.7+NSB_1	$22,243	$31,187	-$1,090	58.42%	$139,729	$165,156	$9,934	-$972	3.14	$21,253	-$117
TG2-RF23-LA7	JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1	$26,437	$26,993	-$5,284	50.58%	$124,714	$146,970	$8,840	-$2,066	3.05	$18,153	-$3,217
TG2-RF23-LA8	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+NSB_1	$22,141	$31,289	-$988	58.61%	$147,978	$175,146	$10,535	-$371	2.97	$20,754	-$616
Additional Component Analysis												
TG2-RF24	TG.2A1+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,491	$33,938	$1,662	63.52%	$175,444	$212,482	$12,780	$1,874	2.66	$21,158	-$212
TG2-RF25	TG.2A3+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,267	$34,162	$1,886	63.94%	$175,000	$211,945	$12,748	$1,842	2.68	$21,414	$44
Last Added Analysis												
TG2-RF25-LA1	TG.2A3+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1	$22,504	$30,926	-$1,351	57.88%	$168,456	$204,018	$12,271	$1,365	2.52	$18,654	-$2,760
TG2-RF25-LA2	TG.2A3+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$20,068	$33,361	$1,085	62.44%	$162,049	$196,259	$11,805	$899	2.83	$21,557	$143
TG2-RF25-LA3	TG.2A3+JR.4+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1+LLP03	$23,088	$30,342	-$1,935	56.79%	$143,202	$173,433	$10,432	-$474	2.91	$19,910	-$1,504
TG2-RF25-LA4	TG.2A+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$21,139	$32,291	$14	60.44%	$169,211	$204,933	$12,236	$1,420	2.62	$19,965	-$1,449
Hollister Optimization (compare to TG2-RF25)												
TG2-RF26	TG.2A3+JR.4+HOL.1+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$21,219	$32,210	-$66	60.29%	$158,251	$191,659	$11,528	$622	2.79	$20,682	-$732
TG2-RF27	TG.2A3+JR.4+HOL.3+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,619	$33,810	$1,534	63.28%	$171,740	$207,996	$12,511	$1,604	2.70	$21,300	-$114
TG2-RF28	TG.2A3+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,575	$33,855	$1,579	63.36%	$166,503	$201,653	$12,129	$1,223	2.79	$21,726	$312
TG2-RF29	TG.2A1+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,372	$34,058	$1,782	63.74%	$166,946	$202,190	$12,161	$1,255	2.80	$21,897	$483

15.0 ANALYSIS OF BEST ALTERNATIVES

Once the optimal combinations for each alternative were found, a comparative analysis of plan economics was conducted. This analysis took into account the costs and benefits associated with each plan, including the probabilistic summary of net benefits. **Table 16** provides a summary of this analysis. A comparison of all final alternatives with the without project conditions can be seen in the economic damage profiles shown in **Exhibit 5**.

15.1 Reduced Damages and Net EA Benefits

The formulated detention plan (DA_4.8) consists of five detention components and one channel component. For comparison purposes, this plan was re-run in the adjusted HEC-FDA model that was used in the plan optimization stage. The residual annual equivalent damages for DA_4.8 are $29 million. This is 45 percent less than the Without Project damages of $53 million. Its net EA benefits are $15.0 million. DA_4.8 has a 75 percent chance of producing annual net benefits greater than -$160,000, a 50 percent chance of producing annual net benefits greater than $8.9 million, and a 25 percent chance of producing annual net benefits greater than $24.3 million. During the computation of AAE benefits, the current version of the HEC-FDA model obtains the mean of values from probability-damage curves that have been truncated to avoid negative damages. However, median values shown in the risk columns are determined from the full range of sampled damage values thus resulting in a discrepancy between the AAE benefits and the median benefits although they theoretically belong to the same probability distribution. The probability that the annual net benefits exceed the expected $15 million is 38 percent.

The TG.8 optimized plan (TG8-RF25) consists of three channel components, five detention components, and one non-structural component. It has residual damages of $22.7 million, which is a $30.8 million (58 percent) reduction from the Without Project condition. The net EA benefits for TG8-RF25 are $18.6 million. TG8-RF25 has a 75 percent chance of producing annual net benefits greater than -$2.5 million, a 50 percent chance of producing annual net benefits greater than $7.7 million, and a 25 percent chance of producing net benefits greater than $29.6 million. At the 25 percent level, the TG.8 plan has greater annual net benefits than the detention plan. However, at the 75 percent level, the TG.8 plan has lower net benefits than the detention plan. This is an indicator of the greater amount of risk that is associated with the TG.8 plan. The probability that the net benefits exceed the expected $18.6 million for this million is 36 percent.

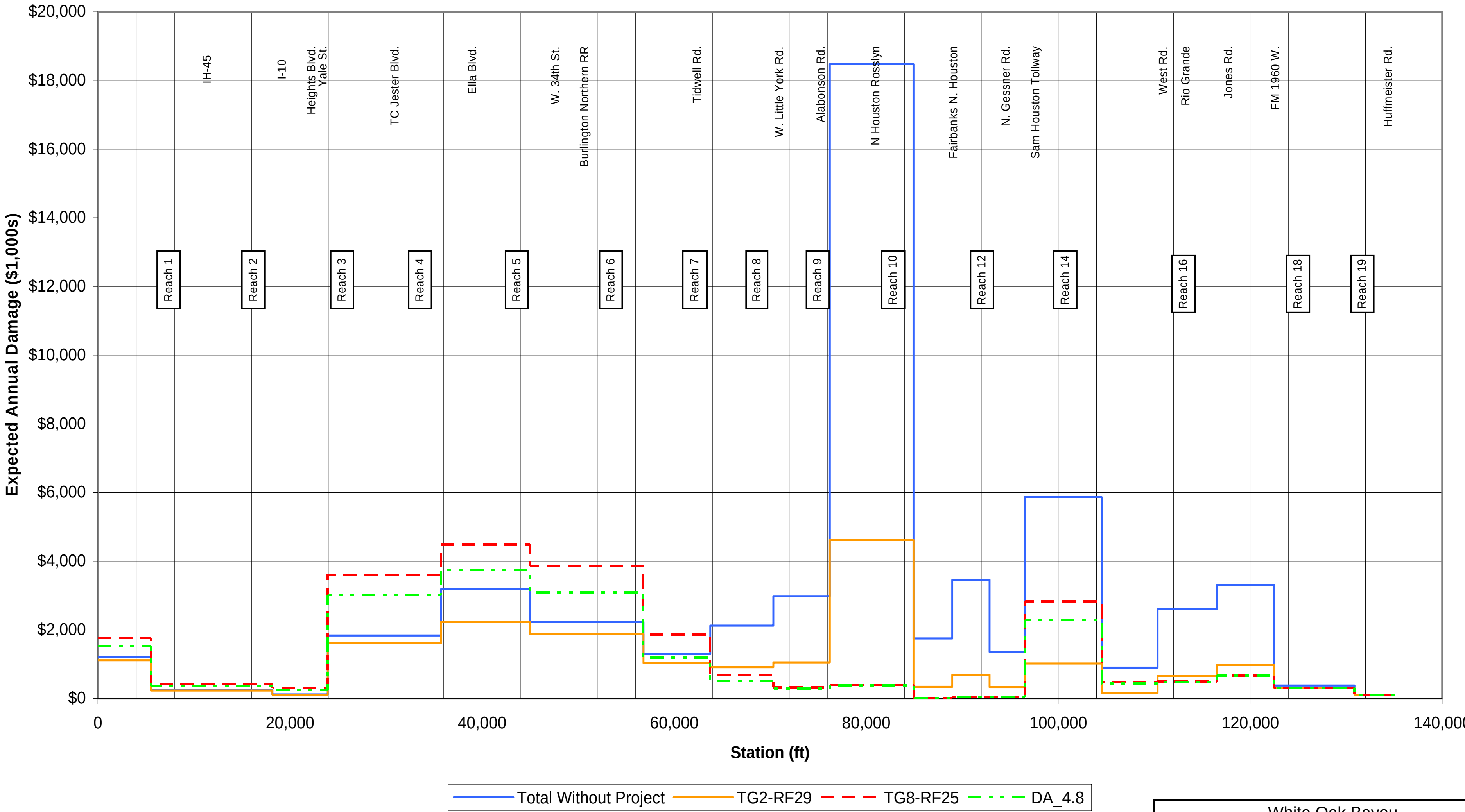
The TG.2 optimized plan (TG2-RF29) includes three channel components, five detention components, and one non-structural component. The residual expected annual damages with the TG.2 plan in place are $19.37 million. This is $35.1 million (59 percent) less than the Without Project condition. The net EA benefits for the plan are $20.27 million. Of the three optimized plans, TG2-RF29 has the highest net EA benefits. It was therefore selected as the National Economic Development (NED) plan. TG2-RF29 also has a 50 percent chance of producing annual net benefits greater than $10.13 million, and a 25 percent chance of producing annual net benefits greater than $32.78 million. This exceeds both TG8-RF25 and DA_4.8 annual net benefits at all probability levels. This reinforces the selection of TG2-RF29 as the NED plan. The probability that the annual net benefits exceed the expected $20.27 million is 41 percent.

Table 16
Summary of Net Economic Benefits and Costs for Optimized Plans
Dollar Values in $Millions, February 2002 Price Levels With FY 2008 Interest Rate 4.875%
(Expected Value and Probabilistic Value of Net Benefits)

		Average Annual National Economic Benefit						Probability Net Benefit Exceeds Indicated Amounts		
Project Alternative	Average Annual Damages	Average Annual Benefits	Costs	Average Annual Costs	Average Annual Net Benefits	Probability of AA Net Benefits	Benefit-Cost Ratio	0.75	0.50	0.25
DA_4.8	$19.39	$35.03	$126.59	$9.22	$25.81	0.38	3.80	$3.11	$15.61	$39.05
TG8-RF25	$22.68	$30.75	$166.73	$12.15	$18.60	0.36	2.53	-$2.46	$7.70	$29.59
TG2-RF29	$19.37	$34.06	$166.95	$13.79	$20.27	0.41	2.47	-$1.91	$10.13	$32.78

Note: AAE Damages for Without Project Conditions computed at $53.4 million

White Oak Bayou Main Stem - Flood Damage Profile ("Best Plan" Comparisons)



White Oak Bayou Section 211(f) Federal Project
Flood Damage Profile Best Plan Comparison
Harris County Flood Control District — Exhibit: 5

15.2 Project Performance

The three optimized plans (DA_4.8, TG8-RF25, and TG2-RF29) were also assessed as to their risk of exceeding specified target stages. Target stages were determined from Without Project condition stage-damage curves by computing, at each reach index location, a stage that, if exceeded, will result in substantial damages. Substantial damage is defined here as flood damage in excess of 5 percent of Without Project damages resulting from a 1 percent exceedance probability event. The risk of exceeding the target stage was evaluated on an annual as well as a long-term basis. In addition, the reliability during specified events (or conditional probability of non-exceedance) for each alternative was compared with the Without Project conditions in each reach.

Table 17 shows each plan's performance to reduce the annual risk of exceeding the target stage in each reach. As an example, in Reach-7, the Without Project condition has a 10.4 percent chance of exceeding the target stage in a given year. This probability is 8.1 percent for the optimized detention plan, 12.7 percent for the TG.8 optimized plan, and 8.2 percent for the TG.2 optimized plan.

Table 17 also shows long-term risk associated with each project. The probabilities of exceeding the target stage in 10, 25, and 50 years are shown. For example, the probability of exceeding the target stage in 10 years in Reach-7 is 66.7 percent for the Without Project condition, 57.0 percent for the optimized detention plan, 74.4 for the TG.8 optimized plan, and 57.6 percent for the TG.2 optimized plan.

Table 18 shows the conditional probabilities of each project containing a specific event. For example, the probability of containing a 2 percent exceedance probability event in Reach-7 is 5.4 percent for the Without Project condition, 10.9 percent for the optimized detention plan, 2.4 percent for the TG.8 optimized plan, and 9.8 percent for the TG.2 optimized plan.

Project performance for each project varies widely by reach. In the upper and middle reaches, the TG.8 plan tends to do better than the detention and TG.2 plans. However, in the downstream reaches, the TG.2 plan clearly does a better job of containing flood events and has a lower long-term risk. This is primarily due to the fact that the TG.8 plan increases water surface elevations downstream, which make it riskier than even the Without Project condition in those reaches. The TG.2 plan, however, consistently lowers risk in all reaches. The economic profiles of the TG.8, TG.2, and detention best performing plans are shown in Exhibit 5.

Table 17
Annual Performance and Equivalent Long-Term Risk
Future With-Project Conditions
Values in $1,000's, February 2002 Price Levels

Project Alternative	Target Stage (ft)	Annual Performance (Expected Annual Probability of Target Stage Being Exceeded)	Equivalent Long Term Risk		
			10 Years	25 Years	50 Years
Reach 1					
Without Project	32.96	0.0630	0.4789	0.8040	0.9616
DA_4.8	32.96	0.0540	0.4279	0.7524	0.9387
TG8-RF25	32.96	0.0820	0.5752	0.8824	0.9862
TG2-RF23	32.96	0.0580	0.4479	0.7736	0.9487
TG2-RF29	32.96	0.0530	0.4177	0.7412	0.9330
Reach 2					
Without Project	32.21	0.1040	0.6676	0.9363	0.9959
DA_4.8	32.21	0.0880	0.6029	0.9006	0.9901
TG8-RF25	32.21	0.1290	0.7474	0.9679	0.9990
TG2-RF23	32.21	0.0940	0.6272	0.9152	0.9928
TG2-RF29	32.21	0.0860	0.5923	0.8939	0.9887
Reach 3					
Without Project	44.17	0.0890	0.6054	0.9022	0.9904
DA_4.8	44.17	0.0720	0.5248	0.8443	0.9758
TG8-RF25	44.17	0.1240	0.7328	0.9631	0.9986
TG2-RF23	44.17	0.0760	0.5486	0.8631	0.9813
TG2-RF29	44.17	0.0740	0.5355	0.8530	0.9784
Reach 4a(L)					
Without Project	39.33	0.3700	0.9902	1.0000	1.0000
DA_4.8	39.33	0.3200	0.9788	0.9999	1.0000
TG8-RF25	39.33	0.4110	0.9950	1.0000	1.0000
TG2-RF23	39.33	0.3420	0.9848	1.0000	1.0000
TG2-RF29	39.33	0.3430	0.9849	1.0000	1.0000
Reach 4(R)					
Without Project	50.30	0.0740	0.5366	0.8538	0.9786
DA_4.8	50.30	0.0580	0.4515	0.7772	0.9504
TG8-RF25	50.30	0.1080	0.6815	0.9427	0.9967
TG2-RF23	50.30	0.0630	0.4795	0.8045	0.9618
TG2-RF29	50.30	0.0610	0.4696	0.7951	0.9580
Reach 4b(L)					
Without Project	50.38	0.0890	0.6069	0.9031	0.9906
DA_4.8	50.38	0.0700	0.5181	0.8388	0.9740
TG8-RF25	50.38	0.1250	0.7384	0.9650	0.9988
TG2-RF23	50.38	0.0760	0.5468	0.8617	0.9809
TG2-RF29	50.38	0.0740	0.5371	0.8542	0.9788
Reach 5					
Without Project	54.85	0.1580	0.8203	0.9863	0.9998
DA_4.8	54.85	0.1260	0.7411	0.9659	0.9988
TG8-RF25	54.85	0.1940	0.8845	0.9955	1.0000
TG2-RF23	54.85	0.1370	0.7721	0.9752	0.9994
TG2-RF29	54.85	0.1390	0.7550	0.9760	0.9994
Reach 6					
Without Project	62.25	0.0970	0.6406	0.9226	0.9940
DA_4.8	62.25	0.0780	0.5550	0.8679	0.9825
TG8-RF25	62.25	0.1350	0.7644	0.9730	0.9993
TG2-RF23	62.25	0.0840	0.5849	0.8890	0.9877
TG2-RF29	62.25	0.0820	0.5752	0.8824	0.9862
Reach 7					
Without Project	68.36	0.1040	0.6672	0.9361	0.9959
DA_4.8	68.36	0.0810	0.5698	0.8786	0.9853
TG8-RF25	68.36	0.1270	0.7443	0.9669	0.9989
TG2-RF23	68.36	0.0800	0.5674	0.8769	0.9848
TG2-RF29	68.36	0.0820	0.5762	0.8831	0.9863
Reach 8a(L)					
Without Project	71.48	0.1200	0.7210	0.9589	0.9983
DA_4.8	71.48	0.0720	0.5260	0.8453	0.9761
TG8-RF25	71.48	0.0770	0.5498	0.8640	0.9815
TG2-RF23	71.48	0.0780	0.5541	0.8672	0.9824
TG2-RF29	71.48	0.0760	0.5449	0.8603	0.9805
Reach 8(R)					
Without Project	72.67	0.2170	0.9129	0.9978	1.0000
DA_4.8	72.67	0.1030	0.6635	0.9343	0.9957
TG8-RF25	72.67	0.0620	0.4748	0.8001	0.9600
TG2-RF23	72.67	0.0920	0.6190	0.9104	0.9920
TG2-RF29	72.67	0.0960	0.6360	0.9201	0.9936
Reach 8b(L)					
Without Project	75.23	0.2040	0.8982	0.9967	1.0000
DA_4.8	75.23	0.0890	0.6042	0.9014	0.9903
TG8-RF25	75.23	0.0290	0.2576	0.5251	0.7745
TG2-RF23	75.23	0.0540	0.4273	0.7518	0.9384
TG2-RF29	75.23	0.0620	0.4742	0.7996	0.9598
Reach 9					
Without Project	77.36	0.3080	0.9749	0.9999	1.0000
DA_4.8	77.36	0.1270	0.7420	0.9662	0.9989
TG8-RF25	77.36	0.0290	0.2558	0.5222	0.7717
TG2-RF23	77.36	0.1150	0.7058	0.9531	0.9978
TG2-RF29	77.36	0.0820	0.5741	0.8816	0.9860

Table 17 cont.
Annual Performance and Equivalent Long-Term Risk
Future With-Project Conditions
Values in $1,000's, February 2002 Price Levels

Project Alternative	Target Stage (ft)	Annual Performance (Expected Annual Probability of Target Stage Being Exceeded)	Equivalent Long Term Risk		
			10 Years	25 Years	50 Years
Reach 10a(R)					
Without Project	80.58	0.2760	0.9606	0.9997	1.0000
DA_4.8	80.58	0.1240	0.7332	0.9632	0.9986
TG8-RF25	80.58	0.0190	0.1725	0.3771	0.6119
TG2-RF23	80.58	0.0740	0.5366	0.8538	0.9786
TG2-RF29	80.58	0.0720	0.5244	0.8440	0.9757
Reach 10a(L)					
Without Project	79.15	0.4230	0.9959	1.0000	1.0000
DA_4.8	79.15	0.2420	0.9373	0.9990	1.0000
TG8-RF25	79.15	0.0340	0.2943	0.5816	0.8250
TG2-RF23	79.15	0.1600	0.8243	0.9871	0.9998
TG2-RF29	79.15	0.1350	0.7653	0.9733	0.9993
Reach 10b(R)					
Without Project	85.62	0.4770	0.9985	1.0000	1.0000
DA_4.8	85.62	0.2570	0.9484	0.9994	1.0000
TG8-RF25	85.62	0.0050	0.0444	0.1072	0.2030
TG2-RF23	85.62	0.0860	0.5917	0.8935	0.9887
TG2-RF29	85.62	0.1350	0.7657	0.9734	0.9993
Reach 10b(L)					
Without Project	86.95	0.4670	0.9981	1.0000	1.0000
DA_4.8	86.95	0.2660	0.9543	0.9996	1.0000
TG8-RF25	86.95	0.0040	0.0436	0.1055	0.1999
TG2-RF23	86.95	0.0750	0.5433	0.8590	0.9801
TG2-RF29	86.95	0.1210	0.7260	0.9607	0.9985
Reach 11					
Without Project	90.37	0.4980	0.9990	1.0000	1.0000
DA_4.8	90.37	0.4290	0.9963	1.0000	1.0000
TG8-RF25	90.37	0.0130	0.1227	0.2791	0.4803
TG2-RF23	90.37	0.2620	0.9518	0.9995	1.0000
TG2-RF29	90.37	0.1190	0.7176	0.9576	0.9982
Reach 12					
Without Project	92.51	0.3690	0.9900	1.0000	1.0000
DA_4.8	92.51	0.2660	0.9548	0.9996	1.0000
TG8-RF25	92.51	0.0050	0.0493	0.1188	0.2235
TG2-RF23	92.51	0.1640	0.8325	0.9885	0.9999
TG2-RF29	92.51	0.0690	0.5125	0.8340	0.9725
Reach 13					
Without Project	96.64	0.2150	0.9117	0.9977	1.0000
DA_4.8	96.64	0.1200	0.7224	0.9594	0.9984
TG8-RF25	96.64	0.0070	0.0666	0.1584	0.2917
TG2-RF23	96.64	0.0970	0.6397	0.9221	0.9939
TG2-RF29	96.64	0.0410	0.3451	0.6529	0.6529
Reach 14					
Without Project	100.24	0.3160	0.9776	0.9999	1.0000
DA_4.8	100.24	0.1070	0.6773	0.9409	0.9965
TG8-RF25	100.24	0.1710	0.8464	0.9908	0.9999
TG2-RF23	100.24	0.1690	0.8427	0.9902	0.9999
TG2-RF29	100.24	0.0640	0.4866	0.8111	0.9643
Reach 15					
Without Project	105.31	0.2390	0.9351	0.9989	1.0000
DA_4.8	105.31	0.0780	0.5565	0.8690	0.9828
TG8-RF25	105.31	0.1210	0.7260	0.9607	0.9985
TG2-RF23	105.31	0.1110	0.6929	0.9477	0.9973
TG2-RF29	105.31	0.0550	0.4315	0.7563	0.9406
Reach 16					
Without Project	110.61	0.2070	0.9014	0.9969	1.0000
DA_4.8	110.61	0.1340	0.7622	0.9724	0.9992
TG8-RF25	110.61	0.0440	0.3621	0.6749	0.8943
TG2-RF23	110.61	0.0700	0.5146	0.8359	0.9731
TG2-RF29	110.61	0.0610	0.4661	0.7917	0.9566
Reach 17					
Without Project	117.04	0.1870	0.8735	0.9943	1.0000
DA_4.8	117.04	0.1430	0.7852	0.9786	0.9995
TG8-RF25	117.04	0.0410	0.3431	0.6503	0.8777
TG2-RF23	117.04	0.0600	0.4618	0.7875	0.9548
TG2-RF29	117.04	0.0570	0.4458	0.7713	0.9477
Reach 18					
Without Project	121.58	0.1410	0.7805	0.9774	0.9995
DA_4.8	121.58	0.1350	0.7663	0.9736	0.9993
TG8-RF25	121.58	0.1150	0.7039	0.9523	0.9977
TG2-RF23	121.58	0.1200	0.7216	0.9591	0.9983
TG2-RF29	121.58	0.1110	0.6931	0.9478	0.9973
Reach 19					
Without Project	124.23	0.2180	0.9148	0.9979	1.0000
DA_4.8	124.23	0.2170	0.9138	0.9978	1.0000
TG8-RF25	124.23	0.2150	0.9115	0.9977	1.0000
TG2-RF23	124.23	0.2160	0.9124	0.9977	1.0000
TG2-RF29	124.23	0.2130	0.9085	0.9975	1.0000

Table 18
Conditional Probability of Target Stage Non-Exceedance
Future With-Project Conditions
Values in $1,000's, February 2002 Price Levels

Project Alternative	Target Stage (ft)	Conditional Probability of Alternative Containing Indicated Event					
		10%	4%	2%	1%	0.4%	0.2%
Reach 1							
Without Project	32.96	0.8234	0.3353	0.1369	0.0503	0.0111	0.0030
DA_4.8	32.96	0.8843	0.4129	0.1736	0.0644	0.0143	0.0039
TG8-RF25	32.96	0.6850	0.1972	0.0595	0.0154	0.0018	0.0003
TG2-RF23	32.96	0.8620	0.3811	0.1573	0.0578	0.0125	0.0033
TG2-RF29	32.96	0.8987	0.4247	0.1744	0.0630	0.0136	0.0036
Reach 2							
Without Project	32.21	0.5223	0.1152	0.0274	0.0051	0.0004	0.0000
DA_4.8	32.21	0.6397	0.1709	0.0462	0.0101	0.0009	0.0001
TG8-RF25	32.21	0.3655	0.0509	0.0073	0.0008	0.0000	0.0000
TG2-RF23	32.21	0.5970	0.1494	0.0386	0.0080	0.0007	0.0001
TG2-RF29	32.21	0.6627	0.1757	0.0461	0.0096	0.0008	0.0001
Reach 3							
Without Project	44.17	0.6328	0.2099	0.0694	0.0184	0.0024	0.0004
DA_4.8	44.17	0.7546	0.2998	0.1108	0.0334	0.0052	0.0010
TG8-RF25	44.17	0.3998	0.0599	0.0091	0.0009	0.0000	0.0000
TG2-RF23	44.17	0.7214	0.2722	0.0966	0.0277	0.0040	0.0007
TG2-RF29	44.17	0.7422	0.2848	0.1011	0.0291	0.0042	0.0007
Reach 4a(L)							
Without Project	39.33	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000
DA_4.8	39.33	0.0074	0.0001	0.0000	0.0000	0.0000	0.0000
TG8-RF25	39.33	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
TG2-RF23	39.33	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000
TG2-RF29	39.33	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000
Reach 4(R)							
Without Project	50.30	0.7402	0.2691	0.1004	0.0361	0.0091	0.0027
DA_4.8	50.30	0.8506	0.3909	0.1612	0.0596	0.0147	0.0047
TG8-RF25	50.30	0.4943	0.0894	0.0174	0.0026	0.0002	0.0000
TG2-RF23	50.30	0.8199	0.3446	0.1354	0.0478	0.0111	0.0033
TG2-RF29	50.30	0.8322	0.3582	0.1419	0.0504	0.0114	0.0033
Reach 4b(L)							
Without Project	50.38	0.6320	0.1991	0.0672	0.0209	0.0040	0.0010
DA_4.8	50.38	0.7639	0.3023	0.1156	0.0388	0.0078	0.0020
TG8-RF25	50.38	0.3894	0.0603	0.0097	0.0012	0.0000	0.0000
TG2-RF23	50.38	0.7255	0.2636	0.0949	0.0304	0.0057	0.0013
TG2-RF29	50.38	0.7391	0.2754	0.1000	0.0322	0.0061	0.0013
Reach 5							
Without Project	54.85	0.2589	0.0411	0.0071	0.0008	0.0000	0.0000
DA_4.8	54.85	0.3885	0.0828	0.0195	0.0034	0.0002	0.0000
TG8-RF25	54.85	0.1385	0.0095	0.0007	0.0000	0.0000	0.0000
TG2-RF23	54.85	0.3395	0.0654	0.0136	0.0022	0.0001	0.0000
TG2-RF29	54.85	0.3377	0.0651	0.0136	0.0022	0.0001	0.0000
Reach 6							
Without Project	62.25	0.5615	0.1830	0.0792	0.0365	0.0128	0.0045
DA_4.8	62.25	0.7027	0.2553	0.1101	0.0495	0.0188	0.0085
TG8-RF25	62.25	0.3466	0.0770	0.0231	0.0058	0.0006	0.0001
TG2-RF23	62.25	0.6559	0.2311	0.0983	0.0433	0.0149	0.0056
TG2-RF29	62.25	0.6699	0.2467	0.1064	0.0452	0.0147	0.0054
Reach 7							
Without Project	68.36	0.5649	0.1690	0.0541	0.0172	0.0038	0.0016
DA_4.8	68.36	0.6837	0.2676	0.1091	0.0414	0.0117	0.0047
TG8-RF25	68.36	0.4390	0.0965	0.0242	0.0055	0.0009	0.0004
TG2-RF23	68.36	0.7013	0.2776	0.1127	0.0425	0.0113	0.0041
TG2-RF29	68.36	0.6939	0.2598	0.0978	0.0336	0.0073	0.0022
Reach 8a(L)							
Without Project	71.48	0.4887	0.1581	0.0557	0.0182	0.0036	0.0011
DA_4.8	71.48	0.7342	0.3552	0.1644	0.0633	0.0148	0.0044
TG8-RF25	71.48	0.7306	0.2856	0.1030	0.0315	0.0052	0.0011
TG2-RF23	71.48	0.7073	0.3283	0.1474	0.0569	0.0140	0.0045
TG2-RF29	71.48	0.7307	0.3242	0.1353	0.0486	0.0105	0.0029
Reach 8(R)							
Without Project	72.67	0.2312	0.0389	0.0083	0.0020	0.0006	0.0002
DA_4.8	72.67	0.5765	0.1878	0.0598	0.0165	0.0024	0.0007
TG8-RF25	72.67	0.8285	0.3797	0.1407	0.0420	0.0064	0.0013
TG2-RF23	72.67	0.6426	0.2499	0.0918	0.0289	0.0054	0.0016
TG2-RF29	72.67	0.6257	0.2077	0.0654	0.0175	0.0025	0.0007
Reach 8b(L)							
Without Project	75.23	0.2440	0.0502	0.0159	0.0064	0.0027	0.0016
DA_4.8	75.23	0.6632	0.2482	0.0881	0.0283	0.0065	0.0027
TG8-RF25	75.23	0.9821	0.7553	0.4366	0.1932	0.0512	0.0175
TG2-RF23	75.23	0.8617	0.4878	0.2340	0.0952	0.0279	0.0121
TG2-RF29	75.23	0.8265	0.3926	0.1590	0.0552	0.0125	0.0042
Reach 9							
Without Project	77.36	0.0928	0.0207	0.0068	0.0022	0.0007	0.0003
DA_4.8	77.36	0.4684	0.1507	0.0515	0.0158	0.0027	0.0008
TG8-RF25	77.36	0.9796	0.7570	0.4525	0.2132	0.0628	0.0234
TG2-RF23	77.36	0.5423	0.1944	0.0710	0.0248	0.0055	0.0019
TG2-RF29	77.36	0.7216	0.1012	0.0104	0.0007	0.0000	0.0000

Table 18 cont.
Conditional Probability of Target Stage Non-Exceedance
Future With-Project Conditions
Values in $1,000's, February 2002 Price Levels

Project Alternative	Target Stage (ft)	Conditional Probability of Alternative Containing Indicated Event					
		10%	4%	2%	1%	0.4%	0.2%
Without Project	80.58	0.1330	0.0226	0.0049	0.0011	0.0002	0.0001
DA_4.8	80.58	0.5644	0.2246	0.0798	0.0225	0.0032	0.0006
TG8-RF25	80.58	0.9939	0.8808	0.6610	0.4186	0.1920	0.0988
TG2-RF23	80.58	0.7655	0.4232	0.2082	0.0863	0.0229	0.0072
TG2-RF29	80.58	0.7683	0.3547	0.1458	0.0500	0.0096	0.0025
Reach 10a(L)							
Without Project	79.15	0.0228	0.0021	0.0003	0.0000	0.0000	0.0000
DA_4.8	79.15	0.2258	0.0576	0.0151	0.0030	0.0004	0.0000
TG8-RF25	79.15	0.9613	0.6876	0.3950	0.1865	0.0586	0.0230
TG2-RF23	79.15	0.4268	0.1540	0.0552	0.0174	0.0029	0.0007
TG2-RF29	79.15	0.4573	0.1264	0.0368	0.0090	0.0010	0.0002
Reach 10b(R)							
Without Project	85.62	0.0268	0.0134	0.0089	0.0062	0.0042	0.0034
DA_4.8	85.62	0.1726	0.0495	0.0216	0.0105	0.0052	0.0038
TG8-RF25	85.62	0.9998	0.9922	0.9593	0.8828	0.7382	0.6373
TG2-RF23	85.62	0.6971	0.3197	0.1408	0.0579	0.0214	0.0128
TG2-RF29	85.62	0.4472	0.1299	0.0449	0.0171	0.0058	0.0034
Reach 10b(L)							
Without Project	86.95	0.0356	0.0230	0.0174	0.0138	0.0107	0.0094
DA_4.8	86.95	0.1670	0.0526	0.0275	0.0174	0.0118	0.0097
TG8-RF25	86.95	0.9998	0.9929	0.9614	0.8864	0.7456	0.6507
TG2-RF23	86.95	0.7366	0.3526	0.1611	0.0695	0.0290	0.0194
TG2-RF29	86.95	0.4822	0.1306	0.0492	0.0229	0.0110	0.0079
Reach 11							
Without Project	90.37	0.0147	0.0046	0.0024	0.0014	0.0008	0.0006
DA_4.8	90.37	0.0382	0.0096	0.0041	0.0018	0.0009	0.0005
TG8-RF25	90.37	0.9943	0.9325	0.7987	0.6102	0.3757	0.2556
TG2-RF23	90.37	0.1992	0.0499	0.0157	0.0045	0.0013	0.0008
TG2-RF29	90.37	0.4902	0.1585	0.0585	0.0208	0.0049	0.0019
Reach 12							
Without Project	92.51	0.0889	0.0395	0.0240	0.0151	0.0092	0.0070
DA_4.8	92.51	0.1858	0.0710	0.0370	0.0201	0.0095	0.0065
TG8-RF25	92.51	0.9997	0.9897	0.9511	0.8640	0.7078	0.6050
TG2-RF23	92.51	0.3945	0.1509	0.0667	0.0310	0.0137	0.0087
TG2-RF29	92.51	0.7633	0.3763	0.1820	0.0818	0.0295	0.0155
Reach 13							
Without Project	96.64	0.2630	0.1153	0.0639	0.0381	0.0201	0.0132
DA_4.8	96.64	0.5133	0.2306	0.1204	0.0617	0.0275	0.0164
TG8-RF25	96.64	0.9996	0.9833	0.9151	0.7729	0.5457	0.4131
TG2-RF23	96.64	0.6364	0.3108	0.1595	0.0781	0.0317	0.0182
TG2-RF29	96.64	0.9175	0.6130	0.3512	0.1789	0.0705	0.0376
Reach 14							
Without Project	100.24	0.0915	0.0293	0.0133	0.0065	0.0027	0.0016
DA_4.8	100.24	0.6366	0.3216	0.1665	0.0810	0.0315	0.0170
TG8-RF25	100.24	0.2910	0.0798	0.0301	0.0117	0.0034	0.0017
TG2-RF23	100.24	0.3437	0.1144	0.0436	0.0168	0.0042	0.0019
TG2-RF29	100.24	0.7961	0.4308	0.2197	0.1030	0.0363	0.0173
Reach 15							
Without Project	105.31	0.2302	0.1081	0.0693	0.0507	0.0379	0.0328
DA_4.8	105.31	0.7438	0.4799	0.3176	0.2070	0.1210	0.0859
TG8-RF25	105.31	0.5116	0.2381	0.1271	0.0662	0.0308	0.0207
TG2-RF23	105.31	0.5695	0.2825	0.1537	0.0818	0.0387	0.0265
TG2-RF29	105.31	0.8435	0.5719	0.3563	0.2017	0.0932	0.0584
Reach 16							
Without Project	110.61	0.3207	0.1336	0.0737	0.0461	0.0297	0.0239
DA_4.8	110.61	0.5757	0.3179	0.1785	0.0945	0.0420	0.0257
TG8-RF25	110.61	0.8844	0.6600	0.4507	0.2716	0.1278	0.0769
TG2-RF23	110.61	0.7780	0.5087	0.3112	0.1687	0.0678	0.0356
TG2-RF29	110.61	0.8212	0.5647	0.3538	0.1325	0.0752	0.0372
Reach 17							
Without Project	117.04	0.3499	0.1678	0.1089	0.0760	0.0516	0.0417
DA_4.8	117.04	0.4918	0.2084	0.1218	0.0859	0.0639	0.0547
TG8-RF25	117.04	0.9016	0.6707	0.4571	0.2844	0.1560	0.1103
TG2-RF23	117.04	0.8177	0.5051	0.3051	0.1886	0.1173	0.0928
TG2-RF29	117.04	0.8313	0.5285	0.3210	0.1949	0.1164	0.0893
Reach 18							
Without Project	121.58	0.5202	0.2670	0.1472	0.0779	0.0339	0.0199
DA_4.8	121.58	0.5365	0.2715	0.1493	0.0791	0.0345	0.0203
TG8-RF25	121.58	0.6212	0.3374	0.1865	0.0975	0.0408	0.0237
TG2-RF23	121.58	0.5944	0.3125	0.1727	0.0907	0.0384	0.0223
TG2-RF29	121.58	0.6356	0.3433	0.1875	0.0956	0.0385	0.0220
Reach 19							
Without Project	124.23	0.3987	0.2202	0.1252	0.0652	0.0267	0.0144
DA_4.8	124.23	0.4024	0.2213	0.1258	0.0655	0.0268	0.0144
TG8-RF25	124.23	0.4082	0.2124	0.1231	0.0665	0.0278	0.0152
TG2-RF23	124.23	0.4031	0.2063	0.1197	0.0650	0.0274	0.0148
TG2-RF29	124.23	0.4256	0.2356	0.1351	0.0706	0.0284	0.0148

15.3 2009 Update & Last Added Analysis

For the TG2 plan, a last added analysis was performed to ensure that each individual component contributed an incremental net benefit with all of the other components in place. The costs and economic data for the plan were updated to 2009 levels as part of the final plan optimization. A review of the current economic performance of the individual components of the TG.2 plan was performed based on the updated cost and economic data. The following process was followed.

Using the 2009 costs and economic data the formulated plan TG2 RF-29 was analyzed with each constituent component removed separately. (The individual components were evaluated as if each one was the 'last-added" in the formulation process.)

The last-added analysis was performed starting with the plan components that were generally the least economically beneficial components of the TG2 Plan. The first three components evaluated were E200H.2A, GE2007A, and RG1. Each was evaluated individually by removing each separately from the TG2 Plan, then running the hydrologic and hydraulic models for the resulting plan, and then running the updated HEC-FDA with the resulting water surface profiles, to determine the resulting damage reduction. Net benefits were then calculated using the 2009 cost information without including each component separately in the TG2 Plan. The results are shown in **Table 19**. It may be seen that the two channel components, E200H.2A and GE200.7A, both remain viable components, each contributing net benefits of over $1.5 million. However, RG.1 is no longer beneficial, since removing RG.1 from the plan increases net benefits by approximately $350,000.

Because RG.1 no longer was a found to add net benefits, it was decided to see if other sizes of RG would provide net benefits. RG.0 and RG.2, which provide 100 acre-feet and 399 acre-feet of detention storage respectively, were added to the remaining TG2 Plan components and the economic benefits were determined following the same procedure used for the other runs. The results are shown in **Table 19**. The results show that neither of these two sizes added net benefits. Because of these results, it was decided that the RG detention component should be eliminated from the plan.

The resulting plan, which eliminated RG as a component, is identified as RF-30. A last added analysis was then performed for this plan. All of the remaining components were removed individually from the plan, and net benefits were then calculated. The results are shown in **Table 19**. The results show that all the channel modifications and detention basins contribute substantial net benefits to the overall plan. The one non-structural component, NSB.1, was shown to no longer contribute net benefits. The resulting economically best-performing plan was identified as RF-30 LA NSB1.

15.4 2011 Update & Last Added Analysis

For the RF-30 LA NSB1 plan, an additional last added analysis was performed to ensure that each individual component contributed an incremental net benefit with all of the other components in place, based on 2011 conditions. The costs and economic data for the plan were updated to 2011 levels as part of this final plan optimization. A review of the current economic performance of the individual components of the RF-30 LA NSB1 plan was performed based on the updated cost and economic data. The following process was followed.

Using the 2011 costs and economic data the formulated plan RF-30 LA NSB1was analyzed with each constituent component removed separately. (The individual components were evaluated as if each one was the ‘last-added” in the formulation process.)

An analysis of the RG detention basin component was also included to assure that RG.0, RG.1 and RG.2, which had been eliminated in the 2009 update analysis, do not increase net benefits as a result of the new price level. The analysis shows that these components do not increase net benefits. The results are shown in **Table 20**.

The results show that all the channel modifications and detention basins of the RF-30 LA NSB1 plan contribute substantial net benefits to the overall plan and that the RG detention basin still does not add net benefits. The one non-structural component, NSB 1, continued to show that it does not contribute net benefits. Based on the 2011 update the RF-30 LA NSB1 plan continues to be the NED Plan. The expected values and probabilistic values for the last added analysis shown in **Table 20** are presented in **Tables 21a-c**.

15.5 Additional Non-Structural Analysis

In the initial component analysis presented previously in Sections 12.5 and 12.6 of this appendix, both non-structural buyout and structure raising were evaluated. They were evaluated for the individual 50, 20, 10, 4, and 2 percent exceedance probabilities for the entire study reach. The results as shown previously in Tables 10 and 11 indicate that buyout or structure raising for only the 20 percent exceedance probability might warrant additional consideration as a major plan component on an individual reach basis.

As shown in the **Table 10**, the buyout capital cost for the 20 percent event is approximately $157 million and produces a B-C ratio only in the range of 1.0, which would be only marginally beneficial at best. However, for the 20 percent event, 475 of the 568 structures in the 20 percent flood plain are located within

Reach 10. In comparison, the NED Plan (RF-30 LA NSB 1) has a capital cost of approximately $248 million, produces net benefits of over $23 million and has a B-C ratio over 2.7.

Based on these results, these two non-structural measures would only be likely to contribute net benefits as a last-added feature, looking at individual properties. To address this possibility, a structure-by-structure buyout and structure raising last-added analysis was performed for the 297 residential structures that show damages in the combined 2-yr, 5-yr and 10-yr events under the current NED HEC-FDA model. The Expected Annual Damages (EAD) for each of these properties, under the NED With Project conditions, was calculated for each property.

The EA damages (damages reduced) for each individual buyout property were calculated by manual integration of the damages that remain in the With Project condition for each structure as produced by the HEC-FDA model. The damages resulting from vehicles associated with these properties were included in this calculation as were the associated utilities and post disaster costs.

The EAD damages reduced for structure raising were calculated as the EAD for each structure under the NED less the EAD calculated in the HEC-FDA model after the structure raising. Calculation of the EAD after structure raising was performed by raising the finished floor elevation of these structures to 1.5 feet above the With Project 100-year stage elevation. A reduction in damages to vehicles was not considered for structure-raising, as raising a structure does not include raising a garage or driveway.

For the 297 residential properties analyzed, no buyouts were found to provide net benefits, and only two structures were found to warrant possible consideration for structure raising. The resulting EA damage reduction for these two totals is only $13,000. Because of the small damage reduction and the uncertainties associated with structure raising, these were not added to the proposed plan.

Table 19
NED Last Added Analysis - 2009 Costs and Economic Data

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Contributed EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Contributed EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Contributed Net EA Benefits ($1,000)
Formulated Plan: TG.2A1+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB1											
TG2 RF-29	Formulated Plan	$21,347	$36,943		$220,520	$257,115	$12,747		2.90	$24,196	
RF-29	Formulated Plan	$21,347	$36,943		$168,946	$194,650	$9,650			$27,292	
TG2_LA1	Remove TG.2A1										
TG2_LA2	Remove JR.4										
TG2_LA3	Remove HOL.3B										
TG2_LA4	Remove GBW.3										
TG2_LA5	Remove FNH.3										
TG2_LA6 (RF-30)	**Remove RG.1**	**$21,713**	**$36,576**	**$367**	**$208,188**	**$242,736**	**$12,034**	**$713**	**3.04**	**$24,542**	**-$346**
TG2_LA7	Remove E200H.2A	$23,399	$34,890	$2,053	$212,114	$247,314	$12,261	$486	2.85	$22,629	$1,567
TG2_LA8	Remove GE200.7A	$23,603	$34,686	$2,257	$208,209	$243,121	$12,053	$694	2.88	$22,633	$1,563
TG2 RF-29 RG.0	Replace RG.1 with RG.0	$21,630	$36,659		$213,475	$248,901	$12,340		2.97	$24,319	-$124
TG2 RF-29 RG.2	Replace RG.1 with RG.2	$20,979	$37,310		$225,600	$263,038	$13,041		2.86	$24,269	-$74
RF-30 (TG2_LA6)	**RF-30 (Remove RG.1 from RF-29)**	**$21,713**	**$36,576**	**$367**	**$208,188**	**$242,736**	**$12,034**	**$713**	**3.04**	**$24,542**	
RF-30 LA FNH.3	last added FNH.3	$29,057	$29,232	$7,344	$144,701	$168,714	$8,364	$3,670	3.49	$20,868	$3,674
RF-30 LA GBW.3	last added GBW.3	$23,835	$34,454	$2,122	$181,811	$211,982	$10,509	$1,525	3.28	$23,945	$597
RF-30 LA HOL.3B	last added HOL3.B	$25,960	$32,329	$4,247	$173,087	$201,810	$10,005	$2,029	3.23	$22,324	$2,218
RF-30 LA JR.4	last added JR.4	$24,602	$33,687	$2,889	$181,797	$211,966	$10,509	$1,526	3.21	$23,178	$1,363
RF-30 LA TG.2A1	last added TG2A.1	$29,694	$28,595	$7,981	$177,187	$206,591	$10,242	$1,792	2.79	$18,353	$6,189
RF-30 LA E200H.2A	last added E200H.2A	$24,084	$34,205	$2,371	$199,474	$232,576	$11,530	$504	2.97	$22,675	$1,867
RF-30 LA GE200.7A	last added GE200.7A	$24,879	$33,410	$3,166	$195,877	$228,382	$11,323	$712	2.95	$22,087	$2,454
RF-30 LA NSB1	last added NSB1	$21,958	$36,331	$245	$203,594	$237,380	$11,769	$266	3.09	$24,562	-$21

Notes:
(1) All values shown in black are based on 2009 costs and assessed values, and the year 2010 Federal discount rate of 4.375%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2010 Federal discount rate of 4.375%.
(3) EA - Expected Annual

Table 20
NED Last Added Analysis - Year 2011 Price Update

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Contributed EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Contributed EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Contributed Net EA Benefits ($1,000)
	Without Project (2011)	**$60,019**									
RF-30 LA NSB1	**NED Plan July 2010 GRR (2011 Damages and Costs)**	**$22,652**	**$37,367**	**N.A.**	**$248,044**	**$286,675**	**$13,632**	**N.A.**	**2.74**	**$23,735**	**N.A.**
	Plan Components TG2A1, E200H2A, GE200.7A, FNH.3,GBW.3, HOL3.B, JR.4										
RF-30 LA FNH.3	**last added FNH.3**	$29,874	$30,146	$7,221	$168,675	$194,945	$9,270	$4,362	3.25	$20,876	$2,859
RF-30 LA GBW.3	**last added GBW.3**	$24,488	$35,531	$1,836	$216,784	$250,546	$11,914	$1,718	2.98	$23,617	$118
RF-30 LA HOL.3B	**last added HOL3.B**	$26,694	$33,326	$4,041	$202,940	$234,546	$11,153	$2,479	2.99	$22,173	$1,562
RF-30 LA JR.4	**last added JR.4**	$25,251	$34,768	$2,599	$218,512	$252,543	$12,009	$1,623	2.90	$22,759	$976
RF-30 LA TG.2A1	**last added TG2A.1**	$30,514	$29,505	$7,862	$210,997	$243,858	$11,596	$2,036	2.54	$17,910	$5,826
RF-30 LA E200H.2A	**last added E200H.2A**	$24,705	$35,314	$2,053	$237,860	$274,905	$13,072	$560	2.70	$22,242	$1,493
RF-30 LA GE200.7A	**last added GE200.7A**	$25,497	$34,522	$2,845	$232,941	$269,220	$12,802	$830	2.70	$21,721	$2,015
TG2 RF-29	**Add RG.1**	$22,182	$37,837	$470	$263,398	$304,420	$14,475	$844	2.61	$23,362	-$374
TG2 RF-29 RG.0	**Replace RG.1 with RG.0**	$22,473	$37,546	$179	$256,122	$296,011	$14,076	$444	2.67	$23,470	-$265
TG2 RF-29 RG.2	**Replace RG.1 with RG.2**	$21,807	$38,212	$845	$270,318	$312,418	$14,856	$1,224	2.57	$23,356	-$379
RF-30 (TG2_LA6)	**Add NSB1**	$22,407	$37,612	$245	$252,576	$291,913	$13,883	$249	2.71	$23,731	-$4

Notes:
(1) All values shown are based on 2011 costs and assessed values, and the year 2011 Federal discount rate of 4.125%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2011 Federal discount rate of 4.125%.
(3) EA - Expected Annual
(4) No contingencies are included in the capital costs

Table 21a
Expected Value and Probabilistic Values of EAD and EAD Reduced

Plan	Expected Annual Damages ($1,000s)		Damage Reduced ($1,000s)		EAD Reduced that is Exceeded with Specified Probability ($1,000s)		
	Without Plan	With Plan	Mean	Standard Deviation	0.75	0.50	0.25
RF-30 LA NSB	$60,019	$22,652	$37,367	$15,883	$12,534	$25,649	$50,814
RF-30 LA FNH.3	$60,019	$29,874	$30,145	$12,793	$9,980	$20,237	$40,751
RF-30 LA GBW.3	$60,019	$24,488	$35,531	$15,065	$12,024	$24,486	$48,336
RF-30 LA HOL.3B	$60,019	$26,694	$33,325	$14,132	$11,137	$22,631	$45,162
RF-30 LA JR.4	$60,019	$25,251	$34,768	$14,813	$11,917	$24,527	$47,686
RF-30 LA TG.2A1	$60,019	$30,514	$29,505	$12,830	$9,218	$19,480	$40,074
RF-30 LA E200H.2A	$60,019	$24,705	$35,314	$14,946	$12,287	$25,529	$48,467
RF-30 LA GE200.7A	$60,019	$25,497	$34,522	$14,670	$11,852	$24,130	$47,237
TG2 RF-29	$60,019	$22,183	$37,836	$16,082	$12,667	$26,001	$51,435
TG2 RF-RG.0	$60,019	$22,473	$37,546	$15,960	$12,593	$25,777	$51,058
TG2 RF-29 RG.2	$60,019	$21,807	$38,212	$16,255	$12,782	$26,248	$51,964
RF-30 (TG2_LA6)	$60,019	$22,407	$37,612	$15,960	$12,665	$25,874	$51,135

Table 21b
Expected Value and Probabilistic Values of Net Benefits

Plan	Expected Annual Benefits and Cost ($1,000s)		Net Benefits ($1,000s)		Prob. Net Benefit is > 0	Net Benefit that is Exceeded with Specified Probability ($1,000)		
	Benefits	Cost	Mean	Standard Deviation		0.75	0.5	0.25
RF-30 LA NSB	$37,367	$13,632	$23,735	$15,883	0.95	-$1,098	$12,017	$37,182
RF-30 LA FNH.3	$30,146	$9,650	$20,496	$12,793	0.95	$330	$10,587	$31,101
RF-30 LA GBW.3	$35,531	$12,402	$23,129	$15,065	0.94	-$378	$12,084	$35,934
RF-30 LA HOL.3B	$33,326	$11,610	$21,716	$14,132	0.94	-$473	$11,021	$33,552
RF-30 LA JR.4	$34,768	$12,501	$22,267	$14,813	0.96	-$584	$12,026	$35,185
RF-30 LA TG.2A1	$29,505	$12,071	$17,434	$12,830	0.91	-$2,853	$7,409	$28,003
RF-30 LA E200H.2A	$35,314	$13,072	$22,242	$14,946	0.93	-$785	$12,457	$35,395
RF-30 LA GE200.7A	$34,522	$13,327	$21,195	$14,670	0.93	-$1,475	$10,803	$33,910
TG2 RF-29	$37,837	$15,069	$22,768	$16,082	0.92	-$2,402	$10,932	$36,366
TG2 RF-RG.0	$37,546	$14,653	$22,893	$15,960	0.92	-$2,060	$11,124	$36,405
TG2 RF-29 RG.2	$38,212	$15,465	$22,747	$16,255	0.92	-$2,683	$10,783	$36,499
RF-30 (TG2_LA6)	$37,612	$14,450	$23,162	$15,960	0.93	-$1,785	$11,424	$36,685

Table 21c
Expected Value and Probabilistic Values of Benefits/Cost Ratio

	Expected Benefit/Cost Ratio			B/C Ratio Value that is Expected with Specified Probability		
Plan	Mean	Standard Deviation	Probability B/C>1	0.75	0.50	0.25
RF-30 LA NSB	2.18	1.17	0.86	0.92	1.88	3.73
RF-30 LA FNH.3	2.45	1.33	0.86	1.03	2.10	4.22
RF-30 LA GBW.3	2.28	1.21	0.85	0.97	1.97	3.90
RF-30 LA HOL.3B	2.27	1.22	0.85	0.96	1.95	3.89
RF-30 LA JR.4	2.24	1.18	0.85	0.95	1.96	3.81
RF-30 LA TG.2A1	1.90	1.06	0.80	0.76	1.61	3.32
RF-30 LA E200H.2A	2.20	1.14	0.84	0.94	1.95	3.71
RF-30 LA GE200.7A	2.08	1.10	0.84	0.89	1.81	3.54
TG2 RF-29	1.99	1.07	0.82	0.84	1.73	3.41
TG2 RF-RG.0	2.03	1.09	0.83	0.86	1.76	3.48
TG2 RF-29 RG.2	1.96	1.05	0.82	0.83	1.70	3.36
RF-30 (TG2_LA6)	2.07	1.10	0.83	0.88	1.79	3.54

16.0 NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN & TENTATIVELY RECOMMENDED PLAN

Economic evaluation of plans during the optimization process resulted in the selection of the optimized RF-30 LA NSB1 as the NED plan. The Local Sponsor has also selected it as the Tentatively Recommended Plan for implementation.

Table 22 shows the capital investment distribution with the implementation of the Tentatively Recommended Plan (RF-30 LA NSB1). These plan changes result in the removal of 825 structures (7.9 percent) from the 0.2 percent exceedance probability floodplain. This translates to a reduction of investment in the 0.2 percent exceedance probability floodplain from $2.3 billion under Without Project conditions to $2.1 billion with the implementation of the Tentatively Recommended Plan.

16.1 Savings in National Flood Insurance Program Costs

Benefits can be derived from a reduction in administrative costs to the National Flood Insurance Program (NFIP) if an insured structure is removed from the 1 percent annual exceedance probability (100-year) floodplain with implementation of a proposed plan. According to the Federal Emergency Management Agency (FEMA), the average costs of administering a flood insurance policy is $192 for Fiscal Year 2006 (*Economic Guidance Memorandum 06-04, National Flood Insurance Program Operating Costs* – Reference 27).

Based on the 1 percent annual exceedance probability (100-year) floodplain and information provided by FEMA on flood insurance policyholders, there are 7,809 flood insurance policyholders enrolled in the NFIP within the boundaries of the 1 percent annual exceedance probability floodplain. The number of residential single-family units within the delineated 1 percent exceedance probability floodplain is 8,257. This represents a 95 percent participation in the study area. Although possessing a FEMA administered flood insurance policy is currently a requirement for obtaining a mortgage for property in the floodplain, 100 percent compliance is not in effect because some of the homes were built and occupied before the law was enacted.

The benefits were calculated by determining the number of single-family homes removed from the 1 percent exceedance probability floodplain under With Project conditions for the alternative plan considered. The number of single-family homes removed from the floodplain with the implementation of the Tentatively Recommended Plan (RF-30 LA NSB1) is 1,152. Assuming 95 percent participation results in 1,094 policyholders removed from the floodplain. This floodplain is the revised FEMA floodplain, which assumes construction of the recommended plan. This translates into savings of $210,125 in National Flood Insurance operating costs. This benefit is added to the inundation reduction benefits for the Tentatively Recommended Plan for use in determining total Net Economic Benefits for the plan.

16.2 Single Occurrence Damages for Tentatively Recommended Plan (RF-30 LA NSB1)

Total damages expected during the various exceedance probability events with the implementation of the Tentatively Recommended Plan (RF-30 LA NSB1) can be seen in **Table 23a**. With the Tentatively Recommended Plan in place, the occurrence of a 1 percent exceedance probability event is expected to cause flood damages of $320 million. This compared to the $423 million expected to occur under Without Project Condition is a 24.3 percent dollar damage reduction during the 1 percent exceedance probability event. Total damage expected during a 0.2 percent exceedance probability event, under implementation of the Tentatively Recommended Plan, is approximately $767 million. This is an $89 million reduction in flood damages from Without Project Condition during the 0.2 percent exceedance probability event.

16.3 Expected Annual Damages for RF-30 LA NSB1

The change in hydrology and hydraulics due to the implementation of the Tentatively Recommended Plan is expected to result in residual EA damages of $22.6 million for the year 2016. When compared to the Without Project condition this is a $37.3 million (62 percent) reduction in EA damages. **Table 24** shows the EA damages with RF-30 LA NSB1 in place.

As seen in **Table 24**, there is a 25 percent chance of annual damage reduction exceeding $50.8 million. This translates to a 25 percent probability of the annual net benefits exceeding $43.6 million with a BCR in excess of 6.95. There is a 50 percent chance that implementation of the Tentatively Recommended Plan (RF-30 LA NSB1) will produce annual net economic benefits exceeding $18.5 million and a BCR exceeding 3.52. These figures include savings in the National Flood Insurance Program. This indicates that the net EA benefits of $30.2 million have a 38 percent chance of being exceeded. Uncertainty related to the Stage-Discharge function and the First Floor Elevation are the greatest contributors to uncertainty in the damage estimates, as discussed previously in Section 8.5.

16.4 Average Annual Equivalent Damages for Tentatively Recommended Plan (RF-30 LA NSB1)

Average Annual Equivalent (AAE) Damages are computed over the 50-year project life and accounts for changes in the development between the base and future years. Since base year and future year conditions will be the same over the 50-year project life EAD and AAE damages are equivalent.

17.0 ENVIRONMENTAL QUALITY (EQ) EFFECTS

The Tentatively Recommended Plan (RF-30 LA NSB1) has been designed to avoid, minimize, and compensate, respectively, for those unavoidable impacts to regulated resources. Unavoidable impacts have been minimized to the extent possible and compensation would be provided for unavoidable impacts. The Tentatively Recommended Plan will result in no net loss of Environmental Quality (EQ).

The potential impacts, proposed mitigation, additional measures conducted by the local sponsor, and construction practices identified in the Environmental Assessment. Only one affected resource is impacted by the Tentatively Recommended Plan-the impact to aquatic environment (including streams and wetlands). Wetlands were identified as the only significant resource warranting compensatory mitigation. Of the approximately 3,440 acres required for channel modifications and detention basin construction, a total of 18.10 acres are considered wetlands. A total of 13.24 acres of wetlands would be impacted during construction of the project, avoiding impacts to 4.86 acres of wetlands. A wetlands mitigation plan has been developed to compensate fully for the impact to these wetlands. A detailed discussion of how this plan was developed is presented in the Environmental Assessment.

The resulting wetlands mitigation plan would include the following:

Seven acres of forested wetlands would be created within the Hollister Road detention basin complex. Native species of forested wetland vegetation would be planted at the Hollister Road detention basin. In addition, native emergent wetland species would be planted among the trees and shrubs. In addition to the on-site forested and emergent wetland creation, previously purchased wetland acreage at the Greens Bayou Wetlands Mitigation Bank would remain in the bank as additional mitigation for the federal project. Exhibit 5-1 of the Environmental Assessment presents a conceptual view of the wetland mitigation plan at the Hollister Road detention basin complex.

Table 22
Section 211(f) - Federal Project - White Oak Bayou
Distribution of Capital Investment within Annual Exceedance Probability Flood Plains
Cumulative Totals based on First-Floor Elevations and With RF-30 LA NSB 1 Hydrology and Hydraulics
Dollar Values in $1,000's, April 2011 Price Levels

	Exceedance Probability Events								
Damage Category	Bank to 50% Flood Plain "2-Year"	Bank to 20% Flood Plain "5-Year"	Bank to 10% Flood Plain "10-Year"	Bank to 4% Flood Plain "25-Year"	Bank to 2% Flood Plain "50-Year"	Bank to 1% Flood Plain "100-Year"	Bank to 0.4% Flood Plain "250-Year"	Bank to 0.2% Flood Plain "500-Year"	NIFP*
Residential Property									
Number of Structures	0	22	40	813	2,791	4,217	6,705	8,815	15,936
Single-Family	0	14	32	756	2,679	4,037	6,128	8,076	14,924
Multi-Family	0	8	8	57	88	142	231	385	933
Mobile Homes	0	0	0	0	24	38	346	354	79
Distribution	0.0%	0.2%	0.5%	9.2%	31.7%	47.8%	76.1%	100.0%	N/A
Structure Value	$0	$2,245	$3,476	$67,610	$197,090	$301,455	$474,817	$650,445	$1,835,213
Content Value**	$0	$1,415	$2,646	$60,589	$188,048	$284,939	$435,121	$582,389	$1,649,146
Total Value	$0	$3,660	$6,122	$128,199	$385,138	$586,395	$909,938	$1,232,834	$3,484,359
Commercial Property									
Number of Structures	0	0	8	81	177	334	590	798	1,062
Distribution	0.0%	0.0%	1.0%	10.2%	22.2%	41.9%	73.9%	100.0%	N/A
Structure Value	$0	$0	$324,939	$26,178	$49,955	$100,274	$164,305	$216,885	$557,544
Content Value	$0	$0	$5,292	$34,219	$64,397	$136,641	$227,215	$306,622	$667,488
Total Value	$0	$0	$330,231	$60,397	$114,351	$236,915	$391,520	$523,508	$1,225,032
Public Property									
Number of Structures	0	0	0	5	7	12	38	57	60
Distribution	0.0%	0.0%	0.0%	8.8%	12.3%	21.1%	66.7%	100.0%	N/A
Structure Value	$0	$0	$0	$36,248	$55,874	$60,612	$100,403	$139,774	$120,441
Content Value	$0	$0	$0	$41,323	$63,696	$69,097	$114,459	$159,342	$137,303
Total Value	$0	$0	$0	$77,571	$119,570	$129,709	$214,861	$299,116	$257,744
Total Property									
Number of Structures	0	22	48	899	2,975	4,563	7,333	9,670	17,058
Distribution	0.0%	0.2%	0.5%	9.3%	30.8%	47.2%	75.8%	100.0%	N/A
Structure Value	$0	$2,245	$328,415	$130,036	$302,918	$462,341	$739,525	$1,007,104	$2,513,198
Content Value	$0	$1,415	$7,938	$136,130	$316,141	$490,678	$776,795	$1,048,354	$2,453,937
Total Value	$0	$3,660	$336,353	$266,166	$619,059	$953,019	$1,516,320	$2,055,458	$4,967,135
Total Roads									
Roadway Lengths (Miles)	13	19	36	100	149	187	232	268	15
Distribution	4.9%	7.0%	13.3%	37.2%	55.8%	70.0%	86.8%	100.0%	N/A

* Not in Flood Plain (these structures were inventoried as part of the study area within the 0.2% exceedance probability floodplain extents, but they have first floor elevations above the floodplain).

** Residential Content Values displayed are based on a 100 percent content-to-structure value ratio (CSVR).

Table 23a
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event
RF-30 LA NSB 1 Hydrology and Hydraulics
April 2011 Values in $1,000's

	Annual Exceedance Probability Events							
	50% "2-Year"	20% "5-Year"	10% "10-Year"	4% "25-Year"	2% "50-Year"	1% "100-Year"	0.40% "250-Year"	0.20% "500-Year"
Damage Category								
Residential Property	$9	$590	$2,129	$35,565	$82,527	$127,015	$217,662	$302,494
Commercial Property	$0	$0	$1,560	$11,357	$26,889	$50,881	$99,303	$143,635
Public Property	$0	$0	$0	$2,360	$20,767	$32,942	$54,452	$76,354
Total Damages to Structures and Contents	$9	$590	$3,689	$49,283	$130,183	$210,838	$371,417	$522,482
Post Disaster Costs	$19	$829	$4,600	$21,500	$40,420	$60,421	$93,169	$127,537
Road Damages	$170	$246	$466	$1,303	$1,953	$2,450	$3,036	$3,499
Utility Damages	$0	$20	$112	$521	$980	$1,465	$2,259	$3,092
Vehicle Damages	$0	$146	$1,118	$12,609	$29,104	$44,687	$78,081	$110,749
Total by Event	$199	$1,830	$9,985	$85,216	$202,641	$319,861	$547,962	$767,359
Percent Distribution								
Residential Property	4.74%	32.22%	21.32%	41.73%	40.73%	39.71%	39.72%	39.42%
Commercial Property	0.00%	0.00%	15.63%	13.33%	13.27%	15.91%	18.12%	18.72%
Public Property	0.00%	0.00%	0.00%	2.77%	10.25%	10.30%	9.94%	9.95%
Post Disaster Costs	9.65%	45.28%	46.07%	25.23%	19.95%	18.89%	17.00%	16.62%
Road Damages	85.37%	13.42%	4.67%	1.53%	0.96%	0.77%	0.55%	0.46%
Utility Damages	0.23%	1.10%	1.12%	0.61%	0.48%	0.46%	0.41%	0.40%
Vehicle Damages	0.00%	7.99%	11.19%	14.80%	14.36%	13.97%	14.25%	14.43%
Total by Event	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 23b
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event and Reach
With Project Hydrology and Hydraulics
April 2011 Values in $1,000's

		Annual Exceedance Probability Events							
	Damage Category	50% "2-Year"	20% "5-Year"	10% "10-Year"	4% "25-Year"	2% "50-Year"	1% "100-Year"	0.40% "250-Year"	0.20% "500-Year"
WOB-1	**Structures and Contents**	$0	$0	$1	$2,941	$21,919	$34,439	$60,188	$81,884
	Other Damages	$17	$32	$75	$125	$192	$350	$1,767	$3,297
	Total	**$17**	**$32**	**$75**	**$3,066**	**$22,111**	**$34,789**	**$61,955**	**$85,181**
WOB-2	**Structures and Contents**	$0	$0	$0	$589	$811	$1,083	$4,388	$12,264
	Non-Physical	$13	$25	$44	$1,595	$1,959	$2,473	$7,716	$15,130
	Total	**$13**	**$25**	**$44**	**$2,184**	**$2,770**	**$3,556**	**$12,104**	**$27,394**
WOB-3	**Structures and Contents**	$0	$0	$0	$417	$643	$1,004	$5,616	$10,499
	Non-Physical	$3	$29	$33	$91	$151	$244	$1,208	$2,091
	Total	**$3**	**$29**	**$33**	**$509**	**$794**	**$1,248**	**$6,823**	**$12,590**
WOB-4a(L)	**Structures and Contents**	$9	$333	$740	$1,675	$2,192	$2,483	$3,135	$3,474
	Non-Physical	$10	$188	$406	$1,036	$1,247	$1,330	$1,476	$1,517
	Total	**$20**	**$521**	**$1,147**	**$2,711**	**$3,439**	**$3,813**	**$4,611**	**$4,991**
WOB-4(R)	**Structures and Contents**	$0	$4	$128	$570	$1,900	$4,182	$15,514	$24,871
	Non-Physical	$17	$24	$87	$247	$1,393	$2,604	$7,484	$13,147
	Total	**$17**	**$29**	**$216**	**$817**	**$3,292**	**$6,787**	**$22,998**	**$38,018**
WOB-4b(L)	**Structures and Contents**	$0	$50	$168	$3,402	$9,338	$14,424	$29,518	$39,016
	Non-Physical	$1	$67	$123	$1,036	$4,468	$8,052	$16,975	$20,703
	Total	**$1**	**$117**	**$291**	**$4,438**	**$13,806**	**$22,476**	**$46,493**	**$59,719**
WOB-5	**Structures and Contents**	$0	$200	$2,136	$11,400	$22,973	$32,610	$47,352	$60,195
	Non-Physical	$4	$740	$1,448	$7,825	$13,753	$20,023	$30,338	$35,306
	Total	**$4**	**$939**	**$3,583**	**$19,225**	**$36,727**	**$52,632**	**$77,690**	**$95,500**
WOB-6	**Structures and Contents**	$0	$0	$15	$5,978	$12,473	$18,304	$28,833	$41,520
	Non-Physical	$5	$7	$3,422	$11,575	$18,008	$23,157	$29,547	$41,885
	Total	**$5**	**$7**	**$3,437**	**$17,553**	**$30,481**	**$41,461**	**$58,380**	**$83,405**
WOB-7	**Structures and Contents**	$0	$0	$9	$1,454	$4,923	$10,055	$19,496	$27,369
	Non-Physical	$2	$5	$18	$432	$2,013	$7,250	$11,716	$15,547
	Total	**$2**	**$5**	**$27**	**$1,886**	**$6,936**	**$17,305**	**$31,212**	**$42,916**
WOB-8a(L)	**Structures and Contents**	$0	$0	$0	$40	$196	$348	$533	$648
	Non-Physical	$0	$1	$3	$11	$90	$244	$369	$417
	Total	**$0**	**$1**	**$3**	**$52**	**$286**	**$592**	**$902**	**$1,065**
WOB-8(R)	**Structures and Contents**	$0	$0	$5	$707	$3,379	$6,067	$9,774	$13,270
	Non-Physical	$2	$2	$7	$458	$1,077	$1,898	$3,148	$4,107
	Total	**$2**	**$2**	**$12**	**$1,164**	**$4,456**	**$7,965**	**$12,922**	**$17,376**
WOB-8b(L)	**Structures and Contents**	$0	$0	$0	$900	$3,725	$9,006	$11,869	$14,482
	Non-Physical	$0	$0	$3	$207	$2,626	$4,411	$5,880	$6,952
	Total	**$0**	**$0**	**$3**	**$1,107**	**$6,351**	**$13,417**	**$17,749**	**$21,434**
WOB-9	**Structures and Contents**	$0	$0	$61	$3,296	$7,999	$12,070	$17,403	$23,434
	Non-Physical	$1	$1	$87	$1,249	$3,413	$5,306	$8,174	$12,580
	Total	**$1**	**$1**	**$148**	**$4,545**	**$11,412**	**$17,376**	**$25,577**	**$36,014**
WOB-10a(R)	**Structures and Contents**	$0	$0	$3	$220	$1,374	$4,514	$12,371	$21,010
	Non-Physical	$0	$0	$69	$534	$904	$2,192	$6,034	$9,870
	Total	**$0**	**$0**	**$72**	**$754**	**$2,278**	**$6,706**	**$18,405**	**$30,880**
WOB-10a(L)	**Structures and Contents**	$0	$1	$118	$5,632	$13,160	$18,816	$25,302	$30,602
	Non-Physical	$19	$20	$328	$3,513	$8,502	$11,667	$15,558	$19,090
	Total	**$19**	**$20**	**$446**	**$9,144**	**$21,662**	**$30,483**	**$40,860**	**$49,691**
WOB-10b(R)	**Structures and Contents**	$0	$0	$49	$3,912	$7,328	$8,971	$10,645	$11,914
	Non-Physical	$28	$29	$29	$1,419	$3,780	$5,074	$5,981	$6,499
	Total	**$28**	**$29**	**$78**	**$5,331**	**$11,108**	**$14,045**	**$16,627**	**$18,413**
WOB-10b(L)	**Structures and Contents**	$0	$0	$231	$3,741	$5,608	$7,036	$8,922	$12,295
	Non-Physical	$16	$16	$17	$3,773	$5,421	$6,105	$7,621	$11,832
	Total	**$16**	**$16**	**$248**	**$7,514**	**$11,029**	**$13,141**	**$16,544**	**$24,126**
WOB-11	**Structures and Contents**	$0	$0	$1	$800	$2,034	$3,042	$4,911	$6,665
	Non-Physical	$22	$23	$23	$123	$1,053	$1,544	$1,862	$2,125
	Total	**$22**	**$23**	**$24**	**$923**	**$3,087**	**$4,586**	**$6,773**	**$8,791**
WOB-12	**Structures and Contents**	$0	$2	$21	$409	$2,841	$7,498	$11,619	$14,220
	Non-Physical	$18	$19	$19	$213	$737	$1,763	$4,913	$5,445
	Total	**$18**	**$21**	**$40**	**$622**	**$3,578**	**$9,262**	**$16,533**	**$19,665**
WOB-13	**Structures and Contents**	$0	$0	$0	$0	$23	$1,869	$8,057	$11,423
	Non-Physical	$1	$1	$1	$5	$18	$32	$49	$80
	Total	**$1**	**$1**	**$1**	**$5**	**$41**	**$1,901**	**$8,106**	**$11,503**
WOB-14	**Structures and Contents**	$0	$0	$1	$1,157	$4,555	$9,052	$18,300	$27,032
	Non-Physical	$7	$7	$28	$339	$1,358	$2,670	$5,204	$6,967
	Total	**$7**	**$7**	**$29**	**$1,496**	**$5,912**	**$11,723**	**$23,505**	**$33,999**
WOB-15	**Structures and Contents**	$0	$0	$0	$0	$4	$58	$453	$1,273
	Non-Physical	$0	$0	$0	$1	$8	$21	$47	$99
	Total	**$0**	**$0**	**$0**	**$1**	**$12**	**$79**	**$500**	**$1,373**
WOB-16	**Structures and Contents**	$0	$0	$0	$18	$247	$1,108	$7,064	$14,334
	Non-Physical	$2	$2	$12	$43	$101	$199	$1,831	$7,289
	Total	**$2**	**$2**	**$12**	**$61**	**$348**	**$1,308**	**$8,895**	**$21,623**
WOB-17	**Structures and Contents**	$0	$0	$0	$24	$490	$2,519	$8,639	$15,030
	Non-Physical	$1	$1	$12	$61	$138	$312	$1,381	$2,463
	Total	**$1**	**$1**	**$12**	**$84**	**$628**	**$2,831**	**$10,020**	**$17,493**
WOB-18	**Structures and Contents**	$0	$0	$0	$0	$30	$200	$1,020	$2,672
	Non-Physical	$1	$1	$2	$19	$48	$93	$182	$314
	Total	**$1**	**$1**	**$2**	**$19**	**$78**	**$293**	**$1,202**	**$2,986**
WOB-19	**Structures and Contents**	$0	$0	$0	$1	$17	$79	$492	$1,086
	Non-Physical	$0	$0	$0	$3	$3	$9	$82	$125
	Total	**$0**	**$0**	**$0**	**$4**	**$20**	**$88**	**$574**	**$1,211**
All Reaches	**Total**	**$199**	**$1,830**	**$9,985**	**$85,216**	**$202,641**	**$319,861**	**$547,962**	**$767,359**

Table 24
Distribution of Expected Annual Damages (EAD) Damages by Reach for Year 2016 & 2065 Conditions
With RF-30 LA NSB 1 Hydrology and Hydraulics and 2011 Values in $1,000s

Reach Name	Total Without Project	Total With Project	Damage Reduced	Percent Reduction	Probability Damaged reduced Exceeds Indicated Values 0.75	0.5	0.25
WOB-1	$1,415.01	$1,327.16	$87.85	6.21%	15.25	54.25	134.90
WOB-2	260.67	243.26	$17.41	6.68%	9.35	18.44	24.49
WOB-3	142.42	132.23	$10.19	7.15%	1.70	7.97	12.48
WOB-4a(L)	425.65	384.59	$41.06	9.65%	29.12	40.48	52.61
WOB-4(R)	443.42	403.70	$39.72	8.96%	5.49	21.67	59.18
WOB-4b(L)	1,163.96	1,031.10	$132.86	11.41%	41.30	100.76	191.65
WOB-5	3,331.81	2,920.02	$411.79	12.36%	191.04	352.33	585.24
WOB-6	2,660.17	2,272.89	$387.28	14.56%	142.75	317.66	561.72
WOB-7	1,344.66	1,055.70	$288.96	21.49%	75.69	193.13	402.73
WOB-8a(L)	39.56	27.38	$12.18	30.79%	4.25	8.88	16.89
WOB-8(R)	1,033.82	495.15	$538.67	52.10%	196.04	389.89	727.14
WOB-8b(L)	1,396.63	579.46	$817.17	58.51%	249.71	574.44	1,136.45
WOB-9	3,145.52	1,160.01	$1,985.51	63.12%	803.68	1,552.15	2,733.13
WOB-10a(R)	2,145.76	646.03	$1,499.73	69.89%	530.35	1,100.35	2,020.69
WOB-10a(L)	6,942.29	1,852.34	$5,089.95	73.32%	2,961.76	4,718.47	6,903.73
WOB-10b(R)	4,046.37	964.84	$3,081.53	76.16%	1,282.64	2,623.82	4,492.88
WOB-10b(L)	7,062.18	1,630.69	$5,431.49	76.91%	1,579.82	3,785.38	7,710.72
WOB-11	2,281.11	433.48	$1,847.63	81.00%	777.77	1,521.31	2,586.49
WOB-12	4,002.98	783.14	$3,219.84	80.44%	671.49	2,068.52	4,599.46
WOB-13	1,613.48	420.91	$1,192.57	73.91%	233.77	587.96	1,578.63
WOB-14	6,640.11	1,263.52	$5,376.59	80.97%	1,537.83	3,716.43	7,264.43
WOB-15	1,073.25	183.85	$889.40	82.87%	237.46	290.07	981.70
WOB-16	2,985.41	769.13	$2,216.28	74.24%	457.20	669.23	2,618.50
WOB-17	3,828.07	1,150.25	$2,677.82	69.95%	472.12	903.00	3,342.19
WOB-18	468.83	394.94	$73.89	15.76%	27.10	33.11	75.79
WOB-19	126.26	126.35	-$0.09	-0.07%	-0.19	-0.24	-0.28
Total	**$60,019.40**	**$22,652.12**	**$37,367.28**	**62.26%**	**$12,534.49**	**$25,649.46**	**$50,813.54**
Net Benefit*			**$30,237.02**		**$5,404.23**	**$18,519.20**	**$43,683.28**
BCR*			**5.12**		**1.74**	**3.52**	**6.95**

* Net Benefit and BCR figures include $210,125 Savings in Administrative Cost of Flood Insurance Benefit

18.0 LOCALLY PREFERRED PLAN (LPP) & RECOMMENDED PLAN

The NED Plan (RF-30 LA NSB1) was identified as the Tentatively Recommended Plan as discussed in the previous section. This plan was presented to the required agencies, interested parties, and to the public for review and comment. Significant public comment was received in opposition to the acquisition of the area identified as the FNH.3-W cell for construction of additional detention storage. Based on the public opposition, the Local Sponsor reviewed the performance of the flood protection plan resulting from the removal of the FNH.3-W cell. The resulting plan is referred to as the Locally Preferred Plan (RF-31) or the Recommended Plan.

Table 25 shows the capital investment distribution with the implementation of the Locally Preferred Plan (RF-31). These plan changes result in the removal of 690 structures (6.6 percent) from the 0.2 percent exceedance probability floodplain. This translates to a reduction of investment in the 0.2 percent exceedance probability floodplain from $2.3 billion under Without Project conditions to $2.1 billion with the implementation of the Locally Preferred Plan.

18.1 Savings in National Flood Insurance Program Costs

Benefits can be derived from a reduction in administrative costs to the National Flood Insurance Program (NFIP) if an insured structure is removed from the 1 percent annual exceedance probability (100-year) floodplain with implementation of a proposed plan. According to the Federal Emergency Management Agency (FEMA), the average costs of administering a flood insurance policy is $192 for Fiscal Year 2006 (*Economic Guidance Memorandum 06-04, National Flood Insurance Program Operating Costs* – Reference 27).

Based on the 1 percent annual exceedance probability (100-year) floodplain and information provided by FEMA on flood insurance policyholders, there are 7,809 flood insurance policyholders enrolled in the NFIP within the boundaries of the 1 percent annual exceedance probability floodplain. The number of residential single-family units within the delineated 1 percent exceedance probability floodplain is 8,257. This represents a 95 percent participation in the study area. Although possessing a FEMA administered flood insurance policy is currently a requirement for obtaining a mortgage for property in the floodplain, 100 percent compliance is not in effect because some of the homes were built and occupied before the law was enacted.

The benefits were calculated by determining the number of single-family homes removed from the 1 percent exceedance probability floodplain under With Project conditions for the alternative plan considered. The number of single-family homes removed from the floodplain with the implementation of the Locally Preferred Plan (RF-31) is 980. Assuming 95 percent participation results in 931 policyholders removed from the floodplain. This floodplain is the revised FEMA floodplain, which assumes construction of the recommended plan. This translates into savings of $178,752 in National Flood Insurance operating costs. This benefit is added to the inundation reduction benefits for the Tentatively Recommended Plan for use in determining total Net Economic Benefits for the plan.

18.2 Single Occurrence Damages for Recommended Plan (RF-31)

Total damages expected during the various exceedance probability events with the implementation of the Locally Preferred Plan (RF-31) can be seen in **Table 26a**. With the Locally Preferred Plan in place, the occurrence of a 1 percent exceedance probability event is expected to cause flood damages of $333 million. This compared to the $423 million expected to occur under Without Project Condition is a 21.3 percent dollar damage reduction during the 1 percent exceedance probability event. Total damage expected during a 0.2 percent exceedance probability event, under implementation of the Locally Preferred Plan, is approximately $782 million. This is an $75 million reduction in flood damages from Without Project Condition during the 0.2 percent exceedance probability event.

18.3 Expected Annual Damages RF-31

The change in hydrology and hydraulics due to the implementation of the Locally Preferred Plan is expected to result in residual EA damages of $25.1 million for the year 2016. When compared to the Without Project condition this is a $34.8 million (58 percent) reduction in EA damages. **Table 27** shows the EA damages with RF-31 in place.

As seen in **Table 27**, there is a 25 percent chance of annual damage reduction exceeding $47.7 million. This translates to a 25 percent probability of the annual net benefits exceeding $42.7 million with a BCR in excess of 9.31. There is a 50 percent chance that implementation of the Locally Preferred Plan (RF-31) will produce annual net economic benefits exceeding $19.6 million and a BCR exceeding 4.81. These figures include savings in the National Flood Insurance Program. This indicates that the net EA benefits of $29.9 million have a 39 percent chance of being exceeded. Uncertainty related to the Stage-Discharge function and the First Floor Elevation are the greatest contributors to uncertainty in the damage estimates, as discussed previously in Section 8.5.

18.4 Average Annual Equivalent Damages for Recommended Plan (RF-31)

Average Annual Equivalent (AAE) Damages are computed over the 50-year project life and accounts for changes in the development between the base and future years. Since base year and future year conditions will be the same over the 50-year project life EAD and AAE damages are equivalent.

Table 25
Section 211(f) - Federal Project - White Oak Bayou
Distribution of Capital Investment within Annual Exceedance Probability Flood Plains
Cumulative Totals based on First-Floor Elevations and With RF-31 Hydrology and Hydraulics
Dollar Values in $1,000's, April 2011 Price Levels

	Exceedance Probability Events								
Damage Category	Bank to 50% Flood Plain "2-Year"	Bank to 20% Flood Plain "5-Year"	Bank to 10% Flood Plain "10-Year"	Bank to 4% Flood Plain "25-Year"	Bank to 2% Flood Plain "50-Year"	Bank to 1% Flood Plain "100-Year"	Bank to 0.4% Flood Plain "250-Year"	Bank to 0.2% Flood Plain "500-Year"	NIFP*
Residential Property									
Number of Structures	0	22	42	1,190	3,011	4,389	6,867	8,947	15,804
Single-Family	0	14	34	1,128	2,898	4,209	6,268	8,198	14,802
Multi-Family	0	8	8	62	89	142	252	395	923
Mobile Homes	0	0	0	0	24	38	347	354	79
Distribution	0.0%	0.2%	0.5%	13.3%	33.7%	49.1%	76.8%	100.0%	N/A
Structure Value	$0	$2,245	$3,642	$94,721	$213,639	$313,572	$508,299	$660,092	$1,825,565
Content Value**	$0	$1,415	$2,812	$87,700	$204,446	$297,056	$453,508	$591,442	$1,640,092
Total Value	$0	$3,660	$6,454	$182,421	$418,085	$610,628	$961,807	$1,251,534	$3,465,657
Commercial Property									
Number of Structures	0	0	8	88	186	348	597	801	1,062
Distribution	0.0%	0.0%	1.0%	11.0%	23.2%	43.4%	74.5%	100.0%	N/A
Structure Value	$0	$0	$3,249	$27,389	$56,122	$106,553	$167,366	$217,132	$557,297
Content Value	$0	$0	$5,292	$36,181	$73,133	$145,968	$231,954	$306,904	$667,206
Total Value	$0	$0	$8,541	$63,570	$129,255	$252,521	$399,320	$524,036	$1,224,503
Public Property									
Number of Structures	0	0	0	5	8	12	38	57	60
Distribution	0.0%	0.0%	0.0%	8.8%	14.0%	21.1%	66.7%	100.0%	N/A
Structure Value	$0	$0	$0	$36,248	$56,458	$60,612	$100,403	$139,774	$120,441
Content Value	$0	$0	$0	$41,323	$64,362	$69,097	$114,459	$159,342	$137,303
Total Value	$0	$0	$0	$77,571	$120,820	$129,709	$214,861	$299,116	$257,744
Total Property									
Number of Structures	0	22	50	1,283	3,205	4,749	7,502	9,805	16,926
Distribution	0.0%	0.2%	0.5%	13.1%	32.7%	48.4%	76.5%	100.0%	N/A
Structure Value	$0	$2,245	$6,891	$158,358	$326,219	$480,737	$776,068	$1,016,998	$2,503,303
Content Value	$0	$1,415	$8,104	$165,204	$341,941	$512,121	$799,921	$1,057,688	$2,444,601
Total Value	$0	$3,660	$14,995	$323,562	$668,160	$992,858	$1,575,988	$2,074,686	$4,947,904
Total Roads									
Roadway Lengths (Miles)	13	19	38	105	151	189	233	268	15
Distribution	4.9%	7.0%	14.2%	39.2%	56.4%	70.4%	86.9%	100.0%	N/A

* Not in Flood Plain (these structures were inventoried as part of the study area within the 0.2% exceedance probability floodplain extents, but they have first floor elevations above the floodplain).

** Residential Content Values displayed are based on a 100 percent content-to-structure value ratio (CSVR).

Table 26a
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event
RF-31 Hydrology and Hydraulics
April 2011 Values in $1,000's

	Annual Exceedance Probability Events							
	50%	20%	10%	4%	2%	1%	0.40%	0.20%
	"2-Year"	"5-Year"	"10-Year"	"25-Year"	"50-Year"	"100-Year"	"250-Year"	"500-Year"
Damage Category								
Residential Property	$9	$590	$3,253	$44,560	$89,172	$133,145	$223,732	$309,254
Commercial Property	$0	$0	$1,560	$11,948	$28,894	$53,489	$101,175	$146,116
Public Property	$0	$0	$0	$2,439	$20,968	$33,049	$54,795	$76,898
Total Damages to Structures and Contents	$9	$590	$4,813	$58,947	$139,034	$219,683	$379,703	$532,268
Post Disaster Costs	$19	$829	$5,458	$24,364	$42,208	$63,010	$96,087	$129,281
Road Damages	$170	$246	$499	$1,376	$1,979	$2,470	$3,047	$3,506
Utility Damages	$0	$20	$132	$591	$1,023	$1,528	$2,329	$3,134
Vehicle Damages	$0	$146	$1,124	$14,653	$31,081	$46,605	$80,154	$113,510
Total by Event	$199	$1,830	$12,027	$99,930	$215,326	$333,296	$561,320	$781,700
Percent Distribution								
Residential Property	4.74%	32.22%	27.05%	44.59%	41.41%	39.95%	39.86%	39.56%
Commercial Property	0.00%	0.00%	12.97%	11.96%	13.42%	16.05%	18.02%	18.69%
Public Property	0.00%	0.00%	0.00%	2.44%	9.74%	9.92%	9.76%	9.84%
Post Disaster Costs	9.65%	45.28%	45.38%	24.38%	19.60%	18.91%	17.12%	16.54%
Road Damages	85.37%	13.42%	4.15%	1.38%	0.92%	0.74%	0.54%	0.45%
Utility Damages	0.23%	1.10%	1.10%	0.59%	0.48%	0.46%	0.41%	0.40%
Vehicle Damages	0.00%	7.99%	9.35%	14.66%	14.43%	13.98%	14.28%	14.52%
Total by Event	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 26b
Section 211(f) - Federal Project - White Oak Bayou
Single Occurrence Damages by Annual Exceedance Probability Event and Reach
With Project Hydrology and Hydraulics
April 2011 Values in $1,000's

		Annual Exceedance Probability Events							
		50%	20%	10%	4%	2%	1%	0.40%	0.20%
	Damage Category	"2-Year"	"5-Year"	"10-Year"	"25-Year"	"50-Year"	"100-Year"	"250-Year"	"500-Year"
WOB-1	**Structures and Contents**	$0	$0	$1	$3,021	$22,107	$34,440	$60,304	$82,145
	Other Damages	$17	$32	$75	$125	$192	$352	$1,777	$3,310
	Total	**$17**	**$32**	**$75**	**$3,146**	**$22,299**	**$34,792**	**$62,081**	**$85,455**
WOB-2	**Structures and Contents**	$0	$0	$0	$589	$811	$1,085	$4,434	$12,390
	Non-Physical	$13	$25	$44	$1,595	$1,959	$2,477	$7,769	$15,217
	Total	**$13**	**$25**	**$44**	**$2,184**	**$2,771**	**$3,561**	**$12,203**	**$27,608**
WOB-3	**Structures and Contents**	$0	$0	$0	$420	$643	$1,033	$5,692	$10,703
	Non-Physical	$3	$29	$33	$92	$151	$244	$1,224	$2,107
	Total	**$3**	**$29**	**$33**	**$511**	**$794**	**$1,278**	**$6,915**	**$12,810**
WOB-4a(L)	**Structures and Contents**	$9	$333	$740	$1,675	$2,196	$2,486	$3,143	$3,488
	Non-Physical	$10	$188	$406	$1,036	$1,248	$1,331	$1,477	$1,519
	Total	**$20**	**$521**	**$1,147**	**$2,711**	**$3,443**	**$3,817**	**$4,620**	**$5,006**
WOB-4(R)	**Structures and Contents**	$0	$4	$128	$570	$1,903	$4,224	$15,738	$25,399
	Non-Physical	$17	$24	$87	$247	$1,401	$2,618	$7,643	$13,275
	Total	**$17**	**$29**	**$216**	**$817**	**$3,304**	**$6,842**	**$23,381**	**$38,674**
WOB-4b(L)	**Structures and Contents**	$0	$50	$168	$3,419	$9,379	$14,485	$29,729	$39,474
	Non-Physical	$1	$67	$123	$1,040	$4,496	$8,094	$17,077	$20,851
	Total	**$1**	**$117**	**$291**	**$4,459**	**$13,875**	**$22,579**	**$46,806**	**$60,325**
WOB-5	**Structures and Contents**	$0	$200	$2,136	$11,428	$22,998	$32,694	$47,832	$61,289
	Non-Physical	$4	$740	$1,448	$7,830	$13,761	$20,099	$30,543	$35,612
	Total	**$4**	**$939**	**$3,583**	**$19,259**	**$36,759**	**$52,794**	**$78,375**	**$96,901**
WOB-6	**Structures and Contents**	$0	$0	$15	$6,120	$12,779	$18,730	$29,526	$42,602
	Non-Physical	$5	$7	$3,422	$11,587	$18,066	$23,303	$30,069	$42,483
	Total	**$5**	**$7**	**$3,437**	**$17,707**	**$30,845**	**$42,033**	**$59,596**	**$85,085**
WOB-7	**Structures and Contents**	$0	$0	$9	$1,863	$5,586	$11,712	$20,332	$28,269
	Non-Physical	$2	$5	$18	$493	$2,322	$8,398	$12,195	$15,798
	Total	**$2**	**$5**	**$27**	**$2,356**	**$7,909**	**$20,110**	**$32,527**	**$44,067**
WOB-8a(L)	**Structures and Contents**	$0	$0	$0	$59	$231	$373	$555	$661
	Non-Physical	$0	$1	$3	$13	$118	$272	$379	$422
	Total	**$0**	**$1**	**$3**	**$73**	**$350**	**$645**	**$934**	**$1,083**
WOB-8(R)	**Structures and Contents**	$0	$0	$17	$1,142	$4,137	$6,648	$10,405	$13,767
	Non-Physical	$2	$2	$7	$588	$1,299	$2,081	$3,393	$4,239
	Total	**$2**	**$2**	**$24**	**$1,730**	**$5,437**	**$8,728**	**$13,798**	**$18,006**
WOB-8b(L)	**Structures and Contents**	$0	$0	$0	$1,494	$5,224	$9,635	$12,461	$14,784
	Non-Physical	$0	$0	$4	$474	$3,026	$4,820	$6,109	$7,091
	Total	**$0**	**$0**	**$5**	**$1,968**	**$8,250**	**$14,456**	**$18,570**	**$21,875**
WOB-9	**Structures and Contents**	$0	$0	$136	$4,722	$9,049	$13,108	$18,616	$24,604
	Non-Physical	$1	$1	$127	$1,900	$3,887	$5,809	$8,963	$14,221
	Total	**$1**	**$1**	**$263**	**$6,623**	**$12,936**	**$18,917**	**$27,579**	**$38,825**
WOB-10a(R)	**Structures and Contents**	$0	$0	$16	$428	$2,067	$5,784	$13,755	$22,576
	Non-Physical	$0	$0	$168	$570	$1,120	$2,865	$6,677	$10,403
	Total	**$0**	**$0**	**$183**	**$998**	**$3,187**	**$8,649**	**$20,432**	**$32,979**
WOB-10a(L)	**Structures and Contents**	$0	$1	$435	$8,555	$15,105	$20,168	$26,124	$31,294
	Non-Physical	$19	$20	$769	$5,422	$9,454	$12,460	$16,111	$19,503
	Total	**$19**	**$20**	**$1,204**	**$13,977**	**$24,559**	**$32,628**	**$42,235**	**$50,797**
WOB-10b(R)	**Structures and Contents**	$0	$0	$286	$5,494	$7,879	$9,297	$10,799	$12,060
	Non-Physical	$28	$29	$227	$2,265	$4,334	$5,252	$6,061	$6,543
	Total	**$28**	**$29**	**$513**	**$7,759**	**$12,213**	**$14,549**	**$16,861**	**$18,603**
WOB-10b(L)	**Structures and Contents**	$0	$0	$673	$4,675	$5,926	$7,418	$9,257	$12,719
	Non-Physical	$16	$16	$145	$4,606	$5,670	$6,260	$8,536	$11,890
	Total	**$16**	**$16**	**$818**	**$9,281**	**$11,596**	**$13,678**	**$17,793**	**$24,609**
WOB-11	**Structures and Contents**	$0	$0	$9	$1,256	$2,277	$3,244	$5,036	$6,785
	Non-Physical	$22	$23	$23	$268	$1,218	$1,597	$1,879	$2,139
	Total	**$22**	**$23**	**$32**	**$1,524**	**$3,495**	**$4,841**	**$6,915**	**$8,924**
WOB-12	**Structures and Contents**	$0	$2	$41	$666	$3,354	$8,004	$11,784	$14,293
	Non-Physical	$18	$19	$20	$333	$895	$1,927	$4,953	$5,469
	Total	**$18**	**$21**	**$62**	**$999**	**$4,249**	**$9,932**	**$16,737**	**$19,762**
WOB-13	**Structures and Contents**	$0	$0	$0	$0	$43	$1,984	$8,098	$11,520
	Non-Physical	$1	$1	$1	$6	$18	$32	$49	$81
	Total	**$1**	**$1**	**$1**	**$6**	**$61**	**$2,016**	**$8,147**	**$11,601**
WOB-14	**Structures and Contents**	$0	$0	$2	$1,308	$4,553	$9,086	$18,413	$27,032
	Non-Physical	$7	$7	$36	$366	$1,356	$2,673	$5,212	$6,967
	Total	**$7**	**$7**	**$38**	**$1,674**	**$5,909**	**$11,759**	**$23,624**	**$33,999**
WOB-15	**Structures and Contents**	$0	$0	$0	$0	$4	$58	$453	$1,273
	Non-Physical	$0	$0	$0	$1	$8	$21	$47	$99
	Total	**$0**	**$0**	**$0**	**$1**	**$12**	**$79**	**$500**	**$1,373**
WOB-16	**Structures and Contents**	$0	$0	$0	$18	$247	$1,156	$7,064	$14,334
	Non-Physical	$2	$2	$12	$43	$101	$206	$1,831	$7,289
	Total	**$2**	**$2**	**$12**	**$61**	**$348**	**$1,361**	**$8,895**	**$21,623**
WOB-17	**Structures and Contents**	$0	$0	$0	$24	$490	$2,555	$8,639	$15,048
	Non-Physical	$1	$1	$12	$61	$138	$320	$1,381	$2,463
	Total	**$1**	**$1**	**$12**	**$84**	**$628**	**$2,875**	**$10,020**	**$17,511**
WOB-18	**Structures and Contents**	$0	$0	$0	$0	$30	$199	$1,020	$2,672
	Non-Physical	$1	$1	$2	$19	$48	$93	$182	$314
	Total	**$1**	**$1**	**$2**	**$19**	**$78**	**$291**	**$1,202**	**$2,986**
WOB-19	**Structures and Contents**	$0	$0	$0	$1	$17	$79	$492	$1,086
	Non-Physical	$0	$0	$0	$3	$3	$9	$82	$125
	Total	**$0**	**$0**	**$0**	**$4**	**$20**	**$88**	**$574**	**$1,211**
All Reaches	**Total**	**$199**	**$1,830**	**$12,027**	**$99,930**	**$215,326**	**$333,296**	**$561,320**	**$781,700**

Table 27
Distribution of Expected Annual Damages (EAD) Damages by Reach for Year 2016 & 2065 Conditions
With RF-31 Hydrology and Hydraulics and 2011 Values in $1,000s

Reach Name	Total Without Project	Total With Project	Damage Reduced	Percent Reduction	Probability Damaged reduced Exceeds Indicated Values 0.75	0.5	0.25
WOB-1	$1,415.01	$1,306.58	$108.43	7.66%	21.13	72.60	165.78
WOB-2	260.67	244.34	$16.33	6.26%	9.94	17.62	23.26
WOB-3	142.42	123.48	$18.94	13.30%	4.31	13.75	24.15
WOB-4a(L)	425.65	380.46	$45.19	10.62%	32.51	44.70	57.38
WOB-4(R)	443.42	371.15	$72.27	16.30%	11.56	41.38	102.26
WOB-4b(L)	1,163.96	954.35	$209.61	18.01%	64.42	160.06	303.52
WOB-5	3,331.81	2,662.66	$669.15	20.08%	297.08	568.74	939.72
WOB-6	2,660.17	2,054.99	$605.18	22.75%	226.36	496.63	876.49
WOB-7	1,344.66	829.68	$514.98	38.30%	156.07	376.30	714.11
WOB-8a(L)	39.56	28.35	$11.21	28.34%	4.20	8.41	15.54
WOB-8(R)	1,033.82	449.65	$584.17	56.51%	214.47	428.56	790.13
WOB-8b(L)	1,396.63	500.64	$895.98	64.15%	282.90	652.23	1,251.41
WOB-9	3,145.52	1,282.52	$1,863.00	59.23%	780.12	1,484.55	2,575.80
WOB-10a(R)	2,145.76	559.78	$1,585.98	73.91%	551.67	1,177.66	2,153.06
WOB-10a(L)	6,942.29	2,107.28	$4,835.01	69.65%	2,934.53	4,591.29	6,541.50
WOB-10b(R)	4,046.37	683.26	$3,363.11	83.11%	1,391.75	2,857.09	4,891.92
WOB-10b(L)	7,062.18	1,136.29	$5,925.89	83.91%	1,669.72	4,128.40	8,423.81
WOB-11	2,281.11	1,129.35	$1,151.76	50.49%	548.87	1,020.24	1,621.22
WOB-12	4,002.98	2,168.75	$1,834.23	45.82%	395.48	1,225.73	2,700.43
WOB-13	1,613.48	847.79	$765.69	47.46%	126.38	426.77	1,045.78
WOB-14	6,640.11	2,460.16	$4,179.95	62.95%	1,255.24	2,939.26	5,698.64
WOB-15	1,073.25	351.77	$721.48	67.22%	162.57	198.59	855.71
WOB-16	2,985.41	804.76	$2,180.65	73.04%	493.40	713.45	2,576.40
WOB-17	3,828.07	1,194.62	$2,633.44	68.79%	462.78	891.59	3,288.32
WOB-18	468.83	395.91	$72.93	15.55%	26.73	32.66	75.26
WOB-19	126.26	126.36	-$0.10	-0.08%	-0.19	-0.23	-0.33
Total	**$60,019.40**	**$25,154.92**	**$34,864.46**	**58.09%**	**$12,124.00**	**$24,568.04**	**$47,711.26**
Net Benefit*			**$29,900.21**		**$7,159.75**	**$19,603.79**	**$42,747.02**
BCR*			**6.81**		**2.39**	**4.81**	**9.31**

* Net Benefit and BCR figures include $178,752 Savings in Administrative Cost of Flood Insurance Benefit
* In Chapter 5 of the Main Report the results were adjusted to FY2013 levels and FY 2013 interest rate of 3.75 % and to include interest during construction

19.0 REGIONAL ECONOMIC DEVELOPMENT

Implementation of the Recommended Plan (RF-31) is expected to have positive benefits for Regional Economic Development (RED). The reduction of flooding will have positive benefits in terms of reduction in business losses, reduced disruption to residents, reduced disruption to traffic patterns and increased public wellbeing. The reduction in flooding events can also be expected to remove the economic stigma for the areas affected, resulting in increases in property values.

Construction related to the Recommended Plan will also create jobs in a wide variety of industries extending throughout the region. In addition to direct construction jobs, this increased economic activity will have a multiplier effect resulting in increased job activity for support industries such as equipment rental, suppliers and contractors that are located throughout the region.

20.0 ECONOMIC BENEFIT UPDATE PLAN

In accordance with ER 1105-2-100, the following plan is included to update the economic benefits of the project every three years after project approval. Only the important economic variables are considered for update.

As part of this economic update, changes to floodplain development will not be considered due to the fact that the study area participates in floodplain development restrictions, thus, inhibiting any development from occurring below the FEMA 1 percent AEP (100-year) floodplain. Also the watershed is over 90 percent developed. Structure values for residential, commercial, industrial, and public categories will be updated using the same procedures that were used in the past, as described in Attachment 4. The resultant index will be used to update all structure values. Automobile values will be updated using the latest published values (for average mid-sized sedans). The NFIP benefit category will be updated using the latest available EGM. Finally, utilities, roads, and post disaster recovery benefit categories will be updated using the most appropriate Consumer Price Index factor.

21.0 REFERENCES

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ATTACHMENT 1A

RESIDENTIAL SAMPLE PILOT SURVEY (VERIFICATION OF HCAD DATA)

Attachment 1A
Residential Sample Pilot Survey (Verification of HCAD Data)
Section 211(f) Federal Project - White Oak Bayou

Estimate ID	Sample Number	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD RCNLD	Estimate Number CEI	Depreciated Cost New by CEI	DC/HCAD Ratio
32793	10	410P	1131830000003	Residential	1979	2,156	$70,220	458	$62,411	0.89
33312	12	410P	1131830000023	Residential	1979	1,650	$53,290	459	$51,079	0.96
16405	8	409G	1150750010009	Residential	1983	2,704	$101,860	460	$102,754	1.01
24989	4	409L	1074430000002	Residential	1983	2,636	$100,370	461	$81,058	0.81
25089	3	409M	0821190000003	Residential	1975	4,466	$196,590	462	$145,549	0.74
33981	5	410Q	1111430000036	Residential	1982	1,782	$56,980	463	$53,700	0.94
37424	25	410V	1093140000098	Residential	1978	881	$42,130	464	$31,882	0.76
32274	9	411N	1032900000009	Residential	1971	2,615	$76,030	465	$77,392	1.02
34376	15	411N	1032850000005	Residential	1971	1,138	$37,790	466	$37,959	1.00
37769	1	411N	1032820000013	Residential	1970	1,398	$44,560	467	$44,130	0.99
41338	46	411P	1031070000009	Residential	1970	2,238	$62,590	468	$59,708	0.95
34272	7	411P	1051880000016	Residential	1972	1,604	$52,630	469	$50,057	0.95
32438	15	411Q	1054640000017	Residential	1974	2,579	$84,820	470	$85,476	1.01
33177	17	411Q	1054650000021	Residential	1974	2,182	$71,320	471	$67,428	0.95
42230	63	411S	1001740000039	Residential	1968	1,116	$35,270	472	$31,780	0.90
41304	14	411S	1020900000217	Residential	1969	1,136	$35,160	473	$32,083	0.91
39056	28	411T	1000980000001	Residential	1969	3,378	$96,270	474	$95,326	0.99
37143	41	411T	1014100000016	Residential	1970	2,107	$67,020	475	$66,297	0.99
43162	8	411U	1142360080039	Residential	1985	3,563	$174,610	476	$172,164	0.99
41203	19	411U	1024350000025	Residential	1970	2,084	$73,560	477	$73,632	1.00
45080	31	411Y	0970630000005	Residential	1972	2,043	$58,600	478	$56,923	0.97
58886	4	451C	1023030000015	Residential	1970	2,672	$68,650	479	$72,767	1.06
58773	6	451C	1023030000038	Residential	1969	2,150	$71,190	480	$63,413	0.89
83842	5	451M	0731000830032	Residential	1952	1,329	$27,570	481	$29,323	1.06
70836	15	452E	0845330000019	Residential	1957	3,098	$100,760	482	$104,371	1.04
66556	19	452E	0931150000002	Residential	1962	1,913	$60,640	483	$60,089	0.99
100712	1	452U	0561630000302	Residential	1940	1,656	$17,610	484	$35,077	1.99
110023	5	452Y	0771810010017	Residential	1970	1,564	$45,720	485	$45,597	1.00
110575	8	492C	0771810060020	Residential	1951	1,104	$23,240	486	$37,228	1.60
118325	7	493B	0611880000013	Residential	1927	1,169	$24,000	487	$35,005	1.46
Totals	30						$2,031,050		$1,961,658	0.97
Count							30	30	30	30
Min							$17,610		$29,323	0.74
Max							$196,590		$172,164	1.99
Median							$61,615		$59,899	0.99
Mean							$67,702		$65,389	1.03
StdDev							$ 39,830		$ 33,308	0.25
Var							$ 1,586,464,104		$ 1,109,436,886	0.06
CV										0.24

Attachment 1A
Residential Sample Pilot Survey (Verification of HCAD Data)
Section 211(f) Federal Project - White Oak Bayou

Statistical Summary

1. Compute Sample Size (n)

$$n = \frac{z^2 * CV^2}{e^2}$$

Level of Confidence = 90%, therefore:

z = 1.64

Level of Precision (Tolerable Error) = 5% or 10%, e = 0.05 or 0.10

Coefficient of Variation (CV)

For e = 5% ***0.05***

n =	***62***

For e = 10% ***0.10***

n =	***15***

2. Determine Sample Survey Level of Precision (Error - e)

For n = 30

e =	***7.19%***

Sample Test Application

Objective:

For this study, market value data for residential structures was readily available from the Harris County Appraisal District (HCAD). Prior to accepting this data for the flood damage analysis, depreciated replacement costs and the ratios of depreciated replacement costs to market value were calculated for a sample of 30 residential structures. Assume we will reject the direct use of market data if we are more than 90 percent certain that depreciated replacement cost techniques estimate a structure value different than the market data.

Analysis:

On the average, the sample buildings have a depreciated replacement cost three (3) percent higher than the market value, a mean ratio of 1.03. The sample standard deviation of the ratios was calculated to be 0.25. Assuming that ratios of structure values are normally distributed, the student t distribution may be used to describe the sample. Measuring the differnce between the sample and the assume population mean (N), the t statistic is calculated as:

$$t = \frac{X - U}{S/(N)^{0.5}}$$

X =	1.03	(sample mean)
U =	1.00	(assumed population mean)
S =	0.25	(sample standard deviation)
N =	30	(sample size)

Compute Student t Distribution:

t =	0.59	N-1 degrees of freedom

Referencing a standard student t distribution table, the critical value of t with 29 degrees of freedom for a two-tailed test at a 10 percent level of significance is 1.699. This indicates within the bound of t = -1.699 to t = +1.6991, there is an 90 percent chance that the population mean = 1.0. Since our calculated t of 0.59 is within the acceptable range, we can conclude the direct use of market data for this study and no provisions are necessary to adjust the market value data for this application.

ATTACHMENT 1B

COMMERCIAL SAMPLE PILOT SURVEY
(VERIFICATION OF HCAD DATA)

Attachment 1B
Commercial Sample Pilot Survey (Verification of HCAD Data)
Section 211 (f) Federal Project - White Oak Bayou

Estimate ID	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Estimate Number CEI	Depreciated Cost New by CEI	DC/HCAD Ratio
39539	408V	0132170070013	Warehouse, Prefab.	1980	9,000	$83,690	23	$89,798	1.07
39537	408V	0132180100002	Warehouse, Prefab.	1980	3,872	$47,570	24	$48,902	1.03
33602	410Q	0451350000016	Strip Shopping Center	1989	6,500	$233,410	25	$186,055	0.80
38004	410S	1151210010005	Office Warehouse	1986	31,150	$788,660	26	$613,809	0.78
43385	410T	0132150030026	Food Stand	1970	520	$4,980	27	$7,390	1.48
41088	410T	0570080000049	Warehouse, Prefab.	1989	5,440	$116,210	28	$111,303	0.96
37412	410T	0451350000037	Warehouse, Prefab.	1979	57,300	$691,330	29	$656,659	0.95
42806	410U	0382900020075	Auto Service Garage	1985	2,100	$52,920	30	$38,549	0.73
42821	411S	0431760000136	Bank	1977	27,724	$284,160	31	$1,206,650	4.25
42093	411T	1165300010001	Garden Apartments	1984	49,074	$1,412,170	32	$1,121,517	0.79
35498	411T	1000480000094	Strip Shopping Center	1983	19,400	$341,520	33	$411,423	1.20
43873	411T	0431760000372	Strip Shopping Center	1979	22,209	$214,210	34	$325,226	1.52
43306	411U	0970710000039	Retail-Single-Occupancy	1979	4,430	$163,610	35	$87,671	0.54
62801	451H	0302430470019	Warehouse, Prefab.	1960	820	$8,180	36	$7,119	0.87
63532	451H	0302440480021	Warehouse, Prefab.	1970	5,000	$45,730	37	$46,487	1.02
62905	451H	0302390350018	Warehouse, Prefab.	1982	9,450	$161,200	38	$139,554	0.87
62635	451H	0302390340035	Warehouse, Prefab.	1979	13,900	$153,670	39	$174,656	1.14
90206	451R	0432050010027	Auto Service Garage	1979	936	$36,390	40	$23,842	0.66
95021	451R	0661120060010	Medical Office	1965	2,625	$65,620	41	$70,231	1.07
98442	452K	0561650000194	Warehouse, Prefab.	1975	4,200	$42,390	42	$45,607	1.08
95218	452N	0661120070003	Garden Apartments	1960	54,840	$1,045,380	43	$1,013,038	0.97
95698	452N	0432050010050	Garden Apartments	1970	73,250	$1,034,580	44	$1,060,789	1.03
95192	452N	0661120060013	Office Building Low Rise	1973	6,312	$107,520	45	$163,079	1.52
89765	452N	0432050050121	Warehouse	1978	19,296	$405,180	46	$194,090	0.48
89915	452N	0432050050205	Office Warehouse	1969	102,015	$1,784,000	47	$881,862	0.49
100890	452Q	0561650000501	Office Warehouse	1940	1,860	$9,870	48	$10,585	1.07
96167	452S	0432050020010	Office Building Low Rise	1974	65,572	$2,864,550	49	$2,981,269	1.04
101905	452T	0561660000235	Apartments (4-9 Units)	1950	1,984	$25,420	50	$20,333	0.80
98555	452T	0440840010004	Apartments (4-9 Units)	1960	2,160	$41,770	51	$29,808	0.71
103637	452T	0440840000201	Neighborhood Shopping Center	1970	15,640	$361,620	52	$342,999	0.95
96802	452T	0440840010026	Office Building Low Rise+5	1977	157,686	$7,074,290	53	$6,793,260	0.96
104163	452U	0561670000487	Auto Service Garage	1977	1,920	$22,330	54	$21,952	0.98
102628	452U	0561670000323	Auto Service Garage	1950	2,240	$14,650	55	$16,847	1.15
102928	452U	0561670000442	Warehouse, Prefab.	1980	7,000	$86,890	56	$94,759	1.09
102062	452U	0561670000312	Warehouse, Prefab.	1979	7,400	$71,410	57	$81,212	1.14
103793	452U	0561670000636	Warehouse, Prefab.	1978	9,000	$97,570	58	$88,843	0.91
102740	452U	0440840000044	Warehouse, Prefab.	1960	5,700	$51,440	59	$43,077	0.84
106792	452Y	0561670000671	Office Warehouse	1982	7,497	$122,430	60	$108,327	0.88
104938	452Y	0561670000364	Warehouse, Prefab.	1970	4,845	$31,210	61	$27,272	0.87

Attachment 1B
Commercial Sample Pilot Survey (Verification of HCAD Data)
Section 211 (f) Federal Project - White Oak Bayou

Estimate ID	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Estimate Number CEI	Depreciated Cost New by CEI	DC/HCAD Ratio
104931	452Y	0561670000522	Warehouse, Prefab.	1950	8,808	$70,980	62	$56,544	0.80
105972	452Y	0391060000007	Warehouse, Prefab.	1976	13,282	$110,380	63	$100,215	0.91
105382	452Y	0561670000370	Warehouse, Prefab.	1970	2,380	$18,040	64	$20,666	1.15
110292	452Y	0391240000930	Warehouse, Prefab.	1968	1,406	$800	65	$1,750	2.19
114369	492B	0440820000546	Warehouse	1954	48,984	$229,520	66	$353,421	1.54
116974	492B	0440820000320	Paper and Allied Products	1956	32,500	$334,740	67	$243,996	0.73
118479	492C	0102020000093	Warehouse, Prefab.	1973	7,020	$67,340	68	$51,733	0.77
120321	492C	0073140000007	Warehouse, Prefab.	1940	13,600	$34,090	69	$40,195	1.18
120315	492D	0073130000007	Auto Service Garage	1938	6,200	$31,380	70	$28,186	0.90
120461	492D	0210310000011	Office Building Low Rise	1962	13,004	$95,350	71	$135,945	1.43
120930	492D	0210470000002	Warehouse, Prefab.	1962	22,740	$134,680	72	$114,134	0.85
122446	492H	0210560000028	Warehouse, Prefab.	1950	5,958	$13,440	73	$25,339	1.89
118243	493B	0620740000018	Apartments (4-9 Units)	1935	4,212	$53,980	74	$57,712	1.07
121614	493E	0210520000003	Apartments (4-9 Units)	1960	2,757	$36,360	75	$49,146	1.35
121587	493F	0051080000011	Warehouse, Prefab.	1950	1,900	$7,340	76	$8,088	1.10
121530	493F	0050930000010	Warehouse, Prefab.	1940	4,456	$14,710	77 and 21	$13,042	0.89
121086	493F	0400300000011	Metal Fabricating	1960	54,236	$255,630	78	$243,425	0.95
121577	493G	0051080000013	Retail-Single-Occupancy	1920	4,594	$39,660	79	$15,865	0.40
123460	493H	0031380000002	Office Warehouse	1964	4,950	$59,720	80	$63,153	1.06
122904	493K	0050840000004	Warehouse, Prefab.	1984	2,000	$22,380	81	$29,055	1.30
9137	369X	1166360000001	Hospitals	1986	72,369	$4,215,050	87	$4,193,243	0.99
24813	409M	1074430000023	Religious	1980	12,563	$1,383,530	88	$1,138,879	0.82
43958	411S	0431760000518	Police or Fire Station	1985	8,109	$431,370	91	$423,478	0.98
40391	411U	0431880000007	Country Club with Golf	1995	39,739	$3,850,250	92	$1,768,347	0.46
95741	451R	0760210070149	Res. Structure on Commercial Land	1958	3,243	$66,140	23	$60,432	0.91
100938	452T	0561650000624	Res. Structure on Commercial Land	1975	2,851	$33,700	94 and 22	$28,464	0.84
120729	493E	0210320000012	Res. Structure on Commercial Land	1920	5,730	$125,320	24	$128,752	1.03
121542	493F	0050930000027	Religious	1900	3,400	$74,190	95	$68,966	0.93
17019	409C	0421070000017	School - Cook MS	N/A	200,583	$6,500,000	96	$7,362,101	1.13
30663	409R	0820810000001	School - Jersey Village HS	N/A	384,712	$23,358,000	97	$16,991,590	0.73
75966	451M	0422240000148	Gethsemane Lutheran Church	N/A	N/A	$2,000,000	98	$1,276,226	0.64
95732	452N	0760210070151	Retail-Single-Occupancy	1980	5,000	$120,970	99	$126,076	1.04
93889	452N	0661120080002	Office Building Low Rise	1979	18,838	$556,440	100	$588,308	1.06
98189	452T	0561650000177	Religious	1945	2,220	$10,430	101	$15,376	1.47
101402005	452T	0561660000210	Apartments	1965	73,942	$204,090	102	$483,055	2.37
100807	452T	0561650000572	Service Station (Self)	1986	2,376	$148,900	103	$83,083	0.56
120091	492D	0210320000003	Hospitals - Daycare	1970	4,700	$123,520	105	$130,567	1.06
120467	492D	0073140000001	Auto Service Garage	1949	4,004	$43,910	106	$41,220	0.94
122418002	493E	0050820000002	Commercial-Mixed Residential	1940	2,364	$7,990	25	$11,134	1.39

Attachment 1B
Commercial Sample Pilot Survey (Verification of HCAD Data)
Section 211 (f) Federal Project - White Oak Bayou

Estimate ID	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Estimate Number CEI	Depreciated Cost New by CEI	DC/HCAD Ratio
122428	493E	0050820000006	Office Warehouse	1960	4,851	$38,170	107	$34,753	0.91
123661	493Q	0031220000001	U.S Customs Office	1927	595,734	$21,066,800	110	$16,539,205	0.79
33495	411P	1000480000092	Religious	1981	5,244	$112,250	111	$202,636	1.81
44087	410U	0382900020078	Auto Service Garage	1992	1,800	$39,560	112	$38,786	0.98
63898	451H	0392150030003	Retail-Single-Occupancy	1960	14,480	$103,180	113	$93,352	0.90
89656	451R	0620050020017	Restaurant	1966	1,520	$27,000	114	$24,342	0.90
117438	493B	0170010000013	Nursing Home	1955	13,228	$350,130	115	$307,711	0.88
Totals						$86,821,140		$73,197,541	
Count						85		85	85
Min						$800		$1,750	0.40
Max						$23,358,000		$16,991,590	4.25
Median						$97,570		$89,798	0.96
Mean						$1,021,425		$861,148	1.05
StdDev						$3,535,518		$2,761,239	0.49
Var						$12,499,890,831,902		$7,624,438,624,863	0.24
CV									0.46

Attachment 1B
Commercial Sample Pilot Survey (Verification of HCAD Data)
Section 211 (f) Federal Project - White Oak Bayou

Statistical Summary

1. Compute Sample Size (n)

n = z2*CV2
e2

Level of Confidence = 90%, therefore:

z =	1.64

Level of Precision (Tolerable Error) = 5% or 10%, e = 0.05 or 0.10

Coefficient of Variation (CV)

For e = 5%	***0.05***
n =	***228***
For e = 10%	***0.10***
n =	***57***

2. Determine Sample Survey Level of Precision (Error - e)

For n =	85
e =	***8.19%***

Sample Test Application

Objective: For this study, market value data for commerical structures was readily available from the Harris County Appraisal District (HCAD). Prior to accepting this data for the flood damage analysis, depreciated replacement costs and the ratios of depreciated replacement costs to market value were calculated for a sample of 96 commercial structures. Assume we will rejec the direct use of market data if we are more than 80 percent certain that depreciated replacement cost techniques estimate a structure value different than the market data.

Analysis: On the average, the sample buildings have a depreciated replacement cost five (5) percent higher than the market value, a mean ratio of 1.05. The sample standard deviation of the ratios was calculated to be 0.49. Assuming that ratios of structure values are normally distributed, the student t distribution may be used to describe the sample. Measuring the differnce between the sample and the assume population mean (N), the t statistic is calculated as:

$$t = \frac{X - U}{S/(N)^{0.5}}$$

X =	1.05	(sample mean)
U =	1.00	(assumed population mean)
S =	0.49	(sample standard deviation)
N =	84.00	(sample size - 1)

Compute Student t Distribution:

t =	1.03	N-1 degrees of freedom

Referencing a standard student t distribution table, the critical value of t with 85 degrees of freedom for a two-tailed test at a 10 percent level of significance is 1.663. This indicates within the bound of t = -1.663 to t = +1.663, there is an 90 percent chance that the population mean = 1.0. Since our calculated t of 1.03 is within the acceptable range, we can conclude that the direct use of market data for this study and no provisions are necessary to adjust the market value data for this application.

ATTACHMENT 1C

RESIDENTIAL SAMPLE PILOT SURVEY
(QUANTIFICATION OF UNCERTAINTY)

Attachment 1C
Residential Sample Pilot Survey (Quantification of Uncertainty)
Section 211(f) Federal Project - White Oak Bayou

Estimate Number CEI	Sample Number	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD RCNLD	Depreciated Cost New by CEI	Error
458	10	410P	1131830000003	Residential	1979	2,156	$70,220	$62,411	-12.51%
459	12	410P	1131830000023	Residential	1979	1,650	$53,290	$51,079	-4.33%
460	8	409G	1150750010009	Residential	1983	2,704	$101,860	$102,754	0.87%
461	4	409L	1074430000002	Residential	1983	2,636	$100,370	$81,058	-23.82%
462	3	409M	0821190000003	Residential	1975	4,466	$196,590	$145,549	-35.07%
463	5	410Q	1111430000036	Residential	1982	1,782	$56,980	$53,700	-6.11%
464	25	410V	1093140000098	Residential	1978	881	$42,130	$31,882	-32.14%
465	9	411N	1032900000009	Residential	1971	2,615	$76,030	$77,392	1.76%
466	15	411N	1032850000005	Residential	1971	1,138	$37,790	$37,959	0.45%
467	1	411N	1032820000013	Residential	1970	1,398	$44,560	$44,130	-0.97%
468	46	411P	1031070000009	Residential	1970	2,238	$62,590	$59,708	-4.83%
469	7	411P	1051880000016	Residential	1972	1,604	$52,630	$50,057	-5.14%
470	15	411Q	1054640000017	Residential	1974	2,579	$84,820	$85,476	0.77%
471	17	411Q	1054650000021	Residential	1974	2,182	$71,320	$67,428	-5.77%
472	63	411S	1001740000039	Residential	1968	1,116	$35,270	$31,780	-10.98%
473	14	411S	1020900000217	Residential	1969	1,136	$35,160	$32,083	-9.59%
474	28	411T	1000980000001	Residential	1969	3,378	$96,270	$95,326	-0.99%
475	41	411T	1014100000016	Residential	1970	2,107	$67,020	$66,297	-1.09%
476	8	411U	1142360080039	Residential	1985	3,563	$174,610	$172,164	-1.42%
477	19	411U	1024350000025	Residential	1970	2,084	$73,560	$73,632	0.10%
478	31	411Y	0970630000005	Residential	1972	2,043	$58,600	$56,923	-2.95%
479	4	451C	1023030000015	Residential	1970	2,672	$68,650	$72,767	5.66%
480	6	451C	1023030000038	Residential	1969	2,150	$71,190	$63,413	-12.26%
481	5	451M	0731000830032	Residential	1952	1,329	$27,570	$29,323	5.98%
482	15	452E	0845330000019	Residential	1957	3,098	$100,760	$104,371	3.46%
483	19	452E	0931150000002	Residential	1962	1,913	$60,640	$60,089	-0.92%
484	1	452U	0561630000302	Residential	1940	1,656	$17,610	$35,077	49.80%
485	5	452Y	0771810010017	Residential	1970	1,564	$45,720	$45,597	-0.27%
486	8	492C	0771810060020	Residential	1951	1,104	$23,240	$37,228	37.57%
487	7	493B	0611880000013	Residential	1927	1,169	$24,000	$35,005	31.44%

Attachment 1C
Residential Sample Pilot Survey (Quantification of Uncertainty)
Section 211(f) Federal Project - White Oak Bayou

Count							30	30	30
Min							$ 17,610.00	$ 29,323.00	-0.35
Max							$ 196,590.00	$ 172,164.00	0.50
Median							$ 61,615.00	$ 59,898.50	-0.01
Mean							$ 67,701.67	$ 65,388.60	-0.01
StdDev							$ 39,830.44	$ 33,308.21	0.17
Var							$ 1,586,464,104.02	$ 1,109,436,886.39	0.03
CV									-15.350

(1) Replacement cost new adjusted for time by a factor of 0.87.

ATTACHMENT 1D

COMMERCIAL SAMPLE PILOT SURVEY (QUANTIFICATION OF UNCERTAINTY)

Attachment 1D
Commercial Sample Pilot Survey (Quantification of Uncertainty)
Section 211(f) Federal Project - White Oak Bayou

Estimate Number CEI	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Depreciated Cost New by CEI	Error
23	408V	0132170070013	Warehouse, Prefab.	1980	9,000	$83,690	$89,798	6.80%
24	408V	0132180100002	Warehouse, Prefab.	1980	3,872	$47,570	$48,902	2.72%
25	410Q	0451350000016	Strip Shopping Center	1989	6,500	$233,410	$186,055	-25.45%
26	410S	1151210010005	Office Warehouse	1986	31,150	$788,660	$613,809	-28.49%
27	410T	0132150030026	Food Stand	1970	520	$4,980	$7,390	32.61%
28	410T	0570080000049	Warehouse, Prefab.	1989	5,440	$116,210	$111,303	-4.41%
29	410T	0451350000037	Warehouse, Prefab.	1979	57,300	$691,330	$656,659	-5.28%
30	410U	0382900020075	Auto Service Garage	1985	2,100	$52,920	$38,549	-37.28%
31	411S	0431760000136	Bank	1977	27,724	$284,160	$1,206,650	76.45%
32	411T	1165300010001	Garden Apartments	1984	49,074	$1,412,170	$1,121,517	-25.92%
33	411T	1000480000094	Strip Shopping Center	1983	19,400	$341,520	$411,423	16.99%
34	411T	0431760000372	Strip Shopping Center	1979	22,209	$214,210	$325,226	34.14%
35	411U	0970710000039	Retail-Single-Occupancy	1979	4,430	$163,610	$87,671	-86.62%
36	451H	0302430470019	Warehouse, Prefab.	1960	820	$8,180	$7,119	-14.90%
37	451H	0302440480021	Warehouse, Prefab.	1970	5,000	$45,730	$46,487	1.63%
38	451H	0302390350018	Warehouse, Prefab.	1982	9,450	$161,200	$139,554	-15.51%
39	451H	0302390340035	Warehouse, Prefab.	1979	13,900	$153,670	$174,656	12.02%
40	451R	0432050010027	Auto Service Garage	1979	936	$36,390	$23,842	-52.63%
41	451R	0661120060010	Medical Office	1965	2,625	$65,620	$70,231	6.57%
42	452K	0561650000194	Warehouse, Prefab.	1975	4,200	$42,390	$45,607	7.05%
43	452N	0661120070003	Garden Apartments	1960	54,840	$1,045,380	$1,013,038	-3.19%
44	452N	0432050010050	Garden Apartments	1970	73,250	$1,034,580	$1,060,789	2.47%
45	452N	0661120060013	Office Building Low Rise	1973	6,312	$107,520	$163,079	34.07%
46	452N	0432050050121	Warehouse	1978	19,296	$405,180	$194,090	-108.76%
47	452N	0432050050205	Office Warehouse	1969	102,015	$1,784,000	$881,862	-102.30%
48	452Q	0561650000501	Office Warehouse	1940	1,860	$9,870	$10,585	6.75%
49	452S	0432050020010	Office Building Low Rise	1974	65,572	$2,864,550	$2,981,269	3.92%
50	452T	0561660000235	Apartments (4-9 Units)	1950	1,984	$25,420	$20,333	-25.02%
51	452T	0440840010004	Apartments (4-9 Units)	1960	2,160	$41,770	$29,808	-40.13%
52	452T	0440840000201	Neighborhood Shopping Center	1970	15,640	$361,620	$342,999	-5.43%
53	452T	0440840010026	Office Building Low Rise+5	1977	157,686	$7,074,290	$6,793,260	-4.14%
54	452U	0561670000487	Auto Service Garage	1977	1,920	$22,330	$21,952	-1.72%
55	452U	0561670000323	Auto Service Garage	1950	2,240	$14,650	$16,847	13.04%
56	452U	0561670000442	Warehouse, Prefab.	1980	7,000	$86,890	$94,759	8.30%
57	452U	0561670000312	Warehouse, Prefab.	1979	7,400	$71,410	$81,212	12.07%

Attachment 1D
Commercial Sample Pilot Survey (Quantification of Uncertainty)
Section 211(f) Federal Project - White Oak Bayou

Estimate Number CEI	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Depreciated Cost New by CEI	Error
58	452U	0561670000636	Warehouse, Prefab.	1978	9,000	$97,570	$88,843	-9.82%
59	452U	0440840000044	Warehouse, Prefab.	1960	5,700	$51,440	$43,077	-19.41%
60	452Y	0561670000671	Office Warehouse	1982	7,497	$122,430	$108,327	-13.02%
61	452Y	0561670000364	Warehouse, Prefab.	1970	4,845	$31,210	$27,272	-14.44%
62	452Y	0561670000522	Warehouse, Prefab.	1950	8,808	$70,980	$56,544	-25.53%
63	452Y	0391060000007	Warehouse, Prefab.	1976	13,282	$110,380	$100,215	-10.14%
64	452Y	0561670000370	Warehouse, Prefab.	1970	2,380	$18,040	$20,666	12.71%
65	452Y	0391240000930	Warehouse, Prefab.	1968	1,406	$800	$1,750	54.29%
66	492B	0440820000546	Warehouse	1954	48,984	$229,520	$353,421	35.06%
67	492B	0440820000320	Paper and Allied Products	1956	32,500	$334,740	$243,996	-37.19%
68	492C	0102020000093	Warehouse, Prefab.	1973	7,020	$67,340	$51,733	-30.17%
69	492C	0073140000007	Warehouse, Prefab.	1940	13,600	$34,090	$40,195	15.19%
70	492D	0073130000007	Auto Service Garage	1938	6,200	$31,380	$28,186	-11.33%
71	492D	0210310000011	Office Building Low Rise	1962	13,004	$95,350	$135,945	29.86%
72	492D	0210470000002	Warehouse, Prefab.	1962	22,740	$134,680	$114,134	-18.00%
73	492H	0210560000028	Warehouse, Prefab.	1950	5,958	$13,440	$25,339	46.96%
74	493B	0620740000018	Apartments (4-9 Units)	1935	4,212	$53,980	$57,712	6.47%
75	493E	0210520000003	Apartments (4-9 Units)	1960	2,757	$36,360	$49,146	26.02%
76	493F	0051080000011	Warehouse, Prefab.	1950	1,900	$7,340	$8,088	9.25%
77 and 21	493F	0050930000010	Warehouse, Prefab.	1940	4,456	$14,710	$13,042	-12.79%
78	493F	0400300000011	Metal Fabricating	1960	54,236	$255,630	$243,425	-5.01%
79	493G	0051080000013	Retail-Single-Occupancy	1920	4,594	$39,660	$15,865	-149.98%
80	493H	0031380000002	Office Warehouse	1964	4,950	$59,720	$63,153	5.44%
81	493K	0050840000004	Warehouse, Prefab.	1984	2,000	$22,380	$29,055	22.97%
87	369X	1166360000001	Hospitals	1986	72,369	$4,215,050	$4,193,243	-0.52%
88	409M	1074430000023	Religious	1980	12,563	$1,383,530	$1,138,879	-21.48%
91	411S	0431760000518	Police or Fire Station	1985	8,109	$431,370	$423,478	-1.86%
92	411U	0431880000007	Country Club with Golf	1995	39,739	$3,850,250	$1,768,347	-117.73%
23	451R	0760210070149	Res. Structure on Commercial Land	1958	3,243	$66,140	$60,432	-9.45%
94 and 22	452T	0561650000624	Res. Structure on Commercial Land	1975	2,851	$33,700	$28,464	-18.40%
24	493E	0210320000012	Res. Structure on Commercial Land	1920	5,730	$125,320	$128,752	2.67%
95	493F	0050930000027	Religious	1900	3,400	$74,190	$68,966	-7.57%
96	409C	0421070000017	School - Cook MS	N/A	200,583	$6,500,000	$7,362,101	11.71%
97	409R	0820810000001	School - Jersey Village HS	N/A	384,712	$23,358,000	$16,991,590	-37.47%
98	451M	0422240000148	Gethsemane Lutheran Church	N/A	N/A	$2,000,000	$1,276,226	-56.71%

Attachment 1D
Commercial Sample Pilot Survey (Quantification of Uncertainty)
Section 211(f) Federal Project - White Oak Bayou

Estimate Number CEI	Key Map	HCAD Acct Number	Property Class	Year Built	HCAD Building Area (SF)	HCAD Assessed Value	Depreciated Cost New by CEI	Error
99	452N	0760210070151	Retail-Single-Occupancy	1980	5,000	$120,970	$126,076	4.05%
100	452N	0661120080002	Office Building Low Rise	1979	18,838	$556,440	$588,308	5.42%
101	452T	0561650000177	Religious	1945	2,220	$10,430	$15,376	32.17%
102	452T	0561660000210	Apartments	1965	73,942	$204,090	$483,055	57.75%
103	452T	0561650000572	Service Station (Self)	1986	2,376	$148,900	$83,083	-79.22%
105	492D	0210320000003	Hospitals - Daycare	1970	4,700	$123,520	$130,567	5.40%
106	492D	0073140000001	Auto Service Garage	1949	4,004	$43,910	$41,220	-6.53%
25	493E	0050820000002	Commercial-Mixed Residential	1940	2,364	$7,990	$11,134	28.24%
107	493E	0050820000006	Office Warehouse	1960	4,851	$38,170	$34,753	-9.83%
110	493Q	0031220000001	U.S Customs Office	1927	595,734	$21,066,800	$16,539,205	-27.37%
111	411P	1000480000092	Religious	1981	5,244	$112,250	$202,636	44.61%
112	410U	0382900020078	Auto Service Garage	1992	1,800	$39,560	$38,786	-2.00%
113	451H	0392150030003	Retail-Single-Occupancy	1960	14,480	$103,180	$93,352	-10.53%
114	451R	0620050020017	Restaurant	1966	1,520	$27,000	$24,342	-10.92%
115	493B	0170010000013	Nursing Home	1955	13,228	$350,130	$307,711	-13.79%
Totals						$86,821,140	$73,197,541	
Count							85	85
Min							$1,750	-149.98%
Max							$16,991,590	76.45%
Median							$89,798	-4.14%
Mean							$861,148	-7.55%
StdDev							$2,761,239	36.96%
Var							$7,624,438,624,863	13.66%
CV								-4.90

(1) Replacement cost new adjusted for time by a factor of 0.87.

ATTACHMENT 1E

ELEVATION DATA SAMPLE PILOT SURVEY

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
2133	0102410000555	5258D	57.446	57.126	0.32	57.16	0.50	57.66	-0.03	0.18	-0.21
6381	0641870000097	5159B	65.639	65.169	0.47	65.36	0.50	65.86	-0.19	0.03	-0.22
6505	1225090010001	5159B	65.709	65.199	0.51	65.26	0.75	66.01	-0.06	0.24	-0.30
6732	0421300000163	5159B	68.909	68.319	0.59	68.25	0.50	68.75	0.07	-0.09	0.16
7283	1165080000001	5159B	72.744	70.654	2.09	72.00	0.50	72.50	-1.35	-1.59	0.24
7446	0590030290005	5159B	71.953	71.363	0.59	72.57	0.75	73.32	-1.21	0.16	-1.37
10378	1143680010002	5161A	78.904	78.704	0.20	77.43	0.75	78.18	1.27	0.55	0.72
20117	1203630010001	4963C	112.699	111.979	0.72	112.39	0.00	112.39	-0.41	-0.72	0.31
20801	1201950010001	4863A	117.248	117.108	0.14	117.80	0.00	117.80	-0.69	-0.14	-0.55
20820	1152900000002	4863A	117.378	116.508	0.87	117.17	0.50	117.67	-0.66	-0.37	-0.29
20969	1201580010001	4963A	114.145	113.845	0.30	111.70	0.25	111.95	2.15	-0.05	2.19
21327	0321050001049	4863B	115.752	114.892	0.86	114.73	0.50	115.23	0.16	-0.36	0.52
26408	1139140000024	4864D	119.375	118.805	0.57	119.09	0.00	119.09	-0.28	-0.57	0.28
7617	0590030100010	5160D	69.332	69.062	0.27	72.73	0.50	73.23	-3.67	0.23	-3.90
19882	1207620010001	4963C	110.897	110.567	0.33	111.15	0.00	111.15	-0.58	-0.33	-0.25
20086	1165760040003	4863C	117.875	117.505	0.37	117.92	0.75	118.67	-0.42	0.38	-0.80
21400	1192020010001	4863A	116.630	116.100	0.53	116.56	0.00	116.56	-0.46	-0.53	0.07
23627	1155570170026	4963A	114.434	113.714	0.72	114.26	0.50	114.76	-0.55	-0.22	-0.33
23831	0321050000080	4863A	120.015	119.905	0.11	117.98	0.00	117.98	1.93	-0.11	2.04
1404	0102210000434	5258D	52.681	52.211	0.47	51.48	0.75	52.23	0.73	0.28	0.45
2003	0102380000462	5258D	55.106	54.586	0.52	54.90	1.00	55.90	-0.31	0.48	-0.79
2237	0102420000591	5258D	58.196	56.846	1.35	57.12	1.00	58.12	-0.27	-0.35	0.08
7814	0844400000012	5160D	72.006	71.576	0.43	71.69	0.50	72.19	-0.11	0.07	-0.18
17624	1064100000033	5062B	88.073	87.593	0.48	87.65	0.50	88.15	-0.06	0.02	-0.08
18860	1188880020061	4963C	108.087	107.017	1.07	108.11	0.50	108.61	-1.09	-0.57	-0.52
20248	1152910000003	4863D	115.311	113.841	1.47	115.96	1.50	117.46	-2.12	0.03	-2.15
21445	1148330030035	4863A	119.247	118.527	0.72	119.09	0.75	119.84	-0.56	0.03	-0.59
21862	1162620210007	4963A	114.547	113.937	0.61	114.59	0.50	115.09	-0.65	-0.11	-0.54
21865	1148320030001	4863A	119.987	119.277	0.71	119.87	0.50	120.37	-0.59	-0.21	-0.38
22350	1157150010001	4863A	121.157	120.067	1.09	119.65	0.75	120.40	0.42	-0.34	0.76
23100	1148310080020	4863A	121.976	121.276	0.70	121.26	0.75	122.01	0.02	0.05	-0.03
23606	1148310120014	4863A	123.356	122.666	0.69	123.16	0.75	123.91	-0.49	0.06	-0.55

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
23666	1147760040005	4864C	120.125	119.645	0.48	120.02	0.25	120.27	-0.38	-0.23	-0.14
24110	1155570160041	4864D	113.878	113.268	0.61	113.81	0.75	114.56	-0.54	0.14	-0.68
24134	1155570190005	4964C	116.908	116.158	0.75	116.78	0.50	117.28	-0.62	-0.25	-0.37
24243	1197890020015	4864D	119.113	118.523	0.59	118.44	0.50	118.94	0.08	-0.09	0.17
24333	1155570130022	4964C	116.378	115.478	0.90	116.45	0.50	116.95	-0.97	-0.40	-0.57
24588	1199360030010	4764D	126.545	125.845	0.70	126.36	0.25	126.61	-0.52	-0.45	-0.06
24912	1200520040014	4864D	118.118	117.458	0.66	117.28	0.25	117.53	0.18	-0.41	0.59
25048	1200520040013	4864D	118.898	118.338	0.56	118.57	0.25	118.82	-0.23	-0.31	0.08
25131	1195370020034	4864C	123.392	123.032	0.36	122.96	0.25	123.21	0.07	-0.11	0.18
25239	1194660030015	4764D	126.926	126.206	0.72	126.18	0.25	126.43	0.03	-0.47	0.50
27160	1171190020013	4864C	126.474	126.074	0.40	126.71	0.75	127.46	-0.64	0.35	-0.99
27697	1187740030007	4864A	127.601	127.191	0.41	126.79	0.25	127.04	0.40	-0.16	0.56
27954	1142680030008	4864A	125.205	124.705	0.50	124.95	0.25	125.20	-0.25	-0.25	0.00
28225	1174580040019		129.409	128.549	0.86	129.12	0.25	129.37	-0.57	-0.61	0.04
28399	1171200040005	4764B	127.628	127.188	0.44	127.27	0.50	127.77	-0.08	0.06	-0.14
3534	1211740010001	5358B	39.520	38.920	0.60	43.21	1.50	44.71	-4.29	0.90	-5.19
6636	1211000010001	5259A	60.260	59.160	1.10	59.58	1.00	60.58	-0.42	-0.10	-0.32
297	0050660000010	5458C	41.660	39.030	2.63	42.94	3.00	45.94	-3.91	0.37	-4.28
3199	0170010000004	5358B	42.700	38.750	3.95	44.53	2.00	46.53	-5.78	-1.95	-3.83
637	0051070000003	5358D	44.850	44.450	0.40	48.31	0.00	48.31	-3.86	-0.40	-3.46
434	0050990000013	5358D	42.490	40.330	2.16	43.45	2.00	45.45	-3.12	-0.16	-2.96
3047	0381400000021	5358B	37.870	35.210	2.66	40.38	2.00	42.38	-5.17	-0.66	-4.51
613	0050820000002	5358D	42.050	39.130	2.92	42.64	2.00	44.64	-3.51	-0.92	-2.59
4587	0400350000030	5258B	60.250	58.150	2.10	60.80	2.00	62.80	-2.65	-0.10	-2.55
3150	0170010000001	5358B	39.150	37.100	2.05	38.87	2.80	41.67	-1.77	0.75	-2.52
65	1216410000014	5457A	35.630	35.120	0.51	35.60	2.50	38.10	-0.48	1.99	-2.47
316	0050840000004	5358D	42.620	42.300	0.32	44.64	0.40	45.04	-2.34	0.08	-2.42
1529	0210320000012	5358C	47.010	43.570	3.44	46.90	2.50	49.40	-3.33	-0.94	-2.39
5156	0561670000384	5259D	52.910	52.540	0.37	52.42	2.50	54.92	0.12	2.13	-2.01
4644	0391240000930	5259D	55.400	55.300	0.10	55.25	2.00	57.25	0.05	1.90	-1.85
3345	0373090000002	5358B	45.190	42.120	3.07	44.04	3.00	47.04	-1.92	-0.07	-1.85
6156	0561650000378	5259B	55.320	54.540	0.78	55.13	2.00	57.13	-0.59	1.22	-1.81

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
877	0142010000001	5358C	47.110	43.550	3.56	46.76	2.00	48.76	-3.21	-1.56	-1.65
3098	0611830090009	5358B	39.420	36.600	2.82	39.00	2.00	41.00	-2.40	-0.82	-1.58
978	0051080000002	5358D	46.190	44.700	1.49	46.73	1.00	47.73	-2.03	-0.49	-1.54
14741	0451350000045	4962D	95.150	91.950	3.20	94.04	2.50	96.54	-2.09	-0.70	-1.39
5735	0561660000216	5259D	55.100	53.800	1.30	54.34	2.00	56.34	-0.54	0.70	-1.24
7457	0432050010027	5160D	71.100	70.450	0.65	71.76	0.50	72.26	-1.31	-0.15	-1.16
306	0050630000022	5458C	31.170	28.500	2.67	32.30	0.00	32.30	-3.80	-2.67	-1.13
6388	0561650000144	5259B	58.450	56.650	1.80	57.54	2.00	59.54	-0.89	0.20	-1.09
5512	0561670000442	5259D	54.450	53.870	0.58	53.99	1.50	55.49	-0.12	0.92	-1.04
6371	0440840010004	5259A	58.800	58.200	0.60	58.78	1.00	59.78	-0.58	0.40	-0.98
6306	0561650000226	5259B	56.600	54.750	1.85	55.58	2.00	57.58	-0.83	0.15	-0.98
5021	0561670000592	5259D	51.900	51.800	0.10	52.44	0.40	52.84	-0.64	0.30	-0.94
6160	0561650000362	5259B	55.960	54.440	1.52	54.89	2.00	56.89	-0.45	0.48	-0.93
8853	0422240040012	5160B	67.100	66.900	0.20	67.89	0.00	67.89	-0.99	-0.20	-0.79
6293	0561630000175	5259B	56.260	54.160	2.10	55.04	2.00	57.04	-0.88	-0.10	-0.78
6462	0561630000099	5259B	56.700	55.850	0.85	57.04	0.40	57.44	-1.19	-0.45	-0.74
5269	0561670000533	5259D	52.480	52.190	0.29	52.66	0.50	53.16	-0.47	0.21	-0.68
3930	0440820000546	5258B	61.550	57.800	3.75	58.21	4.00	62.21	-0.41	0.25	-0.66
6142	0561650000404	5259B	57.200	55.200	2.00	55.84	2.00	57.84	-0.64	0.00	-0.64
5394	0561670000487	5259D	54.960	54.450	0.51	54.78	0.80	55.58	-0.33	0.29	-0.62
5282	0561670000364	5259D	54.020	53.640	0.38	53.63	1.00	54.63	0.01	0.62	-0.61
926	0050930000002	5358D	42.750	40.950	1.80	41.33	2.00	43.33	-0.38	0.20	-0.58
5706	0561660000233	5259D	56.200	54.500	1.70	54.77	2.00	56.77	-0.27	0.30	-0.57
589	0210560000028	5358C	51.100	50.400	0.70	51.67	0.00	51.67	-1.27	-0.70	-0.57
437	0050900000015	5358D	42.880	40.120	2.76	43.04	0.40	43.44	-2.92	-2.36	-0.56
10808	0430120000234	5161A	78.400	77.600	0.80	78.46	0.50	78.96	-0.86	-0.30	-0.56
3458	0301390000003	5358B	41.900	41.310	0.59	42.45	0.00	42.45	-1.14	-0.59	-0.55
5075	0561670000570	5259D	54.200	52.410	1.79	52.74	2.00	54.74	-0.33	0.21	-0.54
5052	0561670000401	5259D	53.820	51.810	2.01	52.32	2.00	54.32	-0.51	-0.01	-0.50
5687	0561660000244	5259D	56.670	54.690	1.98	55.16	2.00	57.16	-0.47	0.02	-0.49
15317	0451350000007	5062A	96.550	96.500	0.05	96.51	0.50	97.01	-0.01	0.45	-0.46
10238	1031180000015	5161D	71.500	70.850	0.65	71.45	0.50	71.95	-0.60	-0.15	-0.45

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
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OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
66	0031290000013	5457A	38.970	35.420	3.55	35.92	3.50	39.42	-0.50	-0.05	-0.45
9789	0392150010002	5161D	70.350	68.950	1.40	70.29	0.50	70.79	-1.34	-0.90	-0.44
6199	0561650000456	5259A	58.850	57.140	1.71	57.29	2.00	59.29	-0.15	0.29	-0.44
13319	0992870000059	5062D	83.700	82.200	1.50	83.59	0.50	84.09	-1.39	-1.00	-0.39
6155	0561650000379	5259B	56.940	54.440	2.50	55.32	2.00	57.32	-0.88	-0.50	-0.38
3114	0620740000018	5358B	46.600	43.850	2.75	43.97	3.00	46.97	-0.12	0.25	-0.37
9804	1040680000163	5161D	69.350	68.650	0.70	69.21	0.50	69.71	-0.56	-0.20	-0.36
5004	0561670000599	5259D	54.040	52.310	1.73	52.59	1.80	54.39	-0.28	0.07	-0.35
5990	0561650000549	5259D	57.360	52.760	4.60	55.70	2.00	57.70	-2.94	-2.60	-0.34
5428	0561670000636	5259D	53.200	51.320	1.88	52.74	0.80	53.54	-1.42	-1.08	-0.34
6992	0851460000650	5259A	59.580	58.870	0.71	59.41	0.50	59.91	-0.54	-0.21	-0.33
12370	1011020000009	5062D	84.600	84.100	0.50	84.40	0.50	84.90	-0.30	0.00	-0.30
4420	0812450000003	5258B	56.340	55.660	0.68	56.14	0.50	56.64	-0.48	-0.18	-0.30
13326	1023160000364	5062D	80.800	80.400	0.40	80.57	0.50	81.07	-0.17	0.10	-0.27
5654	0561670000312	5259D	53.080	52.330	0.75	53.33	0.00	53.33	-1.00	-0.75	-0.25
272	0400100000003		48.200	44.240	3.96	44.44	4.00	48.44	-0.20	0.04	-0.24
5130	0561670000581	5259D	55.400	53.200	2.20	53.61	2.00	55.61	-0.41	-0.20	-0.21
6272	0561650000306	5259B	58.850	57.140	1.71	57.06	2.00	59.06	0.08	0.29	-0.21
6069	0561650000531	5259B	57.100	55.000	2.10	55.30	2.00	57.30	-0.30	-0.10	-0.20
15110	0451350000001	5062C	94.900	91.200	3.70	92.10	3.00	95.10	-0.90	-0.70	-0.20
14782	1067290000002	4962D	97.800	96.400	1.40	96.97	1.00	97.97	-0.57	-0.40	-0.17
6141	0561650000621	5259B	57.520	55.350	2.17	55.69	2.00	57.69	-0.34	-0.17	-0.17
7029	0661120020014	5159B	62.600	61.700	0.90	62.26	0.50	62.76	-0.56	-0.40	-0.16
708	0210490000006	5358C	40.450	39.830	0.62	40.60	0.00	40.60	-0.77	-0.62	-0.15
6227	0561650000384	5259B	57.950	55.400	2.55	56.08	2.00	58.08	-0.68	-0.55	-0.13
4667	0391240000900	5259D	57.350	55.050	2.30	55.47	2.00	57.47	-0.42	-0.30	-0.12
7424	0730070000016	5259A	62.600	62.000	0.60	62.22	0.50	62.72	-0.22	-0.10	-0.12
785	0050920000009	5358D	43.560	41.700	1.86	41.68	2.00	43.68	0.02	0.14	-0.12
14205	1000480000094	5162C	79.700	78.850	0.85	79.32	0.50	79.82	-0.47	-0.35	-0.12
13142	1151210010005	4962D	95.500	95.100	0.40	95.11	0.50	95.61	-0.01	0.10	-0.11
10176	1014300000013	5161D	72.700	71.700	1.00	72.28	0.50	72.78	-0.58	-0.50	-0.08
12235	1125650000449	5062C	87.450	86.950	0.50	87.01	0.50	87.51	-0.06	0.00	-0.06

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
14789	1032800000038	5062D	83.300	82.400	0.90	82.86	0.50	83.36	-0.46	-0.40	-0.06
3151	0533000000003	5358B	37.470	35.040	2.43	35.52	2.00	37.52	-0.48	-0.43	-0.05
18246	0821200000016	4963C	106.400	105.400	1.00	105.93	0.50	106.43	-0.53	-0.50	-0.03
3205	0611820080010	5358B	42.840	40.270	2.57	40.86	2.00	42.86	-0.59	-0.57	-0.02
9726	0302390340035	5160B	69.350	68.100	1.25	68.85	0.50	69.35	-0.75	-0.75	0.00
5900	0561660000203	5259D	57.200	54.670	2.53	55.19	2.00	57.19	-0.52	-0.53	0.01
5627	0440840000070	5259D	54.900	54.600	0.30	54.68	0.20	54.88	-0.08	-0.10	0.02
2990	0611880000011	5358B	41.920	40.520	1.40	39.90	2.00	41.90	0.62	0.60	0.02
3977	0771820290005	5258B	54.120	52.920	1.20	53.69	0.40	54.09	-0.77	-0.80	0.03
4238	0812500000009	5258B	57.200	56.560	0.64	56.67	0.50	57.17	-0.11	-0.14	0.03
1725	0210310000011	5358C	47.050	46.600	0.45	47.01	0.00	47.01	-0.41	-0.45	0.04
13531	0451350000037	4962D	95.400	94.700	0.70	94.36	1.00	95.36	0.34	0.30	0.04
3158	0102040000175	5258B	51.180	50.890	0.29	50.60	0.50	51.10	0.29	0.21	0.08
2603	0101990000994	5258D	51.930	51.060	0.87	51.55	0.30	51.85	-0.49	-0.57	0.08
1329	0210450000022	5358C	46.800	43.800	3.00	46.70	0.00	46.70	-2.90	-3.00	0.10
5719	0610190030008	5259D	54.580	52.960	1.62	52.48	2.00	54.48	0.48	0.38	0.10
80	0031320000006	5457A	36.790	36.100	0.69	36.39	0.30	36.69	-0.29	-0.39	0.10
1009	0050930000010	5358D	41.050	41.450	-0.40	40.94	0.00	40.94	0.51	0.40	0.11
3301	0400530000026	5358B	45.300	42.750	2.55	43.17	2.00	45.17	-0.42	-0.55	0.13
3087	0400530000030	5358B	45.240	42.790	2.45	43.11	2.00	45.11	-0.32	-0.45	0.13
9684	0302430470015	5160B	68.200	68.100	0.10	68.07	0.00	68.07	0.03	-0.10	0.13
5205	0561670000532	5259D	53.950	51.750	2.20	51.99	1.80	53.79	-0.24	-0.40	0.16
5985	0561650000501	5259D	53.700	52.850	0.85	53.52	0.00	53.52	-0.67	-0.85	0.18
11429	0382900020060	5062C	91.350	90.800	0.55	90.65	0.50	91.15	0.15	-0.05	0.20
5876	0610190010043	5259D	58.500	56.390	2.11	56.80	1.50	58.30	-0.41	-0.61	0.20
3406	0301390000002	5358B	45.350	42.800	2.55	43.14	2.00	45.14	-0.34	-0.55	0.21
6056	0561650000542	5259B	57.810	55.050	2.76	55.59	2.00	57.59	-0.54	-0.76	0.22
18339	1074480040005	4963C	105.650	103.400	2.25	104.69	0.50	105.19	-1.29	-1.75	0.46
3120	0533000000004	5358B	36.720	34.370	2.35	34.47	2.00	36.47	-0.10	-0.35	0.25
6328	0561650000289	5259B	58.450	56.350	2.10	56.20	2.00	58.20	0.15	-0.10	0.25
13863	0451350000060	4962D	96.150	95.450	0.70	94.88	1.00	95.88	0.57	0.30	0.27
11367	0970710000039	5162C	76.300	75.000	1.30	75.49	0.50	75.99	-0.49	-0.80	0.31

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
5723	0610190030016	5259D	55.240	53.060	2.18	52.92	2.00	54.92	0.14	-0.18	0.32
6320	0561650000294	5259B	59.470	57.650	1.82	57.14	2.00	59.14	0.51	0.18	0.33
7468	0620050020017	5160D	71.350	70.800	0.55	70.52	0.50	71.02	0.28	-0.05	0.33
15461	1062300000013	5062B	86.500	85.200	1.30	85.65	0.50	86.15	-0.45	-0.80	0.35
1380	0210430000022	5358C	48.200	47.620	0.58	46.84	1.00	47.84	0.78	0.42	0.36
6827	0760210070149	5259A	59.450	59.300	0.15	58.58	0.50	59.08	0.72	0.35	0.37
5138	0391060000007	5259D	56.350	55.900	0.45	55.47	0.50	55.97	0.43	0.05	0.38
6079	0561650000502	5259B	55.400	54.250	1.15	54.70	0.30	55.00	-0.45	-0.85	0.40
5451	0440840000201	5259D	57.250	56.140	1.11	56.33	0.50	56.83	-0.19	-0.61	0.42
6165	0561650000348	5259B	55.890	53.660	2.23	53.47	2.00	55.47	0.19	-0.23	0.42
2890	0611900000002	5358D	44.750	42.400	2.35	42.32	2.00	44.32	0.08	-0.35	0.43
3010	0102020000093	5258D	51.720	51.390	0.33	51.26	0.00	51.26	0.13	-0.33	0.46
5701	0610190030003	5259D	56.030	53.740	2.29	53.56	2.00	55.56	0.18	-0.29	0.47
3069	0562890000007	5358B	45.800	44.100	1.70	43.32	2.00	45.32	0.78	0.30	0.48
6960	0661120060010	5259A	60.550	59.500	1.05	59.55	0.50	60.05	-0.05	-0.55	0.50
1970	0073210000001	5258D	49.840	49.080	0.76	49.33	0.00	49.33	-0.25	-0.76	0.51
4992	0440820000690	5259D	53.950	53.500	0.45	53.23	0.20	53.43	0.27	-0.25	0.52
5975	0561650000624	5259C	57.880	56.880	1.00	57.06	0.30	57.36	-0.18	-0.70	0.52
12368	1013150000147	5162C	80.250	79.100	1.15	79.22	0.50	79.72	-0.12	-0.65	0.53
11272	0431760000372	5161A	79.250	78.400	0.85	78.21	0.50	78.71	0.19	-0.35	0.54
14845	0451350000016	5062C	94.600	94.600	0.00	93.54	0.50	94.04	1.06	0.50	0.56
3239	0611870000001	5358B	43.750	41.800	1.95	41.19	2.00	43.19	0.61	0.05	0.56
6145	0561650000442	5259B	58.850	57.750	1.10	57.78	0.50	58.28	-0.03	-0.60	0.57
5552	0440840000044	5259D	55.050	54.550	0.50	54.48	0.00	54.48	0.07	-0.50	0.57
4226	0812470000012	5258B	56.040	55.610	0.43	54.96	0.50	55.46	0.65	0.07	0.58
5888	0561660000207	5259D	53.870	53.720	0.15	53.28	0.00	53.28	0.44	-0.15	0.59
5139	0561670000674	5259D	55.500	52.250	3.25	52.88	2.00	54.88	-0.63	-1.25	0.62
6419	0561650000210	5259A	58.050	58.000	0.05	57.42	0.00	57.42	0.58	-0.05	0.63
5936	0610190010001	5259D	57.500	56.500	1.00	55.35	1.50	56.85	1.15	0.50	0.65
6364	0561650000194	5259A	57.750	57.100	0.65	57.03	0.00	57.03	0.07	-0.65	0.72
5053	0561670000671	5259D	53.350	52.100	1.25	52.13	0.50	52.63	-0.03	-0.75	0.72
5267	0561670000522	5259D	56.040	53.850	2.19	54.27	1.00	55.27	-0.42	-1.19	0.77

Attachment 1E
Structure Inventory Elevation Data - Sample Survey
Section 211(f) Federal Project - White Oak Bayou

OBJECTID	HCAD_NUM	MAPFACET	FFE_Surv	NG_bldg	Slab_ht_Surv	Lidar_NG	Slab_ht_Est	FFE_Est	DNG_bldg	Dslab_ht	DFFE
6037	0561630000231	5259D	58.150	55.950	2.20	57.07	0.30	57.37	-1.12	-1.90	0.78
6345	0561650000262	5259B	58.410	55.300	3.11	55.39	2.00	57.39	-0.09	-1.11	1.02
3186	0170010000002	5358B	46.100	42.950	3.15	43.03	2.00	45.03	-0.08	-1.15	1.07
1865	0073140000009	5258D	50.830	49.400	1.43	49.04	0.70	49.74	0.36	-0.73	1.09
922	0050930000004	5358D	43.600	40.590	3.01	40.50	2.00	42.50	0.09	-1.01	1.10
2871	0102010000069	5258D	52.700	51.000	1.70	51.18	0.40	51.58	-0.18	-1.30	1.12
6729	0432050020010	5259A	58.140	56.970	1.17	56.02	0.70	56.72	0.95	-0.47	1.42
6201	0561630000191	5259B	65.700	62.800	2.90	62.77	1.50	64.27	0.03	-1.40	1.43
14325	0451350000212	4962D	95.500	92.950	2.55	93.56	0.40	93.96	-0.61	-2.15	1.54
899	0050960000002	5358D	43.710	41.590	2.12	41.40	0.70	42.10	0.19	-1.42	1.61
11498	0382900020007	5062C	92.300	90.950	1.35	90.18	0.50	90.68	0.77	-0.85	1.62
5382	0561670000497	5259D	55.080	54.950	0.13	52.64	0.80	53.44	2.31	0.67	1.64
6618	0561630000013	5259B	64.700	62.800	1.90	61.28	1.50	62.78	1.52	-0.40	1.92
11711	1165300010001	5162C	79.100	78.750	0.35	77.12	0.00	77.12	1.63	-0.35	1.98
591	0050910000002	5358D	44.020	41.690	2.33	41.51	0.40	41.91	0.18	-1.93	2.11
12821	0451620020001	4962D	96.800	94.200	2.60	93.57	1.00	94.57	0.63	-1.60	2.23
18139	0821310000002	4962A	104.800	101.600	3.20	102.17	0.50	102.87	-0.57	-2.70	1.93
5479	0561670000338	5259D	54.440	53.910	0.53	51.49	0.40	51.89	2.42	-0.13	2.55
3577	0440820000320	5258B	57.800	55.510	2.29	54.54	0.70	55.24	0.97	-1.59	2.56
2510	0512050030020	5358D	49.200	48.150	1.05	44.56	2.00	46.56	3.59	0.95	2.64
1314	0400300000011	5358D	50.170	50.200	-0.03	46.57	0.50	47.07	3.63	0.53	3.10
2471	0512050030017	5358D	47.850	46.100	1.75	41.78	2.00	43.78	4.32	0.25	4.07
2985	0381400000030	5358B	38.060	35.610	2.45	33.36	2.00	35.36	2.25	-0.45	2.70
								Average	**-0.41**	**-0.29**	**-0.12**
								Stdev	**1.26**	**0.72**	**1.23**
								Min	**-5.78**	**-3.00**	**-5.19**
								Max	**4.32**	**2.13**	**4.07**
								Count	**215**	**215**	**215**

ATTACHMENT 2

REPORT ON NON-STRUCTURAL DAMAGES (OTHER COSTS) AND INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS

Gulf Engineers & Consultants

Verdl Adam, PE
President

May 27th, 1999

TECHNICAL MEMORANDUM

TO: Melvin Spinks, CivilTech Engineering, Inc.

FROM: David S. Theophilus, GEC Inc.

SUBJECT: Final Report on Non-Structural Damages

Methodology

To develop estimates of the potential non-structural damages in the Brays Bayou project area, historical information from past flood events in the Houston area was developed by contacting public, commercial, and non-profit agencies that operate in the area. Public agencies included those on the federal government level, State of Texas, Harris County, and the City of Houston. Commercial agencies included major utilities and service providers. Non-profit agencies included the American Red Cross and groups affiliated with it.

Discussions with a number of the major government agencies and private companies indicated that the most readily available and complete information on flood damages was for the 1994 flooding in the Houston area. Data requests were narrowed to focus on this event. All of the agencies contacted were provided with a damage information request form, which detailed the specific damage areas that data was requested on. All major agencies and a number of the minor ones provided historical damage information on which the findings of this memorandum are based. A number of the agencies reported no damages from the 1994 flooding, or reported that damages incurred were minor and were included in with normal operating costs. A list of all agencies contacted is provided.

Vehicles

Damages to vehicles includes the labor and parts to dry out and replace materials, if necessary, when a vehicle is inundated. Information on damages to vehicles due to inundation was obtained from Property Claims Service, an insurance industry association that compiles statistics on damages to vehicles and other property from natural disasters, fires, and other events. According to Property Claims Service, the average claims paid on vehicles that have been flooded is $4,500, based on 1997 claims. The data is for claims filed throughout the United States, and is not limited to claims filed in

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the state of Texas, or the Houston area. This damage figure is for all vehicle makes and models, and for all depths of flooding. It includes vehicles that are classified as damaged but repairable, and those classified as a total loss, a total loss being where the amount of the damages exceeds the book value, or where the depth of flooding reaches the level of the vehicles dashboard.

This figure is considerably lower than the damage amount of $8,300 that the U.S. Army Corps of Engineers (COE) used in the 1997 Cypress Creek report. The amount used by the COE was originally developed by the Institute for Water Resources (IWR), based on extensive surveys done with owners whose vehicles had suffered flood damage. Due to the fact that the figure employed by the COE is based on detailed interviews with owners whose vehicles have been damaged by inundation, it includes damages that are not covered by insurance policies (such as the insurance deductible, damage to personal property in the vehicles, damages repaired by vehicle owners on which no insurance claim is made, and damages to vehicles that are not insured) . Because the COE damage figure gives a more complete accounting of actual damages that the estimate compiled by Property Claims Service, it is recommended that the COE damage figure be used, updated to current levels by the Consumer Price Index (CPI).

Vehicle damages used by the COE for the 1997 Cypress Creek report were based on surveys done by IWR following a flood event in 1989. The average amount of damages to vehicles in the 1989 surveys was $7,500.00. The average for the CPI in 1989 was 124.0. For April 1999, the CPI was 166.2, an increase of 42.2 points over the time period, and a percentage increase of 34%. This results in an adjusted 1999 damage amount of average damages of $10,050.00 per vehicle, with a one-to-one ratio of damaged vehicles to flooded homes.

Utilities

Utility damages include losses to electrical transformers and transmission lines, telephone company lines and switch boxes, cable TV lines and equipment, storm and waste sewers, and water and gas pipelines. Information has been provided by FEMA covering damage and expense claims paid to public utilities during the 1994 flood event in Houston. Public utilities in this category include water control structures, water treatment plants, storm sewers, etc. This information only details funds paid to the public utilities by FEMA, and does not include data on damages that are not reimbursable by FEMA, or that may have been absorbed by the utilities themselves. For these reasons, the FEMA data under-represents the actual damages sustained by public utilities. Some damage information has been received from the public utilities themselves, but combines data on damages that were reimbursed by FEMA with damages that were not. It would be extremely difficult to break out the data into the different categories, and this would still not give an accurate and complete picture of the damages from the 1994 flood, since the utilities combine all damages from all events for the year. Separating the damages from the particular event from the yearly damage total would require an intensive effort on the part of these utilities.

Contact has also been made with the major private utilities in Harris County, but none has reported any major damages. Many are "self-insured" (such as Southwester Bell) and handle damages as a regular budgetary item, meaning no insurance claims are made and no reports generated detailing costs for a particular disaster event. Other private utilities, such as AT&T and Equilon Pipeline LLC reported no major damages from any recent storm events, including 1994. Many of the smaller private utilities, including Warner Cable and TCI have also been contacted but were unable to identify any damages that were solely and directly attributable to the flooding in 1994.

Several of the private utilities reported that while there was some anecdotal information concerning expenses and damages from the flooding in 1994, it would be extremely difficult to establish actual damage values from the storm event. Some of the damages and costs were handled as regular expenses, while others were covered using funds budgeted for that purpose. Only when damage costs exceeded the funds set aside for that purpose did the utilities make insurance claims or handle damages as other than a regular expense. In most instances, damages from flooding in 1994 were included in with damages from all causes for the year. Separating out the storm damages would require a very intensive effort, be time consuming, and costly.

Based on the information received, there will not be enough data to establish a reliable and comprehensive new unit cost for utility damages. The information on funds paid out by FEMA under-represents the actual damages sustained by the public utilities. Data from the utilities themselves would include damages reimburse by FEMA (which would result in double counting), or would give a total of damages for the year, without giving a breakdown of the cause of each separate damage occurrence. Some damages were also handled as a regular expense item. For the private utilities, much of the damage data concerns damages for the year, from all causes, not just a particular event. Also, some damages and related expenses were covered by normal operating funds, and not broken out separately.

Based on the incompleteness of the data obtained, and the time, difficulty, and expense that separating the damages from other costs would entail, it is recommended that the best course of action will be to update the utility damages figure that the COE used in the latest Cypress Creek report using the CPI to bring the amount up to 1998 levels.

Utility damage figures used by the Corps for the 1997 Cypress Creek report were based on damage data developed by IWR from Tropical Storm Claudette in 1979. Average utility damages, per household, for that event were $77.00. The average for the CPI in 1979 was 72.6 points. For April 1999, the CPI was 166.2 points. This is an increase of 93.6 points over the time period, and a percentage increase of 129%. This results in adjusted 1999 average utility damages of $176.33 per damaged residential household.

Roads

Data received from the Harris County Human Resources & Risk Management Department details damages to roads from the 1994 flood event in Houston. According to representatives of Risk Management, Harris County sustained $1,389,624 in damages to approximately 10 identifiable miles of roads. This works out to an average of roughly $139,000 in damages per mile. There is no information available on the total miles of road within the area that experienced flooding. Therefore, this figure could not be accurately compared to the average "damages per mile" amount that the COE applies to all roads within a particular reach and flood plain.

Based on information provided by the Galveston District COE, and the time, difficulty and expense that would be required to develop a new "damages per mile" cost estimate, it is recommended that the COE figure for damages per mile, updated to current 1998 levels by using the CPI be utilized. This will result in a much more accurate potential damage amount than would the historical data from Harris County.

Road damage estimates used by the COE for the 1997 Cypress Creek report were developed by IWR. Average damages per mile, for all types of roads within an delineated flood damaged area, were put at $8,500. The average for the CPI in 1994 was 148.2 points. For April 1999, the CPI was 166.2 points. This is an increase of 18 points over the time period, and a percentage increase of 12%. This results in an adjusted 1999 damage amount of $9,520.00 per mile.

Other Costs

Information on this category has been received from the American Red Cross , FEMA, and the Small Business Administration detailing grants made for "other" costs resulting from the 1994 flood event in Harris County. The Red Cross data covered the number of cases of assistance given, and the dollar amount of assistance. The data received from FEMA covers grants made to local, county and state agencies for debris removal and emergency protective measures (mainly rescue efforts and security patrols), and grants made to individuals to obtain emergency shelter, food, clothing, and medical care. When combined, all identifiable "other" costs come to $1,584.00 per household. This is significantly lower than the figure of $6,300.00 used by the COE in the 1997 Cypress Creek report.

The information received does not include any funds that individuals may have paid out of pocket for items in this category, and this may be a significant amount. Without conducting in person interviews with individual flood victims, which would be time consuming and costly, there is no way to develop additional data for this category.

Since the figures utilized by the COE for the Cypress Creek report are based on a more detailed analysis than this estimate, and it would be extremely difficult, time consuming and costly to developed more in depth data, it is recommended that the "other" damages amount from that report be utilized, updated to current values by the CPI.

Studies conducted by IWR established other damages of $5,700 per household in 1990. The average for the CPI in 1990 was 130.7 points. For April 1999, the CPI was 166.2 points. This is an increase of 35.5 points over the time period, and a percentage increase of 27%. This results in an adjusted 1999 value of $7,239.00 in other damages per household.

Conclusion

It is not anticipated that any additional data will be developed to significantly alter the findings and recommendations contained in this memo without a more intensive, longer term, and expensive effort. When estimating the potential non-structural damages for the Brays Bayou project area, the best source of the estimates will be to utilize the updated damage figures from the U.S. Army Corps of Engineers 1997 report on Cypress Creek.

ATTACHMENT 2 - Updated February 2011
INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

	Damage	Event Exceedance Probability								
Reach	**Category**	**0%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
	Single Family Units		0	0	1	2	3	5	18	85
	Multi Family Units		0	0	0	0	0	7	60	60
1	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	1	2	3	12	91	158
	Roads		6840.83	13505.76	18242.91	26857	42012	51568.17	58629.53	68381.31
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
4687	Stage		21.99	27.95	31.13	34.76	35.98	37.2	40.59	43.55
	Damage (Utilities)		$0.00	$0.00	$0.24	$0.48	$0.72	$2.89	$21.93	$38.07
	Damage (Post Disaster)		$0.00	$0.00	$9.94	$19.88	$29.82	$119.27	$904.45	$1,570.36
	Damage (Roads)		$16.93	$33.43	$45.16	$66.49	$104.00	$127.66	$145.14	$169.28
	Single Family Units		0	0	0	4	7	13	60	223
	Multi Family Units		0	0	0	1	1	1	18	144
2	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	112	115	136	288	593
	Roads		5399.8	10900.91	19953.44	27739.09	37800.77	49558.56	58392.58	70230.65
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
9779	Stage		24.47	29.4	32.47	35.84	37.06	38.23	41.45	44.33
	Damage (Utilities)		$0.00	$0.00	$0.00	$26.99	$27.71	$32.77	$69.39	$142.89
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$1,113.17	$1,142.99	$1,351.71	$2,862.44	$5,893.83
	Damage (Roads)		$13.37	$26.99	$49.40	$68.67	$93.58	$122.68	$144.55	$173.86
	Single Family Units		0	0	0	2	2	7	55	97
	Multi Family Units		0	0	0	0	0	0	20	23
3	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	2	2	7	73	120
	Roads		1315.06	12802.12	13704.04	27768.5	35222.98	41592.34	45035.83	50389.84
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
23934	Stage		36.08	41.24	43.87	46.66	48.22	49.47	51.45	52.46
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.48	$0.48	$1.69	$17.59	$28.91
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$19.88	$19.88	$69.57	$725.55	$1,192.68
	Damage (Roads)		$3.26	$31.69	$33.92	$68.74	$87.20	$102.96	$111.49	$124.74

ATTACHMENT 2 - Updated February 2011

INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability								
		0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
4a(L)	Single Family Units		1	12	24	60	61	61	61	61
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		1	12	24	60	61	61	61	61
	Roads		0	784.38	967.02	1429.62	1429.62	1429.62	1429.62	1429.62
Index Station 25536	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		37.8	43.07	45.74	48.37	49.73	50.6	52.79	54.16
	Damage (Utilities)		$0.24	$2.89	$5.78	$14.46	$14.70	$14.70	$14.70	$14.70
	Damage (Post Disaster)		$9.94	$119.27	$238.54	$596.34	$606.28	$606.28	$606.28	$606.28
	Damage (Roads)		$0.00	$1.94	$2.39	$3.54	$3.54	$3.54	$3.54	$3.54
4b(L)	Single Family Units		0	3	5	69	228	391	680	772
	Multi Family Units		0	0	0	0	4	9	16	16
	Mobile Home Units		0	0	0	0	21	33	108	108
	Total Residential Units		0	3	5	68	250	427	799	896
	Roads		303.88	706.08	8993.8	45380.11	61399.95	68793.99	73976.91	78060.47
Index Station 32570	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		42.07	47.41	50.03	52.96	54.15	54.91	56.63	57.79
	Damage (Utilities)		$0.00	$0.72	$1.20	$16.38	$60.24	$102.89	$192.52	$215.89
	Damage (Post Disaster)		$0.00	$29.82	$49.70	$675.85	$2,484.75	$4,243.96	$7,941.27	$8,905.35
	Damage (Roads)		$0.75	$1.75	$22.26	$112.34	$152.00	$170.30	$183.13	$193.24
4 (R)	Single Family Units		0	0	5	11	55	121	372	647
	Multi Family Units		0	0	0	0	60	60	62	76
	Mobile Home Units		0	0	0	0	0	0	0	6
	Total Residential Units		0	0	5	11	114	178	432	728
	Roads		6922.35	10205.19	11510.74	34301.51	54776.67	74097.13	89971.45	98179.53
Index Station 30779	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		41.16	46.53	49.21	52.34	53.66	54.49	56.31	57.49
	Damage (Utilities)		$0.00	$0.00	$1.20	$2.65	$27.47	$42.89	$104.09	$175.41
	Damage (Post Disaster)		$0.00	$0.00	$49.70	$109.33	$1,133.05	$1,769.14	$4,293.65	$7,235.60
	Damage (Roads)		$17.14	$25.26	$28.50	$84.91	$135.60	$183.43	$222.73	$243.05

ATTACHMENT 2 - Updated February 2011

INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

	Damage	**Event Exceedance Probability**								
Reach	**Category**	**0%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
5	Single Family Units		0	0	1	99	265	326	406	485
	Multi Family Units		0	80	80	457	520	815	1221	1281
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	80	81	523	783	1141	1626	1765
	Roads		1814.91	2818.65	16313.62	42415.46	59068.87	75256.57	83196.41	100999.97
Index Station 41337	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		48.91	54.18	56.83	59.09	60.26	61.04	62.38	63.32
	Damage (Utilities)		$0.00	$19.28	$19.52	$126.02	$188.67	$274.93	$391.79	$425.28
	Damage (Post Disaster)		$0.00	$795.12	$805.06	$5,198.10	$7,782.25	$11,340.41	$16,160.83	$17,542.35
	Damage (Roads)		$4.49	$6.98	$40.38	$105.00	$146.23	$186.30	$205.95	$250.03
6	Single Family Units		0	0	0	159	493	685	873	1034
	Multi Family Units		0	0	392	392	392	457	466	997
	Mobile Home Units		0	0	0	0	1	1	1	1
	Total Residential Units		0	0	392	677	1042	1305	1500	2196
	Roads		1916.41	2999.24	38954.57	70173.12	78064.02	84905.86	99755.28	115456.93
Index Station 48942	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		55.07	59.91	62.52	64.74	65.57	66.21	67.29	68.51
	Damage (Utilities)		$0.00	$0.00	$94.45	$163.13	$251.07	$314.44	$361.43	$529.13
	Damage (Post Disaster)		$0.00	$0.00	$3,896.09	$6,728.71	$10,356.45	$12,970.41	$14,908.52	$21,826.07
	Damage (Roads)		$4.74	$7.42	$96.43	$173.72	$193.25	$210.19	$246.95	$285.82
7	Single Family Units		0	0	0	43	192	273	324	351
	Multi Family Units		0	0	0	0	0	436	452	604
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	42	192	709	775	954
	Roads		849.98	2643.55	10344.88	22517.2	28272.34	36158.26	41991.69	45493.52
Index Station 57918	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		62.6	66.55	67.93	69.85	71.13	72.05	73.04	73.87
	Damage (Utilities)		$0.00	$0.00	$0.00	$10.12	$46.26	$170.84	$186.74	$229.87
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$417.44	$1,908.29	$7,046.76	$7,702.73	$9,481.82
	Damage (Roads)		$2.10	$6.54	$25.61	$55.74	$69.99	$89.51	$103.95	$112.62

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INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability 0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
8a(L)	Single Family Units		0	0	0	2	40	55	55	55
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	1	11	19	19	19
	Roads		0	917.47	1707.04	1815.69	1816.01	1827.25	3496.07	3496.07
Index Station 65878	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		66.56	70.06	71.47	73.05	74.27	75.24	76.56	77.34
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.24	$2.65	$4.58	$4.58	$4.58
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$9.94	$109.33	$188.84	$188.84	$188.84
	Damage (Roads)		$0.00	$2.27	$4.23	$4.49	$4.50	$4.52	$8.65	$8.65
8b(L)	Single Family Units		0	0	23	90	140	158	193	201
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	21	100	166	184	219	227
	Roads		0	4075.3	7226.64	11851.63	12601.55	14086.63	14189.88	14421.49
Index Station 69408	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		72.78	74.97	76.26	78.07	78.65	79.02	79.52	79.93
	Damage (Utilities)		$0.00	$0.00	$5.06	$24.10	$40.00	$44.34	$52.77	$54.70
	Damage (Post Disaster)		$0.00	$0.00	$208.72	$993.90	$1,649.88	$1,828.78	$2,176.64	$2,256.16
	Damage (Roads)		$0.00	$10.09	$17.89	$29.34	$31.20	$34.87	$35.13	$35.70
8 (R)	Single Family Units		0	0	24	59	96	121	161	191
	Multi Family Units		0	0	0	0	0	0	48	48
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	24	59	94	121	217	253
	Roads		912.04	3351.4	8002.1	22290.04	25137.7	30777.08	32588.22	34790.2
Index Station 67624	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		70.58	72.42	73.75	75.81	76.83	77.31	77.91	78.47
	Damage (Utilities)		$0.00	$0.00	$5.78	$14.22	$22.65	$29.16	$52.29	$60.96
	Damage (Post Disaster)		$0.00	$0.00	$238.54	$586.40	$934.27	$1,202.62	$2,156.77	$2,514.57
	Damage (Roads)		$2.26	$8.30	$19.81	$55.18	$62.23	$76.19	$80.67	$86.12

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INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability								
		0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
9	Single Family Units		0	22	103	223	314	417	627	706
	Multi Family Units		0	0	0	0	0	0	0	556
	Mobile Home Units		0	0	0	0	0	0	0	2
	Total Residential Units		0	22	111	239	350	444	651	1277
	Roads		308.39	10830.35	26541.39	45482.02	47638.05	50366.42	52810.16	56393.22
Index Station 74115	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		75.9	78.32	79.42	80.52	81.23	81.76	82.95	83.92
	Damage (Utilities)		$0.00	$5.30	$26.75	$57.59	$84.33	$106.98	$156.86	$307.70
	Damage (Post Disaster)		$0.00	$218.66	$1,103.23	$2,375.42	$3,478.65	$4,412.92	$6,470.30	$12,692.12
	Damage (Roads)		$0.76	$26.81	$65.70	$112.59	$117.93	$124.68	$130.73	$139.60
10a(L)	Single Family Units		0	216	520	682	788	906	1049	1098
	Multi Family Units		0	0	0	1	1	1	1	1
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	216	522	693	796	908	1050	1099
	Roads		8087.63	31088	37250.29	41358.89	42701.36	44266.26	45999.21	47672.5
Index Station 77625	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		78.91	81.11	82.27	83.97	84.96	85.66	86.42	86.78
	Damage (Utilities)		$0.00	$52.05	$125.78	$166.98	$191.80	$218.79	$253.00	$264.81
	Damage (Post Disaster)		$0.00	$2,146.83	$5,188.16	$6,887.73	$7,911.45	$9,024.62	$10,435.96	$10,922.97
	Damage (Roads)		$20.02	$76.96	$92.21	$102.39	$105.71	$109.58	$113.87	$118.01
10b(L)	Single Family Units		0	112	138	166	171	186	212	225
	Multi Family Units		0	0	0	0	0	0	0	408
	Mobile Home Units		0	0	1	1	1	2	2	2
	Total Residential Units		0	102	129	157	162	177	202	624
	Roads		6746.04	24574.15	25930.01	26447.64	27285.86	28096.06	28946.03	29367.66
Index Station 83815	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		87.26	89.28	89.6	89.84	89.98	90.13	90.32	90.47
	Damage (Utilities)		$0.00	$24.58	$31.08	$37.83	$39.03	$42.65	$48.67	$150.36
	Damage (Post Disaster)		$0.00	$1,013.78	$1,282.13	$1,560.42	$1,610.12	$1,759.20	$2,007.68	$6,201.94
	Damage (Roads)		$16.70	$60.83	$64.19	$65.47	$67.55	$69.55	$71.66	$72.70

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INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability								
		0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
10a(R)	Single Family Units		0	1	6	82	195	362	536	610
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	48	53	135	255	412	583	657
	Roads		145.87	6297.81	16688.2	26783.21	28481.42	30453.23	31918.21	33644.67
Index Station 77625	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		78.91	81.11	82.27	83.97	84.96	85.66	86.42	86.78
	Damage (Utilities)		$0.00	$11.57	$12.77	$32.53	$61.44	$99.27	$140.48	$158.31
	Damage (Post Disaster)		$0.00	$477.07	$526.77	$1,341.77	$2,534.45	$4,094.87	$5,794.44	$6,529.93
	Damage (Roads)		$0.36	$15.59	$41.31	$66.30	$70.51	$75.39	$79.01	$83.29
10b(R)	Single Family Units		0	145	253	382	421	451	478	487
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	120	212	327	357	380	401	409
	Roads		11789.23	24921.35	25216.77	25517.54	25611.03	25622	25622	25622
Index Station 82633	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		85.98	88.07	88.46	88.82	89.05	89.26	89.52	89.7
	Damage (Utilities)		$0.00	$28.91	$51.08	$78.79	$86.02	$91.56	$96.62	$98.55
	Damage (Post Disaster)		$0.00	$1,192.68	$2,107.07	$3,250.06	$3,548.23	$3,776.82	$3,985.54	$4,065.06
	Damage (Roads)		$29.18	$61.69	$62.42	$63.17	$63.40	$63.43	$63.43	$63.43
11	Single Family Units		0	25	52	63	70	76	82	88
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	1	1	1	1	1	2	2
	Total Residential Units		0	17	28	34	36	40	47	52
	Roads		9449.21	20554.34	23224.92	23886.92	24021.55	24291.56	24666.84	25175.67
Index Station 88972	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		91.15	92.93	93.63	94.24	94.53	94.81	95.16	95.43
	Damage (Utilities)		$0.00	$4.10	$6.75	$8.19	$8.67	$9.64	$11.32	$12.53
	Damage (Post Disaster)		$0.00	$168.96	$278.29	$337.93	$357.80	$397.56	$467.13	$516.83
	Damage (Roads)		$23.39	$50.88	$57.49	$59.13	$59.47	$60.13	$61.06	$62.32

ATTACHMENT 2 - Updated February 2011

INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

	Damage	Event Exceedance Probability								
Reach	**Category**	**0%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
	Single Family Units		2	39	60	76	89	100	107	116
	Multi Family Units		0	0	0	0	0	0	0	0
12	Mobile Home Units		0	0	1	2	234	234	234	234
	Total Residential Units		1	27	42	58	302	312	319	328
	Roads		3742.43	18563.43	22614.62	24369.98	25682.76	26431.51	27476.71	28195.71
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
90490	Stage		91.95	93.89	94.52	95.07	95.37	95.68	96.02	96.29
	Damage (Utilities)		$0.24	$6.51	$10.12	$13.98	$72.77	$75.18	$76.86	$79.03
	Damage (Post Disaster)		$9.94	$268.35	$417.44	$576.46	$3,001.58	$3,100.97	$3,170.54	$3,260.00
	Damage (Roads)		$9.26	$45.95	$55.98	$60.33	$63.58	$65.43	$68.02	$69.80
	Single Family Units		0	0	0	0	0	0	2	12
	Multi Family Units		0	0	0	0	0	0	0	0
13	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	0	0	0	2	12
	Roads		439.14	2455.29	6744.51	12484.9	18253.9	19826.7	23364.25	25488.97
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
95013	Stage		94.36	96.73	97.61	98.4	98.88	99.29	99.83	100.28
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.48	$2.89
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$19.88	$119.27
	Damage (Roads)		$1.09	$6.08	$16.70	$30.91	$45.19	$49.08	$57.84	$63.10
	Single Family Units		0	29	127	239	336	415	518	668
	Multi Family Units		0	0	0	0	0	0	0	0
14	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	29	127	238	336	415	518	668
	Roads		2835.82	34585.72	49251.65	70738.84	93802.11	104289.26	128869.65	139043.59
	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
Index Station	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
100723	Stage		98.8	101.48	102.24	103.06	103.55	104.01	104.52	105.05
	Damage (Utilities)		$0.00	$6.99	$30.60	$57.35	$80.96	$100.00	$124.81	$160.96
	Damage (Post Disaster)		$0.00	$288.23	$1,262.25	$2,365.48	$3,339.51	$4,124.69	$5,148.41	$6,639.26
	Damage (Roads)		$7.02	$85.62	$121.92	$175.12	$232.21	$258.17	$319.02	$344.21

ATTACHMENT 2 - Updated February 2011
INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability								
		0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
15	Single Family Units		0	0	0	0	0	1	10	37
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	0	0	1	10	37
	Roads		37.46	401.91	4291.06	12572.37	19084.01	25048.74	32973.82	40572.53
Index Station 107598	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		103.21	105.66	106.38	107.02	107.38	107.72	108.18	108.62
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.24	$2.41	$8.92
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$0.00	$0.00	$9.94	$99.39	$367.74
	Damage (Roads)		$0.09	$0.99	$10.62	$31.12	$47.24	$62.01	$81.63	$100.44
16	Single Family Units		0	0	0	5	18	82	259	400
	Multi Family Units		0	0	0	0	0	14	14	163
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	5	18	96	273	563
	Roads		730.6	13227.76	33587.69	52430.2	63924.09	77951.09	100110.94	122943.22
Index Station 112547	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		108.57	110.5	111.26	112.03	112.62	113.17	113.63	113.92
	Damage (Utilities)		$0.00	$0.00	$0.00	$1.20	$4.34	$23.13	$65.78	$135.66
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$49.70	$178.90	$954.15	$2,713.35	$5,595.66
	Damage (Roads)		$1.81	$32.75	$83.15	$129.79	$158.25	$192.97	$247.83	$304.35
17	Single Family Units		0	0	0	0	28	86	192	295
	Multi Family Units		0	0	0	0	0	0	0	224
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	0	28	86	188	519
	Roads		293.98	14237.28	48127.9	78017.19	93363.33	106144.92	121413.21	130621.34
Index Station 119390	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		114.84	116.74	117.66	118.38	118.79	119.14	119.51	119.74
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.00	$6.75	$20.72	$45.30	$125.06
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$0.00	$278.29	$854.75	$1,868.53	$5,158.35
	Damage (Roads)		$0.73	$35.24	$119.14	$193.13	$231.12	$262.76	$300.56	$323.36

ATTACHMENT 2 - Updated February 2011
INUNDATED RESIDENTIAL UNITS AND ROAD MILES WITH ASSOCIATED NON-PHYSICAL COSTS (Model 800)

Reach	Damage Category	Event Exceedance Probability							
		0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
18	Single Family Units		0	0	0	0	0	0	2	10
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	0	0	0	2	10
	Roads		249.44	329.7	919.1	9569.6	21847.9	40835.78	68138.9	86694.61
Index Station 127300	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		119	120.59	121.46	122.44	123.17	123.79	124.5	124.94
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.48	$2.41
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$19.88	$99.39
	Damage (Roads)		$0.62	$0.82	$2.28	$23.69	$54.09	$101.09	$168.68	$214.61
19	Single Family Units		0	0	0	0	0	0	4	6
	Multi Family Units		0	0	0	0	0	0	0	0
	Mobile Home Units		0	0	0	0	0	0	0	0
	Total Residential Units		0	0	0	0	0	0	4	6
	Roads		55.44	65.3	144.88	858.63	1379.64	3560.37	13657.93	20213.64
Index Station 131721	Unit Cost (Utilities)		240.95	240.95	240.95	240.95	240.95	240.95	240.95	240.95
	Unit Cost (Post Disaster)		9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01	9939.01
	Unit Cost (Roads)		13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78	13070.78
	Stage		122.77	123.89	124.61	125.25	125.91	126.55	127.4	128
	Damage (Utilities)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.96	$1.45
	Damage (Post Disaster)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$39.76	$59.63
	Damage (Roads)		$0.14	$0.16	$0.36	$2.13	$3.42	$8.81	$33.81	$50.04
Totals	Total Single Family Units		3	604	1342	2518	4012	5298	7336	8960
	Total Mult Family Units		0	80	472	851	978	1800	2378	4601
	Mobile Home Units		0	1	3	4	258	271	347	355
	Totals Residential Units		2	676	1777	3543	5473	7571	10350	14231
	Totals Roads (Miles)		13.48	50.73	90.24	148.69	183.84	215.39	251.63	282.76

ATTACHMENT 3

ECONOMIC TECHNICAL PAPER
ECONOMIC UPDATE

Economic Technical Paper
White Oak Bayou Economic Update Procedures to 2009 Price Levels
Section 211(f) Federal Project – White Oak Bayou

This technical paper documents the methods and procedures used to update the 2002 HEC-FDA structure values (replacement cost new less depreciation) and unit costs for the above referenced project to 2009 price levels. The 2009 values will be used in an update analysis of benefits to be performed using the HEC-FDA model.

1.0 Background

As part of the final report submittals to Head Quarters US Army Corps of Engineers (HQ USACE) and the White House's Office of Management and Budget (OMB), it is required that costs and benefits are displayed in the GRR at current price levels for at least the recommended plan. Current economic analyses results for the recommended plan are February 2002 price levels. An update to February 2009 price levels is required to ensure compliance with ER 1105-2-100 and EC 11-2-187.

2.0 Methodology

Updating the benefits of the recommended plan will entail the computation of damages under Without Project and Recommended Plan conditions using a structure inventory that reflects February 2009 price levels. Changes in structure values from 2002 to 2009 will be analyzed and where necessary, the structure inventory will be updated using a predetermined model for adjustment. Analysis and update of the structure inventory consists of the following:

- A frequency analysis of changes to HEC-FDA structure values between 2002 and 2009 using Harris County Appraisal District (HCAD) data
- Random sampling of 30 residential, commercial, and public properties in the study area for costing using Marshall & Swift (M&S) Cost Estimating Program.
- Comparative statistical testing between 2002 HEC-FDA structure values and 2009 M&S depreciated replacement cost values (e.g. Student t-test)
- Update other costs (unit costs for vehicle, utilities, post disaster costs, and road damage categories) to February 2009 price levels using an adjustment factor based on the Consumer Price Index (CPI).

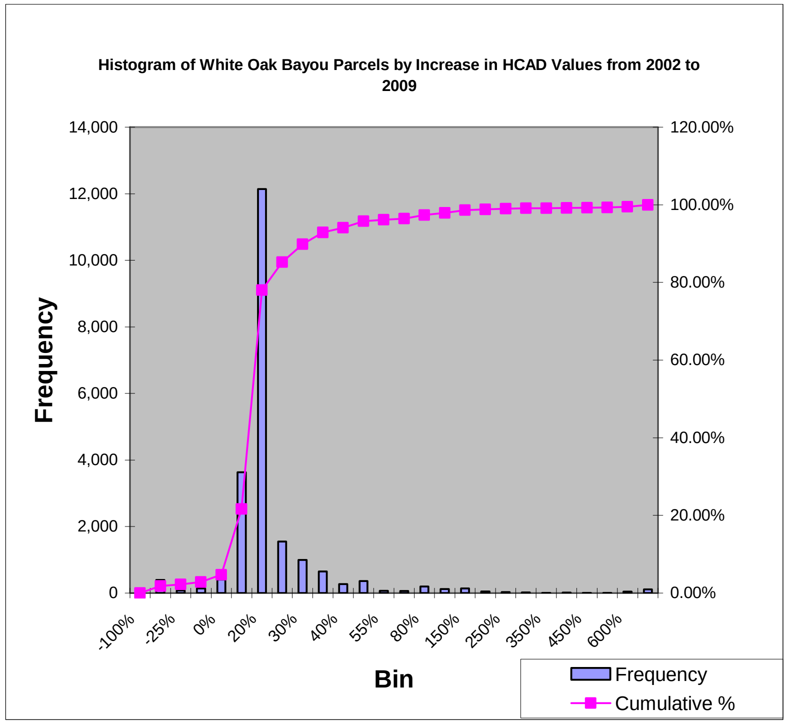
3.0 Frequency Analysis of HCAD Value Change

This GRR has employed the use of HCAD tax data structure values as proxy values for depreciated replacement cost values. To enable an understanding of how HEC-FDA structure values in the study area may have changed between 2002 and 2009, 21,525 properties in the study area with 2009 HCAD values that did not show any documented changes in land use or building square footage and had not been remodeled since the 2002 survey year, were analyzed. The difference between 2009 HCAD based HEC-FDA depreciated replacement value and 2002 HCAD based HEC-FDA depreciated replacement value as a percentage of the 2002 value was computed for each property and a histogram of the differences constructed. As shown in **Figure 1**, the majority of structures show increases in structure value of between 10 and 20 percent. The mode calculated is 14.33 percent with the median value 14.29 percent increase. The mean change in value for the 21,525 properties analyzed was a 33.06 percent increase in value from 2002 to 2009.

Figure 1
Histogram of Percent Increase in HCAD Value from 2002 to 2009
Section 211(f) Federal Project - White Oak Bayou

Frequency Distribution Table

HCAD Value Percent Increase (BinValue)	*Frequency*	*Cumulative Frequency (%)*
-100%	0	0.00%
-50%	397	1.84%
-25%	80	2.22%
-10%	143	2.88%
0%	404	4.76%
10%	3,632	21.63%
20%	12,139	78.03%
25%	1,549	85.22%
30%	1,000	89.87%
35%	650	92.89%
40%	266	94.12%
50%	363	95.81%
55%	71	96.14%
60%	65	96.44%
80%	201	97.38%
100%	123	97.95%
150%	145	98.62%
200%	50	98.85%
250%	31	99.00%
300%	23	99.10%
350%	8	99.14%
400%	13	99.20%
450%	10	99.25%
500%	8	99.28%
600%	43	99.48%
More	111	100.00%
Count	21,525	
	Mean	33.06%
	Median	14.29%
	Mode	14.33%



Note: Each Bin Value is the upper class limit of the range defined between Bin Values.

4.0 Sample Survey

A sample survey of 30 structures in the study area was conducted for costing using the Marshall and Swift Cost Estimator Program. The sample as shown in **Table 1** is comprised of 25 residential and 5 commercial properties within the study area selected at random. The ratio and percent change was calculated for each pairing of 2002 HEC-FDA and 2009 M&S depreciated replacement cost structure values.

The results show that on average 2009 M&S values are 1.18 percent higher than the 2002 HEC-FDA structure values. A statistical description of the ratios of 2009 M&S values to 2002 HEC-FDA values is shown in **Figure 2**. The standard deviation of the ratios is 0.242. The probability that the ratios belong to the normal distribution can be seen to be significant at 0.05 level of significance, hence parametric testing of the data may apply.

The 2-tailed Student t-test was performed on the ratios and as shown in **Figure 3**, the p-value of 0.035 is less than the 0.05 level of significance ($\alpha = 0.025$ for 2-tailed test) thus allowing for acceptance of the alternative hypothesis that the ratio of 2009 M&S values to 2002 HEC-FDA values is not equal to 1. This result means that adjustment of the 2002 HEC-FDA structure values is required to obtain 2009 depreciated replacement cost values for the HEC-FDA model. A summary of the survey and statistical analysis in conformity with the methodology described in IWR Report 95-R-9 can be seen in **Attachment 1** of this technical paper.

Table 1
White Oak Bayou Economics Update
Comparison between 2002 HEC-FDA Structure Value and 2009 M&S Depreciated Cost Values

Number	HCAD_Num	HEC-FDA Struc_Name	Year Built	Street	Zip Code	No. of Units	HEC-FDA 2002 Value	2009 M&S Value	Ratio	Difference
1	0760210050112	R6650R	1953	4114 Ascot Ln	77092	1	$133,710	$112,703	0.84	-15.71%
2	0580940000039	C7348C	1975	2215 W 34th St	77018	1	$134,600	$252,044	1.87	87.25%
3	0620050020023	C7461C	1972	4420 W 34th St	77092	1	$17,720	$23,092	1.30	30.32%
4	0731000880019	R8122R	1952	2210 Lamonte Ln	77018	1	$46,960	$48,352	1.03	2.96%
5	0731000720026	R8348R	1950	1842 Saxon Dr	77018	1	$22,890	$21,557	0.94	-5.83%
6	0731000870021	R7969R	1952	2222 Gardenia Dr	77018	1	$30,800	$37,338	1.21	21.23%
7	0302380300017	C9602C	1982	4811 Broom St	77091	1	$26,000	$44,539	1.71	71.30%
8	1014300000006	R10175R	1969	5034 Bayou Vista Dr	77091	1	$95,940	$89,092	0.93	-7.14%
9	1000970000027	R12608R	1969	6015 Darkwood Dr	77099	1	$77,280	$75,261	0.97	-2.61%
10	1131180000001	R15369R	1978	7903 Midland Forest Dr	77088	1	$72,270	$62,398	0.86	-13.66%
11	1045290000009	R14400R	1970	7631 Kellwood Dr	77040	1	$43,030	$40,503	0.94	-5.87%
12	1043870000014	R13709R	1972	7254 Shady Corners Ln	77040	1	$52,170	$53,585	1.03	2.71%
13	1151210000007	C12766C	1982	9203 Emmott Rd	77040	1	$233,480	$376,947	1.61	61.45%
14	1131790000008	R15563R	1981	7230 Wind Trail St	77040	1	$72,740	$83,391	1.15	14.64%
15	1104680000007	R17264R	1977	14619 Wind Lawn Dr	77040	1	$57,920	$72,006	1.24	24.32%
16	0821040000006	R16425R	1974	15501 Shanghai St	77040	1	$71,760	$61,891	0.86	-13.75%
17	0821050000009	R16771R	1958	16321 Jersey Dr	77040	1	$64,990	$88,687	1.36	36.46%
18	1047610000027	R15229R	1974	15802 Seattle St	77040	1	$85,420	$91,097	1.07	6.65%
19	1178870030010	R20449R	1994	9206 Cabin Creek Dr	77064	1	$119,570	$154,603	1.29	29.30%
20	1179590070006	R18873R	1998	9806 Willowbridge Park Blvd	77064	1	$133,260	$176,949	1.33	32.78%
21	1171870080022	R19238R	1992	10427 Minturn Ln	77064	1	$112,490	$143,170	1.27	27.27%
22	1163330000001	C20781C	1994	9425 Jones Rd	77065	1	$1,012,070	$1,410,993	1.39	39.42%
23	1152000060025	R23823R	1985	10507 Saddlehorn Trl	77064	1	$78,160	$89,169	1.14	14.08%
24	1155570130030	R24528R	1991	10130 Storm Meadow Dr	77064	1	$101,910	$109,753	1.08	7.70%
25	1152000030012	R23530R	1983	9911 Bent Spur Ln	77064	1	$67,590	$78,150	1.16	15.62%
26	1157160010021	R22841R	1994	11515 Autumn Chase Dr	77065	1	$103,470	$133,150	1.29	28.68%
27	1176870010027	R20680R	1994	9423 Tarton Way Ct	77065	1	$108,890	$133,434	1.23	22.54%
28	1174160060010	R27928R	1995	11102 Wortham Blvd	77065	1	$150,510	$156,143	1.04	3.74%
29	1189050010019	R25729R	1997	13019 Durbridge Trail Dr	77065	1	$157,500	$166,816	1.06	5.91%
30	1172310100036	R28407R	1993	13302 Denver Oaks Dr	77065	1	$111,560	$144,391	1.29	29.43%
								Average	1.18	18.37%

Figure 2

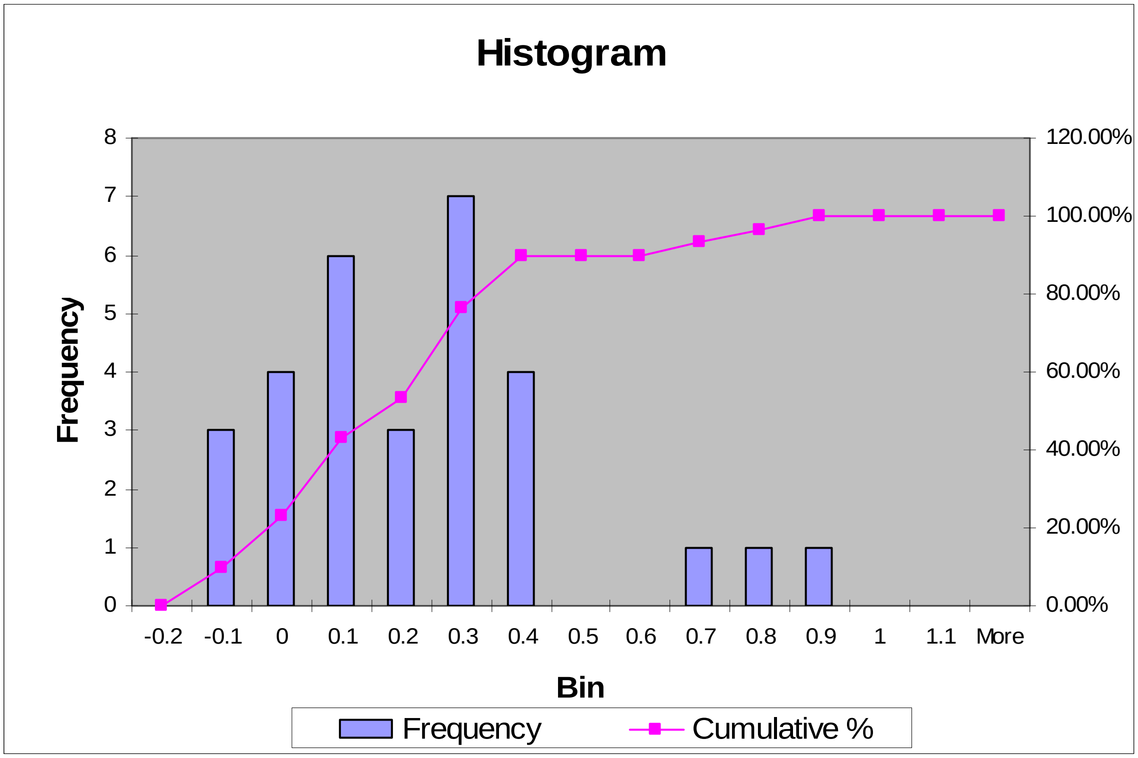


Figure 3

n	31		
Mean	1.184	Median	1.156
95% CI	1.095 to 1.273	97.1% CI	1.037 to 1.287
SE	0.044		
		Range	1.03
Variance	0.059	IQR	0.267
SD	0.242		
95% CI	0.194 to 0.324	Percentile	
		0th	0.843 (minimum)
CV	20.50%	25th	1.028 (1st quartile)
		50th	1.156 (median)
Skewness	1.01	75th	1.294 (3rd quartile)
Kurtosis	1.29	100th	1.873 (maximum)
Shapiro-Wilk W	0.93		
p	0.035		

5.0 Other Costs

Unit costs used in the construction of depth-damage curves for vehicle, utility, post disaster costs, and road damage categories are to be updated using the Consumer Price Index (CPI) as a means for price level adjustment. The change in CPI index for all items in the Houston-Galveston-Brazoria, Texas Metropolitan Statistical Area (MSA) is +20.05% for the period from February 2002 to February 2009. This change is reflected in Attachment 2 with the computation of new unit cost values.

6.0 Conclusions

An analysis was performed to determine the overall change in the HCAD data sets between 2002 and 2009 based on the 2002 HEC-FDA structure database. The majority of structures show increases in structure value of between 10 and 20 percent. The mode calculated is 14.33 percent with the median value 14.29 percent increase. The mean change in value for the 21,525 properties analyzed was a 33.06 percent increase. This is based on a 2002 data which was compared to 2009 values. A Marshall & Swift Cost Estimate of 30 randomly chosen study area properties shows that on average depreciated replacement cost values have increased by 18.0%. A Student t-test confirms the likelihood of a change in value for the 30-sample survey. This methodology is considered to be more accurate due to the age of the original database of 2002. Based on the 2009 Marshall & Swift Cost Estimates compared to the HEC-FDA 2002 values, a recommended adjustment of all 2009 structure price levels by +18.0% to obtain depreciated replacement costs at 2009 price levels. Unit costs for non-structural damage categories are to be inflated to 2009 price levels by +20.0% based on the Consumer Price Index.

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

Estimate ID	HEC-FDA Struc_Name	HCAD Acct Number	Property Class	Year Built	Building Area (SF)	HCAD Assessed Value	Depreciated Cost New by CEI	DC/HCAD Ratio
1	R207	0141960000222	Residential 1 Family	1935	1,170	$21,430	$26,735	1.25
2	R963	0622080140016	Residential 1 Family	1946	1,344	$39,390	$31,172	0.79
3	R40446	0611370660013	Residential 1 Family	1950	3,432	$69,522	$94,915	1.37
4	R41560	1122750010007	Condominium (Common Element)	1979	1,453	$69,480	$68,382	0.98
5	R5769	1118030000011	Residential 1 Family	1979	2,536	$124,010	$103,875	0.84
6	R44224	0840080000041	Residential 1 Family	1975	1,826	$63,170	$82,053	1.30
7	R1121	0610840070007	Residential 1 Family	1940	2,592	$58,560	$64,311	1.10
8	R14100	0831800000001	Residential 1 Family	1960	2,425	$76,070	$79,603	1.05
9	R20206	0980700000028	Residential 1 Family	1968	1,426	$61,880	$59,110	0.96
10	R40907	0611390190004	Residential 1 Family	1950	2,266	$62,050	$61,314	0.99
11	R10358	0720070320018	Residential 1 Family	1953	2,143	$62,850	$75,337	1.20
12	R40855	0511150040001	Residential 1 Family	1981	1,792	$83,170	$74,365	0.89
13	R6612	0730040100002	Residential 1 Family	1947	1,397	$25,970	$33,209	1.28
14	R34548	0601150050007	Residential 1 Family	1940	1,890	$31,753	$39,733	1.25
15	R22814	1072310010012	Condominium (Common Element)	1977	1,404	$61,870	$56,840	0.92
16	P1767	0410070070060	Religious	1950	24,000	$1,660,582	$1,780,843	1.07
17	R16138	0843080000012	Residential 1 Family	1955	2,182	$98,410	$91,917	0.93
18	R21614	0892580000022	Residential 1 Family	1957	2,228	$55,454	$74,813	1.35
19	R8351	0751390070021	Residential 1 Family	1991	3,462	$299,365	$269,258	0.90
20	R9350	0761330020008	Residential 1 Family	1950	1,520	$39,310	$42,091	1.07
21	R17343	0925350000001	Residential 1 Family	1960	1,990	$63,070	$70,575	1.12
22	R23126	0920340000006	Residential 1 Family	1960	3,580	$146,656	$163,126	1.11
23	R24939	0855400000002	Residential 1 Family	1956	2,725	$75,718	$85,688	1.13
24	R43424	0822380000240	Residential 1 Family	1955	1,850	$70,091	$69,854	1.00
25	R43879	0840080000026	Residential 1 Family	1958	1,945	$41,380	$48,400	1.17
26	P13246	0730230000052	Religious	1970	17,382	$248,890	$246,475	0.99
27	C16899	0410900000152	Fast Food	1994	2,437	$285,973	$275,897	0.96
28	C6041	0680170020001	Office Building Low Rise	1970	5,695	$99,720	$126,712	1.27
29	R11753	1104050080001	Condominium (Fee Simple)	1980	1,406	$56,530	$62,661	1.11
30	C30796	0370590250021	Fast Food	1974	2,224	$151,150	$135,230	0.89
Totals						$86,821,140	$73,197,541	
Count						30	30	30
Min						$21,430	$26,735	0.79
Max						$1,660,582	$1,780,843	1.37
Median						$66,325	$74,589	1.07
Mean						$143,449	$149,816	1.07
StdDev						$295,133	$314,884	0.16
Var						$87,103,382,892	$99,151,796,440	0.02
CV								0.15

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

Statistical Summary

1. Compute Sample Size (n)

$$n = \frac{Z^2 CV^2}{e^2}$$

Level of Confidence = 90%, therefore:

z =	1.64

Level of Precision (Tolerable Error) = 5% or 10%, e = 0.05 or 0.10

Coefficient of Variation (CV) = 0.15

For e = 5%	***0.05***
n =	***23***
For e = 10%	***0.10***
n =	***6***

2. Determine Sample Survey Level of Precision (Error - e)

For n =	30
e =	***4.38%***

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

Sample Test Application

Objective: To Update 2001 Depreciated Replacement Cost values obtained direct or by proxy using HCAD data to 2004 Depreciated Replacement Cost Values. A random sample of 30 structures in the Brays Bayou Study Area was obtained and 2004 Depreciated Replacement Costs were estimated using Marshall and Swift Residential and Commercial Cost Estimator. The 2001 values are to be compared to the 2004 values to ascertain difference and adjust accordingly.

Analysis: On the average, the sampled structures have a depreciated replacement cost for year 2004 seven (7) percent higher than the year 2001 value, a mean ratio of 1.07. The sample standard deviation of the ratios was calculated to be 0.16. Assuming that the ratios are normally distributed the Student t distribution can be used to describe the sample. The t-statistic computed from measuring the difference between the sample and the assumed population mean is computed below.

$$t = \frac{X - U}{S/(N)^{0.5}}$$

X =	1.07	(sample mean)
U =	1.00	(assumed population mean)
S =	0.16	(sample standard deviation)
N =	29.00	(sample size - 1)

Compute Student t Distribution:

t =	2.56	N-1 degrees of freedom

Referencing a standard student t distribution table, the critical value of t with 29 degrees of freedom for a two-tailed test at a 10 percent level of significance is 1.699. This indicates within the bound of t = -1.699 to t = +1.699, there is a 90 percent chance that the population mean = 1.0. Since our calculated t of 2.56 is not within the acceptance range, we can conclude that it is necessary to find a means to adjust the HCAD 2001 data to bring in line with M&S 2004 values. Adjustment will be performed based on a linear regression model of paired 2001 and 2004 values.

Attachment 2

Unit Cost Update from February 2002 to February 2009 Price Levels
White Oak Bayou - "Other Cost" Damage Categories

Damage	Event Exceedance Probability								
Category	0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
Unit Cost (Vehicles)	$0	$10,754	$10,754	$10,754	$10,754	$10,754	$10,754	$10,754	$10,754
Unit Cost (Utilities)	$0	$188	$188	$188	$188	$188	$188	$188	$188
Unit Cost (Emergency)	$0	$7,746	$7,745	$7,745	$7,745	$7,745	$7,745	$7,745	$7,745
Unit Cost (Roads)	$0	$10,186	$10,186	$10,186	$10,186	$10,186	$10,186	$10,186	$10,186

ADJUSTED UNIT COSTS VALUES PER THE % CPI INCREASE FROM FEB. 2002 TO FEB. 2009 OF: **20 %**

Damage	Event Exceedance Probability								
Category	0%	50%	20%	10%	4%	2%	1%	0.4%	0.2%
Unit Cost (Vehicles)	$0	$12,904	$12,904	$12,904	$12,904	$12,904	$12,904	$12,904	$12,904
Unit Cost (Utilities)	$0	$225	$225	$225	$225	$225	$225	$225	$225
Unit Cost (Emergency)	$0	$9,295	$9,294	$9,294	$9,294	$9,294	$9,294	$9,294	$9,294
Unit Cost (Roads)	$0	$12,224	$12,223	$12,223	$12,223	$12,223	$12,223	$12,223	$12,223

**The multiplier of 1.200 was obtained from the U.S. Department of Labor Bureau of Labor Statistics web-site (www.bls.gov)"

**The 44-month Percent Change in the Consumer Price Index for "All Items" in the Houston-Galveston-Brazoria, Texas Metropolitan Statistical Area was determined for the time period from February 2002 to February 2009. This value is +20.0% and represents the average increase in the cost of all items for this time period.

**This value was then utilized as a multiplier for the the categories in the above table.

ATTACHMENT 4

EGM 09-04 VEHICLE DAMAGES TECHNICAL PAPER

Economic Technical Memorandum
Vehicle Damage Estimates Using Economic Guidance Memorandum, 09-04
White Oak Bayou Federal Flood Control Project
Issued on September 28, 2009

The U.S. Army Corps of Engineers (USACE) has published guidance for the use of generic vehicle depth-damage curves for USACE flood risk management studies. The generic vehicle depth-damage methodology and curves are documented in Economic Guidance Memorandum (EGM), 09-04, Generic Depth-Damage Relationships for Vehicles dated June 22, 2009, as provided in **Attachment 1**. The purpose of this technical memorandum is to document the methodology and procedures used to estimate vehicle damages under EGM, 09-04 for White Oak Bayou Federal Flood Control Project, Harris County, Texas.

CivilTech Engineering, Inc. was authorized by LJA Engineering & Surveying Inc. to perform vehicle damage estimates using Economic Guidance Memorandum, 09-04, for With and Without Project Conditions in the White Oak Bayou Federal Flood Control Project.

1.0 Technical Analysis

EGM 09-04 established damage functions for five types of vehicles (sedans, pickups, suv's, sports cars, and mini vans) based on a survey sample of 640 vehicles. The damage functions can be used to estimate vehicle damage when applied to expected water surface elevations for flood events. EGM 09-04 notes that the depth-damage functions should be applied to vehicles at ground elevations of affected properties. Damage to vehicles at residences is dependent on the number of vehicles per household; the approximate percentage breakdown by type of vehicle; the average vehicle value based on the make, model, and age; and the percentage of vehicles that are likely to be at the residence at the time the flood waters reach the property and the availability of safe evacuation routes.

There are 13 zip codes located within 26 economic reaches for the White Oak Bayou Federal Flood Control Project as generally depicted in **Figure 1.**

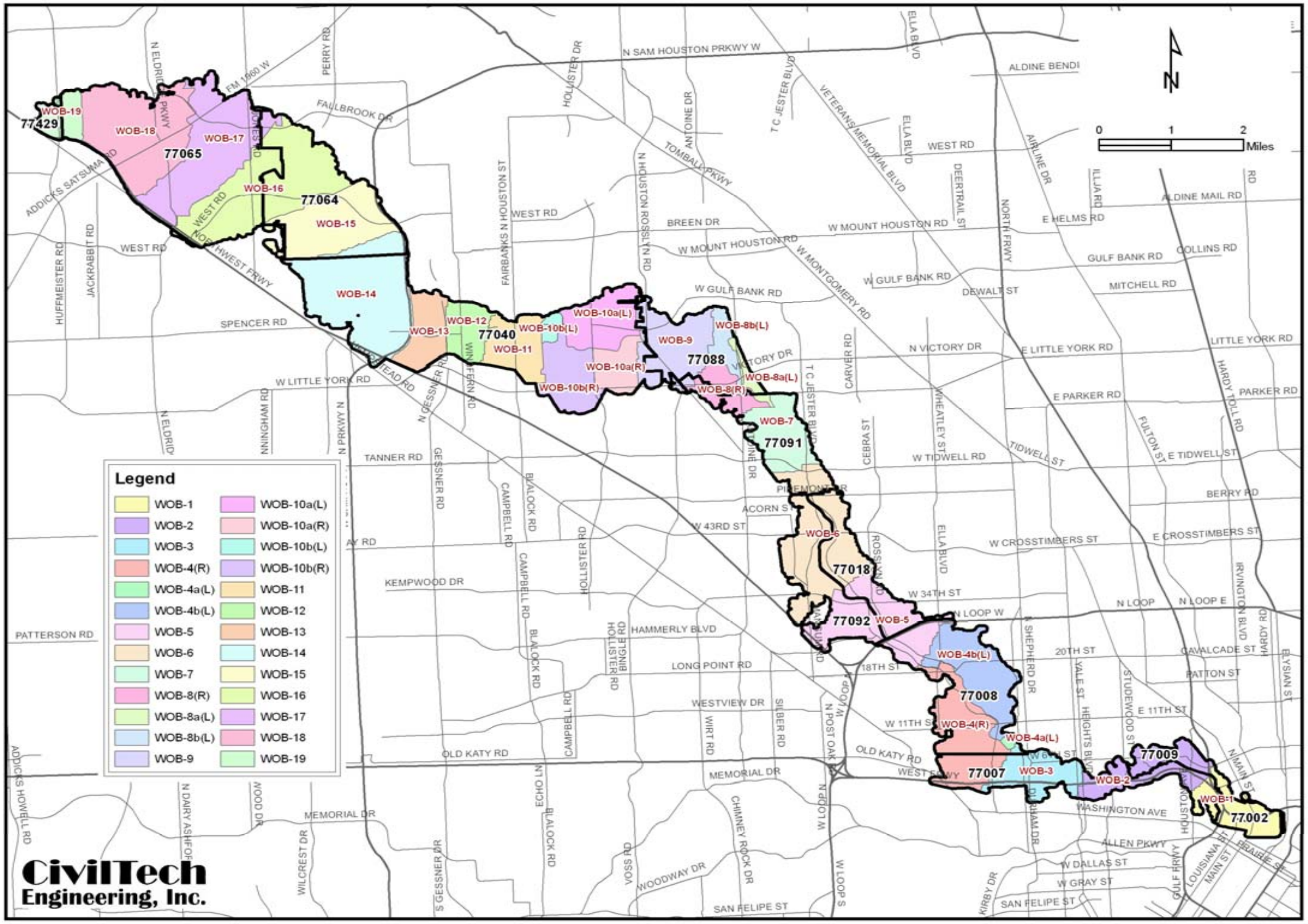


Figure 1. Reach and Zip Code Map for White Oak Bayou

The technical activities are identified below:

- Estimate the average number of vehicles per household (Activity 1)
- Estimate the approximate distribution of type of vehicles (Activity 2)
- Estimate the average value of vehicle based on make, model, age (Activity 3)
- Random distribution of vehicles by zip code (Activity 4)
- Compute vehicle damages using HEC-FDA (Activity 5)

Activity 1 – Estimate the Average Number of Vehicles per Household

EGM 09-04 states the average number of vehicles per household can be estimated using the American FactFinder section of the U.S. Census website by entering the zip code and looking under household characteristics (http://factfinder.census.gov). The U.S. 2000 Census data provides the total residential households by zip code including the number of households with 0, 1, 2 and 3 vehicles as provided in **Table 1**. The census data was used to determine the total number of vehicles by zip code, which is a summation of the residential households (with 0, 1, 2, and 3 vehicles) multiplied by the respective number of vehicles per household. The total vehicles and the average number of vehicles per household for each zip code are presented in **Table 1**.

Table 1. Average Number of Vehicles per Household within Each Zip Code

Zip	Total Households	Households With				Vehicles at Households With				Total Vehicles *	Avg. Vehicles / Household
		0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles	0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles		
77002	1,791	355	1,062	333	41	0	1,062	666	123	1,851	1.034
77007	9,308	1,256	4,478	2,686	888	0	4,478	5,372	2,664	12,514	1.344
77008	12,469	1,338	5,751	4,348	1,032	0	5,751	8,696	3,096	17,543	1.407
77009	14,262	2,110	6,114	4,489	1,549	0	6,114	8,978	4,647	19,739	1.384
77018	10,599	983	4,176	4,270	1,170	0	4,176	8,540	3,510	16,226	1.531
77040	14,578	562	5,263	6,596	2,157	0	5,263	13,192	6,471	24,926	1.710
77064	11,825	247	3,423	5,962	2,193	0	3,423	11,924	6,579	21,926	1.854
77065	10,341	356	3,531	4,755	1,699	0	3,531	9,510	5,097	18,138	1.754
77070	11,998	446	3,767	5,647	2,138	0	3,767	11,294	6,414	21,475	1.790
77088	15,568	1,526	5,324	6,156	2,562	0	5,324	12,312	7,686	25,322	1.627
77091	8,867	1,737	3,823	2,320	987	0	3,823	4,640	2,961	11,424	1.288
77092	14,120	1,477	6,901	4,449	1,293	0	6,901	8,898	3,879	19,678	1.394
77429	14,144	285	2,719	7,909	3,231	0	2,719	15,818	9,693	28,230	1.996
Total	**149,870**	**12,677**	**56,333**	**59,920**	**20,940**	**0**	**56,333**	**119,840**	**62,820**	**238,993**	**1.547**
*** Total Vehicle = (0 * 0V) + (1 * 1V) + (2 * 2V) + (3 * 3V)**											

The percent of households with 0, 1, 2, and 3 vehicles by zip code is listed in **Table 2**. This information corresponds to the data table from the U.S. 2000 Census Data. The percent of households will be maintained in subsequent computations for determining the actual number of vehicles within the economic analysis area.

Table 2. Percent of Households with 0, 1, 2 and 3 Vehicles

Zip	Total Households	Percent of Households With				
		0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles	Total
77002	1,791	19.8%	59.3%	18.6%	2.3%	100.0%
77007	9,308	13.5%	48.1%	28.9%	9.5%	100.0%
77008	12,469	10.7%	46.1%	34.9%	8.3%	100.0%
77009	14,262	14.8%	42.9%	31.5%	10.8%	100.0%
77018	10,599	9.3%	39.4%	40.3%	11.0%	100.0%
77040	14,578	3.9%	36.1%	45.2%	14.8%	100.0%
77064	11,825	2.1%	28.9%	50.4%	18.6%	100.0%
77065	10,341	3.4%	34.1%	46.0%	16.5%	100.0%
77070	11,998	3.7%	31.4%	47.1%	17.8%	100.0%
77088	15,568	9.8%	34.2%	39.5%	16.5%	100.0%
77091	8,867	19.6%	43.1%	26.2%	11.1%	100.0%
77092	14,120	10.5%	48.9%	31.5%	9.1%	100.0%
77429	14,144	2.0%	19.2%	55.9%	22.9%	100.0%
Total	**149,870**					

Source: U.S. 2000 Census, U.S. Department of Commerce

<u>Activity 2 – Estimate Approximate Distribution of Type of Vehicles</u>

EGM 09-04 states that the approximate distribution by type of vehicle can be found by conducting random samples of the study area (when a representative number of vehicles can be expected to be present), or by contacting the state department of motor vehicles to obtain information on motor vehicle registrations. EGM 09-04 also states that vehicle information can be obtained from R.L. Polk & Co. (http://usa.polk.com). R.L. Polk & Co. is the premier provider of automotive information and marketing solutions to the automotive world and its related industries - automotive and commercial vehicle manufacturers and dealers, automotive aftermarket companies, insurance companies, finance companies, media companies, advertising agencies, consulting organizations, government agencies, and market research firms.

The Polk National Vehicle Population Profile (NVPP) database was purchased for Harris County, Texas, from R.L. Polk & Co. The database includes a breakdown of all currently registered passenger cars and light-duty trucks (GVW 1-3) by zip code. This information is compiled from public records for all vehicles registered in Harris County. The R. L. Polk & Co. database was analyzed and organized into the five (5) vehicle types (sedans, pickups, suv's, sports cars, and mini vans) by zip code. The percentage distribution by type of vehicle for each zip code was then computed as summarized in **Table 3**. The primary vehicle type is sedans followed by SUV's and trucks in the study area.

Table 3. Percentage Distribution by Type of Vehicle

PERCENTAGE DISTRIBUTION BY TYPE OF VEHICLE					
Zip Code	**Sedan**	**Truck**	**SUV**	**Sports Car**	**Van**
77002	56.9%	20.3%	15.3%	3.2%	4.3%
77007	52.7%	14.3%	24.4%	4.6%	4.0%
77008	50.1%	20.1%	23.2%	3.1%	3.5%
77009	47.1%	21.8%	19.6%	2.6%	8.9%
77018	45.9%	22.8%	22.7%	2.4%	6.2%
77040	47.0%	22.2%	20.1%	2.8%	7.9%
77064	48.5%	21.5%	21.6%	3.0%	5.4%
77065	50.5%	18.9%	22.0%	3.2%	5.4%
77070	49.8%	18.4%	23.4%	3.4%	5.0%
77088	53.8%	19.4%	19.0%	2.2%	5.6%
77091	56.1%	19.6%	17.0%	2.0%	5.3%
77092	45.1%	27.0%	17.8%	2.4%	7.7%
77429	42.9%	21.2%	27.4%	3.8%	4.7%

Source: R. L. Polk & Co. (First Quarter 2009)

Activity 3 - Estimate Average Value By Type of Vehicle

EGM 09-04 states that the average vehicle values for new and used cars can be obtained from the Kelly's Blue Book (www.kbb.com) and Edmunds (www.edmunds.com). An average monetary value is required for the five (5) vehicle types in each zip code. The EGM indicates that the average vehicle value is to be based on the make, model, and age.

Kelly's Blue Book (www.kbb.com) (KBB) provides search capability by make, model, and year for new and used vehicles listed for sale. The Kelly's Blue Book website used a link to Autotrader.com for advanced search capabilities to identify new and used vehicles for sale by vehicle type or by make, model, and year. KBB does not provide advanced search capability by vehicle type. Therefore, the Autotrader.com website was used to determine the average price values for used vehicles by vehicle type for each zip code. A minimum search distance of 10 miles was selected in each zip code. The average used vehicle value was determined by a search of the vehicle type (sedans, pickups, suv's, sports car, and mini vans) for any make, model, or age in the zip code. Listed vehicle body styles were combined for sedans and sports cars only. The search results provided an average vehicle price for the listed used vehicles in the zip code. The average value by type of vehicle for each zip code is summarized in **Table 4**.

Table 4. Average Value by Type of Vehicle for Each Zip Code

AVERAGE VALUE BY TYPE OF VEHICLE (Calculated from Autotrader.com)					
Zip Code	**Sedan**	**Truck**	**SUV**	**Sports Car**	**Van**
77002	$14,931	$16,176	$18,488	$24,209	$9,876
77007	$17,584	$16,196	$20,744	$28,244	$10,842
77008	$16,224	$16,270	$19,525	$28,284	$11,196
77009	$15,403	$15,746	$18,708	$27,662	$10,279
77018	$16,073	$16,728	$19,737	$28,838	$10,987
77040	$15,913	$17,622	$20,538	$28,314	$11,687
77064	$15,632	$17,871	$21,165	$26,000	$12,277
77065	$15,482	$18,206	$21,234	$26,494	$12,329
77070	$15,370	$18,788	$21,555	$26,168	$12,588
77088	$16,139	$17,413	$20,891	$29,552	$11,843
77091	$16,175	$17,743	$20,915	$29,243	$12,358
77092	$16,012	$17,581	$20,497	$28,448	$12,324
77429	$13,440	$18,483	$20,846	$17,787	$14,848

Source: Autotrader.com (Price Levels - August 2009)

Activity 4 – Random Distribution of Vehicles in Economic Analysis Area

The total number of household units within the economic analysis area (residential single-family household units, multi-family units, and manufactured homes units) was calculated for each zip code. The number of households in the economic analysis area was derived from the HEC-FDA structure inventory for single-family, manufactured homes, and multifamily properties. Each-single family residence and manufactured home equates to one household. The number of manufactured homes located in manufactured home parks was based on the units in the structure database. For multi-family structures, each residential unit or apartment equates to one household.

The total number of vehicles was computed using the total residential households and the percentage of households with 0, 1, 2, and 3 vehicles as derived from Tables 1 and 2 (Activity 1). As mentioned previously, the percentage of households with 0, 1, 2, and 3 vehicles were maintained for each zip code. The total number of vehicles in each zip code for the economic analysis area is provided in **Table 5**.

The total number of vehicles by type was then calculated using the percentage distribution by type of vehicle as provided in Table 3 as described in Activity 2. The distribution of total vehicles by type of vehicle for each zip code is provided in **Table 6**.

Table 5. Total Households and Vehicles in Economic Analysis Area

Zip	Total Households	Percent of Households With					Households With				Vehicles at Households With				Total Vehicles *
		0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles	Total	0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles	0 Vehicles	1 Vehicle	2 Vehicles	3 Vehicles	
77002	78	19.8%	59.3%	18.6%	2.3%	100.0%	15	46	15	2	0	46	30	6	82
77007	1,806	13.5%	48.1%	28.9%	9.5%	100.0%	244	869	522	171	0	869	1,044	513	2,426
77008	3,526	10.7%	46.1%	34.9%	8.3%	100.0%	377	1,625	1,231	293	0	1,625	2,462	879	4,966
77009	1,419	14.8%	42.9%	31.5%	10.8%	100.0%	210	609	447	153	0	609	894	459	1,962
77018	1,760	9.3%	39.4%	40.3%	11.0%	100.0%	164	693	709	194	0	693	1,418	582	2,693
77040	6,477	3.9%	36.1%	45.2%	14.8%	100.0%	253	2,338	2,928	958	0	2,338	5,856	2,874	11,068
77064	5,181	2.1%	28.9%	50.4%	18.6%	100.0%	109	1,497	2,611	964	0	1,497	5,222	2,892	9,611
77065	8,793	3.4%	34.1%	46.0%	16.5%	100.0%	299	2,998	4,045	1,451	0	2,998	8,090	4,353	15,441
77070	7	3.7%	31.4%	47.1%	17.8%	100.0%	0	2	3	2	0	2	6	6	14
77088	2,938	9.8%	34.2%	39.5%	16.5%	100.0%	288	1,005	1,161	484	0	1,005	2,322	1,452	4,779
77091	3,708	19.6%	43.1%	26.2%	11.1%	100.0%	727	1,598	971	412	0	1,598	1,942	1,236	4,776
77092	5,548	10.5%	48.9%	31.5%	9.1%	100.0%	583	2,713	1,748	504	0	2,713	3,496	1,512	7,721
77429	23	2.0%	19.2%	55.9%	22.9%	100.0%	0	4	13	6	0	4	26	18	48
Total	**41,264**						**3,269**	**15,997**	**16,404**	**5,594**	**0**	**15,997**	**32,808**	**16,782**	**65,587**
*Total Vehicles = (0 * 0V) + (1 * 1V) + (2 * 2V) + (3 * 3V)															

Table 6. Distribution of Total Vehicles by Type of Vehicle in Economic Analysis Area

Zip	Total Vehicles	Percentage of Vehicles by Type					Number of Vehicles by Type				
		Sedan	Truck	SUV	Sports Car	Van	Sedan	Truck	SUV	Sports Car	Van
77002	82	56.9%	20.3%	15.3%	3.2%	4.3%	47	17	13	3	2
77007	2,426	52.7%	14.3%	24.4%	4.6%	4.0%	1,279	347	592	112	96
77008	4,966	50.1%	20.1%	23.2%	3.1%	3.5%	2,488	998	1,152	154	174
77009	1,962	47.1%	21.8%	19.6%	2.6%	8.9%	924	428	385	51	174
77018	2,693	45.9%	22.8%	22.7%	2.4%	6.2%	1,236	614	611	65	167
77040	11,068	47.0%	22.2%	20.1%	2.8%	7.9%	5,202	2,457	2,225	310	874
77064	9,611	48.5%	21.5%	21.6%	3.0%	5.4%	4,661	2,066	2,076	288	520
77065	15,441	50.5%	18.9%	22.0%	3.2%	5.4%	7,798	2,918	3,397	494	834
77070	14	49.8%	18.4%	23.4%	3.4%	5.0%	7	3	3	0	1
77088	4,779	53.8%	19.4%	19.0%	2.2%	5.6%	2,571	927	908	105	268
77091	4,776	56.1%	19.6%	17.0%	2.0%	5.3%	2,679	936	812	96	253
77092	7,721	45.1%	27.0%	17.8%	2.4%	7.7%	3,482	2,085	1,374	185	595
77429	48	42.9%	21.2%	27.4%	3.8%	4.7%	21	10	13	2	2
Total	**65,587**						**32,395**	**13,806**	**13,561**	**1,865**	**3,960**

The calculation of vehicle damages and the application of the appropriate damage curve are dependent on the number of vehicles, type of vehicles, the location of the vehicle and those remaining in the flood prone area. The most appropriate method to assign the vehicles to a specific location (i.e. households) is by using a random distribution program. The following tasks present the procedures to randomly distribute the vehicles in the study reach:

- Distribution of Residential Households with 0, 1, 2 and 3 Vehicles (Task 1)
- Distribution of Vehicle by Vehicle Type (Task 2)
- Determine Households with Vehicles Remaining in Flood Prone Location (Task 3)

Task 1: Distribution of Residential Households with 0, 1, 2, and 3 Vehicles

The percentage of households with 0, 1, 2, and 3 or more vehicles was obtained from the Census data for each zip code as described in Activity 1 and shown in **Table 2**. The percent households with 0, 1, 2, and 3 or more vehicles was maintained for each zip code and is used to allocate the residential households and vehicles for the economic analysis area as provided in **Table 5**.

Using **Table 5**, a GIS random generation program was used to assign the residential households with 0, 1, 2, or 3 or more vehicles into the economic analysis area. Households with zero vehicles were initially randomly identified in each zip code. Then, the households with 1, 2 and 3 vehicles were identified until each household was assigned.

Task 2: Distribution of Vehicles by Vehicle Type

The GIS random generation program was used to assign the vehicles by vehicle type (sedans, trucks, suv's, sports cars, and mini vans) to the residential households by zip code in the economic analysis area. The distribution of vehicles by vehicle type was identified in Activity 4 and summarized in **Table 6**. The households (as assigned in Task 1), in each zip code, were randomly assigned a vehicle type based on the percentage distribution by vehicle type. The random generation program employed a procedure to allow any combination of vehicle types for households with more than one vehicle.

Task 3: Determine Households With Vehicles Remaining in Flood Prone Location

EGM 09-04 states that the length of potential warning time and the access to a safe evacuation route to a flood-free location must be considered in estimating the percentage of vehicles that would likely remain in the flood prone location. The guidance provides the percentages from a post-flood data collection of residential respondents that moved vehicles to higher ground by the length of the respondents' warning time. EGM 09-04 provides the results in *Table Five – Percentage of Respondents Moving at Least One Vehicle to Higher Ground*. (Refer to Attachment 1) The Harris County Flood Control District operates a flood alert system to advise residents of potential flooding along the bayous during storm events. Flood warning times are generally less than 6 hours in Harris County. Harris County experiences widespread flooding from tropical storms and hurricane events, heavy rainfall events, and has extensive floodplains throughout the area. Harris County has a very large population that limits evacuation during extreme storm events. During Tropical Storm Allison in 2001, Harris County received over 28 inches of rainfall during a 12-hour period that damaged over 95,000 vehicles, 73,000 residences, and caused over $5 billion in property damage.

Using Table Five in EGM 09-04, the survey results indicate that 50.5% of respondents (households) would move at least one vehicle to higher ground for flood warning times of 6 hours or less. Based on these survey results, 49.5% of the respondents (households) would likely remain in the flood prone location. The GIS random generation program was used to identify the 49.5% of the households with vehicles that would likely remain in the study reach. The remaining vehicles by type of vehicle after this process are summarized in **Table 7**.

Table 7. Distribution of Remaining Vehicles by Type of Vehicle

Zip	REMAINING VEHICLES BY TYPE					Total Remaining Vehicles
	Sedan	Truck	SUV	Sports Car	Van	
77002	24	8	6	1	1	40
77007	597	172	306	51	54	1,180
77008	1,225	469	582	86	98	2,460
77009	454	210	186	23	89	962
77018	594	309	313	30	86	1,332
77040	2,579	1,195	1,113	157	439	5,483
77064	2,302	1,024	1,050	135	260	4,771
77065	3,815	1,452	1,726	245	435	7,673
77070	3	1	1	0	1	6
77088	1,275	445	454	52	128	2,354
77091	1,369	445	407	50	127	2,398
77092	1,735	1,004	682	80	279	3,780
77429	9	5	6	1	1	22
Total	**15,981**	**6,739**	**6,832**	**911**	**1,998**	**32,461**

<u>Activity 5 – Compute Vehicle Damages</u>

The HEC-FDA Model (Version 1.2) developed for the With and Without Project Conditions of the White Oak Bayou Federal Flood Control Project (General Reevaluation Report), Harris County, Texas, served as the base economic model for this case study. The future year conditions were updated with base year conditions. The hydrology and hydraulic inputs for future year in the economic models were modified to reflect the base year conditions. This was done in conformance with the report update which will use the base year conditions as future year conditions. EGM 09-04 states that the depth-damage functions should be applied to vehicles at ground elevations of affected properties. These damage functions can then be used to estimate vehicle damage when applied to expected water surface elevations for flood events. The ground elevation at the structure served as the proxy elevation for the ground elevation of the parked vehicle.

The HEC-FDA model was modified to include the vehicle generic depth-damage functions in accordance with EGM 09-04 as provided in *Table Three – Percent Damage To Vehicles*. There are five (5) vehicle generic depth-damage functions based on the type of vehicle (sedans, pickups, suv's, sports car, and mini-vans). The vehicle generic depth-damage functions include uncertainty values at each stage. The HEC-FDA structure inventory included a unique identification number to represent the remaining vehicles at each structure (household) as determined in Activity 1 through Activity 4. Instances with different vehicles types at the same structure required a unique identification number for each vehicle type.

HEC-FDA models were run without project and with project National Economic Development (NED) optimized plan TG.2 (TG2-RF29). HEC-FDA model runs were made for the Base Year (2010) and Future Year (2060) to compute the Expected Annual Damages (EAD) for With Uncertainty and With No Uncertainty. The Base Year (2010) and the Future Year (2010) conditions are the same. The updated 2009 price levels for the structure inventory and vehicle damages were used. The Average Annual Equivalent Damages (AAED) were computed based on the Federal Interest Rate of 4.625% for Fiscal Year 2009.

The computed Without Project Expected Annual Damages (EAD) and the Without Project Average Annual Equivalent (AAE) Damages (with no uncertainty) for each reach are summarized in **Table 8**. The computed Without Project Expected Annual Damages (EAD) and the Without Project Average Annual Equivalent (AAE) Damages (with uncertainty) for each reach are summarized in **Table 9.** These tables are followed by the equivalent With Project NED optimized plan TG.2 (TG2-RF29) tables.

The computed With NED Project Expected Annual Damages (EAD) and the With NED Project Average Annual Equivalent (AAE) Damages (with no uncertainty) for each reach are summarized in **Table 10**. The computed With NED Project Expected Annual Damages (EAD) and the With Project Average Annual Equivalent (AAE) Damages (with uncertainty) for each reach are summarized in **Table 11.**

Table 8. Vehicle Damages by Reach Without Project Conditions (With No Uncertainty)

VEHICLE DAMAGES BY REACH WITHOUT PROJECT CONDITIONS (With No Uncertainty) Values in 1,000's, 2009 Price Levels (FY 2009 Interest Rate - 4.625%)					
Reach	**Total EAD (1)**	**Total Vehicle EAD (1)**	**Total AAED**	**Total Vehicle AAED**	**Number of Vehicle Damaged**
WOB-01	$1,449.32	$11.14	$1,449.32	$11.14	128
WOB-02	$252.82	$57.80	$252.82	$57.80	805
WOB-03	$100.46	$3.23	$100.46	$3.23	100
WOB-04a(L)	$442.34	$62.40	$442.34	$62.40	46
WOB-04(R)	$363.07	$30.08	$363.07	$30.08	603
WOB-04b(L)	$1,052.63	$143.52	$1,052.63	$143.52	947
WOB-05	$2,854.78	$325.14	$2,854.78	$325.14	1,463
WOB-06	$2,610.33	$560.35	$2,610.33	$560.35	1,649
WOB-07	$866.91	$75.51	$866.91	$75.51	812
WOB-08a(L)	$26.39	$3.13	$26.39	$3.13	16
WOB-08(R)	$590.19	$46.17	$590.19	$46.17	208
WOB-08b(L)	$847.18	$139.18	$847.18	$139.18	411
WOB-09	$1,948.36	$154.63	$1,948.36	$154.63	1,376
WOB-10a(R)	$1,099.79	$76.35	$1,099.79	$76.35	603
WOB-10a(L)	$5,256.18	$490.95	$5,256.18	$490.95	954
WOB-10b(R)	$2,752.69	$166.36	$2,752.69	$166.36	327
WOB-10b(L)	$3,182.12	$878.68	$3,182.12	$878.68	561
WOB-11	$1,110.21	$202.28	$1,110.21	$202.28	173
WOB-12	$1,486.78	$156.22	$1,486.78	$156.22	298
WOB-13	$356.52	$0.71	$356.52	$0.71	201
WOB-14	$3,147.01	$191.10	$3,147.01	$191.10	689
WOB-15	$113.95	$0.78	$113.95	$0.78	83
WOB-16	$524.84	$21.72	$524.84	$21.72	902
WOB-17	$643.79	$16.80	$643.79	$16.80	600
WOB-18	$35.41	$0.11	$35.41	$0.11	19
WOB-19	$9.74	$0.08	$9.74	$0.08	13
White Oak Bayou Total	**$33,123.81**	**$3,814.42**	**$33,123.81**	**$3,814.42**	**13,987**

Note: (1) EAD for Base Year (2010) and Future Year (2060) are the same.

Table 9. Vehicle Damages by Reach Without Project Conditions (With Uncertainty)

VEHICLE DAMAGES BY REACH WITHOUT PROJECT CONDITIONS (With Uncertainty) Values in 1,000's, 2009 Price Levels (FY 2009 Interest Rate - 4.625%)					
Reach	**Total EAD(1)**	**Total Vehicle EAD (1)**	**Total AAED**	**Total Vehicle AAED**	**Number of Vehicle Damaged**
WOB-01	$1,411.28	$10.37	$1,411.28	$10.37	128
WOB-02	$244.04	$53.20	$244.04	$53.20	805
WOB-03	$140.40	$3.84	$140.40	$3.84	100
WOB-04a(L)	$409.68	$55.96	$409.68	$55.96	46
WOB-04(R)	$431.39	$33.78	$431.39	$33.78	603
WOB-04b(L)	$1,128.63	$136.11	$1,128.63	$136.11	947
WOB-05	$2,954.98	$300.57	$2,954.98	$300.57	1,463
WOB-06	$2,521.96	$506.64	$2,521.96	$506.64	1,649
WOB-07	$1,309.59	$113.63	$1,309.59	$113.63	812
WOB-08a(L)	$38.26	$4.31	$38.26	$4.31	16
WOB-08(R)	$1,013.93	$64.51	$1,013.93	$64.51	208
WOB-08b(L)	$1,352.32	$198.80	$1,352.32	$198.80	411
WOB-09	$3,065.55	$243.44	$3,065.55	$243.44	1,376
WOB-10a(R)	$2,097.48	$127.29	$2,097.48	$127.29	603
WOB-10a(L)	$6,726.28	$624.10	$6,726.28	$624.10	954
WOB-10b(R)	$3,937.31	$302.11	$3,937.31	$302.11	327
WOB-10b(L)	$6,813.63	$1,101.15	$6,813.63	$1,101.15	561
WOB-11	$2,225.18	$272.98	$2,225.18	$272.98	173
WOB-12	$3,931.24	$275.06	$3,931.24	$275.06	298
WOB-13	$1,610.50	$13.53	$1,610.50	$13.53	201
WOB-14	$6,544.78	$318.58	$6,544.78	$318.58	689
WOB-15	$1,068.01	$21.92	$1,068.01	$21.92	83
WOB-16	$2,941.63	$163.40	$2,941.63	$163.40	902
WOB-17	$3,781.02	$126.42	$3,781.02	$126.42	600
WOB-18	$464.67	$18.29	$464.67	$18.29	19
WOB-19	$125.51	$2.92	$125.51	$2.92	13
White Oak Bayou Total	**$58,289.25**	**$5,092.91**	**$58,289.25**	**$5,092.91**	**13,987**

Note: (1) EAD for Base Year (2010) and Future Year (2060) are the same.

Table 10. Vehicle Damages by Reach With NED Project Conditions (With No Uncertainty)

VEHICLE DAMAGES BY REACH WITH NED PLAN TG.2 (TG2-RF29) (With No Uncertainty) Values in 1,000's, 2009 Price Levels (FY 2009 Interest Rate - 4.625%)					
Reach	**Total EAD (1)**	**Total Vehicle EAD (1)**	**Total AAED**	**Total Vehicle AAED**	**Number of Vehicle Damaged**
WOB-01	$1,350.00	$11.86	$1,350.00	$11.86	128
WOB-02	$232.52	$55.59	$232.52	$55.59	805
WOB-03	$97.12	$3.35	$97.12	$3.35	100
WOB-04a(L)	$389.70	$54.53	$389.70	$54.53	46
WOB-04(R)	$339.99	$28.88	$339.99	$28.88	603
WOB-04b(L)	$920.08	$128.22	$920.08	$128.22	947
WOB-05	$2,480.05	$282.62	$2,480.05	$282.62	1,463
WOB-06	$2,192.82	$468.12	$2,192.82	$468.12	1,649
WOB-07	$688.42	$52.51	$688.42	$52.51	812
WOB-08a(L)	$18.61	$2.36	$18.61	$2.36	16
WOB-08(R)	$295.27	$20.32	$295.27	$20.32	208
WOB-08b(L)	$378.97	$69.65	$378.97	$69.65	411
WOB-09	$723.02	$67.15	$723.02	$67.15	1,376
WOB-10a(R)	$362.88	$29.83	$362.88	$29.83	603
WOB-10a(L)	$1,235.18	$122.60	$1,235.18	$122.60	954
WOB-10b(R)	$583.87	$40.57	$583.87	$40.57	327
WOB-10b(L)	$738.58	$191.36	$738.58	$191.36	561
WOB-11	$208.24	$31.38	$208.24	$31.38	173
WOB-12	$340.53	$30.43	$340.53	$30.43	298
WOB-13	$122.86	$0.37	$122.86	$0.37	201
WOB-14	$473.86	$27.81	$473.86	$27.81	689
WOB-15	$17.00	$0.07	$17.00	$0.07	83
WOB-16	$180.69	$11.59	$180.69	$11.59	902
WOB-17	$156.40	$3.37	$156.40	$3.37	600
WOB-18	$31.62	$0.07	$31.62	$0.07	19
WOB-19	$9.85	$0.10	$9.85	$0.10	13
White Oak Bayou Total	**$14,568.13**	**$1,734.71**	**$14,568.13**	**$1,734.71**	**13,987**

Note: (1) EAD for Base Year (2010) and Future Year (2060) are the same.

Table 11. Vehicle Damages by Reach With NED Project Conditions (With Uncertainty)

VEHICLE DAMAGES BY REACH WITH NED PLAN TG.2 (TG2-RF29) (With Uncertainty) Values in 1,000's, 2009 Price Levels (FY 2009 Interest Rate - 4.625%)					
Reach	**Total EAD(1)**	**Total Vehicle EAD (1)**	**Total AAED**	**Total Vehicle AAED**	**Number of Vehicle Damaged**
WOB-01	$1,314.61	$10.84	$1,314.61	$10.84	128
WOB-02	$223.86	$50.53	$223.86	$50.53	805
WOB-03	$130.67	$3.75	$130.67	$3.75	100
WOB-04a(L)	$362.74	$49.00	$362.74	$49.00	46
WOB-04(R)	$388.20	$31.31	$388.20	$31.31	603
WOB-04b(L)	$978.89	$120.45	$978.89	$120.45	947
WOB-05	$2,562.69	$260.94	$2,562.69	$260.94	1,463
WOB-06	$2,126.44	$425.57	$2,126.44	$425.57	1,649
WOB-07	$1,008.78	$79.17	$1,008.78	$79.17	812
WOB-08a(L)	$26.09	$3.03	$26.09	$3.03	16
WOB-08(R)	$475.80	$27.49	$475.80	$27.49	208
WOB-08b(L)	$545.10	$88.51	$545.10	$88.51	411
WOB-09	$1,098.30	$103.06	$1,098.30	$103.06	1,376
WOB-10a(R)	$611.61	$42.66	$611.61	$42.66	603
WOB-10a(L)	$1,728.36	$155.52	$1,728.36	$155.52	954
WOB-10b(R)	$911.69	$65.56	$911.69	$65.56	327
WOB-10b(L)	$1,588.06	$244.60	$1,588.06	$244.60	561
WOB-11	$432.53	$45.14	$432.53	$45.14	173
WOB-12	$776.80	$48.40	$776.80	$48.40	298
WOB-13	$395.20	$5.25	$395.20	$5.25	201
WOB-14	$1,131.23	$51.14	$1,131.23	$51.14	689
WOB-15	$177.15	$3.52	$177.15	$3.52	83
WOB-16	$740.50	$42.45	$740.50	$42.45	902
WOB-17	$1,117.61	$34.05	$1,117.61	$34.05	600
WOB-18	$373.27	$14.96	$373.27	$14.96	19
WOB-19	$120.40	$2.82	$120.40	$2.82	13
White Oak Bayou Total	**$21,346.58**	**$2,009.72**	**$21,346.58**	**$2,009.72**	**13,987**

Note: (1) EAD for Base Year (2010) and Future Year (2060) are the same.

2.0 Conclusions

As indicated in **Table 8**, the without project total EA Vehicle Damages and total AAE Vehicle Damages (with no uncertainty) totaled approximately $3,814,000. The vehicle damages represent approximately 12% of the total EA and AAE total damages in each case.

As indicated in **Table 9**, the without project total EA Vehicle Damages and total AAE Vehicle Damages (with uncertainty) totaled approximately $5,093,000. The vehicle damages represent approximately 9% of the total EA and AAE damages in each case.

As indicated in **Table 10**, the with NED project total EA Vehicle Damages and total AAE Vehicle Damages (with no uncertainty) totaled approximately $1,735,000. The vehicle damages represent approximately 12% of the total EA and AAE damages in each case.

As indicated in **Table 11**, the with NED project total EA Vehicle Damages and total AAE Vehicle Damages (with uncertainty) totaled approximately $2,010,000. The vehicle damages represent approximately 9% of the total EA and AAE damages in each case.

ATTACHMENT 1

ECONOMIC GUIDANCE MEMORANDUM (EGM), 09-04, GENERIC DEPTH-DAMAGE RELATIONSHIPS FOR VEHICLES, DEPARTMENT OF THE ARMY, 22 JUNE 2009

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

CECW-CP 22 June 2009

MEMORANDUM FOR PLANNING COMMUNITY OF PRACTICE

SUBJECT: Economic Guidance Memorandum, 09-04, Generic Depth-Damage Relationships for Vehicles

1. Purpose. The purpose of this memorandum is to release and provide guidance for the use of generic vehicle depth-damage curves for U.S. Army Corps of Engineers flood risk management studies.

2. Background. The Flood Damage Data Collection Program provides information from flood events to estimate reliable economic relationships for flood damage reduction studies. As part of residential post-flood damage surveys, data were collected for vehicles kept at residences in ten communities that experienced major flooding. Depth-damage functions were determined using flood victims' self-reported assessments of vehicle values and damage and the depth of flooding above the wheel base for each vehicle.

3. Results. Damage functions were computed for five types of vehicles based on a sample of 640 vehicles. Regression analysis was used to compute the damage functions. The regression equations for all types of vehicles were highly significant. The damage functions are included in the appendix to this memorandum along with a brief summary of the data and analysis used to derive these functions.

4. Application for Vehicles Parked at Residential Locations. These damage functions can be used to estimate vehicle damage when applied to expected water surface elevations for flood events.

   a. Depth-damage functions should be applied to vehicles at ground elevations of affected properties. Damage to vehicles at residences is dependent on the average number of vehicles per household; the approximate percentage breakdown by type of vehicle, the average vehicle value based on the make, model, and age; and the percentage of vehicles that are likely to be at the residence at the time the flood waters reach the property and the availability of safe evacuation routes.

   b. The number of vehicles per household can be estimated using the American FactFinder section of the U.S. Census website by entering the zip code and looking under household characteristics: http://factfinder.census.gov

c. Information for determining the approximate distribution by type of vehicle and value can be found by conducting random samples of the study area, when a representative number of vehicles can be expected to be present, or by contacting the state department of motor vehicles to obtain information on motor vehicle registrations. Vehicle information can also be obtained by contacting R.L. Polk Company at http://usa.polk.com/ The Polk National Vehicle Profile, which has vehicle registration by zip code, is described at: http://usa.polk.com/Products/1_nvpp.htm.

d. Average vehicle values for new and used cars can be obtained from the Kelly's Blue Book at www.kbb.com and Edmunds at www.edmunds.com.

e. The length of potential warning time and the access to a safe evacuation route to a flood-free location must be considered in estimating the percentage of vehicles that would likely remain in the flood prone location. The results section of the attached appendix gives the percentages from a post-flood data collection of residential respondents that moved vehicles to higher ground by the length of the respondents' warning time.

5. Application for Vehicles Parked at Nonresidential Locations. The depth-damage relationships found in this EGM are applicable for vehicles parked at all floodplain locations. The above procedures (paragraph 4) used to estimate the number of vehicles that might be flooded are not generally applicable to non-residential locations such as car sales lots, rental car lots, other commercial facilities and industrial facilities. Additional project specific data and analysis are required to document the assumptions related to potential vehicle damage estimates in nonresidential locations.

6. Points of Contact. The HQUSACE program monitor for the Flood Damage Data Collection Program is Mr. Kenneth Claseman, CECW-PC, at kenneth.g.claseman@usace.army.mil or (202) 761-5451, who can address any questions concerning the program. Questions related to this memorandum should be addressed to Mr. Bruce Carlson, CECW-PC, at bruce.d.carlson@usace.army.mil or by telephone at (202) 761-4703.

Harry E. Kitch

Harry E. Kitch, P.E.
Deputy Chief, Planning and Policy
Directorate of Civil Works

Enclosure

CECW-CP 22 June 2009

MEMORANDUM FOR PLANNING COMMUNITY OF PRACTICE

SUBJECT: Economic Guidance Memorandum, 09-04, Generic Depth-Damage Relationships for Vehicles

1. Purpose. The purpose of this memorandum is to release and provide guidance for the use of generic vehicle depth-damage curves for U.S. Army Corps of Engineers flood risk management studies.

2. Background. The Flood Damage Data Collection Program provides information from flood events to estimate reliable economic relationships for flood damage reduction studies. As part of residential post-flood damage surveys, data were collected for vehicles kept at residences in ten communities that experienced major flooding. Depth-damage functions were determined using flood victims' self-reported assessments of vehicle values and damage and the depth of flooding above the wheel base for each vehicle.

3. Results. Damage functions were computed for five types of vehicles based on a sample of 640 vehicles. Regression analysis was used to compute the damage functions. The regression equations for all types of vehicles were highly significant. The damage functions are included in the appendix to this memorandum along with a brief summary of the data and analysis used to derive these functions.

4. Application for Vehicles Parked at Residential Locations. These damage functions can be used to estimate vehicle damage when applied to expected water surface elevations for flood events.

   a. Depth-damage functions should be applied to vehicles at ground elevations of affected properties. Damage to vehicles at residences is dependent on the average number of vehicles per household; the approximate percentage breakdown by type of vehicle, the average vehicle value based on the make, model, and age; and the percentage of vehicles that are likely to be at the residence at the time the flood waters reach the property and the availability of safe evacuation routes.

   b. The number of vehicles per household can be estimated using the American FactFinder section of the U.S. Census website by entering the zip code and looking under household characteristics: http://factfinder.census.gov

c. Information for determining the approximate distribution by type of vehicle and value can be found by conducting random samples of the study area, when a representative number of vehicles can be expected to be present, or by contacting the state department of motor vehicles to obtain information on motor vehicle registrations. Vehicle information can also be obtained by contacting R.L. Polk Company at http://usa.polk.com/ The Polk National Vehicle Profile, which has vehicle registration by zip code, is described at: http://usa.polk.com/Products/1_nvpp.htm.

d. Average vehicle values for new and used cars can be obtained from the Kelly's Blue Book at www.kbb.com and Edmunds at www.edmunds.com.

e. The length of potential warning time and the access to a safe evacuation route to a flood-free location must be considered in estimating the percentage of vehicles that would likely remain in the flood prone location. The results section of the attached appendix gives the percentages from a post-flood data collection of residential respondents that moved vehicles to higher ground by the length of the respondents' warning time.

5. Application for Vehicles Parked at Nonresidential Locations. The depth-damage relationships found in this EGM are applicable for vehicles parked at all floodplain locations. The above procedures (paragraph 4) used to estimate the number of vehicles that might be flooded are not generally applicable to non-residential locations such as car sales lots, rental car lots, other commercial facilities and industrial facilities. Additional project specific data and analysis are required to document the assumptions related to potential vehicle damage estimates in nonresidential locations.

6. Points of Contact. The HQUSACE program monitor for the Flood Damage Data Collection Program is Mr. Kenneth Claseman, CECW-PC, at kenneth.g.claseman@usace.army.mil or (202) 761-5451, who can address any questions concerning the program. Questions related to this memorandum should be addressed to Mr. Bruce Carlson, CECW-PC, at bruce.d.carlson@usace.army.mil or by telephone at (202) 761-4703.

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Appendix A
Computation of Depth-Damage Relationships for Vehicles

Background

This memorandum presents the results of analysis of vehicle damage data collected from the Flood Damage Data Collection Program post-flood damage surveys. Victims of residential flooding in ten communities were interviewed to determine the extent of flooding costs to their households. The survey instrument included questions about motor vehicles to help determine the damage to vehicles that might be expected from future flooding. These surveys were part of a larger survey effort to establish damage functions for buildings, contents, cleanup costs and time, and emergency costs. Table One gives the number of vehicles for each case study in this data collection:

TABLE ONE VEHICLES BY CASE STUDY		
Case Study	**Frequency**	**Percent of Total**
Wenden, Arizona	7	1%
Elba, Alabama	19	3%
Falmouth, Kentucky	140	22%
Feather River, California	158	25%
Louisville, Kentucky	109	17%
Bound Brook, New Jersey	74	12%
New Orleans, Louisiana	28	4%
Puerto Rico	79	12%
Rocky Mount, North Carolina	2	<1%
Salem, Oregon	24	4%
Total	640	100%

The Survey

The respondents were asked to enumerate the number of motor vehicles that were at their homes at the time of flooding, whether vehicles were moved off the property, the make and model of vehicles, the dollar value of vehicles, the depth of water above ground where vehicles were parked, and the dollar damage to vehicles. The data included here are for vehicles that either remained at the flood victims' homes or were moved, but may have still experienced flood damage from the same flood event. Figure One presents the questions that were asked in each of the surveys to obtain the information for this analysis.

FIGURE ONE: SURVEY QUESTIONS

For each motor vehicle, including cars, trucks, recreational vehicles, boats, and motorcycles, located at this residence during the flood, please indicate the dollar value, whether or not it was moved, the amount of damage to the vehicle, if any, and the level, in feet and inches, that the flood water reached above the bottom of the vehicle's wheels.

Vehicle Category and Year (Categories include: sedan, van, sports utility, sports cars, pickup trucks, and motorcycles)	*Dollar Value*	*Was it Moved? (Yes or no)*	*Dollar Damage*	*Depth Above Ground At Vehicle*
Vehicle 1:				
Vehicle 2:				
Vehicle 3:				
Vehicle 4:				
Vehicle 5:				
Vehicle 6:				

The make and model of vehicle were used to classify each vehicle by category, including sedan, sports utility vehicle, mini van, sports car, pickup truck, motorcycle, or boat. Respondents valued vehicles at the current market value, reflecting depreciation by the age of the vehicle. Information on the make, model, and age of the vehicle served as a check on the respondents' estimate of value. The amount of damage represented the repair cost or the total value of the vehicle, if there was damage beyond repair. The depth of water above ground was the key variable in determining the percent of flood damage to each vehicle. Percent damage to vehicle was computed by dividing estimated vehicle damage by vehicle value. The number of each type of vehicle in the database is reported below in Table Two. The same surveys also included a question regarding the length of warning time, asking the length of time between becoming aware of potential flooding till the water reached the respondents' property.

TABLE TWO VEHICLES BY CATEGORY		
Vehicle Category	**Frequency**	**Percent of Total**
Boat	14	2%
Motor Home	7	1%
Motorcycle	23	4%
Pickup Truck	125	20%
Sedan	369	57%
Sports Car	37	6%
Sports Utility Vehicle	31	5%
Mini Van	34	5%
Total	640	100%

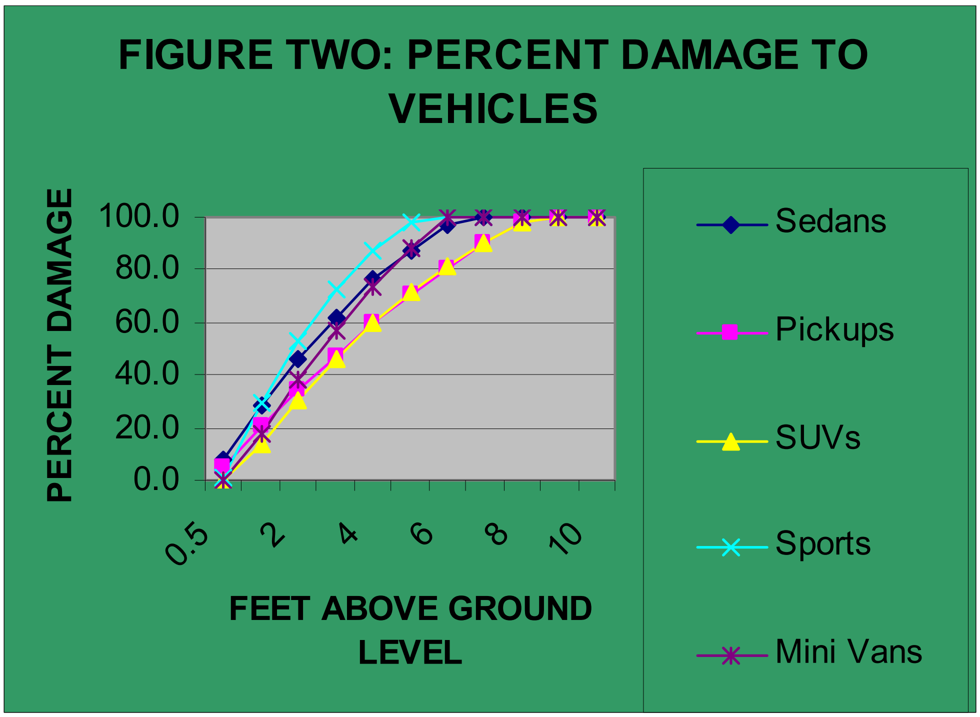
Survey Results
Regression analysis was used to separately compute a damage function for each type of vehicle. Quadratic equations with depth and depth squared serving as the independent variables were the most successful regression models for explaining variations in the percent damage to vehicle. The squared term indicates that in each case there was a point where there was a significant change in the slope of the damage function.

TABLE THREE PERCENT DAMAGE TO VEHICLES										
	Sedans		Pickups		SUVs		Sports		Mini Vans	
Depth Above Ground	Percent Damage	Standard Deviation	Percent Damage	Standard Deviation	Percent Damage	Standard Deviation	Percent Damage	Standard Deviation	Percent Damage	Standard Deviation
.5	7.60%	2.42%	5.20%	3.02%	0.00%	11.28%	1.40%	19.22%	0.00%	9.11%
1	28.00%	1.84%	20.30%	2.53%	13.80%	8.76%	29.20%	16.81%	17.80%	6.82%
2	46.20%	1.51%	34.40%	2.33%	30.60%	6.67%	52.80%	13.17%	38.30%	5.33%
3	62.20%	1.45%	47.50%	2.38%	45.80%	5.24%	72.20%	8.47%	56.80%	4.88%
4	76.00%	1.57%	59.60%	2.57%	59.40%	4.78%	87.40%	3.61%	73.30%	5.34%
5	87.60%	1.74%	70.70%	2.81%	71.40%	5.36%	98.40%	6.12%	87.80%	6.23%
6	97.00%	1.92%	80.80%	3.04%	81.80%	6.61%	100.00%	13.80%	100.00%	7.20%
7	100.00%	2.06%	89.90%	3.21%	90.60%	8.17%	100.00%	13.80%	100.00%	7.20%
8	100.00%	2.06%	98.00%	3.32%	97.80%	9.88%	100.00%	13.80%	100.00%	7.20%
9	100.00%	2.06%	100.00%	3.36%	100.00%	11.70%	100.00%	13.80%	100.00%	7.20%
10	100.00%	2.06%	100.00%	3.36%	100.00%	11.70%	100.00%	13.80%	100.00%	7.20%

Despite the limited sample, the regression equations did have a high explanatory power for cross sectional data. The adjusted R^2, the coefficient of determination for each regression equation, is given below in the Table 4.

TABLE FOUR COEFFICIENT OF DETERMINATION FOR REGRESSION EQUATIONS	
Type of Vehicle	Adjusted R^2
Pickup Truck	.707
Sedan	.674
Sports Car	.695
Sports Utility Vehicle	.795
Mini Van	.712

Results of the regression analysis are also presented in graphic format, below in Figure Two.



Results of the survey also indicated the percentage of households that moved at least one vehicle to higher ground. These percentages are given by the amount of warning time in Table Five.

TABLE FIVE PERCENTAGE OF RESPONDENTS MOVING AT LEAST ONE VEHICLE TO HIGHER GROUND					
Warning of 6 Hours or Less		Warning of Greater than 6 and Up to 12 Hours		Warning Greater than 12 Hours	
Respondents Moving Vehicles to Higher Ground	Respondents Who Did Not Move Vehicles	Respondents Moving Vehicles to Higher Ground	Respondents Who Did Not Move Vehicles	Respondents Moving Vehicles to Higher Ground	Respondents Who Did Not Move Vehicles
50.5%	49.5%	80.6%	19.4%	88.1%	11.9%

ATTACHMENT 5

2011 PRICE LEVEL UPDATE
TECHNICAL PAPER

Economic Technical Paper
White Oak Bayou Economic Update Procedures to 2011 Price Levels
Section 211(f) Federal Project – White Oak Bayou

This technical paper documents the methods and procedures used to update the 2009 HEC-FDA structure values (replacement cost new less depreciation) and unit costs for the above referenced project to 2011 price levels. The 2011 values will be used in an update analysis of benefits to be performed using the HEC-FDA model. A price level update had previously been performed in 2009 to update the 2002 HEC-FDA structure values to 2009 values. The previous analysis is contained in Economic Technical Paper #3. This new update will analyze changes in values since the 2009 price level update.

1.0 Background

As part of the final report submittals to Head Quarters US Army Corps of Engineers (HQ USACE) and the White House's Office of Management and Budget (OMB), it is required that costs and benefits are displayed in the GRR at current price levels for at least the recommended plan. Economic analyses results for the recommended plan are February 2009 price levels. An update to April 2011 price levels is required to ensure compliance with ER 1105-2-100 and EC 11-2-187.

2.0 Methodology

Updating the benefits of the recommended plan will entail the computation of damages under Without Project and Recommended Plan conditions using a structure inventory that reflects April 2011 price levels. Changes in structure values from 2009 to 2011 will be analyzed and where necessary, the structure inventory will be updated using a predetermined model for adjustment. Analysis and update of the structure inventory consists of the following:

- A frequency analysis of changes to HEC-FDA structure values between 2009 and 2011 using Harris County Appraisal District (HCAD) data
- Random sampling of 47 residential and commercial properties in the study area for costing using Marshall & Swift (M&S) Cost Estimating Program.
- Comparative statistical testing between 2009 HEC-FDA structure values and 2011 M&S depreciated replacement cost values (e.g. Student t-test)
- Update other costs (unit costs for vehicle, utilities, post disaster costs, and road damage categories) to April 2011 price levels using an adjustment factor based on the Consumer Price Index (CPI).

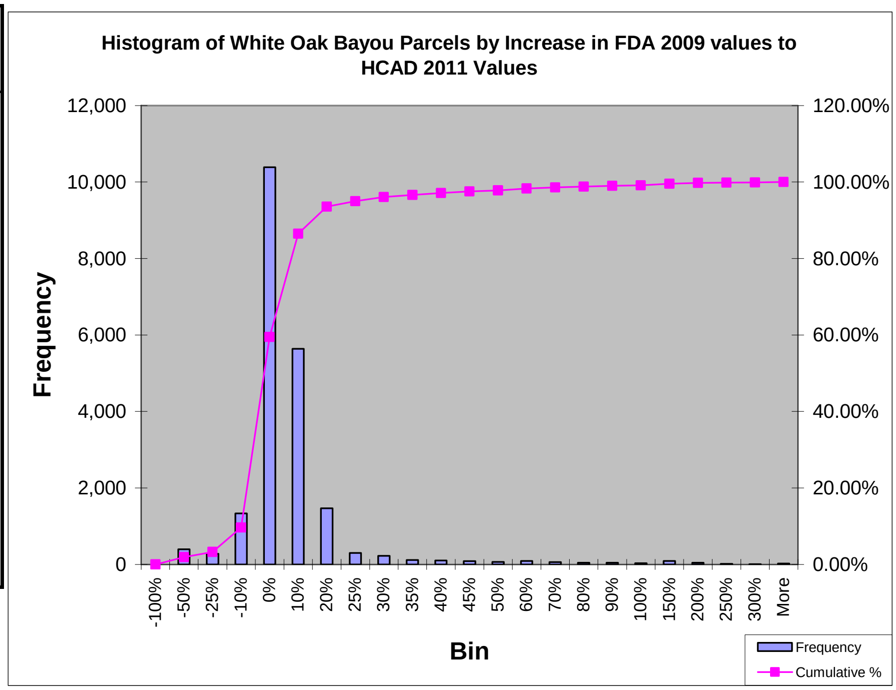
3.0 Frequency Analysis of HCAD Value Change

This GRR has employed the use of HCAD tax data structure values as proxy values for depreciated replacement cost values. To enable an understanding of how HEC-FDA structure values in the study area may have changed between 2009 and 2011, 20,858 properties in the study area with 2011 HCAD values that did not show any documented changes in land use or building square footage and had not been remodeled since the 2002 survey year, were analyzed. The difference between 2011 HCAD depreciated replacement value and 2009 HCAD based HEC-FDA depreciated replacement value as a percentage of the 2009 value was computed for each property and a histogram of the differences constructed. As shown in **Figure 1**, the majority of structures show changes in structure value of between 0 and -10 percent. The mode calculated is -1.34 percent with the median value -1.21 percent change. The mean change in value for the 20,858 properties analyzed was a 1.34 percent increase in value from 2009 to 2011.

Figure 1
Histogram of Percent Increase in FDA 2009 Value to HCAD 2011 Value
Section 211(f) Federal Project - White Oak Bayou

Frequency Distribution Table

HCAD Value Percent Increase (Bin Value)	*Frequency*	*Cumulative Frequency %*
-100%	1	0.00%
-50%	398	1.91%
-25%	279	3.25%
-10%	1336	9.66%
0%	10,388	59.46%
10%	5,639	86.49%
20%	1,469	93.54%
25%	302	94.99%
30%	224	96.06%
35%	115	96.61%
40%	101	97.09%
45%	87	97.51%
50%	66	97.83%
60%	95	98.28%
70%	58	98.56%
80%	46	98.78%
90%	44	98.99%
100%	30	99.14%
150%	91	99.57%
200%	41	99.77%
250%	16	99.85%
300%	8	99.88%
More	24	100.00%
Count	20,858	
Mean		1.34%
Median		-1.21%
Mode		-1.34%



Note: Each bin value is the upper class limit of the range defined between bin values.

4.0 Sample Survey

A sample survey of 47 structures in the study area was conducted for costing using the Marshall and Swift Cost Estimator Program. The sample as shown in **Table 1** is comprised of 40 residential and 7 commercial properties within the study area selected at random. The ratio and percent change was calculated for each pairing of 2009 HEC-FDA and 2011 M&S depreciated replacement cost structure values.

The results show that on average 2011 M&S values are -1.73 percent lower than the 2009 HEC-FDA structure values. A statistical description of the ratios of 2011 M&S values to 2009 HEC-FDA values is shown in **Figure 2**. The standard deviation of the ratios is 0.103. The probability that the ratios belong to the normal distribution can be seen to be significant at 0.05 level of significance, hence parametric testing of the data may apply.

The 2-tailed Student t-test was performed on the ratios and as shown in **Figure 3**, the p-value of 0.639 is greater than the 0.05 level of significance (α = 0.025 for 2-tailed test) thus rejecting acceptance of the alternative hypothesis that the ratio of 2009 M&S values to 2002 HEC-FDA values is not equal to 1. This result means that adjustment of the 2009 HEC-FDA structure values is not required to obtain 2011 depreciated replacement cost values for the HEC-FDA model. A summary of the survey and statistical analysis in conformity with the methodology described in IWR Report 95-R-9 can be seen in **Attachment 1** of this technical paper.

Table 1
White Oak Bayou Economics Update
Comparison between 2009 HEC-FDA Structure Value and 2011 M&S Depreciated Cost New Less Depreciation

Number	HCAD_Num	HEC-FDA Struc_Name	Year Built	Street	Zip Code	HEC-FDA 2009 Value	2011 M&S Value	Ratio	Difference
1	1074530000007	R17086R	WOB-14	16429 CORNWALL ST	77040	$128,691	$129,102	1.00	0.32%
2	0050810000009	R797R	WOB-1	1209 SHEARN ST	77007	$60,251	$59,181	0.98	-1.78%
3	1062320000030	R16806R	WOB-10a(L)	7718 BATTLEWOOD DR	77040	$79,048	$75,107	0.95	-4.99%
4	1088520000050	R16849R	WOB-10a(L)	9907 HANNON DR	77040	$73,597	$77,019	1.05	4.65%
5	1030170000024	R15957R	WOB-10a(R)	9635 OAK THICKET DR	77040	$146,119	$138,329	0.95	-5.33%
6	1030170000009	R15614R	WOB-10a(R)	9623 HEARTHWOOD DR	77040	$154,202	$160,901	1.04	4.34%
7	0821200000025	R18399R	WOB-14	14906 LAKEVIEW DR	77040	$310,765	$243,999	0.79	-21.48%
8	1111460000007	R15731R	WOB-10b(L)	7442 WOOD BLUFF BLVD	77040	$115,923	$116,943	1.01	0.88%
9	1111380000072	R13746R	WOB-10b(R)	8122 BREEZEWAY ST	77040	$89,999	$94,242	1.05	4.71%
10	0451350030015	R13895R	WOB-11	7222 HOLMSLEY LN	77040	$216,754	$220,896	1.02	1.91%
11	1131810000022	R15349R	WOB-11	8710 STORM WOOD ST	77040	$87,049	$90,599	1.04	4.08%
12	0451350020031	R16575R	WOB-12	7604 GAILEY LN	77040	$127,192	$117,050	0.92	-7.97%
13	1031070000005	R12155R	WOB-9	6931 WAGONWHEEL LN	77088	$111,545	$98,022	0.88	-12.12%
14	1104670000007	R17394R	WOB-13	14630 WIND LAWN DR	77040	$92,052	$86,084	0.94	-6.48%
15	0821210010024	R17071R	WOB-14	7819 EQUADOR ST	77040	$125,812	$124,296	0.99	-1.20%
16	1161640060022	R19835R	WOB-15	10502 HOOT OWL RD	77064	$118,968	$132,383	1.11	11.28%
17	1188890040031	R20257R	WOB-15	9202 STONE PORCH LN	77064	$203,526	$181,209	0.89	-10.97%
18	1158670010016	R20197R	WOB-16	9007 BENT SPUR LN	77064	$156,173	$172,388	1.10	10.38%
19	1124730000047	R26830R	WOB-16	10526 RIPPLING FIELDS DR	77064	$75,272	$81,087	1.08	7.73%
20	1147470030007	R26754R	WOB-17	10642 AUTUMN MEADOW LN	77064	$96,040	$98,920	1.03	3.00%
21	1173680020016	R21819R	WOB-17	12519 MERIT WAY CT	77065	$120,525	$120,770	1.00	0.20%
22	1220330040012	R28777R	WOB-18	11851 LEAF OAK DR	77065	$125,033	$122,065	0.98	-2.37%
23	1150240100035	R26063R	WOB-18	10330 BLUE OAK DR	77065	$90,482	$94,260	1.04	4.17%
24	1172310100048	R28082R	WOB-19	10807 ALLENS LANDING DR	77065	$133,423	$164,984	1.24	23.66%
25	0142560000001	R1268R	WOB-2	2100 JOHNSON ST	77007	$63,850	$76,052	1.19	19.11%
26	0121110010020	R2787R	WOB-2	2324 SOUTH ST	77009	$166,463	$144,673	0.87	-13.09%
27	1182990100057	R18947R	WOB-15	8635 BALLINGER DR	77064	$149,329	$154,939	1.04	3.76%
28	0771820170006	R3461R	WOB-3	1522 GLEN OAKS ST	77008	$141,057	$135,906	0.96	-3.65%
29	1214790010002	R2045R	WOB-4(R)	5540 DARLING ST	77007	$132,927	$138,865	1.04	4.47%
30	1000970000030	R12865R	WOB-8b(L)	6027 DARKWOOD DR	77088	$112,749	$124,174	1.10	10.13%
31	1031020000002	R11769R	WOB-9	6119 VINEWOOD DR	77088	$104,383	$96,319	0.92	-7.73%
32	0771820210015	R4024R	WOB-4b(L)	2011 CROYDON CT	77008	$148,527	$165,950	1.12	11.73%
33	1215140010002	R6224R	WOB-4b(L)	1412 W 24TH ST	77008	$210,347	$246,256	1.17	17.07%
34	0892050000051	R5893R	WOB-5	2019 WIDDICOMB CT	77008	$182,723	$162,628	0.89	-11.00%
35	0950800000016	R9375R	WOB-6	2415 BLUE WATER LN	77018	$96,949	$87,516	0.90	-9.73%
36	1031180000021	R10207R	WOB-7	4911 CARIS ST	77091	$119,982	$122,160	1.02	1.81%
37	1138400000018	R10499R	WOB-7	5215 HOLLY VIEW DR	77091	$129,741	$108,572	0.84	-16.32%
38	0991110000004	R11145R	WOB-8(R)	6010 VICTORY DR	77088	$87,308	$71,265	0.82	-18.38%
39	1115380000001	R16272R	WOB-8(R)	7939 GREEN LAWN DR	77088	$173,425	$147,889	0.85	-14.72%
40	1011970000012	R12228R	WOB-8b(L)	7426 ANTOINE DR	77088	$105,834	$87,856	0.83	-16.99%
41	1151210010006	C13102C	WOB-12	9206 EMMOTT RD	77040	$174,650	$141,640	0.81	-18.90%
42	1195680010001	C1084C	WOB-4(R)	6508 WASHINGTON AVE	77007	$484,870	$464,292	0.96	-4.24%
43	1067220000005	C15016C	WOB-13	7415 EMPIRE CENTRAL DR	77040	$664,480	$586,983	0.88	-11.66%
44	1154350000001	C26925C	WOB-17	10851 CRESCENT MOON DR	77064	$3,046,330	$3,164,136	1.04	3.87%
45	0440840010044	C6486C	WOB-5	2748 W T C JESTER BLVD	77018	$355,670	$368,613	1.04	3.64%
46	0973820000012	C10656C	WOB-7	5651 SHERATON OAKS DR	77091	$91,120	$77,504	0.85	-14.94%
47	0431760000090	C11483C	WOB-9	402 N HOUSTON ROSSLYN RI	77088	$129,700	$127,076	0.98	-2.02%
							Average	0.98	-1.73%

Figure 2

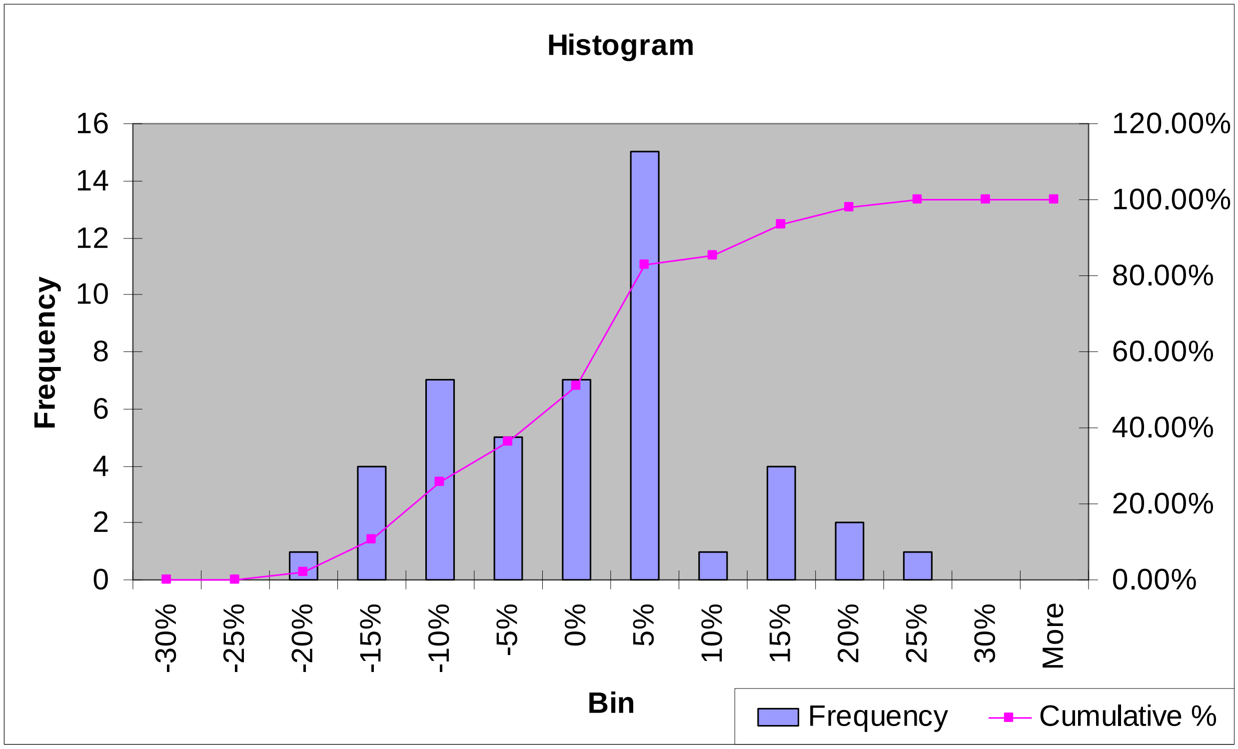


Figure 3

n	48		
Mean	0.983	**Median**	0.985
95% CI	0.953 to 1.013	**97.1% CI**	0.947 to 1.036
SE	0.0149		
		Range	0.45
Variance	0.011	**IQR**	0.147
SD	0.103		
95% CI	0.086 to 0.129	**Percentile**	
		0th	0.785 (minimum)
CV	10.5%	**25th**	0.895 (1st quartile)
		50th	0.985 (median)
Skewness	0.17	**75th**	1.043 (3rd quartile)
Kurtosis	-0.23	**100th**	1.237 (maximum)
Shapiro-Wilk W	0.98		
p	0.639		

5.0 Other Costs

Unit costs used in the construction of depth-damage curves for vehicle, utility, post disaster costs, and road damage categories are to be updated using the Consumer Price Index (CPI) as a means for price level adjustment. The change in CPI index for all items in the Houston-Galveston-Brazoria, Texas Metropolitan Statistical Area (MSA) is +6.93% for the period from February 2009 to April 2011. This change is reflected in Attachment 2 with the computation of new unit cost values.

6.0 Conclusions

A frequency analysis was performed to determine the overall change in the HCAD data sets between 2009 and 2011 based on the 2009 HEC-FDA structure database. The majority of structures show increases in structure value of between 0 and -10 percent. The mode calculated is -1.34 percent with the median value -1.21 percent decrease. The mean change in value for the 20,858 properties analyzed was a 1.34 percent increase. The data indicates that while on average there was an increase in value of just over one percent, more properties decreased in value than increased. Additionally in **Table 1**, a comparison of the 2009 HEC-FDA values and the 2011 Marshall & Swift Cost Estimated values of 47, randomly chosen, study area properties shows that on average depreciated replacement cost values have decreased by -1.73%. A Student t-test indicates the likelihood of no statistical change in value for the 47-sample survey (**Attachment 1**). The two sample sets indicate that structure values over the 2009 to 2011 time frame have not increased significantly. Harris County, along with the rest of the nation, has been adversely affected by the recession. While the Houston Metropolitan area did not suffer the same extent as other parts of the country, there was downward pressure on the existing real estate inventory. The available data showed that nearly as many properties decreased in values as increased in value. Based on the available data it is recommended that no adjustment is required to adjust the HEC-FDA 2009 structure values to 2011 structure price levels. Unit costs for non-structural damage categories are to be inflated to April 2011 price levels by +6.93% based on the Consumer Price Index as seen in **Attachment 2**.

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

Estimate ID	HEC-FDA Struc_Name	HCAD Acct Number	Property Class	Year Built	Building Area (SF)	2009 HCAD RCNLD Value	2011 M&S Depreciated Cost New by CEI	DC/HCAD Ratio
1	R17086R	1074530000007	Residential	1981	2350	$118,858	$129,102	1.09
2	R797R	0050810000009	Residential	1920	2638	$46,359	$59,181	1.28
3	R16806R	1062320000030	Residential	1975	1828	$76,392	$75,107	0.98
4	R16849R	1088520000050	Residential	1975	2053	$68,555	$77,019	1.12
5	R15957R	1030170000024	Residential	1971	3189	$131,781	$138,329	1.05
6	R15614R	1030170000009	Residential	1969	3499	$139,589	$160,901	1.15
7	R18399R	0821200000025	Residential	1978	3429	$162,272	$243,999	1.50
8	R15731R	1111460000007	Residential	1986	2368	$107,626	$116,943	1.09
9	R13746R	1111380000072	Residential	1977	1880	$88,586	$94,242	1.06
10	R13895R	0451350030015	Residential	1996	3331	$206,738	$220,896	1.07
11	R15349R	1131810000022	Residential	1979	1960	$77,479	$90,599	1.17
12	R16575R	0451350020031	Residential	1978	3220	$117,385	$117,050	1.00
13	R12155R	1031070000005	Residential	1970	2500	$96,083	$98,022	1.02
14	R17394R	1104670000007	Residential	1979	2029	$92,778	$86,084	0.93
15	R17071R	0821210010024	Residential	1977	2751	$121,792	$124,296	1.02
16	R19835R	1161640060022	Residential	1987	2368	$112,107	$132,383	1.18
17	R20257R	1188890040031	Residential	1998	3022	$182,005	$181,209	1.00
18	R20197R	1158670010016	Residential	1998	2626	$162,327	$172,388	1.06
19	R26830R	1124730000047	Residential	1982	1576	$73,717	$81,087	1.10
20	R26754R	1147470030007	Residential	1983	2172	$96,080	$98,920	1.03
21	R21819R	1173680020016	Residential	1993	1926	$119,085	$120,770	1.01
22	R28777R	1220330040012	Residential	2001	1712	$124,319	$122,065	0.98
23	R26063R	1150240100035	Residential	1983	2025	$83,924	$94,260	1.12
24	R28082R	1172310100048	Residential	1995	2740	$129,107	$164,984	1.28
25	R1268R	0142560000001	Residential	1979	1634	$74,863	$76,052	1.02
26	R2787R	0121110010020	Residential	1984	3396	$136,662	$144,673	1.06
27	R18947R	1182990100057	Residential	1998	2716	$146,898	$154,939	1.05
28	R3461R	0771820170006	Residential	1950	2015	$151,198	$135,906	0.90
29	R2045R	1214790010002	Residential	2000	2266	$132,627	$138,865	1.05
30	R12865R	1000970000030	Residential	1968	2535	$109,074	$124,174	1.14
31	R11769R	1031020000002	Residential	1975	2495	$112,085	$96,319	0.86
32	R4024R	0771820210015	Residential	1953	3950	$243,350	$165,950	0.68
33	R6224R	1215140010002	Residential	2001	2696	$202,331	$246,256	1.22
34	R5893R	0892050000051	Residential	1965	3158	$159,771	$162,628	1.02
35	R9375R	0950800000016	Residential	1964	2317	$84,516	$87,516	1.04
36	R10207R	1031180000021	Residential	1970	2943	$112,460	$122,160	1.09
37	R10499R	1138400000018	Residential	1982	2370	$116,924	$108,572	0.93
38	R11145R	0991110000004	Residential	1970	1840	$87,414	$71,265	0.82

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

39	R16272R	1115380000001	Residential	1976	2578	$139,700	$147,889	1.06
40	R12228R	1011970000012	Residential	1974	2372	$94,510	$87,856	0.93
41	C13102C	1151210010006	Commercial	1985	9900	$282,700	$141,640	0.50
42	C1084C	1195680010001	Commercial	1998	4998	$113,000	$272,115	2.41
43	C15016C	1067220000005	Commercial	1980	42000	$827,015	$586,983	0.71
44	C26925C	1154350000001	Commercial	1982	58314	$3,019,557	$3,164,136	1.05
45	C6486C	0440840010044	Commercial	1960	12117	$519,714	$368,613	0.71
46	C10656C	0973820000012	Commercial	1970	4184	$98,372	$77,504	0.79
47	C11483C	0431760000090	Commercial	1970	5600	$226,970	$127,076	0.56
Totals						$86,821,140	$73,197,541	
Count						47	47	47
Min						$46,359	$59,181	0.50
Max						$3,019,557	$3,164,136	2.41
Median						$118,858	$124,296	1.05
Mean						$211,205	$208,700	1.04
StdDev						$436,881	$449,207	0.27
Var						$190,864,865,195	$201,787,343,959	0.07
CV								0.26

Attachment 1
HEC-FDA Price Level Update Sample Survey
Section 211 (f) Federal Project - White Oak Bayou

Statistical Summary

1. Compute Sample Size (n)

$$n = \frac{Z^2 CV^2}{e^2}$$

Level of Confidence = 90%, therefore:

z = 1.676

Level of Precision (Tolerable Error) = 5% or 10%, e = 0.05 or 0.10

Coefficient of Variation (CV) = 0.26

For e = 5% ***0.050***

n =	***77***

For e = 10% ***0.100***

n =	***19***

2. Determine Sample Survey Level of Precision (Error - e)

For n = 47

e =	***6.39%***

Sample Test Application

Objective: To Update 2009 Depreciated Replacement Cost values obtained direct or by proxy using HCAD data to 2011 Depreciated Replacement Cost Values. A random sample of 47 structures in the White Oak Study Area was obtained and 2011 Depreciated Replacement Costs

Analysis: On the average, the sampled structures have a depreciated replacement cost for year 2011 four (4) percent higher than the year 2009 value, a mean ratio of 1.04. The sample standard deviation of the ratios was calculated to be 0.27. Assuming that the ratios are normally distributed, the Student t distribution can be used to describe the sample. The t-statistic computed from measuring the difference between the sample and the assumed population mean is computed below.

$$t = \frac{X - U}{S/(N)^{0.5}}$$

X =	1.04	(sample mean)
U =	1.00	(assumed population mean)
S =	0.27	(sample standard deviation)
N =	46.00	(sample size - 1)

Compute Student t Distribution:

t =	0.99	N-1 degrees of freedom

Referencing a standard student t distribution table, the critical value of t with 46 degrees of freedom for a two-tailed test at a 10 percent level of significance is 1.676. This indicates within the bound of t = -1.676 to t = +1.676, there is a 90 percent chance that the population mean = 1.0. Since our calculated t of 0.99 is within the acceptance range, we can conclude that it is not necessary to find a means to adjust the HCAD 2009 data to bring in line with M&S 2011 values.

Attachment 2

Unit Cost Update from February 2009 to April 2011 Price Levels
White Oak Bayou - "Other Cost" Damage Categories

Damage	Event Exceedance Probability								
Category	**0%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Unit Cost (Utilities)	$0	$225	$225	$225	$225	$225	$225	$225	$225
Unit Cost (Emergency)	$0	$9,295	$9,295	$9,295	$9,295	$9,295	$9,295	$9,295	$9,295
Unit Cost (Roads)	$0	$12,224	$12,224	$12,224	$12,224	$12,224	$12,224	$12,224	$12,224

ADJUSTED UNIT COSTS VALUES PER THE % CPI INCREASE FROM FEB. 2009 TO April 2011 OF: **6.93 %**

Damage	Event Exceedance Probability								
Category	**0%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Unit Cost (Utilities)	$0	$241	$241	$241	$241	$241	$241	$241	$241
Unit Cost (Emergency)	$0	$9,939	$9,939	$9,939	$9,939	$9,939	$9,939	$9,939	$9,939
Unit Cost (Roads)	$0	$13,071	$13,071	$13,071	$13,071	$13,071	$13,071	$13,071	$13,071

**The multiplier of 1.0693 was obtained from the U.S. Department of Labor Bureau of Labor Statistics web-site (www.bls.gov)"

**The 26-month Percent Change in the Consumer Price Index for "All Items" in the Houston-Galveston-Brazoria, Texas Metropolitan Statistical Area was determined for the time period from February 2009 to April 2011. This value is +6.93% and represents the average increase in the cost of all items for this time period.

**This value was then utilized as a multiplier for the the categories in the above table.