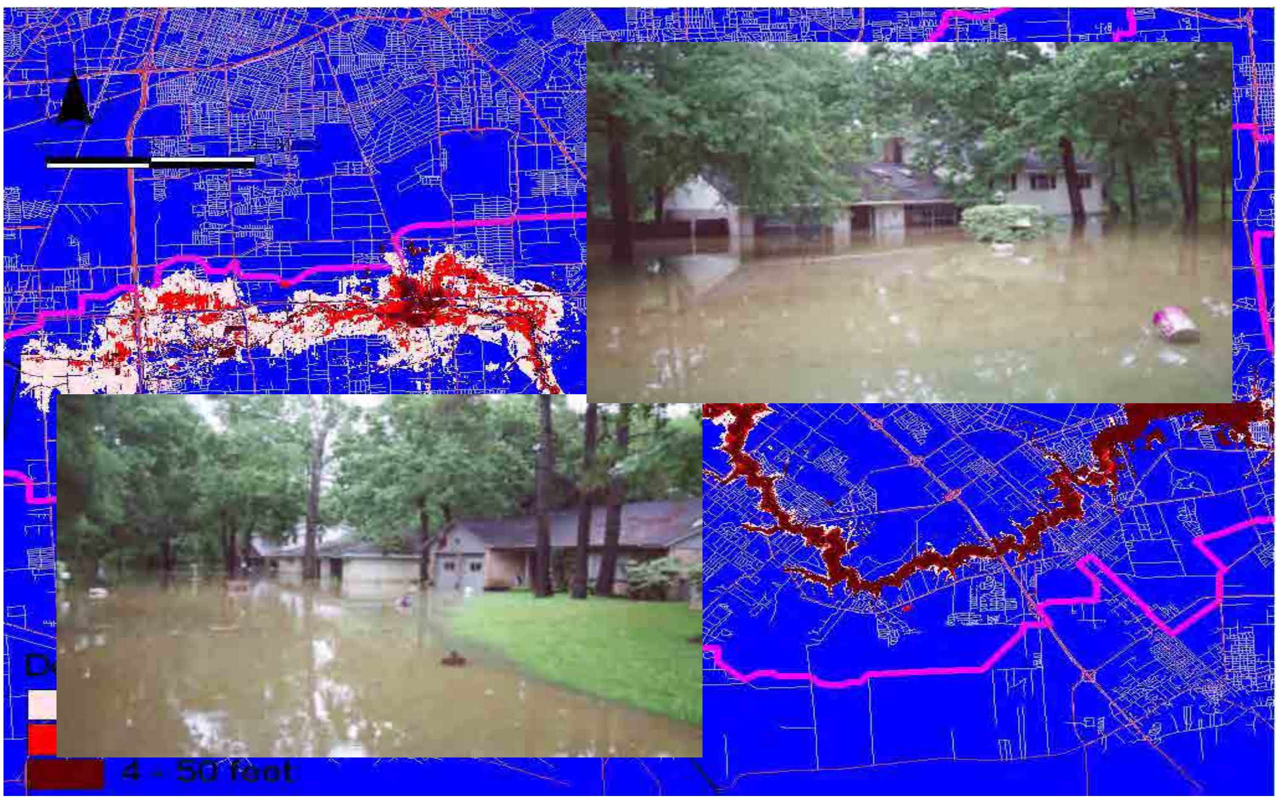
U.S. Army Corps of Engineers

Galveston District
Southwestern Division

Clear Creek, Texas

Flood Risk Management

Final
General Reevaluation Report
Appendices



October 2012

APPENDIX A
Section 575 (WRDA ’96) Implementation Guidance

CECW-PC 10 October 1997

MEMORANDUM FOR Commander, Southwestern Division

SUBJECT: Guidance for Implementing Section 575, Harris County, Texas, of the Water Resources Development Act of 1996

The subject guidance is provided in the enclosure for your implementation.

FOR THE COMMANDER:

/Signed/

Enclosure

G. EDWARD DICKEY
Chief, Planning Division
Directorate of Civil Works

CF: CECS
CECW-AA
CECW-AG
CECW-AR
CECW-BC
CECW-EH
CECW-P
CECW-PE (Lee)
CECW-PC (Kitch)
CECW-ZD (2)
CESWD-ETP
OASA(CW)
RET to: CECW-PC

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

REPLY TO
ATTENTION OF:

CECW-PC

10 OCT 1997

MEMORANDUM FOR Commander, Southwestern Division

SUBJECT: Guidance for Implementing Section 575, Harris County, Texas, of the Water Resources Development Act of 1996

The subject guidance is provided in the enclosure for your implementation.

FOR THE COMMANDER:

Enclosure

G. EDWARD DICKEY
Chief, Planning Division
Directorate of Civil Works

CECW-PC
GUIDANCE FOR IMPLEMENTING CERTAIN PROVISIONS OF THE WATER RESOURCES DEVELOPMENT ACT OF 1996

SECTION: 575 Harris County, Texas

CITATION: (a) IN GENERAL.-During any evaluation of economic benefits and costs for projects set forth in subsection (b) that occurs after the date of the enactment of this Act, the Secretary shall not consider flood control works constructed by non-Federal interests within the drainage area of such projects prior to the date of such evaluation in the determination of conditions existing prior to construction of the project.

(b) SPECIFIC PROJECTS.-The projects to which subsection (a) apply are-

(1) the project for flood control, Buffalo Bayou Basin, Texas, authorized by section 203 of the Flood Control Act of 1954 (68 Stat. 1258);

(2) the project for flood control, Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610); and

(3) the project for flood control, Cypress Creek, Texas, authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 4014).

SYNOPSIS: The Corps of Engineers 1989 feasibility report for Buffalo Bayou accounted for future project development by non-Federal interests and indicated that non-Federal development would not affect the Federal plan formulation and would increase the level of protection provided by the Corps projects. The sponsor, Harris County Flood Control District (HCFCD,) has planned and started construction of a series of detention basin, levee improvement and channel modification projects to enhance the level of flood protection to be provided by authorized, but as yet not completed, Corps projects. Because these facilities are not specifically authorized by Congress as part of the Corps projects, HCFCD fears that their construction will diminish the economic feasibility of the Corps projects in ongoing and future analyses.

The Conference Report on H.R. 3816, Energy and Water Development Appropriations Act, 1997, provides $1,110,000 for Brays Bayou studies, $860,000 for Greens Bayou studies, and $400,000 for Cypress Creek studies. Brays Bayou and Greens Bayou are tributaries of Buffalo Bayou.

The Brays Bayou project was developed as part of the comprehensive flood control plan for Buffalo Bayou. The Buffalo Bayou Feasibility Report and EIS were approved in 1989. The authorized project consists of three miles of channel improvements, three flood detention basins, seven miles of stream diversion and various recreation features at an estimated total cost of $330 million (October 1995 price level). The project consists of two separable elements. A Project Design Memorandum (PDM) for the detention element was initiated in September 1995. A General Reevaluation Report (GRR), initiated in September 1995 and scheduled for completion in August 1998, will address alternatives to the diversion element. FY 1997 funds will be used to complete the PDM for detention facilities, continue the GRR, and continue other PED efforts. HCFCD has initiated the construction of two detention basins in the Brays Bayou basin. One has just been started and the other is half-completed. Both are part of the authorized project. HCFCD may consider constructing other parts of the authorized project itself in the future.

The authorized Greens Bayou project consists of 25 miles of channel improvements, 14 miles of selective clearing, acquisition of flood-prone structures, and four flood detention basins at an estimated cost of $228 million (October 1995 price level). A GRR was initiated in 1996 to reformulate the project. FY 1997 funds will be used to continue the GRR. The highway department and others have used borrow materials from a site that will eventually become a detention basin. This detention basin will not be part of the authorized project.

The authorized Cypress Creek project consists of enlarging 29.4 miles of channel improvements, floodplain management, recreation features, and 885 acres of habitat creation/management at an estimated cost of $146 million (October 1995 price level). A GRR initiated in 1994 has reformulated the project. The economic analyses supporting the GRR were completed prior to enactment of WRDA 96, therefore Section 575 does not apply to this project reevaluation and these economic analyses were performed without the Section 575 requirements. The draft GRR was submitted for policy compliance review in April 1997. The final GRR is scheduled for completion in December 1997. HCFCD has constructed a levee and completed channelization work in the Cypress Creek basin. Neither is part of the authorized project. HCFCD has no current plans to construct detention basins in the Cypress Creek basin.

Section 575 states that during any evaluation of economic benefits and costs for the specified projects after 12 October 1996, flood control works previously constructed by non-Federal interests will not be included in the determination of conditions existing prior to construction. The House Report 104-695 on WRDA 96 stated, "The intent of this provision is to not jeopardize the economic viability of the specified projects simply because non-Federal sponsors have demonstrated initiative in making advance drainage improvements." Non-Federal interests could conceivably make investment decisions in local projects once they perceive that the Corps has selected a plan for further development. This perception could occur when the district engineer releases a draft feasibility report or similar level decision document for public and agency review. A public hearing was held on 20 June 1950 regarding a review report on a survey of the Houston Ship Channel and Buffalo Bayou, Texas. This led to the 1954 authorization of the Buffalo Bayou project. This predates the public documents that led to the authorization of the Buffalo Bayou and Tributaries project in 1990. The draft Interim Report on Cypress Creek, San Jacinto River and Tributaries, Texas, was released for public and agency review in October, 1983. This led to the 1988 authorization of the Cypress Creek project. Subsequent to the public release of these documents, the sponsor has developed some features of the authorized projects along with additional features intended to further increase the level of protection.

To meet the intent of the legislation, ongoing and future reevaluation studies of the specified authorized Federal projects will need to exclude the non-Federal flood control works completed after the district engineer released a draft feasibility report or similar level decision document for public and agency review, and completed before the economic reevaluation.

These local projects should be excluded from both the "without project" conditions and the "with project" conditions for the various alternatives considered in detail. Excluding the completed non-Federal flood control works from the "without project" conditions is required directly by Section 575. Excluding the completed non-Federal flood control works from the "with project" conditions is necessary to ensure that the impacts of the non-Federal works do not affect the economic and cost evaluations of the various alternatives. Since the selection of the recommended plan is largely dependent on the economic evaluations of the alternatives, the selection of the recommended plan must be based on these analyses which fully exclude the completed non-Federal flood control works. It is anticipated that hydrologic and economic analyses will be needed to simulate both the "with project" and "without project" conditions that exclude the completed non-Federal works.

The above procedure ensures that the completed non-Federal flood control works do not affect the plan selection, but it could conceivably result in a recommended plan that is larger and less efficient than one that would be formulated under normal procedures. It could also result in a project that provides greater protection than the supporting analyses indicate. Knowledge of the actual project operation capabilities is absolutely necessary to ensure an appropriate and safe operation. Without compromising the intent of Section 575, the effects of the completed non-Federal flood control works on the recommended plan should be examined to ensure that the recommended plan is efficient and to identify the project's actual operating characteristics. This can be accomplished with the following steps: (a) add the completed non-Federal flood control works to the recommended plan to form a total flood control "with project" condition; (b) perform a hydrologic/hydraulic analysis of the total project and assess the impacts; (c) define the total project outputs, including operating capabilities; and (d) reevaluate and adjust the design and operation of the recommended plan to reduce costs while still providing the same total project output. The total project outputs can be identified in terms of residual flood damages and/or other parameters. It may be possible to reduce project costs without affecting the total project outputs by downsizing the recommended plan, modifying a completed non-Federal flood control feature, or adjusting the manner in which features are incorporated into the recommended plan.

IMPLEMENTATION GUIDANCE: The following steps should be applied in the order presented to any current and future economic analyses of the Buffalo Bayou projects, including the Brays Bayou and Greens Bayou projects, and the Cypress Creek project specified in Section 575(b):

1. Exclude non-Federal flood control works, that meet the two following tests, from existing and future "without project" condition descriptions:

(a) Construction was completed after June 1950 within the Buffalo Bayou and Tributaries basin and after October 1983 within the Cypress Creek basin, and

(b) Construction was completed prior to the current or planned evaluation of benefits and costs.

These "without project" conditions will provide the baseline for the next step which includes the proposed Federal project alternatives.

2. Exclude the same completed non-Federal flood control works from the "with project" conditions for each alternative considered. Compare these "with project" conditions to the step 1 "without project" conditions to determine the incremental benefits, costs, and other impacts for each alternative. Recommend a plan, possibly the "no action" plan, for implementation based on these analyses.

3. Combine the completed non-Federal flood control works with the recommended Federal project to form a total project. Identify the total project output.

4. Reexamine and possibly modify the design and operation of the recommended Federal project to more efficiently achieve the total project output. The total project output should not be compromised without the sponsor's concurrence.

APPENDIX B
Economic Appendix

Economic Appendix

Final

August 2012

THE STUDY AREA

The study area for the economic analysis is the Harris, Galveston, and Brazoria County portions of the Clear Creek watershed impacted by the estimated median 0.2 percent annual exceedance probability (AEP) flood event on the main stem and five of its tributaries as defined by the most likely future 2070 hydrology without runoff controls. This area, extends from Galveston Bay to the Brazoria County-Fort Bend County boundary, and includes the main stem of Clear Creek, Mud Gully and Turkey Creek in Harris County, and Mary's, Cowart, and Chigger Creeks in Brazoria and Galveston Counties, as shown in Figure 1.

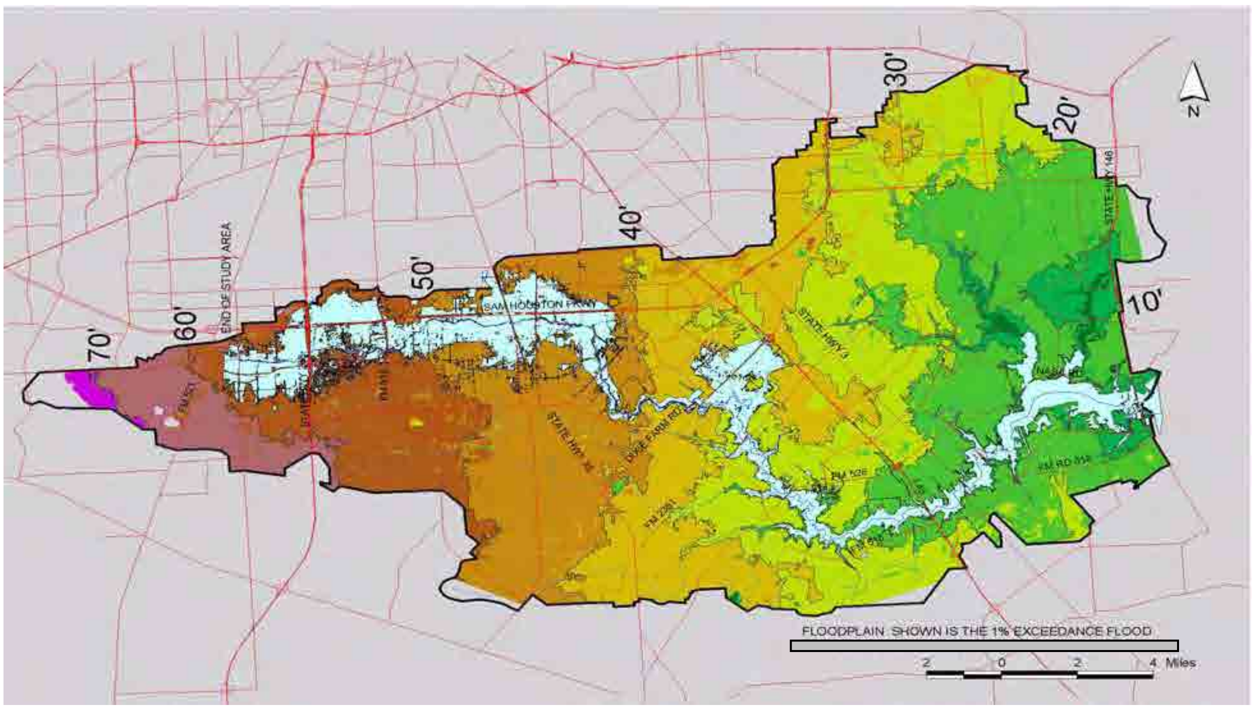


Figure 1. Clear Creek Watershed, 1% AEP Floodplain (light blue) and Associated Land Surface Elevations, Main Stem

Flooding of residential and commercial developments situated near Clear Creek and its tributaries is the principal problem within the watershed. As a result of rapid expansion and urbanization in recent years, the capacity of the existing channels has been exceeded on an increasingly frequent basis, even with runoff from moderate rainfalls. The present extent of flooding from the 100-year flood plain in Galveston, Harris, and Brazoria Counties is now restricted by land use regulations adopted by these counties to qualify for the National Flood Insurance Program.

THE PERIOD OF ANALYSIS, INTEREST RATE, AND PRICE LEVEL

The period of analysis begins in the year 2020, the first year in which a project would become operational. Therefore, the base year is defined as 2020. The period of analysis extends 50 years in the future to the year 2070, in accordance with ER 1105-2-100, Appendix D-6(a) (3), dated June 30, 2004. The most probable future condition reflects changes in hydrologic conditions from anticipated development within the watershed tempered by runoff restrictions imposed by local authorities over the period of analysis, 2020 to 2070. This assumption is consistent with current guidance.

For the purpose of plan comparison, a uniform period of analysis is required to incorporate the time value of money. Guidance requires that all project benefits be reported as average annual equivalent values (AAEV) which involve calculating benefits over the entire 50-year period of analysis, discounting those benefits to the base year, the first year the project is fully operational, and then amortizing them over 50 years using a mandated interest rate. The interest rate for discounting is set each fiscal year in accordance with Section 80 of Public Law 93-251. The USACE obtains the rate from the U.S. Treasury Department, which computes it as the average yield on interest-bearing marketable securities of the United States having 15 or more years to maturity. The computed rate is effective as of October 1of each year. The interest rate for Fiscal Year 2012 (FY12) is 4.0 percent and is applied to the final analysis.

Current interest rates were used during the multi-year study period and applied uniformly during each phase of plan formulation. In order to avoid confusion in the presentation of alternative screening results and to remain true to the results of the plan formulation, the interest rate applicable at the time the analysis was conducted is reported where appropriate. The final results are presented in FY12 price levels.

Data collection for development of the Clear Creek main stem structure inventory began in the year 2000. Data for over 12,000 structures on the main stem were collected during 2000-2001 and data for another 12,000 structures for the tributaries were collected during the period 2002-2003. Values presented in this analysis reflect certified year 2001 tax appraisal district valuations updated and adjusted to October, 2011 depreciated replacement values. For purposes of plan formulation and initial screening of flood risk management reduction measures, the year 2001 tax valuations were used as proxy values for depreciated replacement values. For the final refinement of alternatives, prices were adjusted to reflect depreciated replacement values, as required by guidance, for the current year.

ECONOMIC REACHES

Property surveyed within the most likely future median 0.2 percent AEP floodplain (or 500-year floodplain) of the Clear Creek main stem was allocated to the nearest stream cross-section between river cross-section 0+00 and 236609+00. These cross-sections were aggregated into 19 economic reaches in order to facilitate analysis. The following Table 1 shows the aggregations of cross-sections into economic reaches with geographic or other physical descriptors. The backwater effects of the main stem on the tributaries in the study area were incorporated into the main stem analysis. Properties that lie on the tributaries, but whose hydrology was controlled by that of the main stem, were assigned to the main stem.

TABLE 1
ECONOMIC REACH DELINEATIONS FOR CLEAR CREEK MAIN STEM

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	0	GALVESTON BAY	7020	ROSEWOOD
2	7020	ROSEWOOD	23263	BAL HARBOR
3	23263	BAL HARBOR	37212	FM270
4	37212	FM270	46388	SH3
5	46388	SH3	55615	IH45
6	55615	IH45	73893	W BAY AREA BLVD
7	73893	W BAY AREA BLVD	90072	FM528
8	90072	FM528	95406	WHISPERING PINES
9	95406	WHISPERING PINES	103330	NEAR MARY'S CRK
10	103330	NEAR MARY'S CRK	112394	FM2351
11	112394	FM2351	125782	NEAR TURKEY CRK
12	125782	NEAR TURKEY CRK	143346	DIXIE FARM RD
13	143346	DIXIE FARM RD	160053	COUNTRY CLUB DR
14	160053	COUNTRY CLUB DR	170703	BENNIE KATE
15	170703	BENNIE KATE	185548	SH35
16	185548	SH35	189373	MYKAWA
17	189373	MYKAWA	205888	STONE RD
18	205888	STONE RD	223445	SH288
19	223445	SH288	236609	ALMEDA SCHOOL RD

note: All properties north of the main stem lie in Harris County; Properties in Reaches 1-12 south of the main stem lie in Galveston County; properties in Reaches 13-19 south of the main stem lie in Brazoria County

A similar procedure was followed with the five Clear Creek tributaries studied. Property improvements were surveyed and allocated to the nearer cross-sections of the respective tributaries.

Tables 2 through 6 display the economic reaches created for the tributaries to which properties were assigned. ER 1165-2-21, 30 Oct 80, describes one criterion for Federal participation in urban water damage problems as "… downstream from the point where the flood discharge of such a stream or waterway within an urban area is greater than 800 cubic feet per second (cfs) for the 10 percent flood …." This criterion was especially critical for determining the Federal interest in the Clear Creek tributaries. Hickory Slough a tributary of Clear Creek that drains part of the City of Pearland, Brazoria County, did not qualify for consideration based on this "800 cfs" criterion. Economic reaches are presented in Figure 2 along with the 0.2 percent AEP (500-year) floodplain delineation.

TABLE 2

ECONOMIC REACH DELINEATIONS FOR MUD CREEK

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	9960	90 DEGREE TURN SW	17833.5	HALL ROAD
2	17833.5	HALL ROAD	20262.9	BELTWAY 8
3	20262.9	BELTWAY 8	23454.6	KINGSPOINT
4	23454.6	KINGSPOINT	26578.6	UPPER 800 CFS LIMIT

note: All reaches are located in Harris County

TABLE 3

ECONOMIC REACH DELINEATIONS FOR TURKEY CREEK

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	13518.95	END OF BACKWATER	17666.00	NYACK
2	17666.00	NYACK	19778.71	SCARSDALE
3	19778.71	SCARSDALE	22476.28	BELTWAY 8
4	22476.28	BELTWAY 8	23604.19	SAGEDOWNE—800 CFS LIMIT

note: All reaches are located in Harris County

TABLE 4
ECONOMIC REACH DELINEATIONS FOR MARY'S CREEK

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	4400	EDGEWIID DR,	10775	COUNTY LINE
2	10776	COUNTY LINE	25407	LONGERRIDGE DR.
3	25408	LONGERRIDGE DR.	37897	AT&SF RAILROAD
4	37898	AT&SF RAILROAD	48122	HARKEY RD.
5	48123	HARKEY RD.	57133	CHARLES AVE. – 800 CFS LIMIT

note: Reaches 1-4 are located in Galveston County; Reach 5 lies in Brazoria County

TABLE 5

ECONOMIC REACH DELINEATIONS FOR COWART CREEK

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	5560	CASTLEWOOD	9826	SUNSET DR
2	9827	SUNSET DR	16256	COUNTY LINE
3	16257	COUNTY LINE	26581	800 CFS LIMIT

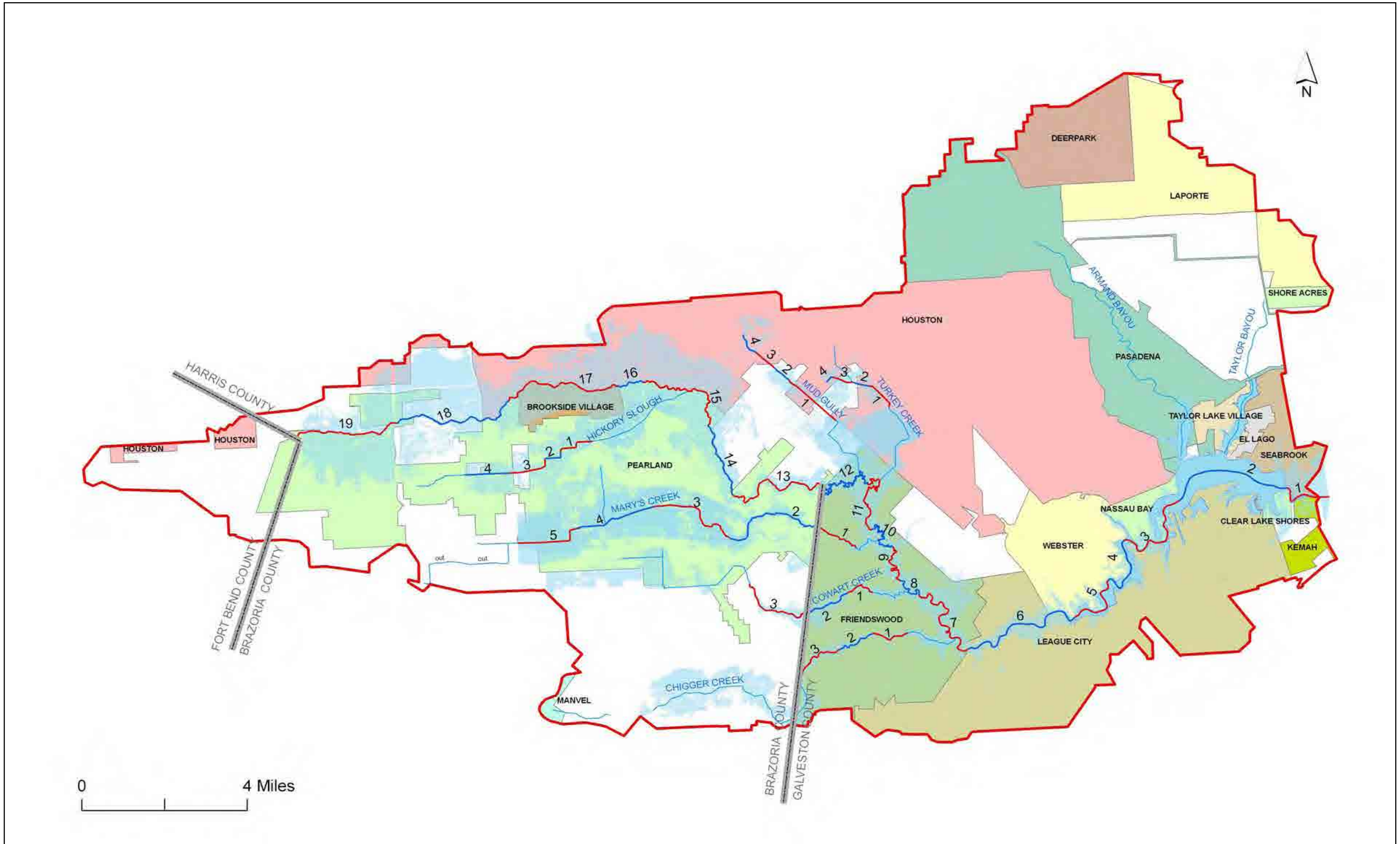
note: Reaches 1 and 2 are located in Galveston County; Reach 3 lies in Brazoria County

TABLE 6
ECONOMIC REACH DELINEATIONS FOR CHIGGER CREEK

REACH	LOWER XSEC	LOWER LIMIT NEAR	UPPER XSEC	UPPER LIMIT NEAR
1	6990	FM 518	12696	GREENBRIAR
2	12697	GREENBRIAR	17901	NARINA
3	17902	NARINA	25090	CONFLUENCE WITH BYPASS—800 CFS LIMIT
4	25091	CONFLUENCE WITH BYPASS	31259	BRAZORIA COUNTY LINE
5	31260	BRAZORIA COUNTY LINE	55600	HEADWATERS OF STREAM

note: Reaches 1-4 are located in Galveston County; Reach 5 lies in Brazoria County

Figure 2. Clear Creek Watershed, 2020 Condition, Economic Reaches and 0.2% Floodplain (light blue)



DATA COLLECTION AND ANALYSIS PROCEDURES

The methodology detailed below describes the procedures taken to determine project benefits in accordance with the most current guidance, ER 1105-2-100, dated April 22, 2000, and ER 1105-2-101, dated January 3, 2006. Benefit categories investigated for justification of flood risk management measures consist primarily of inundation reduction to structures and contents, inundation reduction to utilities, vehicles, and roads, and reductions in costs sustained by individuals following flood events not identified elsewhere, such as temporary relocation and reoccupation costs. Reduction in administrative costs to the National Flood Insurance Administration (NFIA) is another benefit category applicable to removing structures from the regulatory NFIA floodplain.

Survey of Existing Development. The methodology employed for survey of existing development relied on remote sensing and secondary sources for base information. The inventory of structures within the most likely future median 0.2 percent AEP floodplain was coordinated with the development of the hydrologic baseline information by using shared digital orthophotos flown of the watershed in February, 2000. Horizontal projections were referenced to NAD 83 and the State Plane Coordinate system, South Central Zone. Vertical elevations were referenced to NAVD 88. Photogrammetric digital terrain data were developed within the floodplain with an average spacing of 1 point per 50 feet and an average spacing of 1 point per 100 feet outside the floodplain but within the watershed. A digital terrain model was created using a triangulated irregular network (TIN).

Over 12,000 structures were inventoried on the main stem and an additional 12,000 structures were inventoried along five tributaries using orthophotographs as a base coverage. Points were placed on footprints of structures visually identified on the photographs. Property boundaries, or parcel delineations, were purchased from a vendor who supplied not only the digitized property boundaries but also the attribute tables containing certified year 2001 tax appraisal district records for each parcel. Cross-sections were added as a data layer to associate the hydrology to each structure's point. The ground elevation of the point was assigned from the digital elevation model (TIN) developed from the orthophotographs. Land survey crews surveyed first floor elevations for over 3,300 structures lying closest to the creek. The first floor corrections of the remaining structure inventory were estimated by windshield survey. A data verification team viewed the entire study area to complete the data record—ascertaining the accuracy of the secondary data and making corrections, additions, and deletions as needed from the field. The point file was assigned all the attributes of the various coverages so that a complete data record exists for each structure that contains the tax appraisal district record, the ground elevation, and either the first-floor correction and/or surveyed first-floor elevation, and the nearer cross-section. After the field verification work was complete, the data record was matched with appropriate depth-damage functions based on structure type and exterior construction. Commercial, public, and industrial structures were also assigned appropriate depth-damage functions for contents based on the current use of the structure coupled with content values taken from the business and personal property tax valuations. Missing structure values for tax-exempt properties were determined by the District's Real Estate Division.

All data developed for the structure inventory is in ESRI ArcGIS format and is archived along with other coverages of the Clear Creek study area.

ANALYTICAL TOOLS AND RISK AND UNCERTAINTY

The Analytical Model. The Hydrologic Engineering Center's Flood Damage Analysis Version 1.2.5 release (HEC-FDA) model is employed in this analysis because its risk-based analysis methods for flood risk management studies meet the requirements of EM 1110-2-1419 and ER 1105-2-101. HEC-FDA Version 1.2.5 is a certified model and appropriate for this application. The analytical method explicitly incorporates descriptions of uncertainty within key parameters and functions into project benefit and performance analyses. Stage frequency data were not adjusted for the dynamic economic model and, therefore, reflect median discharge frequencies, a procedure consistent with current guidance.

Uncertainty in Depth-Damage Functions. ER 1105-2-101, January 3, 2006, explicitly states that uncertainty will be expressed in the following economic variables, as appropriate: depth-damage curves; structure values; content values; structure first-floor elevations; structure types; flood warning times; and flood evacuation effectiveness. Uncertainty in depth-damage relationships is incorporated into the HEC-FDA model with the use of generic depth-damage functions for residential structures without basements as published in Economic Guidance Memorandum 01-03, dated December 4, 2000, and with commercial depth-damage functions prepared by GEC, Inc. under contract with the New Orleans District. The generic depth-damage functions for residential structures negate the need for uncertainty expressions in content values and content-to-structure ratios because the content damage is calculated as a percent of the structure value rather than as a percent of the content value as was once the traditional method. Commercial depth-damage functions pertain to four generalized exterior construction types. ((Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies, Final Report, May, 1997)). The depth damage functions produced for the New Orleans District were deemed appropriate to the study area because of similar flooding patterns and construction techniques within Louisiana and Texas Gulf Coasts. The New Orleans functions were applied to commercial, industrial, and public structures as appropriate. Galveston District commercial, public, and municipal inventory and equipment damage curves were used to estimate content damages to those uses.

Uncertainty in Structure Values. Uncertainty in structure values was determined by expert solicitation of the District's Real Estate Division's appraisal staff. Uncertainty was determined to range within ten percent of the improvement depreciated replacement value and was incorporated into the HEC-FDA model.

Uncertainty in First Floor Elevations. The first floor elevation survey performed for over 3,300 structures closest to Clear Creek was accomplished using GPS Real Time Kinematic-On the Fly (RTK-OTF) for establishing survey control and the Wild TC 1010 Total Station with TDS data collection package for collection and management of the first floor elevation data. The mean precision achieved using Trimble's Real Time Kinematic surveying for determining horizontal positions at control points was ±0.018 feet. Mean vertical precision achieved during the survey was ±0.032 feet (Larry J. Broussard, PLS, John Chance Land Surveys, Inc., letter memorandum, August 21, 2000).

The ground elevations and floor corrections of the remaining structures within the 0.2 percent floodplain of the main stem and for all five tributaries was determined by deriving the ground elevation of the structure footprint from the TIN and by visual estimate of the floor correction. Uncertainty in the first floor elevations of these structures along the main stem and along the five tributaries was determined by comparing a sample of structures within the 1 percent flood plain for which both the land survey and the windshield survey were conducted. The standard error of the estimate associated with the ground elevation error from the digital terrain model coupled with the error associated with the windshield survey method of determining the first floor elevation correction produced a regression coefficient of 1.44 feet.

The standard deviation specific to the survey method used was entered into HEC-FDA for each individual structure (i.e. 0.032 for land-surveyed structures and 1.44 for windshield-surveyed structures).

DAMAGE CATEGORIES

Residential Structures. Residential structure damages include inundation losses for single- and multi-family dwellings including one-, one-and-a-half-, and two-story dwellings, mobile homes, garages, high-raised homes, apartments with living space on one floor, and townhomes/condominiums with living space on multiple floors. Separate depth-percent damage relationships were applied to the residential inventory based on classification of the structure. No structures within the inventory have basements.

Residential Property Values. Current guidance (ER 1105-2-100) states that if percent damage functions are used in the assessment of stage-damage relationships, replacement cost less depreciation is the correct measure of structure value. In order to comply with this directive, a methodology for assigning depreciated replacement value to inventoried structures has been developed and was applied to the proxy values used to develop the without-project condition. A statistically significant random sample of 50 structures within the 0.2 percent AEP floodplain was drawn for calculation of depreciated replacement values at October, 2005 prices. These values were regressed against their year 2001 assessed values for a factor adjustment of 1.68 at the 85 percent confidence level. These values were again updated to 2008 price levels using Marshall and Swift Estimator software for depreciated replacement value estimation; the results were regressed against their 2001 assessed values for a factor adjustment of 1.73. Another price level update was prepared during the draft phase of the analysis, Marshall and Swift Estimator again utilized to establish the 2010 price levels (directly updating values from 2001 to 2010). The factor adjustment for the draft analysis was 1.68 at the 85 percent confidence level. Price levels were once again updated to 2012 price levels for the final analysis, again utilizing Marshall and Swift Estimator. The final factor was 1.69 at the 85 percent confidence level for the updating of price levels from 2001 to 2012. No property values presented in this report include land values.

It should be noted that the price level indices developed for 2005, 2008, 2010 and 2012 are not simply construction cost indices. The percent increase in tax assessor values from the 2001 base takes into account the difference in appraisal methodology, homestead value limitations and price level changes from 2001 to 2012. The development of the indices was necessary to transform the tax assessor values into values required by guidance (depreciated replacement values).

In addition, the 2005 appraisal was conducted by a certified RE appraiser. That appraisal resulted in an index of 1.68 (depreciated replacement cost appraisal), further indicating the reasonableness of the Marshall and Swift-developed indices for 2008 and 2010 of 1.73 and 1.68, respectively.

Commercial and Industrial. Commercial and industrial damages include losses to all properties used in commerce, industry, business trade, servicing, or entertainment. Separate depth-damage relationships were used to assess inundation damage to structures, equipment, and inventories. The total of these assessed damages are presented under the general commercial or industrial category. All commercial and industrial structures in the study area were assigned one of four exterior construction types by visual inspection by the field verification team. Structure and content values were acquired initially from the respective tax appraisal district certified 2001 values for each county within which the structure was located. These values were then adjusted to reflect depreciated replacement values at current prices using the method described for residential values.

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 or municipal entities. Separate depth damage relationships were used to assess inundation damage to structures, equipment, and inventories. The total of these assessed damages are presented under the general public category. Depreciated replacement values for these structures were as previously described and updated using Marshall and Swift software.

Vehicles. The nature of development within the study area is such that streets are graded lower than the surrounding land in order to function as tertiary drainage conduits from the surrounding urban development. Due to the dual function of roadways for transportation and drainage, vehicles are especially vulnerable to damage from flooding. Flood damage to vehicles includes the labor and parts to dry out and replace materials, as necessary, whenever a vehicle is inundated. The methodology used for this damage category is consistent with EGM 09-04," Generic Depth-Damage Relationships for Vehicles."

GEC, Inc. under contract with the New Orleans District developed generic depth-damage functions for vehicular inundation based on interviews with automobile dealership operators. The New Orleans District (NOD) generic depth-damage functions were utilized due the similar flooding characteristics between study areas. The EGM 09-04 depth-damage curves were deemed inappropriate based upon recent experiences in vehicle flooding in the Houston area (i.e. Tropical Storm Allison, Hurricane Ike). Specifically, the NOD curves have the first significant damages being realized at 2 feet of flooding (above ground level), while the EGM 09-04 depth-damage curves have significant damages occurring with just 1 foot of flooding (above ground level). The EGM curves are inconsistent with flooding circumstances and related vehicle damages in this area. Due to the dual function of the roadways to transport vehicles, water over the roads are extremely common and significant damages are not occurring at the 1 foot level. In addition, the NOD vehicle damage curve has 100 percent damage occurring at the 3 foot level of flooding, while the EGM damage curves only expect approximately 50 percent damage at that level. Again, the NOD curve is more consistent with the damages experienced in the study area, with most vehicles being totaled by the insurance company with just 2 to 3 feet of water. The EGM curves do not have 100 percent damage until the water level is 6 feet – a level vastly different than local experience of totaled vehicles at 2 to 3 feet of water.

The New Orleans survey concentrated on three broad classes of automobiles: compact, mid-size, and full-size (Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies, Final Report, May, 1997). For this analysis the depth-damage relationship for the mid-size vehicles was used as the mean value for damage estimation relative to the ground elevation while the depth-damage relationship for the compact vehicles established the lower limit of uncertainty and the depth-damage relationship for the full-size vehicles established the upper limit of uncertainty.

The value of vehicles was determined using a triangular distribution for Houston-area used vehicles. The Edmunds.com website was used to ascertain the average depreciated replacement values of 1-year, 5-year and 10-year-old vehicles. The average value was determined to be $13,800, with the low-end value being $6,600 and the high-end value being $25,860.

Stuart Davis established a one-vehicle damaged-to-one-residential-structure-damaged ratio in his unpublished “Houston Residential Flood Survey” (Institute for Water Resources, Fort Belvoir, Va., 1991). In addition, the latest vehicle damage guidance, EGM 09-04, suggests the use of the U.S. Census findings for number of vehicles per household in the study area. In the Clear Creek study area, the census data further supports the use of a one-vehicle-damaged-to-one-residential-structure-damaged ratio. Therefore, the estimate of vehicular damages assumes the same one-to-one ratio based on inundated residential structures. The ground elevation of the structure was used as the proxy for the ground elevation of the associated vehicle.

<u>Utilities.</u> Utility damages include losses to electrical transformers and transmission lines, telephone company lines and switch boxes, and water and gas pipelines. A unit value of $330 per structure damaged was used for the calculation of damages based upon a post flood damage assessment following Tropical Storm Claudette, 1979. The uncertainty estimate for utility damages ranges from a lower limit of zero percent damage to an upper limit of 100 percent damage for a given stage.

<u>Roads.</u> Road damages include repair costs for roads, bridges, street signals, and street lighting. Damage data from Tropical Storm Allison, occurring in June, 2001, were gathered from the Federal Emergency Management Agency (FEMA), the Texas Department of Transportation, Harris County, and the City of Houston. The data showed that over $9,608,000 in damages occurred to roads in the affected area. However, the data did not contain sufficient information regarding the miles of road damaged, and it was impossible to calculate an average cost per mile of damaged road with the information.

Because more recent information could not be utilized for purposes of estimating damages, stage-damage relationships for roads are based on the April 1979 Montgomery County and Tropical Storm Claudette flood data collected from FEMA by the Galveston District. From the FEMA data, an average repair cost per mile of inundated asphalt, concrete, and dirt road was developed. That unit value applied to road repairs is $13,500 per mile at October, 2009 prices, using the CPI-U as a price adjuster.

Miles of roadway were measured using topographic base maps for each reach within the floodplain of each AEP event in the without-project condition. Depth-damage relationships were derived by applying the event stage at the reach index to the value of repair for the road-miles measured.

Post Disaster Recovery Costs. The Institute for Water Resources' (IWR) 1990 survey of flood victims within the Cypress Creek and Greens Bayou watersheds in Harris County revealed other associated costs of flooding to individuals that lacked prior quantification. These costs include lodging and travel costs, food costs, costs of clean up, costs of moving and storing furniture, vandalism and looting costs, and medical costs all associated directly with the flood experience (Stuart Davis, unpublished "Houston Residential Flood Survey," Institute for Water Resources, Fort Belvoir, Va., 1991). On average, each surveyed household reported costs exceeding $5,700 based on the costs iterated. In the absence of more current data, this value was escalated to current prices and incorporated into the estimate of damages at $8,800 per residential structure damaged. The uncertainty estimate for post-disaster damages ranges from a lower limit of zero percent damage to an upper limit of 100 percent damage for a given stage.

Emergency Response. Many attempts were made to collect data regarding costs of emergency services related to flood events; however, no usable data was available. Due to the unavailability of data, and the relative minor impact of this category on plan formulation, this category was omitted from the analysis.

Recreational Watercraft, Marinas, and Piers. Historically major flood events along Clear Creek and Clear Lake such as Tropical Storm Claudette in 1979 and Hurricane Alicia in 1983 have caused massive damage to watercraft and piers skirting the lake. Following Tropical Storm Allison, which occurred in June, 2001, economists at the Galveston District interviewed marina operators for damages sustained. It was discovered that, even though property along the creek sustained extensive damage, very little damage occurred to lakefront property. The Clear Lake Second Outlet was in place and functioning during the storm in 2001. Not only was the Second Outlet credited with protecting the Clear Lake area, but also advancements in construction for marinas, such as floating piers, and in operational methods, such using tide risers, now allow water levels to rise without damaging watercraft or marinas. No further attempt was made to ascertain benefits for this category.

Savings in National Flood Insurance Administration Costs**.** Benefits can be derived from a reduction in administrative costs to the National Flood Insurance Program if implementation of a proposed plan removes structures from the existing 1 percent AEP floodplain. According to FEMA, the average cost of administering a flood insurance policy was $192 for Fiscal Year 2006 (Economic

Guidance Memorandum 06-04 “National Flood Insurance Program Operating Costs, Fiscal Year 2006,” April 6, 2006).

Based on hydrologic stages for a median 1 percent AEP flood under 2020 conditions, an estimated 3,800 structures are physically located within the existing floodplain of main stem and tributaries of Clear Creek.

Participation rates in the NFIP vary by county with an estimated 70 percent participation in Brazoria County, 70 percent in Galveston County (Galveston County Engineer, April, 2006), and 60 percent in Harris County (Harris County Engineer in consultation with NFIP Regional Manager, April 2007). Based on this information, a total of 2,461 structures within the 1 percent AEP floodplain hold NFIP policies in the without-project condition. The total annual cost of administering policies for these structures is estimated to be approximately $472,500.

HYDROLOGIC CONDITIONS IN THE WITHOUT-PROJECT FUTURE

The local sponsors, as well as local municipalities, have adopted watershed management policies and practices for minimizing increases in future development-induced runoff. To evaluate the effect of these policies analytically, a hydrologic model, which estimates the impact on discharges were these local ordinances not in place, was also developed and is referenced as the without-project uncontrolled condition. The without-project condition assumes that these local measures are functioning. The without-project “near term” and “most likely future” conditions applied to this analysis incorporate local sponsors’ initiatives for minimizing development-induced runoff. The following comparison of these conditions in Table 7 displays the impact of local initiatives for flood risk management.

Another important aspect of the without-project hydrologic condition integral to this analysis is the assumption that the Clear Lake Second Outlet was not in place for the screening of alternatives. The Second Outlet was added into the final analysis, however. The Second Outlet is a component of the Authorized Federal Project that was actually constructed and operated prior to the project’s reevaluation. The existence of the outlet presented an analytical challenge in that it was initially constructed as a mitigation measure to the Authorized Federal Project. But, as it is in place and functional, whereas the Authorized Project is not, the Second Outlet is included in the final planning for the General Reevaluation Study (GRR). The exclusion of the Second Outlet from the earlier screenings does not impact the plan formulation for the GRR.

While the future without-project H&H condition includes an increase in run-off, the changes in water surface elevations are minimal when compared to the near term. Also, there are no projections associated with the economic-side of the analysis. The inventory as shown in the without-project near-term condition is the same as future without-project inventory. No increase in development is projected. Only existing development (structures and contents) is modeled in the future without-project condition economics.

TABLE 7
COMPARISON OF RUNOFF SCENARIOS FOR WITHOUT-PROJECT CONDITION
CLEAR CREEK MAIN STEM
(Values in $1,000s, Oct 2011 Price Level)

REACH	Without Project Condition, Uncontrolled Runoff			Without Project Condition, Local Sponsor's Initiatives to Control Runoff		
	EXPECTED ANNUAL DAMAGES		EQUIVALENT ANNUAL DAMAGES, 4.0%	EXPECTED ANNUAL DAMAGES		EQUIVALENT ANNUAL DAMAGES, 4.0%
	2020	2070		2020	2070	
1	$117	$245	$160	$105	$139	$116
2	$94	$185	$123	$84	$112	$93
3	$100	$158	$120	$93	$111	$99
4	$128	$176	$144	$127	$133	$129
5	$0	$0	$0	$0	$0	$0
6	$185	$234	$201	$193	$201	$196
7	$824	$1,130	$924	$868	$992	$909
8	$861	$1,252	$988	$919	$1,070	$970
9	$660	$1,030	$781	$706	$863	$759
10	$1,374	$2,276	$1,666	$1,414	$1,782	$1,538
11	$220	$449	$295	$211	$281	$235
12	$99	$186	$127	$89	$131	$103
13	$844	$2,015	$1,228	$685	$1,221	$865
14	$203	$650	$351	$151	$333	$212
15	$5,479	$9,796	$6,887	$4,950	$7,055	$5,658
16	$785	$1,183	$913	$789	$906	$829
17	$2,803	$4,032	$3,198	$2,891	$3,105	$2,963
18	$5,356	$6,802	$5,817	$5,179	$5,387	$5,249
19	$246	$324	$271	$237	$251	$242
Total	$20,379	$32,124	$24,195	$19,692	$24,072	$21,165

Note: Individual numbers may not sum to totals due to rounding.

WITHOUT-PROJECT CONDITION

Description of the Floodplains and Flooding Problems. The Clear Creek watershed is included among the top ten repetitive loss property areas in the nation, in terms of dollar damages, according to a study by the National Wildlife Federation.

The Clear Creek study area is characterized as relatively flat floodplain with shallow flooding associated with all events. Flooding is based on backwater for the main stem and on normal depth for the tributaries. Velocities do not pose a significant threat to life in any studied reach, with velocities typically ranging from 1 to 5 cubic feet per second (cfs) for all flood events.

Development on the main stem consists of approximately 92 percent residential structures followed by 6 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified within the main stem floodplain, 70 percent are 1-story single family residential, primarily of slab-on-grade construction. Another 22 percent of the residential structures are 2-story single family residential, again constructed slab-on-grade. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on the main stem is just over $117,000. The average structure value for commercial structures on the main stem is approximately $147,000.

The problem along the Clear Creek main stem is flood damages to residential, commercial and public investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact over 850 structures on the main stem, with an average depth of flooding of 0.7 feet. The majority of the frequently flooded structures located on the main stem, are located in the upper and middle reaches in the cities of Brookside, Pearland, Friendswood and Houston. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence), impact over 3,100 structures on the main stem, with an average depth of flooding of 1.2 feet.

Development on Mary's Creek consists of approximately 82 percent residential structures followed by 15 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Mary's Creek floodplain, 72 percent are 1-story single-family residential, primarily of slab-on-grade construction. Another 19 percent of the residential structures are 2-story single family residential, again constructed slab-on-grade. The Mary's Creek residential structures also include 7 percent mobile homes. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Mary's Creek is just over $115,000. The average structure value for commercial structures on Mary's Creek is approximately $46,000.

The problem along Mary's Creek is again flood damages to residential, commercial and public investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact approximately 580 structures on Mary's Creek, with an average depth of flooding of 0.6 feet. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence), impact over 1,900 structures on Mary's Creek, with an average depth of flooding of 0.9 feet.

Development on Turkey Creek consists of approximately 99 percent residential structures followed by 1 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Turkey Creek floodplain, 83 percent are 1-story single-family residential, primarily of slab-on-grade construction. Another 7 percent of the residential structures are 2-story single-family residential, again constructed slab-on-grade. The Turkey Creek residential structures also include 11 percent apartments. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Turkey Creek is over $92,000. The average structure value for commercial structures on Turkey Creek is approximately $198,000.

The problem along Turkey Creek is again flood damages to residential and commercial investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact a minimal number of structures, only 7 structures on Turkey Creek, with an average depth of flooding of 0.2 feet. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence), impact over 750 structures on Turkey Creek, with an average depth of flooding of 0.5 feet.

Development on Mud Gully consists of approximately 96 percent residential structures followed by 4 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Mud Gully floodplain, 76 percent are 1-story single-family residential, primarily of slab-on-grade construction. Another 20 percent of the residential structures are 2-story single-family residential, again constructed slab-on-grade. The Mud Gully residential structures also include 4 percent apartments. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Mud Gully is over $46,000. The average structure value for commercial structures on Mud Gully is almost $34,000.

The problem along Mud Gully is again flood damages to residential and commercial investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact approximately 90 structures on Mud Gully, with an average depth of flooding of 0.2 feet. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence), impact over 1,200 structures on Mud Gully, with an average depth of flooding of 0.8 feet.

Development on Cowart Creek consists of approximately 44 percent residential structures followed by 43 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Cowart Creek floodplain, 45 percent are 1-story single-family residential, primarily of slab-on-grade construction. Another 40 percent of the residential structures are 2-story single-family residential, again constructed slab-on-grade. The Cowart Creek residential structures also include 14 percent mobile homes. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Cowart Creek is over $143,000. The average structure value for commercial structures on Cowart Creek is approximately $13,000.

The problem along Cowart Creek is again flood damages to residential and commercial investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact approximately 30 structures on Cowart Creek, with an average depth of flooding of 1.4 feet. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence) impact almost 100 structures on Cowart Creek, with an average depth of flooding of 1.5 feet.

Development on Chigger Creek consists of approximately 88 percent residential structures followed by 12 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Chigger Creek floodplain, 43 percent are 1-story single-family residential, primarily of slab-on-grade construction. Another 43 percent of the residential structures are 2-story single-family residential, again constructed slab-on-grade. The Chigger Creek residential structures also include 14 percent mobile homes. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Chigger Creek is approximately $232,000. The average structure value for commercial structures on Chigger Creek is approximately $26,000.

The problem along Chigger Creek is again flood damages to residential and commercial investment caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a 4% probability of occurrence) impact approximately 6 structures on Chigger Creek, with an average depth of flooding of 1.2 feet. The more infrequent flood events (associated with a 2% to 0.2% probability of occurrence) impact approximately 25 structures on Chigger Creek, with an average depth of flooding of 1.4 feet.

<u>Capital Investment within the Various Floodplains</u>. Table 8 displays a summary of the number of structures and the distribution of capital investment within eight existing median discharge AEP floodplains of the Clear Creek main stem and tributaries based on first floor elevations for the 2020 condition. As can be noted from Table 8, approximately 90 percent of the structures inventoried within the estimated existing median 0.2 percent AEP (500-year) floodplain are residential. In total the 0.2 percent AEP floodplain on the main stem and tributaries contains over 7,300 structures valued at over $741 million dollars, at October 2011 price levels. Of those inventoried, approximately 163 residential structures have been purchased and removed from the floodplain under the FEMA's Hazard Mitigation Program on the main stem of Clear Creek. Under authority of Section 575, WRDA 96, as amended, those properties will remain in the structure inventory for Federal project justification. Presentation of the Section 575 analysis will be detailed later in this appendix.

As previously noted, over 24,000 structures were inventoried on the main stem and tributaries. The 7,300 structures identified in Table 8 represent the structures inundated by the 0.2 percent AEP flood event (or the 500-year event) on the main stem and tributaries in the 2020 without-project condition. In other words, only 7,300 structures (of the original 24,000 study area structures inventoried) are actually within the 500-year floodplain, the rest fall outside the 500-year floodplain.

In development of the structure inventory (of 12,000 structures for the main stem and 12,000 structures for the tributaries), the area was over-inventoried because the H&H had not yet been established and, given the method used, aerial photography with a DTM, no major increase in expense was incurred. The survey boundary was set at the FEMA 500-year plus 1,000 feet outward. Every attempt was made to be absolutely inclusive. And, too, there is always an issue of induced damages so that, over-inventorying can capture the effects of a plan that produces stages higher than the without-project condition.

Table 9 displays the structure inventory and distribution of capital investment within the eight existing median discharge AEP floodplains for the main stem and tributaries for the without-project 2070 condition. As with the 2020 condition, the 2070 condition also reveals the majority of structures in the 0.2 percent AEP floodplain to be residential, representing approximately 91 percent. For the 2070 condition, the 0.2 percent AEP floodplain contains over 8,400 structures valued at over $870 million dollars. For a break-down of the distribution of capital investment within the individual tributaries and main stem floodplains, see Attachment 1.

TABLE 8
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK – SUM OF MAINSTEM AND ALL TRIBUTARIES
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	1	133	528	1,298	2,261	3,279	4,944	6,599
Value of Structures	$95	$14,455	$50,301	$118,357	$208,050	$305,633	$479,032	$665,811
Value of Contents	$48	$7,227	$25,178	$59,179	$104,784	$154,642	$243,763	$340,912
Percent of Structures Inundated/Zone	25%	68%	77%	83%	86%	89%	91%	90%
Commercial								
Number of Structures	3	56	131	214	296	352	427	598
Value of Structures	$34	$4,572	$12,523	$15,596	$21,574	$25,983	$35,477	$47,318
Value of Contents	$1	$1,388	$7,442	$9,586	$16,856	$19,777	$28,861	$39,062
Percent of Structures Inundated/Zone	75%	29%	19%	14%	11%	10%	8%	8%
Industrial								
Number of Structures	0	1	14	28	36	38	47	50
Value of Structures	$0	$218	$4,387	$8,374	$9,959	$9,959	$10,000	$10,422
Value of Contents	$0	$1,156	$5,604	$9,481	$14,626	$14,626	$16,026	$16,313
Percent of Structures Inundated/Zone	0%	1%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	0	6	15	26	34	36	39	59
Value of Structures	$0	$1,291	$2,380	$7,270	$8,300	$8,469	$10,040	$17,326
Value of Contents	$0	$430	$639	$1,655	$2,178	$2,267	$2,946	$5,699
Percent of Structures Inundated/Zone	0%	3%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	4	196	688	1,566	2,627	3,705	5,457	7,306
Value of Structures	$129	$20,535	$69,591	$149,596	$247,883	$350,044	$534,549	$740,877
Value of Contents	$48	$10,200	$38,863	$79,901	$138,444	$191,312	$291,596	$401,986
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 9
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK – SUM OF MAIN STEM AND ALL TRIBUTARIES
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	12	302	713	1,698	2,751	4,348	6,168	7,706
Value of Structures	$1,160	$29,923	$68,593	$157,536	$256,266	$447,374	$638,767	$785,900
Value of Contents	$580	$14,962	$34,324	$78,621	$128,918	$225,706	$322,982	$400,814
Percent of Structures Inundated/Zone	50%	76%	79%	85%	88%	89%	90%	91%
Commercial								
Number of Structures	11	77	152	242	316	457	561	624
Value of Structures	$130	$7,163	$13,129	$17,985	$24,309	$30,727	$43,303	$57,500
Value of Contents	$66	$3,730	$7,844	$12,018	$18,668	$24,765	$35,435	$89,049
Percent of Structures Inundated/Zone	46%	19%	17%	12%	10%	9%	8%	7%
Industrial								
Number of Structures	0	8	21	33	39	41	46	47
Value of Structures	$0	$661	$5,175	$8,965	$9,959	$10,363	$10,807	$10,826
Value of Contents	$0	$2,819	$6,047	$9,884	$14,626	$14,900	$16,575	$16,588
Percent of Structures Inundated/Zone	0%	2%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	1	9	19	29	33	51	53	64
Value of Structures	$16	$1,443	$2,754	$7,428	$8,300	$16,199	$16,204	$16,719
Value of Contents	$6	$528	$826	$1,722	$2,178	$5,267	$5,270	$5,442
Percent of Structures Inundated/Zone	4%	2%	2%	1%	1%	1%	1%	1%
Total								
Number of Structures	24	396	905	2,002	3,139	4,897	6,828	8,441
Value of Structures	$1,306	$39,191	$89,651	$191,913	$298,834	$504,663	$709,082	$870,945
Value of Contents	$652	$22,039	$49,042	$102,245	$164,390	$270,637	$380,263	$511,893
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Determination of Flood Damages to Existing Development. Flood damages were estimated for all property within the most likely future median 0.2 percent AEP floodplain of Clear Creek. Damages from inundation are based on data obtained from the survey of existing development. Damage estimates were computed for structures and contents of various types of physical properties classified as residential, commercial, public, or industrial. Damages were also estimated for vehicles, utilities, and roads as well as other costs associated with post disaster recovery. Intangible damages were not evaluated. Benefits not evaluated include erosion, reduced fill, fill, aesthetics, affluence, or intensification.

Single Occurrence Damages. A summary of damages expected to accrue from various flood events along the main stem and tributaries of Clear Creek is displayed in Table 10. These values represent damages expected for individual events under the without-project near-term hydrologic condition and include structure and content damages as well as other benefit categories. Similarly, Table 11 displays the summary of single occurrence damages by event for the tributaries in the future hydrologic condition. The detailed single occurrence damages for the main stem and tributaries individually are shown in Attachment 1 to this appendix. Attachment 1 details the single occurrence damages in both the near-term and future without-project conditions as well.

In comparing Table 8 and Table 10, the 50 percent AEP flood, or 2-year event, produces an estimated $532,000 in residential damages (Table 10), however, Table 8 shows that only one residential structure is in the 50 percent AEP flood zone. This structure has a total value of structures and contents of $143,000, making the damages seem illogical. The reason for the high level of damages at the 50 percent AEP flood event is that some structure depth-percent damage curves have start-of-damages below the structure's first floor. In fact, some depth-percent damage curves have start-of-damages at -2.0 feet below the first floor (i.e. mobile homes). Structures are assigned to the flood zone coinciding with their finished floor elevation. Single event damages are being incurred with a 50 percent AEP event by structures that actually sit in a higher flood zone. This same effect is carried throughout all the flood zones, but is not as readily apparent in the tables as with the 50 percent AEP event.

HEC-FDA was modified to assure that no damages are being accrued to the 1-year event (100 percent AEP event). This was done by adding a line under the exceedance probability-discharge portion of HEC-FDA corresponding to a 0.999 probability and a corresponding non-damaging cfs. This method is recommended by the Hydrologic Engineering Center as the best method to assure no 1-year damages accrue. This modification was prepared by H&H personnel during input of H&H data into HEC-FDA to ensure correctness.

Additional measures were taken to ensure that damages are not being overstated in the 50 percent AEP event. For structures that are low-lying, the associated depth-damage curve was altered by zeroing-out the percent damage below the first floor. In addition, the ground elevations of all structures located in the frequent events were re-checked and corrected (if necessary) for the final analysis.

In the without-project 2020 condition, a 1 percent AEP event is expected to cause approximately $180 million in structural damages. The value of properties located in the 1 percent AEP floodplain is on the order of $350 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 51 percent. The average value of the floodplain properties in the 1 percent AEP floodplain is $95 thousand.

In the without-project 2070 condition, a 1 percent AEP event is expected to cause approximately $238 million in structural damages. The value of properties located in the 1 percent AEP floodplain is on the order of $504 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 47 percent. The average value of the floodplain properties in the 1 percent AEP floodplain is $103 thousand.

TABLE 10
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
CLEAR CREEK – SUM OF MAINSTEM AND ALL TRIBUTARIES
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$532.0	$11,027.1	$36,320.7	$76,160.8	$117,701.6	$167,019.8	$242,603.8	$328,203.9
Public	$0.1	$1.7	$20.2	$64.2	$97.6	$111.3	$1,754.4	$2,799.9
Commercial	$8.2	$480.1	$1,793.0	$3,644.1	$5,434.6	$6,580.9	$10,260.9	$15,066.6
Industrial	$0.0	$0.9	$588.5	$4,404.9	$6,634.9	$6,673.8	$7,447.8	$14,042.2
Damages to Structures, Contents	$540.3	$11,509.8	$38,722.5	$84,274.1	$129,868.6	$180,385.7	$262,066.9	$360,112.5
Postdisaster Recovery Costs	$413.4	$4,533.6	$11,995.0	$23,093.7	$35,054.8	$47,976.6	$65,899.4	$81,260.0
Utilities	$15.6	$170.6	$451.6	$869.4	$1,319.7	$1,806.2	$2,480.9	$3,059.2
Vehicles	$0.8	$565.6	$1,982.5	$4,906.0	$8,756.2	$13,506.2	$23,070.8	$39,107.9
Roads	$327.5	$801.3	$1,448.5	$2,087.4	$2,580.1	$3,108.6	$4,111.9	$7,273.4
Total Damages by Event	$1,297.6	$17,580.9	$54,600.0	$115,230.5	$177,579.5	$246,783.4	$357,630.0	$490,813.1
Percent Distribution by Event								
Residential	41.0%	62.7%	66.5%	66.1%	66.3%	67.7%	67.8%	66.9%
Public	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.5%	0.6%
Commercial	0.6%	2.7%	3.3%	3.2%	3.1%	2.7%	2.9%	3.1%
Industrial	0.0%	0.0%	1.1%	3.8%	3.7%	2.7%	2.1%	2.9%
Postdisaster Recovery Costs	31.9%	25.8%	22.0%	20.0%	19.7%	19.4%	18.4%	16.6%
Utilities	1.2%	1.0%	0.8%	0.8%	0.7%	0.7%	0.7%	0.6%
Vehicles	0.1%	3.2%	3.6%	4.3%	4.9%	5.5%	6.5%	8.0%
Roads	25.2%	4.6%	2.7%	1.8%	1.5%	1.3%	1.1%	1.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 11
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
CLEAR CREEK – SUM OF MAINSTEM AND ALL TRIBUTARIES
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$1,882.8	$20,553.2	$47,508.4	$94,858.8	$142,524.2	$218,641.2	$300,207.1	$371,428.6
Public	$0.4	$9.4	$26.7	$92.9	$108.6	$617.6	$2,440.5	$2,785.6
Commercial	$45.1	$746.4	$2,195.6	$4,101.1	$5,988.3	$8,177.4	$12,883.1	$16,723.5
Industrial	$0.0	$33.7	$945.8	$6,061.8	$6,115.0	$10,716.1	$17,958.6	$23,440.3
Damages to Structures, Contents	$1,928.4	$21,342.7	$50,676.5	$105,114.6	$154,736.1	$238,152.2	$333,489.4	$414,378.0
Postdisaster Recovery Costs	$1,034.9	$7,814.0	$14,946.7	$28,926.3	$42,382.9	$58,015.7	$76,343.5	$91,418.7
Utilities	$38.8	$294.2	$562.7	$1,089.0	$1,595.6	$2,184.1	$2,874.1	$3,441.6
Vehicles	$9.3	$976.2	$2,816.6	$6,394.6	$10,698.8	$21,832.1	$33,803.2	$44,506.3
Roads	$511.5	$1,155.7	$1,687.3	$2,285.1	$2,787.3	$3,284.0	$5,532.8	$7,245.9
Total Damages by Event	$3,522.8	$31,582.8	$70,689.7	$143,809.6	$212,200.7	$323,468.2	$452,043.0	$560,990.5
Percent Distribution by Event								
Residential	53.4%	65.1%	67.2%	66.0%	67.2%	67.6%	66.4%	66.2%
Public	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.5%	0.5%
Commercial	1.3%	2.4%	3.1%	2.9%	2.8%	2.5%	2.8%	3.0%
Industrial	0.0%	0.1%	1.3%	4.2%	2.9%	3.3%	4.0%	4.2%
Postdisaster Recovery Costs	29.4%	24.7%	21.1%	20.1%	20.0%	17.9%	16.9%	16.3%
Utilities	1.1%	0.9%	0.8%	0.8%	0.8%	0.7%	0.6%	0.6%
Vehicles	0.3%	3.1%	4.0%	4.4%	5.0%	6.7%	7.5%	7.9%
Roads	14.5%	3.7%	2.4%	1.6%	1.3%	1.0%	1.2%	1.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Expected Annual and Average Annual Equivalent (AAE) Damages. Expected annual and AAE damages over the 50-year period of analysis are presented for the without-project or base condition in Table 12 for the main stem and Table 13 for the tributaries inventoried. These damages reflect damages accruing to structures and their contents, utilities, vehicles, roads and costs associated with post-disaster recovery. As can be seen in Table 12 over two-thirds of the damages along the main stem are concentrated within three reaches, numbered 15, 17, and 18.

As shown in Table 13, over 85 percent of the damages along Mud Gully are concentrated in reaches numbered 1 and 2. While damages for Turkey Creek are relatively evenly distributed throughout the tributary's four reaches. As can be seen in Table 13, approximately 46 percent of the damages on Mary's Creek are concentrated within Reach 4. Approximately 55 to 60 percent of the damages incurred along Cowart Creek and Chigger Creek are coincidentally centered in Reach 3 of both of the tributaries.

It should be noted, once again, that the increase in damages occurring over the period of analysis is attributed solely to increases in runoff. No projections were made on the economic-side of the analysis (i.e. the floodplain investment remains as it currently stands). Overall, there is an increase in damages of 38 percent from 2020 to 2070. This is equivalent to an average annual growth in damages of approximately 0.65 percent.

As seen from Table 13, Mary's Creek has the most significant increase in damages between the 2020 and 2070 condition, with a 63 percent increase in damages. Investigation of the water surface elevations reveals that the average increase in water surface elevation between 2020 and 2070 is less than 0.5 feet for the 1 percent AEP event on Mary's Creek. The increase in the number of structures inundated by that slight increase in water surface is almost 900 structures. The increase in damages is simply due to the distribution of structures and the flat nature of the floodplain. With the Clear Creek floodplain, a small increase in flood depth (i.e. less than 0.5 feet) can cause hundreds of additional structures to be inundated.

TABLE 12
EXPECTED ANNUAL AND AVERAGE ANNUAL EQUIVALENT DAMAGES
ALL DAMAGE CATEGORIES
WITHOUT-PROJECT CONDITION
CLEAR CREEK MAIN STEM
(Values in 1000’s, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES 2020	EXPECTED ANNUAL DAMAGES 2070	EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
MAIN STEM						
1	GALVESTON BAY	ROSEWOOD	$105	$138	$116	1.0%
2	ROSEWOOD	BAL HARBOR	$84	$111	$93	0.8%
3	BAL HARBOR	FM 270	$88	$106	$94	0.8%
4	FM 270	SH 3	$118	$125	$121	1.0%
5	SH 3	IH 45	$0	$0	$0	0.0%
6	IH 45	W BAY AREA BLVD	$179	$185	$181	1.6%
7	W BAY AREA BLVD	FM 528	$589	$658	$612	5.3%
8	FM 528	WHISPERING PINES	$331	$370	$344	3.0%
9	WHISPERING PINES	NEAR MARY'S CRK	$210	$241	$220	1.9%
10	NEAR MARY'S CRK	FM 2351	$330	$398	$353	3.1%
11	FM 2351	NEAR TURKEY CRK	$49	$59	$52	0.5%
12	NEAR TURKEY CRK	DIXIE FARM RD	$107	$125	$113	1.0%
13	DIXIE FARM RD	COUNTRY CLUB DR	$766	$835	$789	6.8%
14	COUNTRY CLUB DR	BENNIE KATE	$159	$175	$164	1.4%
15	BENNIE KATE	SH 35	$3,428	$3,655	$3,505	30.4%
16	SH 35	MYKAWA	$294	$294	$294	2.5%
17	MYKAWA	STONE RD	$1,078	$1,118	$1,091	9.5%
18	STONE RD	SH 288	$2,965	$3,526	$3,154	27.3%
19	SH 288	ALMEDA SCHOOL RD	$235	$251	$240	2.1%
		SUBTOTAL - Mainstem	$11,115	$12,370	$11,537	100%

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.
Individual numbers may not sum to totals due to rounding.

TABLE 13
EXPECTED ANNUAL AND AVERAGE ANNUAL EQUIVALENT DAMAGES
ALL DAMAGE CATEGORIES
WITHOUT-PROJECT CONDITION
CLEAR CREEK TRIBUTARIES
(Values in 1000's, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES 2020	EXPECTED ANNUAL DAMAGES 2070	EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
MUD GULLY						
1	90 DEGREE TURN SW	HALL RD	$1,209	$1,504	$1,076	61.4%
2	HALL RD	BELTWAY 8	$839	$999	$606	34.6%
3	BELTWAY 8	KINGSPOINT	$90	$115	$51	2.9%
4	KINGSPOINT	UPPER LIMIT	$443	$625	$20	1.1%
		SUBTOTAL - Mud Gully	$2,581	$3,242	$1,753	100.0%
TURKEY CREEK						
1	START	NYACK	$68	$115	$84	13.5%
2	NYACK	SCARSDALE	$76	$124	$92	14.8%
3	SCARSDALE	BELTWAY 8	$96	$148	$114	18.3%
4	BELTWAY 8	SAGEDOWNE	$284	$427	$332	53.4%
		SUBTOTAL - Turkey Creek	$525	$813	$622	100.0%
MARY'S CREEK						
1	EDDEWOOD DR.	COUNTY LINE	$78	$87	$81	1.6%
2	COUNTY LINE	LONGHERRIDGE DR	$925	$1,396	$1,084	20.7%
3	LONGHERRIDGE DR.	AT&SF RR	$1,273	$2,151	$1,568	30.0%
4	AT&SF RR	HARKEY RD	$853	$1,373	$1,028	19.6%
5	HARKEY RD	CHARLES AVE	$1,342	$1,736	$1,474	28.2%
		SUBTOTAL - Mary's Creek	$4,471	$6,743	$5,235	100.0%

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits. .
Individual numbers may not sum to totals due to rounding.

TABLE 13 (continued)
EXPECTED ANNUAL AND AVERAGE ANNUAL EQUIVALENT DAMAGES
ALL DAMAGE CATEGORIES
WITHOUT-PROJECT CONDITION
CLEAR CREEK TRIBUTARIES
(Values in 1000's, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES 2020	EXPECTED ANNUAL DAMAGES 2070	EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
COWART CREEK						
1	CASTLEWOOD	SUNSET DR	$28	$31	$29	9.6%
2	SUNSET DR	COUNTY LINE	$100	$110	$102	34.5%
3	COUNTY LINE	800 CFS LIMIT	$163	$174	$166	55.9%
		SUBTOTAL - Cowart Creek	$290	$316	$297	100.0%
CHIGGER CREEK						
1	FM 518	GREENBRIAR	$81	$101	$88	28.9%
2	GREENBRIAR	NARINA	$35	$41	$37	12.0%
3	NARINA	CONFLUENCE W/ BYPASS (800 CFS LIMIT)	$176	$186	$179	59.0%
4	CONFLUENCE WITH BYPASS	BRAZORIA COUNTY LINE	$0	$0	$0	0.0%
5	BRAZORIA COUNTY LINE	HEADWATERS OF STREAM	$0	$0	$0	0.0%
		SUBTOTAL - Chigger Creek	$292	$328	$304	100.0%
TOTAL - MAIN STEM AND ALL TRIBUTARIES			**$19,274**	**$23,812**	**$19,748**	

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.
Individual numbers may not sum to totals due to rounding.

WITH-PROJECT CONDITION

Various structural and nonstructural solutions to flooding were considered to mitigate flood damages in the study area. These include construction of detention basins, channel modifications, watershed management, bridge replacements, floodplain buyout, raising-in-place, etc., and several combinations of the aforementioned.

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 from each alternative were computed and compared with the without-project condition. The aim of the economic analysis was to select a plan that maximized net benefits. A detailed discussion of the analytical process followed throughout the study is provided in Attachment 2 to the Economic Appendix.

Structural Analysis. The analysis of structural measures took place in phases over the study period. Each measure was optimized and incrementally justified. In this way, poor performing and less-beneficial measures were eliminated from further consideration. The resultant optimized structural alternative was carried forward to the final array.

In addition, analysis of two legacy plans took place, namely, the Sponsor's Preferred Alternative and of the Authorized Federal Plan. The Authorized Federal Plan (AFP) includes conveyance improvement from Mykawa Road to Clear Lake plus the Second Outlet Channel and Gate Structure. The second outlet and gate structure were developed as part of the AFP to mitigate flows into Clear Lake from the enlarged channel upstream. As previously mentioned, the second outlet and gate structure have been constructed and are considered sunk costs with no benefits being claimed in this analysis. The second outlet and gate were not initially included in the analysis, but were added at the end of the study to better reflect existing conditions. The effect of the outlet is negligible and does not impact plan formulation.

The Sponsor's Proposed Alternative (SPA) was developed in 1997 as an alternative to the AFP. This alternative reduced the size of the proposed federal alternative channel and included a bypass channel near the Friendswood area.

Nonstructural Analysis. Nonstructural measures were investigated early in the first-added measures phase of the study, but with the many changes and updates made over time, in-depth analysis, including the tributaries, was deemed necessary. In addition, nonstructural measures were analyzed in addition to structural measures. The detailed nonstructural analysis results are shown in Attachment 4 of the economic appendix.

COMPARISON OF ALTERNATIVES

Based upon the results of the first-added and second-added measures analysis (detailed in Attachment 2) the optimized plan unfolded as the analysis took place. Several combinations of measures meet the objective of positive net benefits. However, with each step of the analysis a combination of measures producing greater net benefits than the previous was revealed until the General Reevaluation Plan (hereafter referred to as the GRP) was identified. In addition, two other plans were carried forward from previous studies, including the Authorized Federal Plan (AFP) and the Sponsor's Preferred Alternative (SPA). Incremental analysis was conducted throughout the analysis, resulting in the final array of alternatives being considered.

No Action Alternative

The No Action Alternative would retain the existing Clear Creek and tributaries at their present configurations. Many of the municipalities in the area have incorporated no impact policies in addressing new development. These are generally established to protect the flow at a 1 percent AEP level of protection. However, these requirements are not in place for the entire watershed. Development upstream of Clear Lake will continue to increase flows into Clear Creek and its tributaries. These increased flows will continue to cause increases in water elevation sufficient to cause flooding in many areas. For the Clear Creek GRR study, the No Action Alternative and the without-project condition are the same.

Authorized Federal Project Alternative

The Authorized Federal Project (AFP) Alternative is detailed in a Preconstruction Authorization Planning Report dated May 1982. The plan includes conveyance improvement from Mykawa Road to Clear Lake plus the Second Outlet Channel and Gate Structure. The newly designed channel project was sized to contain a 10-percent annual exceedance flood for future watershed development conditions. The design included a trapezoidal earthen channel (1v:3h side slopes). Bottom widths varied from 70 feet to 130 feet. The Second Outlet Channel and Gate Structure were developed as part of the AFP to mitigate increased flows into Clear Lake from the enlarged channel upstream. The Clear Lake community was concerned that the channel modifications upstream would increase their likelihood of being impacted by increased flows into the lake. The Second Outlet was designed to ensure that flows would be allowed to continue into Galveston Bay with no impact to houses around the lake. The channel was gated to ensure that Clear Lake did not experience an increase in salinities due to water flowing from the bay in high tide circumstances. A formal agreement was signed in 1986 by the local sponsors (Harris County Flood Control District and Galveston County) and the US Army Corps of Engineers to construct the 14-mile reach of the project downstream of Dixie Farm Road. Only the Second Outlet Channel and Gate Structure were ever constructed.

Sponsor Proposed Alternative

This plan was developed in 1997 as an alternative to the AFP. Concerns about the impacts associated with the AFP caused the non-Federal sponsors to request that construction halt so that they could develop a potential plan with reduced impact. A detailed description of the Sponsor Proposed Alternative (SPA) is provided in the December 1997 report titled "Clear Creek, Federal Flood Control Project Review." The main features of the plan were "reduced channel rectification" and a bypass channel. The channel rectification was reduced in size (smaller bottom widths) from the AFP. The reach of the natural Clear Creek channel near the Friendswood area would be avoided by providing the needed flood capacity with a bypass channel. The design included a trapezoidal channel that follows the alignment of the existing AFP except for the bypass channel near the Friendswood area. Bottom widths for the plan vary from 30 feet to 80 feet.

General Reevaluation Plan (GRP)

This alternative consists of channelization on Clear Creek including 200-foot bench cut from SH 288 to 4,000 feet downstream of Bennie Kate, and 90-foot bench cut from 4,000 feet downstream of Bennie Kate to Dixie Farm Road. This channel improvement is 15.1 miles in length.

In addition, the GRP consists of channel improvement on Mud Gully (45-foot concrete-lined trapezoid section) from downstream of Sagedowne to downstream of Astoria. The alternative also includes channel improvement on Turkey Creek 2.4 miles in length with a 20 to 25 –foot trapezoid section, from Dixie Farm Road to the mouth. Also included is channelization on Mary's Creek at varying widths (from 15-feet to 35-feet) from Harkey Road to SH 35. The channel improvement on Mary's Creek is 2.1 miles in length.

The GRP includes linear detention on the main stem. The inline detention has a capacity of 485 acre-feet from Cullen to downstream of SH-35.

Table 14 shows the damages reduced by each of the alternatives above, under 2020 conditions. Damage reductions for the plans are between -$1.8 million and $19.0 million. Net economic benefits are between -$21.6 million and $9.1 million. The plan that reasonably maximizes net benefits is the GRP, which is, therefore, carried forward as the NED Plan.

TABLE 14
COMPARISON OF ALTERNATIVES
AVERAGE ANNUAL DAMAGES, 2020 CONDITION
(Values in 1000's, Oct 2011 Price Levels, 4.0%)

Alternative	Average Annual Damages 2020	Average Annual Damage Reduction	Average Annual Cost	Net Excess Benefits	Benefit-to-Cost Ratio
Without Project	$38,338.0				
Authorized Federal Plan	$29,756.5	$8,581.5	$18,356.5	-$9,775.0	0.47
Sponsor Preferred Alternative	$40,162.2	-$1,824.2	$19,784.1	-$21,608.3	-0.09
GRP Alternative	$19,274.0	$19,064.0	$9,962.9	$9,101.1	1.91

* Note - Average annual damages (2020 condition) are shown rather than average annual equivalent values. Future condition H&H runs were not provided for the AFP and SPA Alternatives due to lack of feasibility of the alternatives.

REFINEMENT OF THE NED PLAN

<u>Capital Investment within the Various Floodplains for the NED Plan.</u> Table 15 displays a summary of the number of structures and the distribution of capital investment within eight median discharge AEP floodplains of the main stem and tributaries of Clear Creek based on first floor elevations with the NED Plan in place in the 2020 condition. As can be noted from Table 15, approximately 90 percent of the structures inventoried within the estimated existing median 0.2 percent AEP (500-year) floodplain are residential. In total the 0.2 percent AEP floodplain on the main stem and tributaries contains over 4,200 structures valued at over $427 million dollars, at October 2011 price levels. For a break-down of the distribution of capital investment within the individual tributaries and main stem floodplains, see Attachment 4.

As shown in Table 15, the 1 percent AEP (100-year) floodplain with the NED Plan in place on the contains 1,601 structures, a reduction of over 1,500 structures when compared to the without-project condition. The NED Plan effectively removes over 3,000 structures from the 0.2 percent AEP (500-year) floodplain of the entire study area, a reduction of over 40 percent of the structures inundated by the 500-year event in the near-term condition.

Similar to Table 15, Table 16 displays the structure inventory and distribution of capital investment within the eight existing median discharge AEP floodplains for the main stem and tributaries for the future without-project 2070 condition. As with the 2020 condition, the 2070 condition also reveals the majority of structures in the 0.2 percent AEP floodplain to be residential, representing 90 percent. For the 2070 condition, the 0.2 percent AEP floodplain contains over 4,800 structures valued at over $502 million dollars.

TABLE 15
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
SUMMARY OF MAIN STEM AND ALL TRIBUTARIES
Cumulative Totals Based on First-Floor Elevations and NED Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	1	39	188	421	901	1,343	2,540	3,824
Value of Structures	$95	$4,989	$21,411	$43,711	$91,780	$134,054	$253,477	$382,584
Value of Contents	$48	$2,494	$10,706	$21,905	$45,839	$67,448	$128,239	$194,864
Percent of Structures Inundated/Zone	25%	53%	76%	77%	81%	84%	87%	89%
Commercial								
Number of Structures	3	34	53	106	171	213	305	371
Value of Structures	$34	$467	$2,187	$8,441	$15,274	$17,815	$23,245	$25,993
Value of Contents	$1	$268	$838	$4,294	$9,034	$10,070	$14,766	$18,957
Percent of Structures Inundated/Zone	75%	46%	21%	19%	15%	13%	10%	9%
Industrial								
Number of Structures	0	0	3	8	15	22	36	44
Value of Structures	$0	$0	$93	$1,943	$4,586	$6,258	$7,556	$9,675
Value of Contents	$0	$0	$63	$3,690	$5,739	$8,043	$10,976	$14,634
Percent of Structures Inundated/Zone	0%	0%	1%	1%	1%	1%	1%	1%
Public								
Number of Structures	0	1	5	10	19	23	32	36
Value of Structures	$0	$16	$1,156	$5,764	$6,396	$7,210	$8,710	$8,762
Value of Contents	$0	$6	$378	$825	$1,168	$1,650	$2,443	$2,464
Percent of Structures Inundated/Zone	0%	1%	2%	2%	2%	1%	1%	1%
Total								
Number of Structures	4	74	249	545	1,106	1,601	2,913	4,275
Value of Structures	$129	$5,471	$24,848	$59,858	$118,036	$165,337	$292,988	$427,014
Value of Contents	$48	$2,768	$11,985	$30,714	$61,781	$87,211	$156,423	$230,919
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 16
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
SUMMARY OF MAIN STEM AND ALL TRIBUTARIES
Cumulative Totals Based on First-Floor Elevations and NED Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	4	54	239	615	1,116	1,597	3,249	4,386
Value of Structures	$273	$7,237	$25,931	$63,946	$111,043	$159,151	$317,597	$444,086
Value of Contents	$136	$3,619	$12,965	$32,361	$55,658	$80,585	$161,547	$225,788
Percent of Structures Inundated/Zone	40%	57%	73%	78%	82%	84%	89%	90%
Commercial								
Number of Structures	6	35	76	138	200	246	349	406
Value of Structures	$57	$468	$2,781	$10,207	$17,413	$20,815	$25,235	$38,745
Value of Contents	$17	$269	$1,227	$5,250	$9,942	$11,231	$16,459	$72,201
Percent of Structures Inundated/Zone	60%	37%	23%	18%	15%	13%	10%	8%
Industrial								
Number of Structures	0	5	8	17	19	25	35	40
Value of Structures	$0	$93	$189	$4,463	$5,771	$6,930	$9,221	$10,266
Value of Contents	$0	$63	$128	$5,404	$6,545	$8,499	$12,108	$15,037
Percent of Structures Inundated/Zone	0%	5%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	0	1	6	16	20	28	35	42
Value of Structures	$0	$16	$1,173	$6,024	$6,503	$7,855	$8,762	$8,926
Value of Contents	$0	$6	$384	$982	$1,208	$1,986	$2,464	$2,525
Percent of Structures Inundated/Zone	0%	1%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	10	95	329	786	1,355	1,896	3,668	4,874
Value of Structures	$330	$7,814	$30,074	$84,640	$140,730	$194,750	$360,816	$502,024
Value of Contents	$153	$3,956	$14,705	$43,997	$73,353	$102,303	$192,578	$315,550
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Single Occurrence Damages for the NED Plan. Damages expected to accrue from various flood events along the main stem and tributaries of Clear Creek for the NED Plan are displayed in Table 17. These values represent damages expected for individual events under the with-project near-term hydrologic condition and include structure and content damages as well as other benefit categories. Similarly, Table 18 displays the summary of single occurrence damages by event for the main stem and tributaries in the future hydrologic condition. The detailed single occurrence damages for the main stem and tributaries individually are shown in Attachment 4 to this appendix. Attachment 4 details the single occurrence damages in both the near-term and future without-project conditions as well.

In the with-project 2020 condition, a 1 percent AEP event is expected to cause approximately $86 million in damages to structures and contents, representing over 50 percent reduction in damages when compared to the without-project condition 1 percent AEP event. The value of properties located in the 1 percent AEP floodplain is on the order of $252 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 46 percent. The average value of the residual floodplain properties in the 1 percent AEP floodplain is $100 thousand.

In the with-project 2070 condition, a 1 percent AEP event is expected to cause approximately $96 million in damages to structures and contents. The value of properties located in the 1 percent AEP floodplain is on the order of $194 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 44 percent. The average value of the residual floodplain properties in the 1 percent AEP floodplain is $102 thousand.

TABLE 17
SINGLE OCCURRENCE DAMAGES BY EVENT
NED PLAN, 2020 CONDITION
SUMMARY OF CLEAR CREEK MAINSTEM AND ALL TRIBUTARIES
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$304.6	$4,438.7	$13,834.4	$30,035.6	$56,281.1	$80,848.7	$139,144.0	$201,533.3
Public	$0.1	$1.5	$2.2	$5.8	$18.7	$31.5	$1,445.9	$1,751.4
Commercial	$1.9	$58.9	$281.2	$880.6	$2,102.0	$3,267.8	$5,415.6	$7,413.4
Industrial	$0.0	$0.9	$12.5	$91.1	$857.2	$1,427.0	$3,369.8	$5,462.2
Damages to Structures, Contents	$306.6	$4,500.0	$14,130.3	$31,013.0	$59,258.9	$85,575.0	$149,375.2	$216,160.3
Postdisaster Recovery Costs	$260.8	$1,929.3	$5,142.5	$9,514.5	$15,986.4	$21,919.9	$37,673.7	$53,302.3
Utilities	$9.8	$72.5	$193.6	$358.2	$601.8	$825.2	$1,418.3	$2,006.7
Vehicles	$0.7	$105.3	$692.4	$1,650.0	$3,175.5	$5,594.8	$10,949.1	$17,995.9
Roads	$309.1	$552.6	$863.3	$1,346.7	$1,829.2	$2,251.1	$2,998.1	$4,194.9
Total Damages by Event	$887.1	$7,159.6	$21,022.1	$43,882.4	$80,851.9	$116,165.9	$202,414.4	$293,660.1
Percent Distribution by Event								
Residential	34.3%	62.0%	65.8%	68.4%	69.6%	69.6%	68.7%	68.6%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.6%
Commercial	0.2%	0.8%	1.3%	2.0%	2.6%	2.8%	2.7%	2.5%
Industrial	0.0%	0.0%	0.1%	0.2%	1.1%	1.2%	1.7%	1.9%
Postdisaster Recovery Costs	29.4%	26.9%	24.5%	21.7%	19.8%	18.9%	18.6%	18.2%
Utilities	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%
Vehicles	0.1%	1.5%	3.3%	3.8%	3.9%	4.8%	5.4%	6.1%
Roads	34.8%	7.7%	4.1%	3.1%	2.3%	1.9%	1.5%	1.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 18
SINGLE OCCURRENCE DAMAGES BY EVENT
NED PLAN, 2070 CONDITION
SUMMARY OF CLEAR CREEK MAINSTEM AND ALL TRIBUTARIES
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$151.3	$5,073.3	$16,116.4	$36,038.1	$60,986.6	$89,729.5	$162,074.3	$215,700.2
Public	$0.0	$18.5	$110.0	$317.0	$682.2	$1,034.6	$1,472.0	$1,763.9
Commercial	$1.0	$55.8	$323.3	$1,093.4	$2,267.6	$3,545.9	$6,102.4	$8,507.9
Industrial	$0.0	$1.5	$36.8	$234.8	$717.7	$1,316.1	$3,330.7	$5,001.1
Damages to Structures, Contents	$152.3	$5,149.2	$16,586.4	$37,683.3	$64,654.1	$95,626.1	$172,979.4	$230,973.1
Postdisaster Recovery Costs	$217.0	$2,214.0	$5,962.6	$10,679.4	$16,843.6	$24,253.7	$44,310.2	$56,594.5
Utilities	$8.1	$83.3	$224.5	$402.0	$634.1	$913.1	$1,668.1	$2,130.6
Vehicles	$0.3	$114.7	$715.2	$1,813.7	$3,581.8	$6,091.8	$13,261.5	$20,204.6
Roads	$343.1	$620.0	$993.7	$1,456.6	$1,912.3	$2,354.5	$3,355.7	$4,366.0
Total Damages by Event	$720.7	$8,181.2	$24,482.4	$52,035.0	$87,625.9	$129,239.2	$235,574.9	$314,268.8
Percent Distribution by Event								
Residential	21.0%	62.0%	65.8%	69.3%	69.6%	69.4%	68.8%	68.6%
Public	0.0%	0.2%	0.4%	0.6%	0.8%	0.8%	0.6%	0.6%
Commercial	0.1%	0.7%	1.3%	2.1%	2.6%	2.7%	2.6%	2.7%
Industrial	0.0%	0.0%	0.2%	0.5%	0.8%	1.0%	1.4%	1.6%
Postdisaster Recovery Costs	30.1%	27.1%	24.4%	20.5%	19.2%	18.8%	18.8%	18.0%
Utilities	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%
Vehicles	0.0%	1.4%	2.9%	3.5%	4.1%	4.7%	5.6%	6.4%
Roads	47.6%	7.6%	4.1%	2.8%	2.2%	1.8%	1.4%	1.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Average Annual Equivalent Damages for the NED Plan. Tables 19 through 24 show the average annual equivalent damages reduced for the NED Plan for the main stem and tributaries inventoried. Also shown are the probabilities that annual damages exceed indicated values for the 0.75, 0.50, and 0.25 probabilities. To illustrate, for Reach 8 on the main stem, equivalent annual damages reduced are $625,000 with the NED plan in place. For the same reach, there is a 75 percent probability that the damages reduced (or benefits) exceed $249,000, a 50 percent probability that the benefits exceed $440,000, and a 25 percent probability that the benefits exceed $770,000.

For the main stem, the greatest reductions in damages are realized in Reaches 8 through 11 (with reductions ranging from 65 to 78 percent). Additional significant reductions in damages on the main stem are realized in Reaches 15 through 18, with reductions ranging from 40 to 65 percent.

On Mud Gully, the NED Plan reduces damages significantly in the all of the four reaches, with reductions ranging from over 56 percent to 96 percent from the without-project condition. For Turkey Creek, damages are reduced significantly in all reaches, with percent reduction ranging from 78 percent to 94 percent. On Mary’s Creek, the greatest reduction in damages with the NED Plan in place occurs in Reaches 3 and 4, ranging from 48 to 81 percent.

The overall change in hydrology and hydraulics due to implementation of the NED Plan is expected to result in residual average annual equivalent (AAE) damages of $19.7 million. When compared with the without-project condition, this is a $22.9 million reduction in AAE damages.

Figures 3 through 6 graphically illustrate the reduction in AAE damages for each the Main Stem (Figure 3), Mud Gully (Figure 4), Turkey Creek (Figure 5), and Mary’s Creek (Figure 6). Cowart and Chigger Creeks are not shown graphically since there is no damage reduction expected to these two tributaries with the NED plan in place.

TABLE 19
EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE
NED PLAN
CLEAR CREEK MAIN STEM
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	GALVESTON BAY	ROSEWOOD	$116	$116	$0	0.4%	$3	-$1	$0
2	ROSEWOOD	BAL HARBOR	$93	$93	$1	0.7%	$0	$1	$0
3	BAL HARBOR	FM 270	$99	$94	$5	4.9%	$2	$2	$6
4	FM 270	SH 3	$129	$121	$9	6.7%	$3	$5	$12
5	SH 3	IH 45	$0	$0	$0	3.7%	$0	$0	$0
6	IH 45	W BAY AREA BLVD	$196	$181	$15	7.7%	$7	$12	$19
7	W BAY AREA BLVD	FM 528	$909	$612	$297	32.6%	$177	$254	$352
8	FM 528	WHISPERING PINES	$970	$344	$625	64.5%	$249	$440	$770
9	WHISPERING PINES	NEAR MARY'S CRK	$759	$220	$538	71.0%	$206	$397	$679
10	NEAR MARY'S CRK	FM 2351	$1,538	$353	$1,185	77.1%	$596	$953	$1,428
11	FM 2351	NEAR TURKEY CRK	$235	$52	$182	77.6%	$60	$117	$214
12	NEAR TURKEY CRK	DIXIE FARM RD	$103	$113	-$10	-9.4%	-$8	-$14	-$24
13	DIXIE FARM RD	COUNTRY CLUB DR	$865	$789	$77	8.8%	-$40	-$64	-$101
14	COUNTRY CLUB DR	BENNIE KATE	$212	$164	$48	22.5%	-$5	-$3	-$9
15	BENNIE KATE	SH 35	$5,658	$3,505	$2,153	38.1%	$961	$1,418	$1,988
16	SH 35	MYKAWA	$829	$294	$535	64.5%	$228	$408	$676
17	MYKAWA	STONE RD	$2,963	$1,091	$1,872	63.2%	$952	$1,562	$2,410
18	STONE RD	SH 288	$5,249	$3,154	$2,095	39.9%	$1,121	$1,763	$2,814
19	SH 288	ALMEDA SCHOOL RD	$242	$240	$2	0.7%	$2	$4	$4
TOTAL			$21,165	$11,537	$9,628	45.5%	$4,511	$7,252	$11,239

Note: Individual numbers may not sum to totals due to rounding.

TABLE 20

EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE NED PLAN

MUD GULLY

Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	90 DEGREE TURN SW	HALL RD	$2,384	$1,076	$1,308	54.9%	$493	$849	$1,348
2	HALL RD	BELTWAY 8	$1,489	$606	$883	59.3%	$315	$476	$707
3	BELTWAY 8	KINGSPOINT	$149	$51	$98	65.6%	$20	$36	$60
4	KINGSPOINT	UPPER LIMIT	$520	$20	$500	96.2%	$8	$16	$27
TOTAL			$4,542	$1,753	$2,789	61.4%	$837	$1,376	$2,143

Note: Individual numbers may not sum to totals due to rounding.

TABLE 21

EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE NED PLAN

TURKEY CREEK

Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	START	NYACK	$1,328	$84	$1,245	93.7%	$267	$472	$763
2	NYACK	SCARSDALE	$742	$92	$650	87.6%	$137	$253	$424
3	SCARSDALE	BELTWAY 8	$671	$114	$557	83.0%	$133	$218	$338
4	BELTWAY 8	SAGEDOWNE	$1,518	$332	$1,186	78.1%	$288	$445	$656
TOTAL			$4,259	$622	$3,638	85.4%	$825	$1,388	$2,181

Note: Individual numbers may not sum to totals due to rounding.

TABLE 22
EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE NED PLAN
MARY'S CREEK
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	EDGEWOOD DR.	COUNTY LINE	$84	$81	$3	3.5%	$31	$44	$63
2	COUNTY LINE	LONGHERRIDGE DR	$1,604	$1,084	$521	32.5%	$187	$396	$1,072
3	LONGHERRIDGE DR.	AT&SF RR	$3,009	$1,568	$1,441	47.9%	$596	$1,143	$2,066
4	AT&SF RR	HARKEY RD	$5,525	$1,028	$4,497	81.4%	$2,817	$4,617	$7,346
5	HARKEY RD	CHARLES AVE	$1,807	$1,474	$333	18.4%	-$343	-$310	-$251
TOTAL			$12,030	$5,235	$6,795	56.5%	$3,287	$5,891	$10,295

Note: Individual numbers may not sum to totals due to rounding.

TABLE 23
EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE NED PLAN
COWART CREEK
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	CASTLEWOOD	SUNSET DR	$29	$29	$0	0.0%	$0	$0	$0
2	SUNSET DR	COUNTY LINE	$102	$102	$0	0.0%	$0	$0	$0
3	COUNTY LINE	800 CFS LIMIT	$166	$166	$0	0.0%	$0	$0	$0
TOTAL			$297	$297	$0	0.0%	$0	$0	$0

Note: Individual numbers may not sum to totals due to rounding.

TABLE 24

EQUIVALENT ANNUAL DAMAGES REDUCED AND DISTRIBUTED FOR THE NED PLAN

CHIGGER CREEK

Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	FM 518	GREENBRIAR	$88	$88	$0	0.0%	$0	$0	$0
2	GREENBRIAR	NARINA	$37	$37	$0	0.0%	$0	$0	$0
3	NARINA	CONFLUENCE W/ BYPASS (800 CFS LIMIT)	$179	$179	$0	0.0%	$0	$0	$0
4	CONFLUENCE WITH BYPASS	BRAZORIA COUNTY LINE	$0	$0	$0	0.0%	$0	$0	$0
5	BRAZORIA COUNTY LINE	HEADWATERS OF STREAM	$0	$0	$0	0.0%	$0	$0	$0
TOTAL			$304	$304	$0	0.0%	$0	$0	$0

Note: Individual numbers may not sum to totals due to rounding.

Figure 3
Clear Creek Main Stem
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

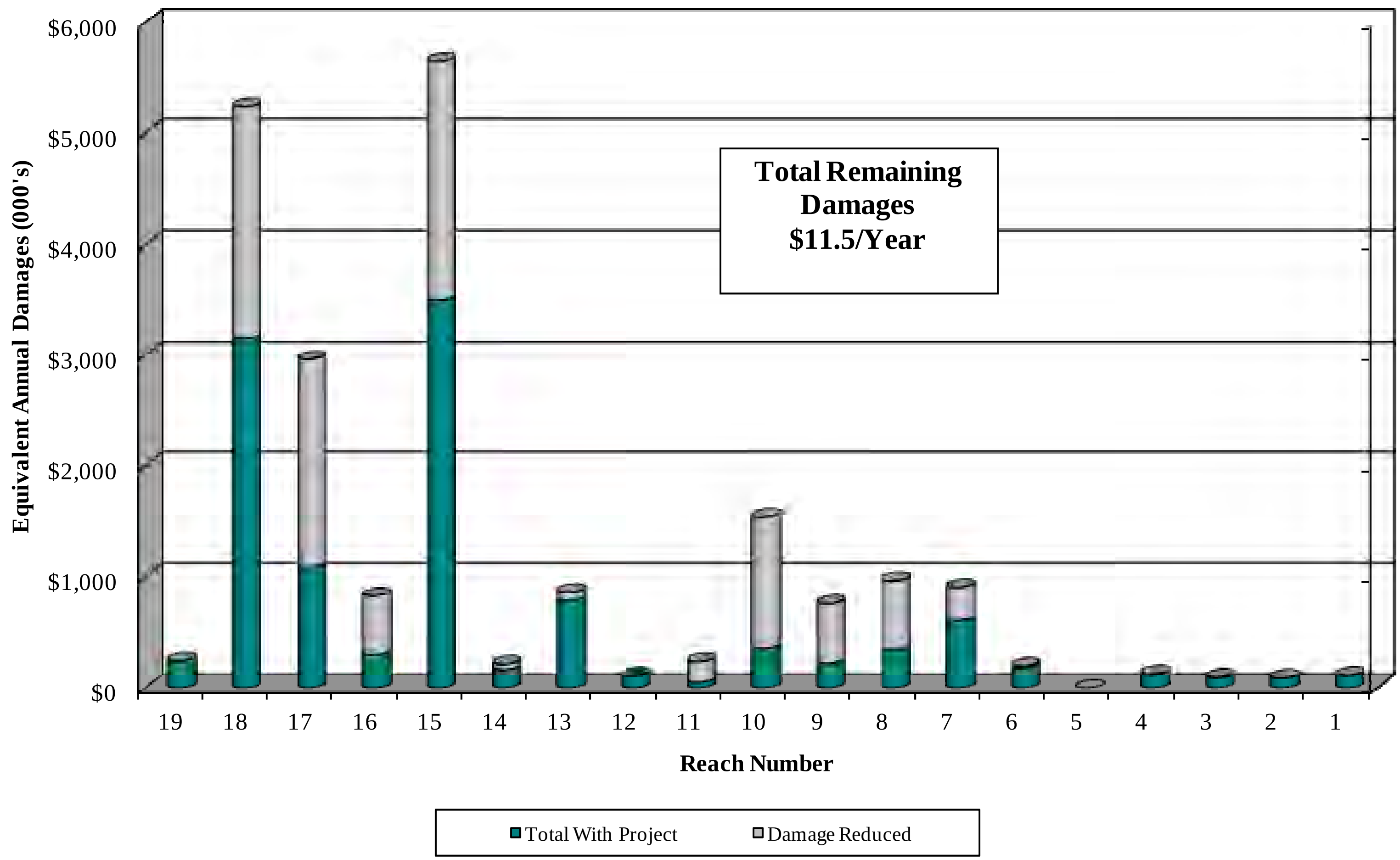


Figure 4
Mud Gully
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

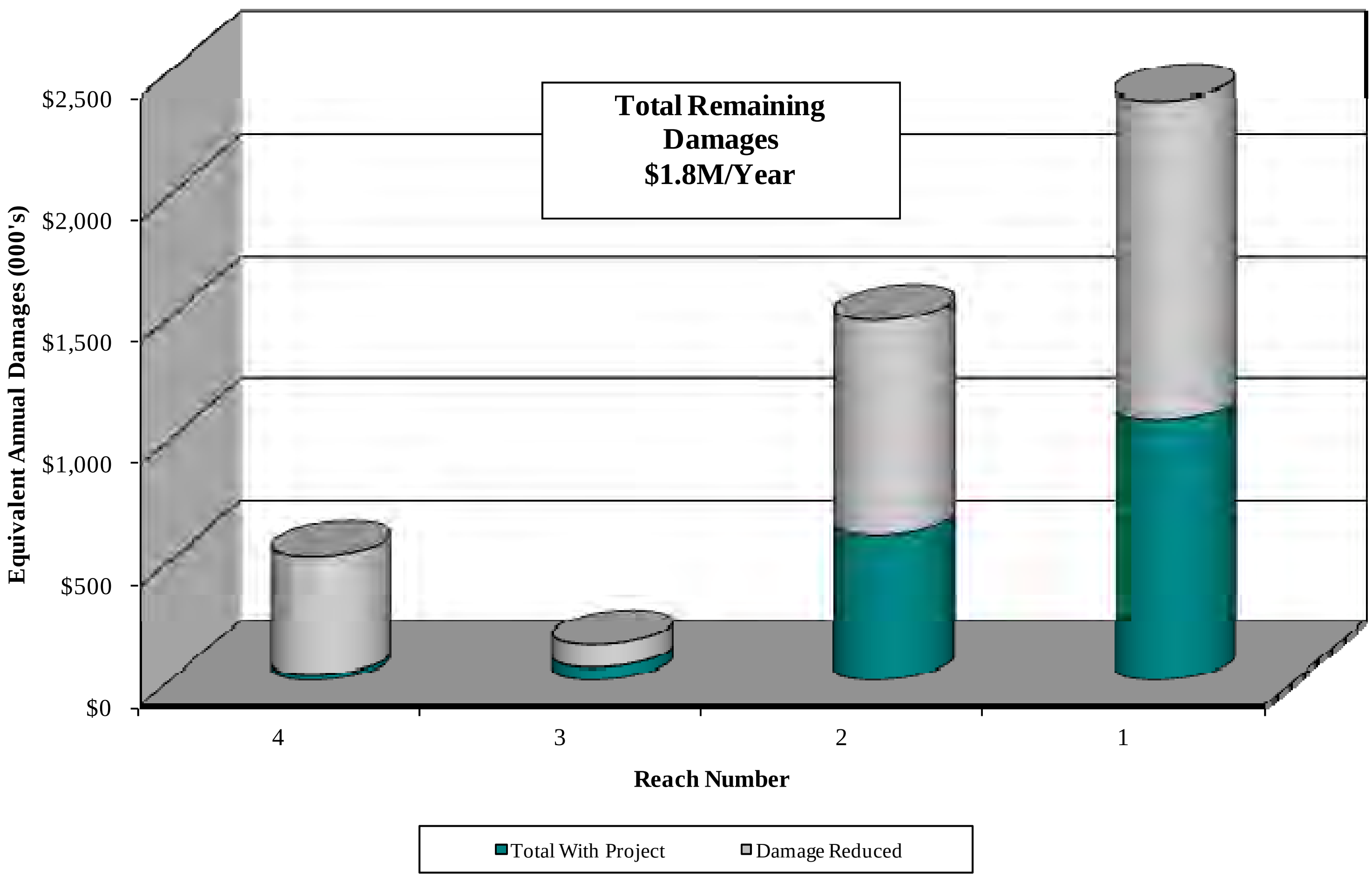


Figure 5
Turkey Creek
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

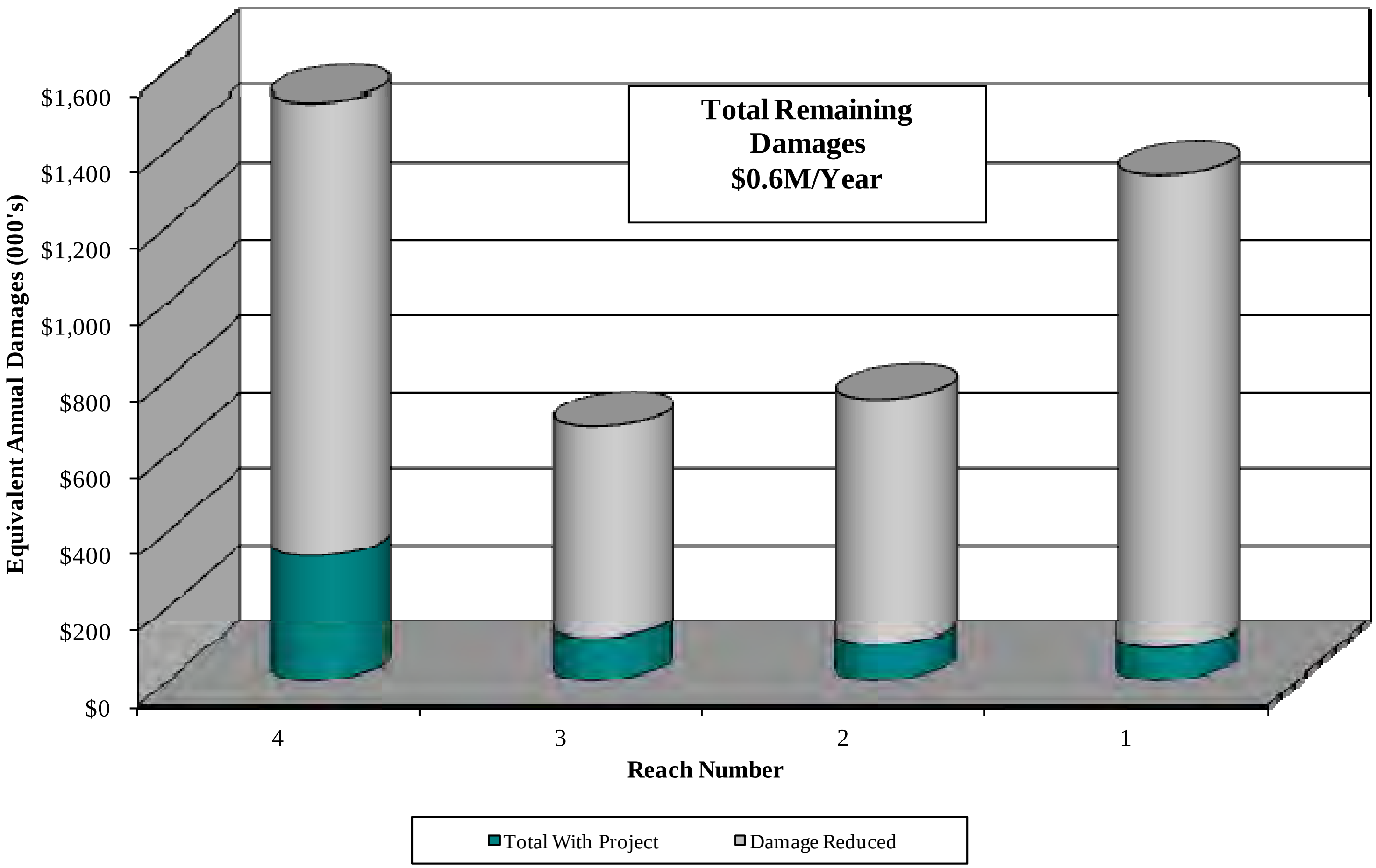
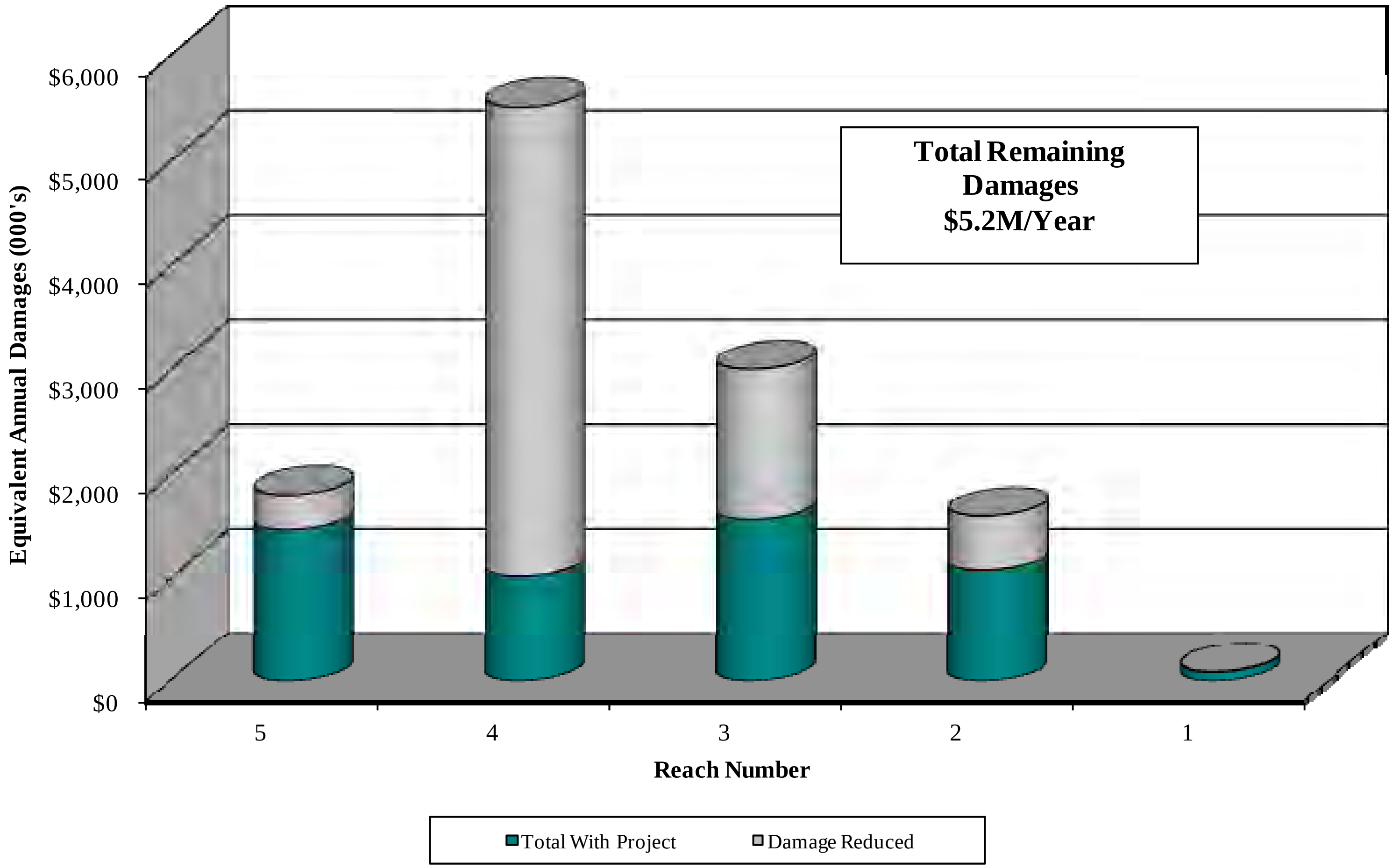


Figure 6
Mary's Creek
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)



Consideration of Induced Flooding Effects. Conveyance measures work to reduce flooding by increasing flow capacity and reducing storage. This generally results in higher flood flows (i.e. induced flooding) in the adjacent, downstream reach. The resulting increase in damage can offset economic benefits to the upstream reach. Even when the downstream reach is undeveloped, there is still an impact since property values are affected. Harris County and some other entities generally prohibit projects that cause induced flooding.

The GRR NED formulation was predicated on economic optimization without the constraint that induced flooding must be mitigated. Components were selected and sized to optimize net benefits. Investigation of the water surface elevations reveals that there is a maximum of 0.15 feet (less than 2 inches) of induced flooding in the Clear Creek watershed with the NED plan in place. This is well within one standard deviation of uncertainty in water surface elevations (one standard deviation is generally on the order of 0.75 feet) and, therefore, the induced damages for the NED plan are considered statistically insignificant. Since induced damages are statistically insignificant (meaning there is no statistical basis indicating that induced damages actually exist), a real estate analysis was not undertaken.

Savings in National Flood Insurance Administration Costs. Benefits can be derived from a reduction in administrative costs to the National Flood Insurance Program if implementation of a plan removes structures from the existing 1 percent AEP (100-year) floodplain. According to FEMA, the average cost of administering a flood insurance policy was $192 for Fiscal Year 2006 (Economic Guidance Memorandum 06-04 "National Flood Insurance Program Operating Costs, Fiscal Year 2006," April 6, 2006). This is the latest estimate available for NFIP operating costs.

Based on hydrologic stages for a median 1 percent AEP flood under the NED plan, an estimated 1,602 structures are physically located within the improved floodplain of main stem and tributaries of Clear Creek under the 2020 condition.

As previously stated, participation rates in the NFIP vary by county with an estimated 70 percent participation in Brazoria County, 70 percent in Galveston County (Galveston County Engineer, April, 2006), and 60 percent in Harris County (Harris County Engineer in consultation with NFIP Regional Manager, April 2007). Based on this information, a total of 1,050 structures within the 1 percent chance flood plain hold NFIP policies with the NED Plan in place. The total estimated cost of administering policies for the 1 percent AEP floodplain with the NED Plan in place is $201,500. The total annual cost of administering policies for the structures under the without-project condition was estimated to be approximately $472,500. The difference, or reduction in NFIP costs, represents a project benefit and is estimated at $271,000.

LOCALLY PREFERRED PLAN

Economic evaluation of plans during the analytical process resulted in selection the GRP as the NED Plan. This alternative has no adverse economic impacts downstream and meets the local sponsor's criteria of no increase in water surface elevations. In addition, the plan was formulated to alleviate the environmental issues the sponsors had with the AFP. As a result, no additional locally preferred plans were investigated or recommended.

RECOMMENDED PLAN

The Recommended Plan for Clear Creek, Texas is the NED Plan. Table 25 presents the summary of the benefits and costs of the Recommended Plan at the current discount rate of 4.0 percent and the rate of 7.0 percent. The rate of 7.0 percent is presented for annual budget presentation purposes and in accordance with Executive Order 12893. Detailed calculations for interest during construction and operations and maintenance costs are shown in Attachment 5. The recommended plan has a BCR of 2.3 at 4.0 percent and a BCR of 1.4 at 7.0 percent.

Attachment 6 to this appendix details the results of several sensitivity analyses conducted. These sensitivities were conducted based upon a variety of review comments and concerns raised regarding the results of this analysis. The sensitivity analyses further support the selection of the recommended plan.

TABLE 25
SUMMARY OF THE RECOMMENDED PLAN
AVERAGE ANNUAL EQUIVALENT VALUES
(50-year Period of Analysis, dollar values in thousands, October 2011 Price Levels)

Recommended Plan Average Annual Impacts	**Discount Rate** 4.000%	7.000%
Without-Project Conditions:		
Flood Damages	$42,587.0	$41,524.0
NFIP Costs	$472.5	$472.5
Subtotal Without-Project	$43,059.5	$41,996.5
Recommended Plan Conditions:		
Flood Damages	$19,748.0	$20,411.0
NFIP Costs	$201.5	$201.5
Subtotal Without-Project	$19,949.5	$20,612.5
Recommended Plan Annual Benefits	$23,110.0	$21,384.0
Project First Costs:	$189,135.0	$189,135.0
Annual Costs:		
Interest and Amortization	$8,804.3	$13,704.7
Interest During Construction	$276.0	$765.0
OMRR&R	$1,060.7	$718.2
Total Annual Project Costs	$10,140.9	$15,187.9
Benefit/Cost Ratio	2.3	1.4

Note: Discount Rate of 7% is shown for annual budget comparison purposes and in accordance with Executive Order 12893.
Individual numbers may not sum to totals due to rounding.

MODIFIED AUTHORIZED PROJECT (RECOMMENDED PLAN PLUS SECOND OUTLET AND GATE STRUCTURES)

The Modified Authorized Project for Clear Creek, Texas was analyzed for programming and budget purposes. Table 26 presents the summary of the benefits and costs of the Modified Authorized Project at the current discount rate of 4.0 percent and the rate of 7.0 percent. Both are presented for budget and cost-sharing purposes, but should not be used for economic benefit or BCR purposes. The Modified Authorized Project has a BCR of 1.8 at 4.0 percent and a BCR of 1.1 at 7.0 percent. Detailed calculations for interest during construction and operations and maintenance costs are shown in Attachment 5.

TABLE 26
SUMMARY OF THE MODIFIED AUTHORIZED PROJECT (INCLUDING SECOND OUTLET AND GATES)
AVERAGE ANNUAL EQUIVALENT VALUES
(50-year Period of Analysis, dollar values in thousands, October 2011 Price Levels)

	Discount Rate	
Modified Authorized Project Average Annual Impacts	**4.000%**	**7.000%**
Without-Project Conditions:		
Flood Damages	$42,587.0	$41,524.0
NFIP Costs	$472.5	$472.5
Subtotal Without-Project	$43,059.5	$41,996.5
Modified Authorized Project Conditions:		
Flood Damages	$19,748.0	$20,411.0
NFIP Costs	$201.5	$201.5
Subtotal Without-Project	$19,949.5	$20,612.5
Recommended Plan Annual Benefits	$23,110.0	$21,384.0
Annual Benefits of Second Outlet & Gates	$446.0	$446.0
Total Benefits	$23,556.0	$21,830.0
Project First Costs:	$243,624.0	$243,624.0
Annual Costs:		
Interest and Amortization	$11,340.7	$17,653.0
Interest During Construction	$351.4	$882.5
OMRR&R	$1,060.7	$718.2
Total Annual Project Costs	$12,752.8	$19,253.6
Benefit/Cost Ratio	1.8	1.1

Note: Modified Authorized Project is presented for budget, cost sharing and programming purposes. Do not use these numbers for economic benefits or BCR purposes.

SECTION 575 ANALYSES

Section 575 of WRDA 1996 provides that "during an evaluation of economic benefits and costs for projects set forth in subsection (b) that occurs after the date of the enactment of this Act, the Secretary shall not consider flood control works constructed by non-Federal interests within the drainage area of such projects prior to the date of such evaluation in the determination of conditions existing prior to construction of the project." Section 354 of WRDA 99 amended Section 575 to include Clear Creek. The WRDA 96, Section 575 (b) provides that:

> (b) SPECIFIC PROJECTS. –The projects to which subsection (a) apply are—
> (1) the project for flood control, Buffalo Bayou Basin, Texas, authorized by Section 203 of the Flood Control Act of 1954 (68 Stat. 1258);
> (2) the project for flood control, Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610); and
> (3) the project for flood control, Cypress Creek, Texas authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 401Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610); and
> (3) the project for flood control, Cypress Creek, Texas authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 4014).

The WRDA 99, Section 354 states:

Section 575 of the Water Resources Development Act of 1996 (110 Stat. 3789) is amended –

(1) In subsection (a)-
  (A) By inserting "or nonstructural actions" after "flood control works constructed"; and
  (B) By inserting "or nonstructural actions" after "construction of the project"; and
(2) In subsection (b)-
  (A) In paragraph (2), by striking "and" at the end;
  (B) In paragraph (3), by striking the period at the end and inserting "; and"; and
  (C) By adding at the end the following:

"(4) the project for flood control, Clear Creek, Texas, authorized by section 203 of the Floor Control Act of 1968 (82 Stat. 742).".

To meet the intent of the legislation, the without-project condition for Clear Creek (main stem and tributaries) was formulated without consideration of ongoing construction and property relocations within the study area. Only after the Federal Recommended Plan was developed and fully evaluated was additional analysis performed, testing the effect of activities by non-Federal interests. Two activities had the potential for altering either the hydrologic or economic profile of the study area—the construction of detention basins on Mary's Creek and the purchase and demolition of 163 properties along the main stem of Clear Creek following Tropical Storm Allison, which occurred June, 2001. FEMA's Hazard Mitigation Grant Program (HMGP) and the Harris County Flood Control District funded the buyouts.

Section 575 Implementation Guidance states that the following steps should be applied in the order presented to any current and future analyses:

1. Exclude non-Federal flood control works completed prior to the evaluation of benefits and costs from the existing and future "without-project" condition descriptions.

2. Exclude the same completed non-Federal flood control works from the "with-project" conditions for each alternative considered.

3. Combine the completed non-Federal flood control works with the recommended Federal project to form a total project. Identify the total project output.

4. Reexamine and possibly modify the design and operation of the recommended Federal project to more efficiently achieve the total project output.

Since there are two separate water bodies on Clear Creek affected by Section 575, it is necessary to analyze them in two parts.

<u>Main Stem Section 575 Analysis</u>. Of the structures inventoried, 163 residential structures have been purchased and removed from the floodplain under the FEMA's Hazard Mitigation Program on the main stem of Clear Creek. Under authority of Section 575, WRDA 96, as amended, those properties remain in the structure inventory for Federal project justification. The Section 575 analysis for the FEMA buyouts is shown in Table 27.

The removal of 163 damageable properties from the 0.2 percent AEP floodplain of the main stem of Clear Creek reduced residual damages in the with-project condition by $948,000 on an average annual equivalent basis and decreased the benefits attributable to the total Federal/Nonfederal actions by 8 percent. The benefit-cost ratio of the main stem portion of the

Recommended plan with the non-Federal project in place is 1.2, compared to the benefit-to-cost ratio (BCR) of the main stem portion of the Recommended plan without the non-Federal project in place ratio of 1.3.

TABLE 27
SECTION 575 ANALYSIS
AVERAGE ANNUAL EQUIVALENT DAMAGES 4.0%, 50 years
CLEAR CREEK MAIN STEM
VALUES IN THOUSANDS, OCT 2011 PRICES

				ANALYSIS WITHOUT NON-FEDERAL PROJECTS IN PLACE		ANALYSIS WITH BOTH FEDERAL AND NON-FEDERAL PROJECTS IN PLACE				
REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	Without Project	NED Plan	Damage Reduced	Without Project (w/ non-Fed project)	NED plan (w/ non-Fed project)	Damage Reduced	Change in Benefits with non-Fed project	Percent Change in Residual Damages w/ and w/o non-Fed project
1	GALVESTON BAY	ROSEWOOD	$116	$116	$0	$116	$116	$0	$0	0%
2	ROSEWOOD	BAL HARBOR	$93	$93	$0	$93	$93	$0	$0	0%
3	BAL HARBOR	FM 270	$99	$94	$5	$99	$94	$5	$0	0%
4	FM 270	SH 3	$129	$121	$8	$129	$121	$8	$0	0%
5	SH 3	IH 45	$0	$0	$0	$0	$0	$0	$0	0%
6	IH 45	W BAY AREA BLVD	$196	$181	$15	$170	$157	$13	-$2	-13%
7	W BAY AREA BLVD	FM 528	$909	$612	$297	$867	$588	$279	-$18	-4%
8	FM 528	WHISPERING PINES	$970	$344	$626	$775	$225	$550	-$76	-35%
9	WHISPERING PINES	NEAR MARY'S CRK	$759	$220	$539	$577	$161	$416	-$123	-27%
10	NEAR MARY'S CRK	FM 2351	$1,538	$353	$1,185	$654	$103	$551	-$634	-71%
11	FM 2351	NEAR TURKEY CRK	$235	$52	$183	$202	$42	$160	-$23	-19%
12	NEAR TURKEY CRK	DIXIE FARM RD	$103	$113	-$10	$91	$100	-$9	$1	-12%
13	DIXIE FARM RD	COUNTRY CLUB DR	$865	$789	$76	$621	$561	$61	-$15	-29%
14	COUNTRY CLUB DR	BENNIE KATE	$212	$164	$48	$212	$164	$48	$0	0%
15	BENNIE KATE	SH 35	$5,658	$3,505	$2,153	$5,444	$3,349	$2,095	-$58	-4%
16	SH 35	MYKAWA	$829	$294	$535	$829	$294	$535	$0	0%
17	MYKAWA	STONE RD	$2,963	$1,091	$1,872	$2,963	$1,091	$1,872	$0	0%
18	STONE RD	SH 288	$5,249	$3,154	$2,095	$5,249	$3,154	$2,095	$0	0%
19	SH 288	ALMEDA SCHOOL RD	$242	$240	$2	$242	$240	$2	$0	0%
TOTAL			$21,164	$11,536	$9,628	$19,332	$10,652	$8,680	-$948	-8%

First Costs of Construction (Main Stem Only)	$126,538	$126,538
AAEV Cost at 4.0%, 50-yrs (includes IDC & O&M)	$7,186	$7,186
Net Benefits	$2,442	$1,494
B/C Ratio (Main Stem Only)	1.3	1.2

Note: Individual numbers may not sum to totals due to rounding.

Mary's Creek Section 575 Analysis. During the study of this project, offline detentions on Mary's Creek were constructed by the local sponsor. These detentions, named SWEC and West Mary's Detentions, were initially analyzed for inclusion in the Federal plan, so the detention sizes were optimized (see Attachment 2 of this appendix). The detentions were eventually dropped from analysis and analyzed as Section 575 projects. Analysis of the effect of the construction of these detentions on the Federal plan is show in Table 28. As can be seen from the table, the Mary's Creek detentions further reduces residual damages along Mary's Creek on an average annual equivalent basis of $1.1 million and increased benefits attributable to the total Federal/Nonfederal actions by 16 percent.

The benefit-cost ratio of the Mary's Creek portion of Recommended Plan with the non-Federal project is 5.9, compared to the BCR of the Recommended Plan without the non-Federal project in place ratio of 7.0. The non-Federal project (detentions) impacts the recommended plan by simultaneously reducing residual damages and decreasing benefits.

Since the recommended plan (with the detention on Mary's Creek) has a very robust BCR, additional modification to the design and operation of the recommended Federal plan is not required.

TABLE 28
SECTION 575 ANALYSIS

AVERAGE ANNUAL EQUIVALENT DAMAGES 4.0%, 50 years

MARY'S CREEK
VALUES IN THOUSANDS, OCT 2011 PRICES

				ANALYSIS WITHOUT NON-FEDERAL PROJECTS IN PLACE		ANALYSIS WITH BOTH FEDERAL AND NON-FEDERAL PROJECTS IN PLACE				
REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	Without Project	NED Plan	Damage Reduced	Without Project (w/ non-Fed project)	NED plan (w/ non-Fed project)	Damage Reduced	Change in Benefits with non-Fed project	Percent Change in Residual Damages w/ and w/o non-Fed project
1	EDGEWOOD DR.	COUNTY LINE	$84	$81	$3	$113	$72	$41	$38	-11%
2	COUNTY LINE	LONGHERRIDGE DR	$1,604	$1,084	$520	$2,001	$1,013	$989	$469	-7%
3	LONGHERRIDGE DR.	AT&SF RR	$3,009	$1,568	$1,441	$2,111	$1,203	$908	-$534	-23%
4	AT&SF RR	HARKEY RD	$5,525	$1,028	$4,497	$4,348	$725	$3,622	-$875	-29%
5	HARKEY RD	CHARLES AVE	$1,807	$1,474	$333	$1,509	$1,366	$143	-$190	-7%
TOTAL			$12,030	$5,235	$6,795	$10,082	$4,380	$5,703	-$1,093	-16%

First Costs of Construction (Mary's Creek Only)	$20,765	$20,765
AAEV Cost at 4.0%, 50-yrs (includes IDC & O&M)	$967	$967
Net Benefits	$5,828	$4,736
B/C Ratio (Mary's Creek Only)	7.0	5.9

Note: Individual numbers may not sum to totals due to rounding.

ABILITY TO PAY ANALYSIS

In accordance with ER 1165-2-121, an ability to pay analysis was conducted for the Clear Creek GRR flood damage mitigation project. The ability to pay test determines the eligibility of the study sponsors to qualify for a reduction in the amount they are required to cost share. To qualify for a reduction the results of both the benefit and income portions of the two-fold ability to pay test must fall within the specified guidelines.

The benefits' test determines the maximum reduction, called the "benefits based floor" (or BBF), in the level of non-Federal cost sharing for any project. The factor is determined by dividing the BCR by four. If the factor (expressed as a percentage) is less than the standard level of cost sharing, the project may be eligible for a reduction in the non-Federal share to this BBF. The standard level cost share for a flood control project is 25 percent. The Recommended Plan's BCR of 2.3 was divided by four to yield a BBF of 58 percent.

The income test determines qualification for the reduction calculated in the benefit step. Qualification depends on the measure of current economic resources of both the project area and the state in which the project is located.

In accordance with the factors released in Economic Guidance Memorandum 08-05, the income index factor for the State of Texas is 93.38 and for the counties of Galveston, Harris and Brazoria, the index factors are 96.69, 118.36, and 87.13, respectively. The Eligibility Factor (EF) for a flood damage mitigation project is calculated according to the following formula:

$$EF = a - b_1 * (\text{State Factor}) - b_2 * (\text{Area Factor})$$

Where: $a = 18.12$
$b_1 = .078$
$b_2 = .156$

When a project area, as determined by the location of the project's beneficiaries, includes more than one county, calculation of a composite project area index is necessary by taking a weighted average of the county index numbers, the weights being equal to the relative levels of benefits received in each county. The composite area index for the Clear Creek study area is 102.14.

Utilizing the above formula and the composite area index, an EF of or the Clear Creek Recommended Plan is -5.10. An EF less than zero indicates ineligibility for a reduction in construction cost sharing.

As stated previously, a BBF factor for the Recommended Plan was calculated at 58 percent. To qualify for a reduction, the BBF factor must be less than the standard level of cost sharing. According to ER-1165-2-121 paragraph 5a(2), the project and sponsors do not meet the criteria for a reduction in cost sharing. This project does not meet either of the tests; therefore, the sponsors must pay the standard percentage of the total project cost.

ECONOMIC BENEFIT UPDATE PLAN

In accordance with ER 1105-2-100, a 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 100-year floodplain. Structure values for residential, commercial, industrial and public categories will be updated by creating a random sample of inventoried structures and valuing these structures using off-the-shelf valuation software. 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 National Flood Insurance Program benefit category will be updated using the latest available Economic Guidance Memorandum. Finally, utilities, roads and post disaster recovery benefit categories will be updated using the most appropriate CPI index.

Attachment 1
Detailed Tables for Main Stem and Tributaries
Without-Project 2020 and 2070 Conditions

Details of Distribution of Capital Investment within the Without-Project Floodplain. Tables 1-1 through 1-6 of this attachment show the detailed distribution of structures by type by flood event for the 2020 without-project condition. For example, Table 1-3 shows the distribution of capital investment on Turkey Creek in the 2020 without-project condition. Tables 1-7 through 1-12 likewise display the distribution of structures by type by flood event; however, the condition is for the 2070 future without-project condition.

TABLE 1-1
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK MAIN STEM
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	105	358	758	1,184	1,636	2,443	2,949
Value of Structures	$0	$10,869	$38,167	$76,002	$124,984	$180,853	$281,605	$344,648
Value of Contents	$0	$5,434	$19,083	$38,001	$62,492	$90,427	$140,802	$172,324
Percent of Structures Inundated/Zone	0%	78%	83%	89%	90%	91%	92%	92%
Commercial								
Number of Structures	$1	23	57	74	98	127	170	202
Value of Structures	$33	$4,138	$10,780	$12,115	$15,111	$17,677	$25,929	$29,836
Value of Contents	$0	$1,120	$6,313	$7,054	$10,923	$12,124	$20,015	$22,848
Percent of Structures Inundated/Zone	100%	17%	13%	9%	7%	7%	6%	6%
Industrial								
Number of Structures	$0	1	4	7	14	14	17	17
Value of Structures	$0	$218	$692	$1,179	$2,173	$2,173	$2,213	$2,213
Value of Contents	$0	$1,156	$3,091	$4,589	$9,331	$9,331	$10,732	$10,732
Percent of Structures Inundated/Zone	0%	1%	1%	1%	1%	1%	1%	1%
Public								
Number of Structures	$0	5	10	16	19	19	19	23
Value of Structures	$0	$1,275	$2,104	$6,885	$7,740	$7,740	$7,740	$7,840
Value of Contents	$0	$424	$495	$1,443	$1,900	$1,900	$1,900	$1,950
Percent of Structures Inundated/Zone	0%	4%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	1	134	429	855	1,315	1,796	2,649	3,191
Value of Structures	$33	$16,500	$51,743	$96,180	$150,008	$208,443	$317,487	$384,538
Value of Contents	$0	$8,134	$28,983	$51,087	$84,645	$113,781	$173,448	$207,854
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-2
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MUD GULLY
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	1	87	382	640	988	1,236
Value of Structures	$0	$0	$14	$5,900	$20,950	$35,226	$50,073	$56,558
Value of Contents	$0	$0	$35	$2,951	$11,234	$19,438	$29,283	$36,285
Percent of Structures Inundated/Zone				98%	93%	94%	96%	96%
Commercial								
Number of Structures	0	0	0	2	26	38	42	48
Value of Structures	$0	$0	$0	$18	$530	$1,286	$1,314	$1,629
Value of Contents	$0	$0	$0	$1	$1,236	$1,635	$1,665	$2,069
Percent of Structures Inundated/Zone				2%	6%	6%	4%	4%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	2	2	2	2
Value of Structures	$0	$0	$0	$0	$18	$18	$18	$18
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	1	89	410	680	1,032	1,286
Value of Structures	$0	$0	$14	$5,917	$21,498	$36,529	$51,405	$58,205
Value of Contents	$0	$0	$35	$2,952	$12,470	$21,073	$30,948	$38,354
Percent of Structures Inundated/Zone	n/a	n/a	n/a	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-3
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
TURKEY CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	0	6	55	313	697	744
Value of Structures	$0	$0	$0	$733	$4,951	$24,988	$63,275	$68,652
Value of Contents	$0	$0	$0	$366	$2,476	$12,494	$31,638	$34,326
Percent of Structures Inundated/Zone				86%	95%	98%	99%	99%
Commercial								
Number of Structures	0	0	0	1	2	5	9	9
Value of Structures	$0	$0	$0	$193	$462	$1,295	$1,781	$1,781
Value of Contents	$0	$0	$0	$176	$420	$1,574	$2,177	$2,177
Percent of Structures Inundated/Zone				14%	3%	2%	1%	1%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	1	1	1	1
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	0	7	58	319	707	754
Value of Structures	$0	$0	$0	$926	$5,413	$26,283	$65,056	$70,433
Value of Contents	$0	$0	$0	$542	$2,896	$14,069	$33,815	$36,503
Percent of Structures Inundated/Zone	n/a	n/a	n/a	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-4
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MARY'S CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	1	24	162	433	622	665	765	1,606
Value of Structures	$95	$3,266	$11,229	$34,322	$54,894	$61,481	$74,999	$184,837
Value of Contents	$48	$1,633	$5,614	$17,161	$27,447	$30,740	$37,499	$92,419
Percent of Structures Inundated/Zone	33%	52%	69%	75%	78%	79%	79%	82%
Commercial								
Number of Structures	2	21	59	119	145	148	163	295
Value of Structures	$1	$142	$1,439	$2,962	$5,069	$5,216	$5,841	$13,442
Value of Contents	$1	$97	$950	$2,173	$4,088	$4,202	$4,702	$11,654
Percent of Structures Inundated/Zone	67%	46%	25%	21%	18%	18%	17%	15%
Industrial								
Number of Structures	0	0	8	17	18	18	18	20
Value of Structures	$0	$0	$3,602	$7,006	$7,598	$7,598	$7,598	$8,001
Value of Contents	$0	$0	$2,450	$4,764	$5,166	$5,166	$5,166	$5,440
Percent of Structures Inundated/Zone	0%	0%	3%	3%	2%	2%	2%	1%
Public								
Number of Structures	0	1	5	10	12	14	17	33
Value of Structures	$0	$16	$275	$385	$543	$712	$2,283	$9,468
Value of Contents	$0	$6	$144	$212	$279	$368	$1,046	$3,748
Percent of Structures Inundated/Zone	0%	2%	2%	2%	2%	2%	2%	2%
Total								
Number of Structures	3	46	234	579	797	845	963	1,954
Value of Structures	$96	$3,424	$16,545	$44,675	$68,103	$75,005	$90,719	$215,748
Value of Contents	$48	$1,735	$9,158	$24,310	$36,981	$40,476	$48,414	$113,262
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-5
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
COWART CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	3	5	9	13	17	32	42
Value of Structures	$0	$66	$139	$319	$1,189	$1,553	$4,329	$6,006
Value of Contents	$0	$33	$69	$160	$594	$776	$2,164	$3,003
Percent of Structures Inundated/Zone		21%	24%	30%	32%	31%	38%	44%
Commercial								
Number of Structures	0	11	14	17	24	32	40	41
Value of Structures	$0	$257	$269	$272	$367	$447	$535	$552
Value of Contents	$0	$171	$179	$182	$188	$243	$302	$314
Percent of Structures Inundated/Zone		79%	67%	57%	59%	58%	48%	43%
Industrial								
Number of Structures	0	0	2	4	4	6	12	13
Value of Structures	$0	$0	$93	$189	$189	$189	$189	$208
Value of Contents	$0	$0	$63	$128	$128	$128	$128	$141
Percent of Structures Inundated/Zone		0%	10%	13%	10%	11%	14%	14%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	14	21	30	41	55	84	96
Value of Structures	$0	$323	$500	$780	$1,745	$2,188	$5,052	$6,766
Value of Contents	$0	$204	$312	$470	$911	$1,147	$2,595	$3,459
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-6
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CHIGGER CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	1	2	5	5	8	19	22
Value of Structures	$0	$253	$753	$1,082	$1,082	$1,532	$4,752	$5,109
Value of Contents	$0	$127	$377	$541	$541	$766	$2,376	$2,555
Percent of Structures Inundated/Zone		50%	67%	83%	83%	80%	86%	88%
Commercial								
Number of Structures	0	1	1	1	1	2	3	3
Value of Structures	$0	$35	$35	$35	$35	$62	$78	$78
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		50%	33%	17%	17%	20%	14%	12%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	2	3	6	6	10	22	25
Value of Structures	$0	$289	$789	$1,117	$1,117	$1,595	$4,830	$5,187
Value of Contents	$0	$127	$377	$541	$541	$766	$2,376	$2,555
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-7
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK MAIN STEM
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	2	197	506	899	1,375	1,795	2,631	3,180
Value of Structures	$137	$21,654	$54,029	$92,767	$148,940	$206,636	$308,593	$373,859
Value of Contents	$69	$10,827	$27,015	$46,384	$74,470	$103,318	$154,297	$186,929
Percent of Structures Inundated/Zone	67%	84%	86%	90%	90%	91%	92%	93%
Commercial								
Number of Structures	1	30	63	78	115	134	181	212
Value of Structures	$33	$6,432	$11,060	$12,192	$16,899	$17,928	$26,708	$37,410
Value of Contents	$0	$3,220	$6,477	$7,553	$11,626	$12,150	$20,403	$70,667
Percent of Structures Inundated/Zone	33%	13%	11%	8%	8%	7%	6%	6%
Industrial								
Number of Structures	0	3	5	8	14	14	17	17
Value of Structures	$0	$569	$838	$1,179	$2,173	$2,173	$2,213	$2,213
Value of Contents	$0	$2,756	$3,098	$4,589	$9,331	$9,331	$10,732	$10,732
Percent of Structures Inundated/Zone	0%	1%	1%	1%	1%	1%	1%	0%
Public								
Number of Structures	0	5	13	17	19	19	20	27
Value of Structures	$0	$1,275	$2,477	$6,885	$7,740	$7,740	$7,740	$8,111
Value of Contents	$0	$424	$681	$1,443	$1,900	$1,900	$1,900	$2,018
Percent of Structures Inundated/Zone	0%	2%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	3	235	587	1,002	1,523	1,962	2,849	3,436
Value of Structures	$170	$29,931	$68,404	$113,024	$175,751	$234,477	$345,255	$421,593
Value of Contents	$69	$17,227	$37,270	$59,969	$97,327	$126,699	$187,331	$270,346
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-8
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MUD GULLY
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	1	138	383	626	973	1,229
Value of Structures	$0	$0	$14	$7,751	$20,803	$33,682	$49,704	$56,392
Value of Contents	$0	$0	$35	$3,729	$11,187	$18,860	$28,451	$36,060
Percent of Structures Inundated/Zone				99%	94%	94%	96%	96%
Commercial								
Number of Structures	0	0	0	2	23	38	41	48
Value of Structures	$0	$0	$0	$18	$498	$1,286	$1,300	$1,629
Value of Contents	$0	$0	$0	$1	$1,228	$1,635	$1,665	$2,069
Percent of Structures Inundated/Zone				1%	6%	6%	4%	4%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	2	2	2	2
Value of Structures	$0	$0	$0	$0	$18	$18	$18	$18
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	1	140	408	666	1,016	1,279
Value of Structures	$0	$0	$14	$7,768	$21,319	$34,986	$51,022	$58,038
Value of Contents	$0	$0	$35	$3,730	$12,415	$20,495	$30,115	$38,129
Percent of Structures Inundated/Zone	n/a	n/a	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-9
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
TURKEY CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	2	62	334	449	881	1,377
Value of Structures	$0	$0	$248	$5,464	$25,679	$36,246	$80,213	$121,313
Value of Contents	$0	$0	$124	$2,732	$12,839	$18,123	$40,106	$60,656
Percent of Structures Inundated/Zone				97%	99%	99%	99%	99%
Commercial								
Number of Structures	0	0	0	2	5	6	9	20
Value of Structures	$0	$0	$0	$462	$1,295	$1,563	$1,781	$4,289
Value of Contents	$0	$0	$0	$420	$1,574	$2,033	$2,177	$4,547
Percent of Structures Inundated/Zone				3%	1%	1%	1%	1%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	2	64	339	455	890	1,397
Value of Structures	$0	$0	$248	$5,926	$26,974	$37,809	$81,993	$125,602
Value of Contents	$0	$0	$124	$3,152	$14,414	$20,156	$42,283	$65,204
Percent of Structures Inundated/Zone	n/a	n/a	n/a	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-10
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MARY'S CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	10	101	196	585	639	1,449	1,629	1,853
Value of Structures	$1,023	$7,950	$13,404	$50,153	$58,310	$166,882	$190,799	$222,381
Value of Contents	$511	$3,975	$6,702	$25,077	$29,155	$83,441	$95,400	$111,190
Percent of Structures Inundated/Zone	48%	72%	69%	77%	78%	83%	83%	84%
Commercial								
Number of Structures	10	35	74	141	146	245	287	300
Value of Structures	$97	$438	$1,765	$4,919	$5,190	$9,440	$12,901	$13,542
Value of Contents	$66	$339	$1,188	$3,860	$4,034	$8,703	$10,888	$11,451
Percent of Structures Inundated/Zone	48%	25%	26%	19%	18%	14%	15%	14%
Industrial								
Number of Structures	0	0	9	18	18	20	22	22
Value of Structures	$0	$0	$4,148	$7,598	$7,598	$8,001	$8,405	$8,405
Value of Contents	$0	$0	$2,821	$5,166	$5,166	$5,440	$5,715	$5,715
Percent of Structures Inundated/Zone	0%	0%	3%	2%	2%	1%	1%	1%
Public								
Number of Structures	1	4	6	12	12	30	31	35
Value of Structures	$16	$168	$277	$543	$543	$8,442	$8,447	$8,591
Value of Contents	$6	$104	$145	$279	$279	$3,367	$3,371	$3,424
Percent of Structures Inundated/Zone	5%	3%	2%	2%	1%	2%	2%	2%
Total								
Number of Structures	21	140	285	756	815	1,744	1,969	2,210
Value of Structures	$1,136	$8,556	$19,595	$63,212	$71,640	$192,765	$220,552	$252,918
Value of Contents	$583	$4,418	$10,856	$34,382	$38,634	$100,952	$115,374	$131,781
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-11
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
COWART CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	3	6	9	14	19	34	43
Value of Structures	$0	$66	$144	$319	$1,195	$1,817	$4,688	$6,344
Value of Contents	$0	$33	$72	$160	$598	$908	$2,344	$3,172
Percent of Structures Inundated/Zone		16%	22%	26%	30%	33%	42%	47%
Commercial								
Number of Structures	0	11	14	18	26	32	40	41
Value of Structures	$0	$257	$269	$358	$391	$447	$535	$552
Value of Contents	$0	$171	$179	$182	$205	$243	$302	$314
Percent of Structures Inundated/Zone		58%	52%	53%	55%	55%	49%	45%
Industrial								
Number of Structures	0	5	7	7	7	7	7	8
Value of Structures	$0	$93	$189	$189	$189	$189	$189	$208
Value of Contents	$0	$63	$128	$128	$128	$128	$128	$141
Percent of Structures Inundated/Zone		26%	26%	21%	15%	12%	9%	9%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	19	27	34	47	58	81	92
Value of Structures	$0	$415	$601	$866	$1,775	$2,452	$5,412	$7,104
Value of Contents	$0	$267	$380	$470	$931	$1,279	$2,775	$3,628
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-12
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CHIGGER CREEK
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	1	2	5	6	10	20	24
Value of Structures	$0	$253	$753	$1,082	$1,339	$2,111	$4,770	$5,612
Value of Contents	$0	$127	$377	$541	$669	$1,055	$2,385	$2,806
Percent of Structures Inundated/Zone		50%	67%	83%	86%	83%	87%	89%
Commercial								
Number of Structures	0	1	1	1	1	2	3	3
Value of Structures	$0	$35	$35	$35	$35	$62	$78	$78
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		50%	33%	17%	14%	17%	13%	11%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	2	3	6	7	12	23	27
Value of Structures	$0	$289	$789	$1,117	$1,374	$2,173	$4,848	$5,690
Value of Contents	$0	$127	$377	$541	$669	$1,055	$2,385	$2,806
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Details of Single Occurrence Damages in the Without-Project Condition. Tables 1-13 through 1-18 of this attachment show the damages expected to accrue from various flood events along the individual streams on Clear Creek under the 2020 condition. These values represent damages expected for individual events under the without-project near-term hydrologic condition and include structure and content damages as well as other benefit categories. Similarly, Tables 1-19 through 1-24 display the summary of single occurrence damages by event for the tributaries in the future hydrologic condition.

It should be noted, once again, that the increase in damages occurring over the period of analysis is attributed solely to increases in runoff. No projections were made on the economic-side of the analysis (i.e. the floodplain investment remains as it currently stands). Overall, there is an increase in damages of 10 percent from 2020 to 2070. This is equivalent to an average annual growth in damages of approximately 0.1 percent over the period of analysis.

TABLE 1-13
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
CLEAR CREEK MAIN STEM
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$285.1	$9,101.4	$23,181.1	$40,187.4	$60,153.8	$85,558.2	$127,994.4	$157,447.6
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$1,603.8	$1,815.9
Commercial	$7.2	$449.8	$1,445.7	$2,531.4	$3,852.1	$4,541.3	$7,521.1	$9,676.9
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$722.3	$759.2
Damages to Structures, Contents	$292.3	$9,551.2	$24,626.8	$42,718.8	$64,005.8	$90,099.6	$137,841.5	$169,699.6
Postdisaster Recovery Costs	$216.4	$3,562.8	$7,745.1	$12,682.9	$18,133.5	$23,597.2	$32,795.6	$38,593.5
Utilities	$8.1	$134.1	$291.6	$477.5	$682.7	$888.4	$1,234.7	$1,452.9
Vehicles	$0.0	$511.7	$1,717.3	$3,909.8	$6,794.6	$10,301.7	$17,041.6	$21,199.8
Roads	$316.1	$691.0	$991.0	$1,304.9	$1,599.4	$1,902.1	$2,617.5	$5,564.5
Total Damages by Event	$833.0	$14,450.9	$35,371.9	$61,093.8	$91,216.0	$126,789.0	$191,530.9	$236,510.4
Percent Distribution by Event								
Residential	34.2%	63.0%	65.5%	65.8%	65.9%	67.5%	66.8%	66.6%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.8%
Commercial	0.9%	3.1%	4.1%	4.1%	4.2%	3.6%	3.9%	4.1%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%
Postdisaster Recovery Costs	26.0%	24.7%	21.9%	20.8%	19.9%	18.6%	17.1%	16.3%
Utilities	1.0%	0.9%	0.8%	0.8%	0.7%	0.7%	0.6%	0.6%
Vehicles	0.0%	3.5%	4.9%	6.4%	7.4%	8.1%	8.9%	9.0%
Roads	38.0%	4.8%	2.8%	2.1%	1.8%	1.5%	1.4%	2.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-14
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
MUD GULLY
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$205.0	$2,515.2	$9,346.3	$19,672.8	$29,259.9	$42,813.4	$51,283.0
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$1.6	$33.4	$195.8	$483.5	$900.6	$1,145.8
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$0.0	$205.1	$2,516.7	$9,379.7	$19,868.6	$29,743.4	$43,714.0	$52,428.8
Postdisaster Recovery Costs	$0.0	$0.0	$8.8	$779.2	$3,502.0	$5,822.1	$8,720.0	$10,812.4
Utilities	$0.0	$0.0	$0.3	$29.3	$131.8	$219.2	$328.3	$407.1
Vehicles	$0.0	$0.0	$0.5	$42.5	$320.8	$1,041.8	$2,656.1	$4,092.1
Roads	$0.0	$2.0	$23.7	$95.7	$223.1	$345.3	$519.5	$636.1
Total Damages by Event	$0.0	$207.1	$2,550.0	$10,326.4	$24,046.4	$37,171.8	$55,937.8	$68,376.4
Percent Distribution by Event								
Residential	0.0%	99.0%	98.6%	90.5%	81.8%	78.7%	76.5%	75.0%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.1%	0.3%	0.8%	1.3%	1.6%	1.7%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.3%	7.5%	14.6%	15.7%	15.6%	15.8%
Utilities	0.0%	0.0%	0.0%	0.3%	0.5%	0.6%	0.6%	0.6%
Vehicles	0.0%	0.0%	0.0%	0.4%	1.3%	2.8%	4.7%	6.0%
Roads	0.0%	1.0%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
	n/a	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-15
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
TURKEY CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$67.6	$486.5	$3,548.6	$6,950.8	$17,575.4	$30,253.2	$31,621.4
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$1.1	$11.5	$28.2	$110.7	$260.7	$266.5
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.4	$0.4
Damages to Structures, Contents	$0.0	$67.6	$487.7	$3,560.1	$6,979.0	$17,686.1	$30,514.4	$31,888.3
Postdisaster Recovery Costs	$0.0	$4.9	$39.9	$899.9	$2,186.5	$6,411.8	$10,662.1	$11,007.4
Utilities	$0.0	$0.2	$1.5	$33.9	$82.3	$241.4	$401.4	$414.4
Vehicles	$0.0	$0.0	$0.0	$8.4	$41.6	$325.3	$1,054.8	$1,198.5
Roads	$0.8	$20.9	$67.7	$140.1	$164.1	$215.1	$239.6	$241.2
Total Damages by Event	$0.8	$93.6	$596.8	$4,642.3	$9,453.6	$24,879.7	$42,872.3	$44,749.8
Percent Distribution by Event								
Residential	0.0%	72.2%	81.5%	76.4%	73.5%	70.6%	70.6%	70.7%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.2%	0.2%	0.3%	0.4%	0.6%	0.6%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	5.2%	6.7%	19.4%	23.1%	25.8%	24.9%	24.6%
Utilities	0.0%	0.2%	0.3%	0.7%	0.9%	1.0%	0.9%	0.9%
Vehicles	0.0%	0.0%	0.0%	0.2%	0.4%	1.3%	2.5%	2.7%
Roads	100.0%	22.4%	11.3%	3.0%	1.7%	0.9%	0.6%	0.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-16
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
MARY'S CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$240.9	$1,449.1	$9,736.7	$22,349.0	$29,705.6	$32,607.3	$37,837.7	$82,544.3
Public	$0.1	$1.7	$20.2	$64.2	$97.6	$111.3	$150.6	$984.0
Commercial	$1.0	$18.1	$305.3	$1,018.7	$1,301.7	$1,378.9	$1,496.6	$3,883.6
Industrial	$0.0	$0.0	$576.7	$4,382.5	$6,605.3	$6,638.1	$6,682.7	$13,235.9
Damages to Structures, Contents	$242.0	$1,468.8	$10,638.9	$27,814.4	$37,710.3	$40,735.6	$46,167.7	$100,647.8
Postdisaster Recovery Costs	$163.5	$704.2	$3,766.4	$8,128.8	$10,445.0	$11,133.8	$12,395.4	$19,239.1
Utilities	$6.2	$26.4	$141.8	$306.0	$393.2	$419.2	$466.7	$724.3
Vehicles	$0.8	$49.3	$233.1	$876.7	$1,497.0	$1,680.8	$2,045.1	$12,210.1
Roads	$9.1	$79.3	$350.6	$519.7	$549.9	$575.6	$609.8	$664.7
Total Damages by Event	$421.7	$2,328.0	$15,130.8	$37,645.7	$50,595.3	$54,545.0	$61,684.7	$133,486.0
Percent Distribution by Event								
Residential	57.1%	62.2%	64.4%	59.4%	58.7%	59.8%	61.3%	61.8%
Public	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.7%
Commercial	0.2%	0.8%	2.0%	2.7%	2.6%	2.5%	2.4%	2.9%
Industrial	0.0%	0.0%	3.8%	11.6%	13.1%	12.2%	10.8%	9.9%
Postdisaster Recovery Costs	38.8%	30.2%	24.9%	21.6%	20.6%	20.4%	20.1%	14.4%
Utilities	1.5%	1.1%	0.9%	0.8%	0.8%	0.8%	0.8%	0.5%
Vehicles	0.2%	2.1%	1.5%	2.3%	3.0%	3.1%	3.3%	9.1%
Roads	2.2%	3.4%	2.3%	1.4%	1.1%	1.1%	1.0%	0.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-17
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
COWART CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$40.3	$115.5	$264.2	$489.9	$851.7	$1,727.7	$2,496.5
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$10.6	$34.9	$43.4	$49.8	$57.1	$69.2	$79.1
Industrial	$0.0	$0.9	$11.8	$22.5	$29.6	$35.6	$42.4	$46.7
Damages to Structures, Contents	$0.0	$51.9	$162.2	$330.1	$569.3	$944.4	$1,839.2	$2,622.3
Postdisaster Recovery Costs	$32.5	$222.9	$374.1	$524.3	$665.4	$812.4	$1,023.4	$1,171.0
Utilities	$1.2	$8.4	$14.1	$19.7	$25.0	$30.6	$38.5	$44.1
Vehicles	$0.0	$3.7	$23.5	$48.0	$74.2	$114.7	$197.3	$278.3
Roads	$0.4	$1.5	$4.8	$9.7	$16.7	$27.7	$54.0	$77.0
Total Damages by Event	$34.1	$288.4	$578.6	$931.8	$1,350.6	$1,929.8	$3,152.5	$4,192.7
Percent Distribution by Event								
Residential	0.0%	14.0%	20.0%	28.4%	36.3%	44.1%	54.8%	59.5%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	3.7%	6.0%	4.7%	3.7%	3.0%	2.2%	1.9%
Industrial	0.0%	0.3%	2.0%	2.4%	2.2%	1.8%	1.3%	1.1%
Postdisaster Recovery Costs	95.2%	77.3%	64.7%	56.3%	49.3%	42.1%	32.5%	27.9%
Utilities	3.6%	2.9%	2.4%	2.1%	1.9%	1.6%	1.2%	1.1%
Vehicles	0.0%	1.3%	4.1%	5.1%	5.5%	5.9%	6.3%	6.6%
Roads	1.2%	0.5%	0.8%	1.0%	1.2%	1.4%	1.7%	1.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-18
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2020 CONDITION
CHIGGER CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$6.0	$163.6	$285.7	$465.3	$728.7	$1,167.4	$1,977.4	$2,811.2
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$1.6	$4.4	$5.7	$7.0	$9.3	$12.7	$14.6
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$6.0	$165.2	$290.1	$471.0	$735.7	$1,176.7	$1,990.1	$2,825.8
Postdisaster Recovery Costs	$1.0	$38.8	$60.6	$78.5	$122.5	$199.3	$302.9	$436.5
Utilities	$0.0	$1.5	$2.3	$3.0	$4.6	$7.5	$11.4	$16.4
Vehicles	$0.0	$0.9	$8.1	$20.6	$27.9	$41.9	$75.9	$129.1
Roads	$1.0	$6.6	$10.8	$17.4	$27.0	$42.8	$71.5	$89.8
Total Damages by Event	$8.0	$212.9	$371.8	$590.5	$917.6	$1,468.2	$2,451.8	$3,497.7
Percent Distribution by Event								
Residential	74.5%	76.9%	76.8%	78.8%	79.4%	79.5%	80.6%	80.4%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.7%	1.2%	1.0%	0.8%	0.6%	0.5%	0.4%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	12.0%	18.2%	16.3%	13.3%	13.3%	13.6%	12.4%	12.5%
Utilities	0.5%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%
Vehicles	0.0%	0.4%	2.2%	3.5%	3.0%	2.9%	3.1%	3.7%
Roads	13.0%	3.1%	2.9%	2.9%	2.9%	2.9%	2.9%	2.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-19
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
CLEAR CREEK MAIN STEM
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$1,210.9	$14,303.2	$29,781.6	$47,996.2	$72,377.1	$97,050.8	$140,235.7	$173,356.8
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$1,643.8	$1,869.0
Commercial	$40.9	$646.6	$1,701.2	$2,713.2	$4,268.1	$4,820.6	$8,106.3	$10,518.0
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$750.8	$760.6
Damages to Structures, Contents	$1,251.7	$14,949.8	$31,482.9	$50,709.4	$76,645.2	$101,871.4	$150,736.6	$186,504.4
Postdisaster Recovery Costs	$546.2	$5,129.3	$9,466.1	$14,470.2	$20,765.9	$25,581.7	$34,937.0	$41,194.1
Utilities	$20.6	$193.1	$356.4	$544.8	$781.8	$963.1	$1,315.3	$1,550.8
Vehicles	$3.2	$838.5	$2,433.8	$4,835.5	$8,414.9	$11,618.4	$18,743.1	$23,165.9
Roads	$449.1	$848.6	$1,159.4	$1,467.3	$1,778.7	$2,061.1	$4,010.1	$5,546.4
Total Damages by Event	$2,270.9	$21,959.2	$44,898.7	$72,027.2	$108,386.4	$142,095.6	$209,742.1	$257,961.7
Percent Distribution by Event								
Residential	53.3%	65.1%	66.3%	66.6%	66.8%	68.3%	66.9%	67.2%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.7%
Commercial	1.8%	2.9%	3.8%	3.8%	3.9%	3.4%	3.9%	4.1%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%
Postdisaster Recovery Costs	24.1%	23.4%	21.1%	20.1%	19.2%	18.0%	16.7%	16.0%
Utilities	0.9%	0.9%	0.8%	0.8%	0.7%	0.7%	0.6%	0.6%
Vehicles	0.1%	3.8%	5.4%	6.7%	7.8%	8.2%	8.9%	9.0%
Roads	19.8%	3.9%	2.6%	2.0%	1.6%	1.5%	1.9%	2.2%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-20
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
MUD GULLY
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$2.5	$215.3	$2,753.7	$10,020.6	$19,355.1	$28,406.3	$41,357.3	$50,873.4
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.1	$1.6	$35.5	$180.5	$438.6	$850.2	$1,130.1
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$2.5	$215.3	$2,755.3	$10,056.1	$19,535.5	$28,844.8	$42,207.5	$52,003.5
Postdisaster Recovery Costs	$0.0	$0.0	$8.8	$1,208.2	$3,423.2	$5,603.2	$8,509.9	$10,786.2
Utilities	$0.0	$0.0	$0.3	$45.5	$128.9	$210.9	$320.4	$406.1
Vehicles	$0.0	$0.0	$0.6	$49.1	$296.4	$942.1	$2,427.9	$4,019.8
Roads	$0.1	$2.5	$24.1	$100.2	$216.8	$330.2	$500.3	$628.7
Total Damages by Event	$2.6	$217.8	$2,789.1	$11,459.1	$23,600.8	$35,931.4	$53,966.0	$67,844.2
Percent Distribution by Event								
Residential	96.7%	98.8%	98.7%	87.4%	82.0%	79.1%	76.6%	75.0%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.1%	0.3%	0.8%	1.2%	1.6%	1.7%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.3%	10.5%	14.5%	15.6%	15.8%	15.9%
Utilities	0.0%	0.0%	0.0%	0.4%	0.5%	0.6%	0.6%	0.6%
Vehicles	0.0%	0.0%	0.0%	0.4%	1.3%	2.6%	4.5%	5.9%
Roads	3.3%	1.1%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-21
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
TURKEY CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$275.4	$2,626.8	$7,944.7	$17,848.6	$22,174.9	$35,060.7	$49,646.8
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.3	$1.1
Commercial	$0.0	$0.0	$9.9	$38.7	$139.3	$198.6	$310.8	$500.6
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.6	$1.3
Damages to Structures, Contents	$0.0	$275.4	$2,636.8	$7,983.3	$17,987.9	$22,373.5	$35,372.4	$50,149.8
Postdisaster Recovery Costs	$0.0	$18.5	$568.5	$2,606.9	$6,530.2	$8,223.2	$12,119.2	$15,987.2
Utilities	$0.0	$0.7	$21.4	$98.1	$245.8	$309.6	$456.3	$601.9
Vehicles	$0.0	$0.0	$2.7	$48.7	$286.3	$449.7	$1,565.2	$3,833.1
Roads	$3.3	$32.8	$108.7	$149.8	$186.4	$194.0	$225.5	$231.0
Total Damages by Event	$3.3	$327.4	$3,338.1	$10,886.9	$25,236.7	$31,550.0	$49,738.6	$70,803.1
Percent Distribution by Event								
Residential	0.0%	84.1%	78.7%	73.0%	70.7%	70.3%	70.5%	70.1%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.3%	0.4%	0.6%	0.6%	0.6%	0.7%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	5.6%	17.0%	23.9%	25.9%	26.1%	24.4%	22.6%
Utilities	0.0%	0.2%	0.6%	0.9%	1.0%	1.0%	0.9%	0.9%
Vehicles	0.0%	0.0%	0.1%	0.4%	1.1%	1.4%	3.1%	5.4%
Roads	100.0%	10.0%	3.3%	1.4%	0.7%	0.6%	0.5%	0.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-22
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
MARY'S CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

Damage Category	Annual Exceedance Probability Events							
	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$663.4	$5,547.9	$11,933.7	$28,149.3	$31,672.0	$68,891.0	$79,737.1	$92,128.5
Public	$0.4	$9.4	$26.7	$92.9	$108.6	$617.6	$796.4	$915.5
Commercial	$4.3	$84.5	$442.8	$1,264.1	$1,343.0	$2,652.1	$3,532.9	$4,480.1
Industrial	$0.0	$32.2	$933.3	$6,038.7	$6,084.7	$10,679.7	$17,164.3	$22,631.2
Damages to Structures, Contents	$668.1	$5,674.0	$13,336.5	$35,545.0	$39,208.2	$82,840.3	$101,230.7	$120,155.2
Postdisaster Recovery Costs	$437.8	$2,390.9	$4,456.5	$10,026.8	$10,855.8	$17,569.1	$19,431.4	$21,823.4
Utilities	$16.3	$90.0	$167.8	$377.5	$408.7	$661.4	$731.5	$821.6
Vehicles	$6.1	$131.7	$345.8	$1,390.8	$1,594.6	$8,657.8	$10,782.9	$13,067.8
Roads	$57.4	$263.3	$379.0	$539.9	$559.7	$624.6	$667.4	$669.5
Total Damages by Event	$1,185.6	$8,549.9	$18,685.5	$47,880.1	$52,627.0	$110,353.2	$132,843.9	$156,537.6
Percent Distribution by Event								
Residential	56.0%	64.9%	63.9%	58.8%	60.2%	62.4%	60.0%	58.9%
Public	0.0%	0.1%	0.1%	0.2%	0.2%	0.6%	0.6%	0.6%
Commercial	0.4%	1.0%	2.4%	2.6%	2.6%	2.4%	2.7%	2.9%
Industrial	0.0%	0.4%	5.0%	12.6%	11.6%	9.7%	12.9%	14.5%
Postdisaster Recovery Costs	36.9%	28.0%	23.8%	20.9%	20.6%	15.9%	14.6%	13.9%
Utilities	1.4%	1.1%	0.9%	0.8%	0.8%	0.6%	0.6%	0.5%
Vehicles	0.5%	1.5%	1.9%	2.9%	3.0%	7.8%	8.1%	8.3%
Roads	4.8%	3.1%	2.0%	1.1%	1.1%	0.6%	0.5%	0.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-23
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
COWART CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$47.8	$126.8	$282.7	$542.7	$950.9	$1,839.0	$2,612.0
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$13.7	$35.7	$43.9	$50.5	$58.2	$70.2	$79.9
Industrial	$0.0	$1.5	$12.5	$23.1	$30.4	$36.4	$42.9	$47.2
Damages to Structures, Contents	$0.0	$63.0	$175.0	$349.7	$623.6	$1,045.6	$1,952.0	$2,739.2
Postdisaster Recovery Costs	$49.9	$236.6	$386.2	$535.6	$685.4	$839.2	$1,043.2	$1,191.3
Utilities	$1.9	$8.9	$14.5	$20.2	$25.8	$31.6	$39.3	$44.8
Vehicles	$0.0	$5.2	$25.6	$49.8	$78.6	$122.2	$208.2	$290.5
Roads	$0.5	$1.9	$5.4	$10.6	$18.7	$31.2	$57.9	$80.5
Total Damages by Event	$52.3	$315.6	$606.6	$965.9	$1,432.2	$2,069.8	$3,300.6	$4,346.3
Percent Distribution by Event								
Residential	0.0%	15.2%	20.9%	29.3%	37.9%	45.9%	55.7%	60.1%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	4.3%	5.9%	4.5%	3.5%	2.8%	2.1%	1.8%
Industrial	0.0%	0.5%	2.1%	2.4%	2.1%	1.8%	1.3%	1.1%
Postdisaster Recovery Costs	95.4%	75.0%	63.7%	55.5%	47.9%	40.5%	31.6%	27.4%
Utilities	3.6%	2.8%	2.4%	2.1%	1.8%	1.5%	1.2%	1.0%
Vehicles	0.0%	1.6%	4.2%	5.2%	5.5%	5.9%	6.3%	6.7%
Roads	1.0%	0.6%	0.9%	1.1%	1.3%	1.5%	1.8%	1.9%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 1-24
SINGLE OCCURRENCE DAMAGES BY EVENT
WITHOUT-PROJECT 2070 CONDITION
CHIGGER CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$6.0	$163.6	$285.7	$465.3	$728.7	$1,167.4	$1,977.4	$2,811.2
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$1.6	$4.4	$5.7	$7.0	$9.3	$12.7	$14.6
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$6.0	$165.2	$290.1	$471.0	$735.7	$1,176.7	$1,990.1	$2,825.8
Postdisaster Recovery Costs	$1.0	$38.8	$60.6	$78.5	$122.5	$199.3	$302.9	$436.5
Utilities	$0.0	$1.5	$2.3	$3.0	$4.6	$7.5	$11.4	$16.4
Vehicles	$0.0	$0.9	$8.1	$20.6	$27.9	$41.9	$75.9	$129.1
Roads	$1.0	$6.6	$10.8	$17.4	$27.0	$42.8	$71.5	$89.8
Total Damages by Event	$8.0	$212.9	$371.8	$590.5	$917.6	$1,468.2	$2,451.8	$3,497.7
Percent Distribution by Event								
Residential	74.5%	76.9%	76.8%	78.8%	79.4%	79.5%	80.6%	80.4%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.7%	1.2%	1.0%	0.8%	0.6%	0.5%	0.4%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	12.0%	18.2%	16.3%	13.3%	13.3%	13.6%	12.4%	12.5%
Utilities	0.5%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%
Vehicles	0.0%	0.4%	2.2%	3.5%	3.0%	2.9%	3.1%	3.7%
Roads	13.0%	3.1%	2.9%	2.9%	2.9%	2.9%	2.9%	2.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Attachment 2
First and Second-Added Analysis Process

First-Added Measures Analysis – Initial Screening of Stand-Alone Features. The first-added measures phase of the formulation process is described in the report entitled *Clear Creek General Reevaluation Report, Flood Damage Reduction, 1st Added Measures Results,* dated July 2004, (see attachment to the main report). The 1st Added Measures report documents the identification and ranking of individual flood risk mitigation measures analyzed for the Clear Creek GRR study. A total of twenty-four different structural and nonstructural measures were analyzed on a stand-alone basis to determine their costs and benefits. The measures can be grouped into the following broad categories:

Nonstructural measures:

Buyout – Buyout of structures at various frequencies along the main stem of Clear Creek.

Structural measures:

Conveyance measures – Ten measures in three sizes each including channel rectification, clearing and snagging, cutoffs and bypasses, bridge modifications, removal of side-cast dredge material mounds, and increasing the outlet capacity from Clear Lake.

Detention measures – Twelve measures in three sizes each including off-line detention and linear detention at sites along the main stem and major tributaries.

Watershed management – Creation of 100 percent effective, basin-wide detention policy for new development.

For the first-added measures analysis, each measure was analyzed without risk and uncertainty using the HEC-FDA program, at 2001 price levels. Early in the screening of measures the decision was made to screen alternatives in the base condition only; the reason being that any measures should be justified in the base condition before moving on to the next step. The analytical results of the first-added measures are shown in the First-Added Measures report, Table 1 – Summary Table.

The results of the first-added measures analysis helped provide insight into the relative effectiveness of the proposed measures. This helped the team plan a strategy for formulating the Recommended Plan, the plan that maximizes net benefits. With the knowledge gained from the first-added process, it was determined that the process for combining and testing measures should begin in the upstream reach of Clear Creek.

Second-Added Measures Analysis - Building a System for Flood Risk Management. The second-added measures phase of the formulation process involved combining measures to arrive at a complete Recommended Plan. The second-added measures process can be separated into four phases for economic purposes. The first phase was conducted at 2001 prices levels and discount rate appropriate at the time, with uncertainty. Not all uncertainty parameters or benefit categories were defined at the time of the first phase, as the analysis and data were continuing to evolve. The second phase was conducted at 2005 price levels and discount rate appropriate at the time. Additional damage categories were added during the second phase of the analysis, as well as additional uncertainty parameters applied, however, the data and analysis was continuing to evolve, with minor damage categories to be added later. The third phase of the second-added analysis was conducted at October 2007 price levels and 4.875 percent discount rate. The fourth phase was initiated in 2008 price levels and discount rate, but was completed in 2010 price levels and at the rate of 4.375 percent. The sequence of competing and aggregating second-added measures is described in detail below.

The second-added measures analysis included optimization and incremental justification of every measure investigated. In this way, poor performing and less-optimal measures were eliminated from further consideration. This phase began with optimization of an upstream anchor component. Additional measures were added sequentially in a downstream direction. The individual measures were tested in three or more sizes. If a measure was optimized and incrementally justified, it was carried through with any previously selected measures to the next step. This systematic approach ensured that the resultant combination of measures improved, economically speaking, with each step, or measure, added.

Measures analyzed in the second-added measures phase of the analysis included:

Nonstructural measures:

Buyout – Buyout of structures at various frequencies along the main stem and tributaries of Clear Creek.

Structural measures:

Conveyance measures – Fourteen conveyance measures on the upstream of the main stem in order to establish the anchor. Three conveyance measures were investigated on Mud Gully. Conveyance improvement investigated on Turkey Creek in five sizes, as well as conveyance improvement on Mary’s Creek in fourteen sizes. Upper reach main stem conveyance measures were investigated in five sizes. Mid-reach conveyance measures on the main stem in nine sizes, and lower reach measures on the main stem in eight sizes.

Detention measures – At least seven measures in twenty-five sizes each including off-line detention and linear detention at sites along the main stem and major tributaries.

Phase 1 – Second-Added Measures Analysis: This phase began with testing and optimization of an upstream anchor component. Additional measures were added sequentially in a downstream direction. The individual measures were tested in three or more sizes. If a measure was optimized and incrementally justified, it was carried through with any previously selected measures to the next step. This systematic approach ensured that the resultant alternative improved with each step, or measure, added. The specific measures tested are described below and in the Second-Added Measures Notebook (Exhibit 2-4 to the H&H portion of the Engineering Appendix). Table 2-1 illustrates the optimization and incremental analysis of the first phase of the second-added analysis for the main stem and tributaries. Tables 2-2, 2-3 and 2-4 detail the first phase of the second-added measures optimization and incremental analysis for the individual tributaries (Mud, Turkey and Mary's, respectively).

Phase 1 of the second-added measures process resulted in optimization of upstream anchor channel improvement on the main stem, additional upstream channelization on the main stem, mid-reach channelization on the main stem, channelization on Mud Gully, channelization on Turkey Creek, and channelization on Mary's Creek.

Details of Phase 1 – Second-Added Measures Process:

Step 1: Selection and optimization of Upstream Anchor

- Conveyance improvement on the main stem (SH 288 to Bennie Kate Rd.) (SuperC)
- System testing of conveyance measure combined with detention near Bennie Kate (Super Ca with Detention)
- Shortened bench-cut conveyance measure on Clear Creek (SH288 to BNSF RR) (SuperC Shortened)
- System testing of conveyance measure combined with offline detention near Mykawa (SuperCa with Detention)

Measure Justified/Optimized? Yes, Conveyance improvements on main stem (SuperCd)

Step 2: Test for Clear Creek upper-reach measures

- Linear Detention on Clear Creek from Bennie Kate to Dixie Farm Road (LD4)
- Bench-cut conveyance on Clear Creek from Bennie Kate to Dixie Farm Road (C5)

Measure Justified/Optimized? No

Step 3: Test for measures on Mud Gully

- Conveyance improvement from Sagedowne to Astoria (MUC1)

  Measure Justified/Optimized? Yes, Mud conveyance from Sagedowne to Astoria (MUC1b) – for detailed incremental analysis on Mud Gully, Table 2-2.

Step 4: Test for measures on Turkey Creek

- Conveyance improvement from Dixie Farm Road to Mouth (TKC1)

  Measure Justified/Optimized? Yes, Turkey conveyance from Dixie Farm Road to Mouth (TKC1d) - for detailed incremental analysis on Turkey, see Table 2-3.

Step 5: Test for measures on Mary's Creek

- Conveyance from BN&SF RR to SH 35 (MAC1)
- Conveyance from Harkey Road to SH35 (MAC2)
- Conveyance on Mary's Creek By-Pass Channel (MAC3)
- Offline detention at existing West Mary's and SWEC Facilities (MAD1)
- System testing of detention measure (MAD1b) combined with 3 sizes of conveyance (MAC2)

  Measure Justified/Optimized? Yes, Mary's conveyance from Harkey Road to SH35 (MAC2a) - for detailed incremental analysis on Mary's Creek, see Table 2-4.

Step 6: Re-test Best Performing Upper Reach Main Stem Measure

- Bench-cut conveyance on Clear from Bennie Kate to Dixie Farm Road (C5d)

  Measure Justified/Optimized? Yes, system effect with other measures in place improved performance of C5d

Step 7: Test for Clear Creek mid-reach measures

- Enlarge existing high-flow bypasses on main stem (EHFB)
- Conveyance improvement on Clear Creek from FM2351 to FM528 (C4)
- Conveyance improvement on Clear Creek (clearing and snagging) from FM2351 to D/S of Chigger Confluence (CS)

  Measure Justified/Optimized? Yes, Conveyance Improvement (clearing and snagging) from FM 2351 to D/S of Chigger confluence (CSb)

Step 8: Test for Clear Creek lower-reach measures

- Conveyance improvement on main stem (enlarge/add to I-45 bridge opening) (I-45)
- Conveyance improvement on main stem (additional Clear Lake outlet capacity) (ACLO)

  Measure Justified/Optimized: No

Table 2-1

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2001 price levels

Formulation Sequence	**Plan Description/Measure Added**	**2020 Expected Annual Damages in thousands**	**Net Expected Annual Damages Reduced in thousands**	**PWE Damages Reduced in thousands 6.125% a**	**Total Project Cost in thousands b**	**net excess benefits a-b**	**AAEV net excess benefits 6.125%**	**BCR a/b**
	Without project condition, mainstem and tributaries	**$12,900.0**						
Step 1 - Selection and Optimization of Upstream Anchor Component	SuperCa	$10,034.4	$2,865.5	$44,389.7	$32,152.8	$12,236.9	$789.9	1.38
	SuperCb	$9,879.7	$3,020.3	$46,787.4	$41,689.6	$5,097.8	$329.1	1.12
	SuperCc	$9,845.9	$3,054.1	$47,310.9	$51,281.4	-$3,970.5	-$256.3	0.92
	SuperCd	**$10,533.6**	**$2,366.4**	**$36,658.0**	**$20,724.1**	**$15,933.9**	**$1,028.6**	**1.77**
	SuperCe	$11,814.4	$1,085.6	$16,816.6	$6,861.7	$9,954.9	$642.6	2.45
	SuperCa w/Detention a	$9,333.4	$3,566.6	$55,249.3	$84,192.7	-$28,943.4	-$1,868.4	0.66
	SuperCa w/Detention b	$9,002.1	$3,897.9	$60,381.2	$120,265.8	-$59,884.6	-$3,865.8	0.50
	SuperCa w/Detention c	$8,996.9	$3,903.1	$60,462.6	$156,469.9	-$96,007.3	-$6,197.7	0.39
	SuperC Shortened a	$12,814.6	$85.4	$1,322.3	$2,649.7	-$1,327.4	-$85.7	0.50
	SuperC Shortened b	$12,794.3	$105.6	$1,636.3	$5,180.7	-$3,544.4	-$228.8	0.32
	SuperC Shortened c	$12,698.0	$201.9	$3,128.1	$7,509.4	-$4,381.3	-$282.8	0.42
	Super Ca	$10,034.4	$2,865.5	$44,389.7	$32,152.8	$12,236.9	$789.9	1.38
	with increment detention a	$12,198.9	$701.0	$10,859.6	$52,039.9	-$41,180.3	-$2,658.4	0.21
	with increment detention b	$11,867.7	$1,032.3	$15,991.6	$88,113.0	-$72,121.4	-$4,655.7	0.18
	with increment detention c	$11,862.4	$1,037.6	$16,072.9	$124,317.1	-$108,244.2	-$6,987.6	0.13

Notes: ^[1] C5e costs subtracted from all previous C5 sizes to estimate FDR costs only (C5e provided ecosystem restoration only).

Only FDR features modeled for NED benefit analysis.

PWE = Present worth equivalent (6.125%, 50-yr)

AAEV = Average Annual Equivalent Value (6.125%, 50-yr)

Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.

Screening level cost estimates provided by Cost Engineering.

Table 2-1 - continued

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2001 price levels

Formulation Sequence	**Plan Description/Measure Added**	**2020 Expected Annual Damages in thousands**	**Net Expected Annual Damages Reduced in thousands**	**PWE Damages Reduced in thousands 6.125% a**	**Total Project Cost in thousands b**	**net excess benefits a-b**	**AAEV net excess benefits 6.125%**	**BCR a/b**
	Without project condition, mainstem and tributaries	**$12,900.0**						
Step 2 - Test for Upper Reach Measures	Super Cd + LD4a	$10,337.2	$2,562.8	$39,700.4	$32,274.1	$7,426.3	$479.4	1.23
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment LD4a		$196.4	$3,042.4	$11,550.0	-$8,507.6	-$549.2	0.26
	Super Cd + LD4b	$9,988.8	$2,911.2	$45,097.1	$39,387.6	$5,709.5	$368.6	1.14
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment LD4b		$544.8	$8,439.1	$18,663.5	-$10,224.4	-$660.0	0.45
	Super Cd + LD4c	$9,793.4	$3,106.5	$48,123.0	$48,070.1	$52.8	$3.4	1.00
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment LD4c		$740.1	$11,465.0	$27,346.0	-$15,881.0	-$1,025.2	0.42
	SuperCd + C5a^[1]	$10,187.4	$2,712.5	$42,019.6	$32,119.9	$9,899.7	$639.1	1.31
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment C5a^[1]		$346.1	$5,361.6	$11,395.8	-$6,034.2	-$389.5	0.47
	SuperCd + C5b^[1]	$10,023.4	$2,876.5	$44,560.2	$36,836.6	$7,723.6	$498.6	1.21
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment C5b^[1]		$510.1	$7,902.2	$16,112.5	-$8,210.2	-$530.0	0.49
	SuperCd + C5c^[1]	$9,877.7	$3,022.3	$46,817.7	$41,876.2	$4,941.5	$319.0	1.12
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment C5c^[1]		$655.8	$10,159.7	$21,152.1	-$10,992.4	-$709.6	0.48
	SuperCd + C5d ^[1]	$10,472.8	$2,427.1	$37,598.5	$23,361.9	$14,236.5	$919.0	1.61
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment C5d^[1]		$60.7	$940.5	$2,637.8	-$1,697.4	-$109.6	0.36
	SuperCd + C5e	$11,305.0	$1,594.9	$24,707.1	$20,724.1	$3,982.9	$257.1	1.19
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment C5e (eco_restoration only, no FDR)		-$771.5	-$11,950.9	$0.0	-$11,950.9	-$771.5	

Notes: ^[1] C5e costs subtracted from all previous C5 sizes to estimate FDR costs only (C5e provided ecosystem restoration only).
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Table 2-1 – continued
Phase 1 – Optimization and Incremental Justification of Second-Added Measures
Clear Creek – Main Stem and Tributaries
Oct 2001 price levels

Formulation Sequence	**Plan Description/Measure Added**	**2020 Expected Annual Damages in thousands**	**Net Expected Annual Damages Reduced in thousands**	**PWE Damages Reduced in thousands 6.125% a**	**Total Project Cost in thousands b**	**net excess benefits a-b**	**AAEV net excess benefits 6.125%**	**BCR a/b**
	Without project condition, mainstem and tributaries	**$12,900.0**						
Steps 3 & 4 - Mud & Turkey (see trib analysis tables)	SuperCd+MUC1b+TKC1d	$9,519.0	$3,381.0	$52,374.3	$34,712.0	$17,662.3	$1,140.2	1.51
	with increment SuperCd	$10,533.6	$2,366.4	$36,658.0	$20,724.1	$15,933.9	$1,028.6	1.77
	with increment MUC1b+TKC1d		**$1,014.6**	**$15,716.3**	**$13,987.9**	**$1,728.4**	**$111.6**	**1.12**
Step 5 - Mary's Creek (see trib analysis table)	SuperCd +MUC1b+TKC1d+MAC2a	$8,054.7	$4,845.3	$75,057.3	$42,055.0	$33,002.3	$2,130.4	1.78
	with increment 2nd Added-SuperCd+MUC1b+TKC1d	$9,519.0	$3,381.0	$52,374.3	$34,712.0	$17,662.3	$1,140.2	1.51
	with increment MAC2a		**$1,464.3**	**$22,683.0**	**$7,343.0**	**$15,340.0**	**$990.3**	**3.09**
Step 6 - Re-Test Best Perform-ing Upper Reach Measure	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment 2nd Added-SuperCd +MUC1b+TKC1d+MAC2a	$8,054.7	$4,845.3	$75,057.3	$42,055.0	$33,002.3	$2,130.4	1.78
	with increment C5d		**$196.5**	**$3,044.6**	**$2,637.8**	**$406.8**	**$26.3**	**1.15**

Notes: ^[1] C5e costs subtracted from all previous C5 sizes to estimate FDR costs only (C5e provided ecosystem restoration only).
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Table 2-1 – continued
Phase 1 – Optimization and Incremental Justification of Second-Added Measures
Clear Creek – Main Stem and Tributaries
Oct 2001 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced in thousands	PWE Damages Reduced in thousands 6.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 6.125%	BCR a/b
	Without project condition, mainstem and tributaries	**$12,900.0**						
Step 7 - Test for Mid-Reach Measures	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+EHFBa	$7,804.1	$5,095.9	$78,939.7	$45,636.9	$33,302.8	$2,149.8	1.73
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment EHFBa		$54.1	$837.7	$944.1	-$106.3	-$6.9	0.89
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+EHFBb	$7,789.3	$5,110.7	$79,168.8	$45,908.6	$33,260.2	$2,147.1	1.72
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment EHFBb		$68.9	$1,066.9	$1,215.8	-$148.9	-$9.6	0.88
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+EHFBc	$7,774.0	$5,126.0	$79,406.6	$46,388.0	$33,018.5	$2,131.5	1.71
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment EHFBc		$84.2	$1,304.6	$1,695.2	-$390.6	-$25.2	0.77
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + CSa	$7,734.6	$5,165.4	$80,016.6	$45,005.6	$35,011.0	$2,260.1	1.78
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment CSa		$123.6	$1,914.7	$312.8	$1,601.9	$103.4	6.12
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment CSb		**$706.1**	**$10,937.4**	**$3,682.4**	**$7,255.0**	**$468.3**	**2.97**
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + CSc	$7,105.4	$5,794.6	$89,763.9	$53,334.3	$36,429.7	$2,351.7	1.68
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment CSc		$752.8	$11,662.0	$8,641.5	$3,020.6	$195.0	1.35
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + C4a	$6,697.4	$6,202.6	$96,083.3	$58,023.8	$38,059.5	$2,456.9	1.66
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment C4a		$1,160.8	$17,981.4	$13,331.0	$4,650.4	$300.2	1.35
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + C4b	$6,601.7	$6,298.3	$97,565.9	$61,853.8	$35,712.1	$2,305.4	1.58
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment C4b		$1,256.5	$19,464.0	$17,161.0	$2,303.0	$148.7	1.13
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a + C4c	$6,577.6	$6,322.4	$97,939.6	$65,747.8	$32,191.7	$2,078.1	1.49
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$7,858.2	$5,041.8	$78,101.9	$44,692.8	$33,409.1	$2,156.7	1.75
	with increment C4c		$1,280.6	$19,837.7	$21,055.0	-$1,217.3	-$78.6	0.94

Notes: ^[1] C5e costs subtracted from all previous C5 sizes to estimate FDR costs only (C5e provided ecosystem restoration only).
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Table 2-1 – continued

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2001 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced in thousands	PWE Damages Reduced in thousands 6.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 6.125%	BCR a/b
	Without project condition, mainstem and tributaries	**$12,900.0**						
Step 8 - Test for Lower Reach Measures	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb+I-45a	$7,148.1	$5,751.9	$89,101.4	$50,138.9	$38,962.5	$2,515.2	1.78
	with increment SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment I-45a		$4.0	$62.1	$1,763.7	-$1,701.6	-$109.8	0.04
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb+I-45b	$7,146.2	$5,753.7	$89,130.7	$51,388.0	$37,742.6	$2,436.4	1.73
	with increment SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment I-45b		$5.9	$91.4	$3,012.8	-$2,921.4	-$188.6	0.03
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb+I-45c	$7,140.9	$5,759.1	$89,213.5	$52,379.3	$36,834.3	$2,377.8	1.70
	with increment SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment I-45c		$11.3	$174.3	$4,004.1	-$3,829.8	-$247.2	0.04
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb+I-45d	$7,150.9	$5,749.1	$89,058.3	$48,666.7	$40,391.7	$2,607.4	1.83
	with increment SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment I-45d		$1.2	$19.1	$291.5	-$272.4	-$17.6	0.07
	SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb+I-45e	$7,133.1	$5,766.8	$89,333.6	$49,742.6	$39,591.0	$2,555.8	1.80
	with increment SuperCd+C5d^[1]+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment I-45e		$19.0	$294.3	$1,367.4	-$1,073.0	-$69.3	0.22
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb+ACLOa	$6,964.5	$5,935.5	$91,946.0	$59,913.3	$32,032.7	$2,067.8	1.53
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment ACLOa		$187.6	$2,906.7	$11,538.1	-$8,631.4	-$557.2	0.25
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb+ACLOb	$6,936.7	$5,963.3	$92,376.2	$65,682.4	$26,693.8	$1,723.2	1.41
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment ACLOb		$215.4	$3,336.9	$17,307.2	-$13,970.3	-$901.8	0.19
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb+ACLOc	$6,914.8	$5,985.2	$92,715.9	$71,451.4	$21,264.4	$1,372.7	1.30
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb	$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84
	with increment ACLOc		$237.3	$3,676.6	$23,076.2	-$19,399.6	-$1,252.3	0.16
Measures carried forward to Phase 2: SuperCd + C5d^[1] + MUC1b + TKC1d + MAC2a + CSb		$7,152.1	$5,747.8	$89,039.3	$48,375.2	$40,664.1	$2,625.0	1.84

Notes: ^[1] C5e costs subtracted from all previous C5 sizes to estimate FDR costs only (C5e provided ecosystem restoration only).

Only FDR features modeled for NED benefit analysis.

PWE = Present worth equivalent (6.125%, 50-yr)

AAEV = Average Annual Equivalent Value (6.125%, 50-yr)

Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.

Screening level cost estimates provided by Cost Engineering.

Table 2-2

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Mud Gully

Oct 2001 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 6.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 6.125%	BCR a/b
	Without project condition, Mud Gully	$1,180.7						
Step 3 - Test for Measures on Mud Gully	MUC1a	$705.3	$475.4	$7,363.6	$5,406.5	$1,957.1	$126.3	1.36
	MUC1b	**$594.8**	**$585.9**	**$9,075.5**	**$6,467.8**	**$2,607.7**	**$168.3**	**1.40**
	MUC1c	$551.1	$629.6	$9,753.1	$7,527.4	$2,225.7	$143.7	1.30

Notes: * Includes main stem effect (downstream of Reach 13)
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Table 2-3

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Turkey Creek

Oct 2001 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 6.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 6.125%	BCR a/b
	Without project condition, Turkey Creek	$656.0						
Step 4 - Test for Measures on Turkey Creek	TKC1a	$86.6	$569.4	$8,820.1	$7,357.4	$1,462.7	$94.4	1.20
	TKC1b	$42.6	$613.4	$9,502.1	$10,519.7	-$1,017.5	-$65.7	0.90
	TKC1c	$19.1	$636.9	$9,865.7	$13,717.4	-$3,851.7	-$248.6	0.72
	TKC1d (smaller than a)	**$108.4**	**$547.6**	**$8,482.4**	**$6,152.9**	**$2,329.5**	**$150.4**	**1.38**
	TKC1e (smaller than d)	$149.7	$506.3	$7,843.0	$5,645.0	$2,198.1	$141.9	1.39

Notes: * Includes main stem effect (downstream of Reach 12)
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Table 2-4

Phase 1 – Optimization and Incremental Justification of Second-Added Measures

Mary's Creek

Oct 2001 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 6.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 6.125%	BCR a/b
	Without project condition, Mary's Creek	**$2,944.1**						
Step 5 - Test for Measures on Mary's Creek	MAC1a	$2,237.0	$707.1	$10,953.5	$2,277.6	$8,675.8	$560.1	4.81
	MAC1b	$2,214.4	$729.7	$11,303.6	$4,089.2	$7,214.4	$465.7	2.76
	MAC1c	$2,163.0	$781.0	$12,098.6	$5,899.4	$6,199.1	$400.2	2.05
	MAC2a	**$1,489.6**	**$1,454.4**	**$22,530.4**	**$7,343.0**	**$15,187.4**	**$980.4**	**3.07**
	MAC2b	$1,359.5	$1,584.6	$24,546.9	$12,676.0	$11,870.9	$766.3	1.94
	MAC2c	$1,259.9	$1,684.1	$26,088.9	$18,032.0	$8,056.9	$520.1	1.45
	MAC2d	$1,129.1	$1,815.0	$28,115.7	$21,323.0	$6,792.7	$438.5	1.32
	MAC2e	$1,574.8	$1,369.3	$21,211.5	$8,312.4	$12,899.1	$832.7	2.55
	MAC3a	$2,937.1	$7.0	$108.3	$668.6	-$560.3	-$36.2	0.16
	MAC3b	$2,548.5	$395.5	$6,127.3	$1,112.7	$5,014.5	$323.7	5.51
	MAC3c	$2,426.4	$517.7	$8,019.3	$1,577.1	$6,442.2	$415.9	5.08
	MAD1a	$2,275.4	$668.6	$10,357.5	$7,189.5	$3,168.1	$204.5	1.44
	MAD1b	$1,831.3	$1,112.7	$17,237.2	$12,295.5	$4,941.7	$319.0	1.40
	MAD1c	$1,366.9	$1,577.1	$24,431.0	$22,460.7	$1,970.3	$127.2	1.09

Notes: * Includes main stem effect (downstream of Reach 11)
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (6.125%, 50-yr)
AAEV = Average Annual Equivalent Value (6.125%, 50-yr)
Not all damage categories included, not all uncertainty parameters defined at this early stage of analysis.
Screening level cost estimates provided by Cost Engineering.

Phase 2 – Second-Added Measures Analysis: Phase 2 of the second-added measures analysis was simply a continuation of the phase 1, however, price levels and discount rates were updated to 2005 levels. All risk parameters were applied during this phase and all but the minor category of damages to roads were included. The phase 1 analysis resulted in a complete channelization project, so phase 2 would focus on feasibility of the addition of detention measures.

This phase began with re-evaluation of the mid-reach measure, Clearing and Snagging (CSb). An in-depth environmental analysis was conducted by the Inter-Agency Coordination Team (ICT) on this particular measure due to the environmentally pristine nature of the area. The environmental analysis revealed that the mitigation costs would be significantly higher than the preliminary estimate, resulting in failure of the measure to be incrementally justified. Therefore, Clearing and Snagging (CSb) was dropped from further consideration. Of note is the fact that the measure C4 from the phase 1 analysis was also dropped from further consideration because the measure has the same footprint in the same reach.

The specific measures tested in phase 2 are described below. Table 2-5 illustrates the optimization and incremental analysis of the second phase of the second-added analysis. Tables 2-6, 2-7 and 2-8 detail the second phase of the second-added measures optimization and incremental analysis for the tributaries (Mud, Chigger and Mary's, respectively).

Phase 2 of the second-added measures process resulted in removal of one of the previously selected measures, clearing and snagging, from the mid-reach of the main stem, addition of detention on Mud Gully, addition of inline and offline detention on the main stem, as well as detention on Mary's Creek.

Details of Phase 2 – Second-Added Measures Process:

Step 1: Re-evaluation of selected Clear Creek mid-reach measures due to detailed environmental analysis

- Conveyance improvement on Clear Creek (clearing and snagging) from FM 2351 to D/S of Chigger Confluence (CS) – size CSb optimized in Phase 1. Re-evaluated sizes CSa & CSb with revised environmental mitigation estimates.

  Measure Justified/Optimized? No, resulting in CSb removed from further consideration

Step 2: Test for additional measures on Mud Gully

- Offline detention on Mud Gully (Mud Det) (for detailed incremental analysis on Mud Creek see Table 2-6)

  Measure Justified/Optimized? Yes, 1,515 acre-foot detention, representing largest size detention size analyzed; size is limited by the maximum available capacity at the site (Mud Det C).

Step 3: Test for measures on Chigger Creek

- Inline detention on Chigger Creek (Chig Det) (for detailed incremental analysis on Chigger Creek, see Table 2-7)

  Measure Justified/Optimized? No

Step 4: Test for additional measures on Clear Creek

- Inline and offline detention on Clear Creek (tested as one measure in three sizes (a, b & c) and three roughness coefficients (rough, average, & smooth), for a total of 9 combinations). The naming convention for the measure is as follows: ClrCrk Det rough-a (rough, size a), ClrCrk Det average-b (average roughness, size b), etc.

  Measure Justified/Optimized? Yes, ClrCrk Det smooth-b (smooth, size b)

Step 5: Test for additional measures on Mary's Creek

- Offline detention on Mary's Creek (incorporation of percentage of existing detention sites, SWEC and West Mary's) (MAD1) (for detailed incremental analysis on Mary's Creek, see Table A-8)

  Measure Justified/Optimized? Yes, 857 acre-feet detention (representing 75 percent of existing SWEC and West Mary's sites) (Size MAD1b1/2)

Table 2-5

Phase 2 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2005 price levels

Formulation Sequence	**Plan Description/Measure Added**	**2020 Expected Annual Damages in thousands**	**Net Expected Annual Damages Reduced* in thousands**	**PWE Damages Reduced in thousands 5.125% a**	**Total Project Cost in thousands b**	**net excess benefits a-b**	**AAEV net excess benefits 5.125%**	**BCR a/b**
	Without project condition, mainstem and tributaries	**$37,157.0**						
	End of Phase 1: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb (with revised environmental analysis)	**$21,074.5**	**$16,082.6**	**$288,021.6**	**$120,402.7**	**$167,618.9**	**$9,359.5**	**2.39**
Step 1 - Re-evaluation of mid-reach measures using detailed environmental analysis	End of Phase 1: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSb (with revised environmental analysis)	$21,074.5	$16,082.6	$288,021.6	$120,402.7	$167,618.9	$9,359.5	2.35
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	**$22,710.3**	**$14,446.7**	**$258,725.3**	**$64,448.4**	**$194,276.9**	**$10,848.0**	**4.01**
	with increment CSb (with revised environmental analysis)		$1,635.9	$29,296.3	$55,954.3	-$26,658.0	-$1,488.5	0.52
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+CSa (with revised environmental analysis)	$22,426.4	$14,730.6	$263,809.1	$92,452.9	$171,356.2	$9,568.2	2.85
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$22,710.3	$14,446.7	$258,725.3	$64,448.4	$194,276.9	$10,848.0	4.01
	with increment CSa		$283.9	$5,083.8	$28,004.5	-$22,920.7	-$1,279.8	0.18
Step 2 - Test add'l measures on Mud (see trib analysis table)	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$22,710.3	$14,446.7	$258,725.3	$64,448.4	$194,276.9	$10,848.0	4.01
	with increment Mud Det C (largest capacity available at site)		**$1,557.2**	**$27,887.4**	**$25,790.1**	**$2,097.3**	**$117.1**	**1.08**
Step 3 - Test measures on Chigger Creek (see trib analysis table)	No measures justified - see Phase 2 table for Chigger Creek for details							

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (5.125%, 50-yr)
AAEV = Average Annual Equivalent Value (5.125%, 50-yr)
All damage categories included, except roads.
Calculated with risk & uncertainty.
Screening level cost estimates provided by Cost Engineering.

Table 2-5 - continued

Phase 2 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2005 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 5.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 5.125%	BCR a/b
	Without project condition, mainstem and tributaries	**$37,157.0**						
Step 4 - Test for additional measures on Clear Creek	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det average-a	$19,190.4	$17,966.6	$321,762.2	$124,337.6	$197,424.6	$11,023.8	2.59
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det average-a		$1,962.7	$35,149.5	$34,099.1	$1,050.4	$58.7	1.03
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det average-b	$17,649.6	$19,507.5	$349,357.5	$146,102.5	$203,255.0	$11,349.4	2.39
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det average-b		$3,503.6	$62,744.8	$55,864.0	$6,880.8	$384.2	1.12
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det average-c	$16,741.7	$20,415.3	$365,615.8	$195,803.5	$169,812.2	$9,482.0	1.87
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det average-c		$4,411.4	$79,003.1	$105,565.0	-$26,561.9	-$1,483.2	0.75
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det rough-a	$19,951.9	$17,205.1	$308,124.9	$125,235.5	$182,889.5	$10,212.2	2.46
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det rough-a		$1,201.2	$21,512.2	$34,996.9	-$13,484.7	-$753.0	0.61
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det rough-b	$18,435.1	$18,721.9	$335,289.4	$147,000.4	$188,289.0	$10,513.7	2.28
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det rough-b		$2,718.0	$48,676.6	$56,761.9	-$8,085.2	-$451.5	0.86
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det rough-c	$17,423.0	$19,734.0	$353,415.2	$196,701.4	$156,713.7	$8,750.6	1.80
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det rough-c		$3,730.1	$66,802.5	$106,462.9	-$39,660.4	-$2,214.6	0.63
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-a	$18,635.6	$18,521.4	$331,698.3	$123,482.8	$208,215.4	$11,626.3	2.69
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det smooth-a		$2,517.5	$45,085.5	$33,244.3	$11,841.2	$661.2	1.36
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b	$17,157.2	$19,999.9	$358,175.9	$145,247.8	$212,928.1	$11,889.5	2.47
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det smooth-b		**$3,996.0**	**$71,563.2**	**$55,009.2**	**$16,553.9**	**$924.3**	**1.30**
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-c	$16,624.2	$20,532.9	$367,721.7	$194,948.8	$172,772.9	$9,647.3	1.89
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C	$21,153.1	$16,003.9	$286,612.7	$90,238.5	$196,374.2	$10,965.2	3.18
	with increment ClrCrk Det smooth-c		$4,529.0	$81,109.0	$104,710.3	-$23,601.3	-$1,317.8	0.77
Step 5 - Test additional measures on Mary's (see trib analysis table)	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,035.7	$22,121.4	$396,170.0	$165,434.8	$230,735.2	$12,883.8	2.39
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b	$17,157.2	$19,999.9	$358,175.9	$145,247.8	$212,928.1	$11,889.5	2.47
	with increment MAD1B1/2		**$2,121.5**	**$37,994.2**	**$20,187.1**	**$17,807.1**	**$994.3**	**1.88**

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (5.125%, 50-yr)
AAEV = Average Annual Equivalent Value (5.125%, 50-yr)
All damage categories included, except roads.
Calculated with risk & uncertainty.
Screening level cost estimates provided by Cost Engineering.

Table 2-6
Phase 2 – Optimization and Incremental Justification of Second-Added Measures
Mud Gully
Oct 2005 price levels

Formulation Sequence	**Plan Description/Measure Added**	**2020 Expected Annual Damages in thousands**	**Net Expected Annual Damages Reduced* in thousands**	**PWE Damages Reduced in thousands 5.125% a**	**Total Project Cost in thousands b**	**net excess benefits a-b**	**AAEV net excess benefits 5.125%**	**BCR a/b**
	Without project condition, Mud Gully	$3,248.1						
Phase 1	**MUC1b**	**$1,831.5**	**$1,416.6**	**$25,369.8**	**$7,835.0**	**$17,534.8**	**$979.1**	**3.24**
Step 2 - Test additional measures on Mud Gully	MUC1b+Mud Det A	$1,407.8	$1,840.3	$32,957.8	$16,509.5	$16,448.3	$918.4	2.00
	with increment MUC1b	$1,831.5	$1,416.6	$25,369.8	$7,835.0	$17,534.8	$979.1	3.24
	with increment Mud Det A		$423.7	$7,588.0	$8,674.4	-$1,086.4	-$60.7	0.87
	MUC1b+Mud Det B	$938.9	$2,309.3	$41,356.2	$25,037.2	$16,319.0	$911.2	1.65
	with increment MUC1b	$1,831.5	$1,416.6	$25,369.8	$7,835.0	$17,534.8	$979.1	3.24
	with increment Mud Det B		$892.7	$15,986.4	$17,202.2	-$1,215.7	-$67.9	0.93
	MUC1b+Mud Det C	$121.3	$3,126.8	$55,997.6	$33,625.1	$22,372.5	$1,249.2	1.67
	with increment MUC1b	$1,831.5	$1,416.6	$25,369.8	$7,835.0	$17,534.8	$979.1	3.24
	with increment Mud Det C (largest capacity available at site)		**$1,710.2**	**$30,627.8**	**$25,790.1**	**$4,837.7**	**$270.1**	**1.19**

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (5.125%, 50-yr)
AAEV = Average Annual Equivalent Value (5.125%, 50-yr)
All damage categories included, except roads.
Calculated with risk & uncertainty.
Screening level cost estimates provided by Cost Engineering.

Table 2-7
Phase 2 – Optimization and Incremental Justification of Second-Added Measures
Chigger Creek
Oct 2005 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 5.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 5.125%	BCR a/b
	Without project condition	**$3,759.7**						
Step 3 - Test measures on Chigger	Chig Det A	$3,571.5	$188.1	$3,369.4	$4,826.4	-$1,457.0	-$81.4	0.70
	Chig Det B	$3,550.8	$208.9	$3,740.6	$9,593.2	-$5,852.5	-$326.8	0.39
	Chig Det C	$3,532.4	$227.3	$4,069.8	$14,411.9	-$10,342.1	-$577.5	0.28

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (5.125%, 50-yr)
AAEV = Average Annual Equivalent Value (5.125%, 50-yr)
All damage categories included, except roads.
Calculated with risk & uncertainty.
Screening level cost estimates provided by Cost Engineering.

Table 2-8
Phase 2 – Optimization and Incremental Justification of Second-Added Measures
Mary's Creek
Oct 2005 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced in thousands	PWE Damages Reduced in thousands 5.125% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 5.125%	BCR a/b
	Without project condition	**$8,674.3**						
Phase 1	**MAC2a**	**$4,558.9**	**$4,115.3**	**$73,701.2**	**$8,537.7**	**$65,163.5**	**$3,638.6**	**8.63**
Step 4 -Test additional measures on Mary's Creek	MAC2a + MAD1a (25%)*	$3,709.6	$4,964.6	$88,910.8	$16,695.9	$72,214.9	$4,032.3	5.33
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MAD1a (25%)*		$849.3	$15,209.7	$8,158.2	$7,051.5	$393.7	1.86
	MAC2a + MAD1b (50%)*	$3,019.3	$5,654.9	$101,273.9	$23,155.8	$78,118.1	$4,362.0	4.37
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MAD1b (50%)*		$1,539.6	$27,572.8	$14,618.1	$12,954.7	$723.4	1.89
	MAC2a + MAD1b1/2 (75%)*	$2,530.1	$6,144.1	$110,035.0	$28,725.5	$81,309.4	$4,540.2	3.83
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MADb1/2 (75%)*		**$2,028.8**	**$36,333.8**	**$20,187.8**	**$16,146.0**	**$901.6**	**1.80**
	MAC2a + MAD1d (12.5%)*	$4,315.9	$4,358.3	$78,052.7	$12,358.9	$65,693.8	$3,668.2	6.32
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MAD1d (12.5%)*		$243.0	$4,351.5	$3,821.2	$530.4	$29.6	1.14
	MAC2a + MAD1e (5%)*	$4,506.5	$4,167.8	$74,639.9	$10,274.2	$64,365.7	$3,594.1	7.26
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MAD1e (5%)*		$52.4	$938.8	$1,736.5	-$797.8	-$44.5	0.54
	MAC2a + MAD Large Det (200%)*	$2,420.8	$6,253.5	$111,993.1	$68,579.4	$43,413.7	$2,424.1	1.63
	with increment MAC2a	$4,558.9	$4,115.3	$73,701.2	$8,537.7	$65,163.5	$3,638.6	8.63
	with increment MAD Large Det (200%)*		$2,138.2	$38,292.0	$60,041.7	-$21,749.7	-$1,214.5	0.64

Notes: *Percent of SWEC and West Mary's existing detentions
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (5.125%, 50-yr)
AAEV = Average Annual Equivalent Value (5.125%, 50-yr)
All damage categories included, except roads.
Calculated with risk & uncertainty.
Screening level cost estimates provided by Cost Engineering

Phase 3 – Second-Added Measures Analysis: The third phase of the second-added measures process began with Mii cost estimate of the phase 2 optimized structural plan to-date. The Mii estimate is over two times higher than the planning level estimate, however, the overall project remained justified. In addition, the right-of-way buyouts necessary for implementation of the optimized structural plan were isolated and captured as a project benefit, however minimal. Phase 3 was conducted at Oct 2007 price levels and at the current 4.875% discount rate. All risk parameters were applied during this phase and the damage category of roads was added.

Phase 3 continued with re-evaluation of nonstructural buyouts as a first-added measure. Nonstructural measures were investigated early in the study, but many changes and updates were made over time, therefore re-analysis was deemed necessary. Nonstructural measures generally work best in frequent, deep flooding events. The flooding that occurs in the Clear Creek watershed is frequent but shallow due to the nature of the floodplain. Detailed discussion and analysis of nonstructural measures can be found in Attachment 3.

Buyouts were considered both as stand-alone alternatives and with the optimized structural plan in place (i.e. the phase 2 optimized plan plus residual flood plain buyout). Buyouts were formulated by flood zone, specifically 0-2-year, 0-5-year and 0-10-year buyouts. Buyout of the 0-25-year flood zone was not analyzed as experience has proven that buyout to be unjustifiable.

The buyout analysis was further broken down by analyzing the plans by varying levels of participation. For example, buyout as a stand-alone measure is more likely to be a "mandated" buyout, while buyout in addition to a structural plan would be much less likely to be "mandated." It is highly unlikely that there would be 100 percent participation in any case; therefore the highest level of participation for the high-most likely-low ranges is 95 percent, in the case of a without-project buyout of flood plain structures. All ranges of participation and results are detailed in Table 2-9 below.

The specific measures tested in phase 3 are described below. Table 2-9 illustrates the optimization and incremental analysis of the third phase of the second-added analysis.

Details of Phase 3 – Second-Added Measures Process:

Step 1: Update of Optimized Structural Plan Costs with Mii Cost Estimate

- Mii estimate prepared for optimized structural measures – Upstream Anchor Main Stem Conveyance (SuperCd), Upstream Main Stem Conveyance (C5d) , Mary's

Conveyance (MAC2a), Turkey Conveyance (TKC1d), Mud Conveyance, (MUC1b), Main Stem Inline and Offline Detention (Clr Crk Det smooth-b), Mud Detention (Mud Det C), Mary's Detention (MAD1b1/2)

Measure Justified? Yes

Step 2: Nonstructural Analysis (stand-alone buyout)

- Buyout of the 2-, 5- and 10-year flood zones as first-added measures (i.e. without-project in place) (Tested at various levels of participation)

  Measure Justified/Optimized? No

Step 3: Nonstructural Analysis (with GRR Plan in Place)

- Buyout of the residual 2-, 5- and 10-year flood plain (i.e. with the optimized structural plan in place) (Tested at various levels of participation)

  Measure Justified/Optimized? No

Table 2-9

Phase 3 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2007 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 4.875% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 4.875%	BCR a/b
	Without project condition, mainstem and tributaries	**$39,187.7**						
Step 1 - Mii Estimate	Phase 2 Optimized Structural Plan w/Mii Cost Estimate: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
Step 2 - Nonstructural Analysis - Test of buyout by zone as Stand-Alone Project at various levels of participation	100% Participation Buyout - 0-2 yr (w/o project) 5 structures	$39,058.8	$128.9	$2,398.8	$15,560.4	($13,161.6)	($707.1)	0.15
	100% Participation Buyout - 0-5 yr (w/o project) - 176 structures	$36,466.0	$2,721.7	$50,662.4	$80,944.0	($30,281.6)	($1,626.8)	0.63
	100% Participation Buyout - 0-10 yr (w/o project) - 549 structures	$32,456.1	$6,731.6	$125,302.8	$235,043.4	($109,740.7)	($5,895.5)	0.53
	High Participation 95% Buyout - 0-2 yr (w/o project)	$39,065.2	$122.4	$2,278.9	$15,407.9	($13,129.0)	($705.3)	0.15
	High Participation 95 % Buyout - 0-5 yr (w/o project)	$36,602.0	$2,585.6	$48,129.3	$77,941.5	($29,812.2)	($1,601.6)	0.62
	High Participation 95% Buyout - 0-10 yr (w/o project)	$32,792.7	$6,395.0	$119,037.6	$225,913.3	($106,875.7)	($5,741.6)	0.53
	Most Likely Participation 85% Buyout - 0-2 yr (w/o project)	$39,078.1	$109.5	$2,039.0	$15,102.9	($13,063.9)	($701.8)	0.14
	Most Likely Participation 85% Buyout - 0-5 yr (w/o project)	$36,874.2	$2,313.4	$43,063.0	$71,936.6	($28,873.5)	($1,551.2)	0.60
	Most Likely Participation 85% Buyout - 0-10 yr (w/o project)	$33,465.8	$5,721.8	$106,507.3	$207,653.2	($101,145.8)	($5,433.8)	0.51
	Low Participation 75% Buyout - 0-2 yr (w/o project)	$39,091.0	$96.7	$1,799.1	$14,798.0	($12,998.8)	($698.3)	0.12
	Low Participation 75% Buyout - 0-5 yr (w/o project)	$37,146.4	$2,041.3	$37,996.8	$65,931.7	($27,934.9)	($1,500.7)	0.58
	Low Participation 75% Buyout - 0-10 yr (w/o project)	$34,139.0	$5,048.7	$93,977.1	$189,393.0	($95,416.0)	($5,126.0)	0.50

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (4.875%, 50-yr)
AAEV = Average Annual Equivalent Value (4.875%, 50-yr)
All damage categories included.
Calculated with risk & uncertainty.
Mii for optimized structural plan by Cost Engineering.

Table 2-9 - continued

Phase 3 – Optimization and Incremental Justification of Second-Added Measures

Clear Creek – Main Stem and Tributaries

Oct 2007 price levels

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced* in thousands	PWE Damages Reduced in thousands 4.875% a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits 4.875%	BCR a/b
	Without project condition, mainstem and tributaries	**$39,187.7**						
Step 3 - Nonstructural Analysis - Test of buyout by zone in Addition to Optimized Structural Plan at various levels of participation	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + 100% 0-5-yr Buyout (27 structures)	$15,545.7	$23,642.0	$440,077.7	$385,025.2	$55,052.5	$2,957.5	1.14
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment 100% 0-5-yr Buyout (27 structures)		$430.8	$8,019.2	$9,441.2	($1,422.0)	($76.4)	0.85
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + 100% 0-10-yr Buyout (136 structures)	$14,457.4	$24,730.3	$460,335.1	$419,959.0	$40,376.1	$2,169.1	1.10
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment 100% 0-10-yr Buyout (136 structures)		$1,519.1	$28,276.5	$44,374.9	($16,098.4)	($864.8)	0.64
				$0.0				
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + High Participation 75% 0-5-yr Buyout	$15,653.4	$23,534.3	$438,072.9	$382,748.0	$55,324.9	$2,972.2	1.14
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment High Participation 75% 0-5-yr Buyout		$323.1	$6,014.4	$7,164.0	($1,149.6)	($61.8)	0.84
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + High Participation 75% 0-10-yr Buyout	$14,837.2	$24,350.5	$453,265.9	$410,088.9	$43,177.0	$2,319.6	1.11
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment High Participation 75% 0-10-yr Buyout		$1,139.3	$21,207.4	$34,504.8	($13,297.4)	($714.4)	0.61
				$0.0				
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + Most Likely Participation 50% 0-5-yr Buyout	$15,761.1	$23,426.6	$436,068.1	$380,470.8	$55,597.3	$2,986.8	1.15
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Most Likely Participation 50% 0-5-yr Buyout		$215.4	$4,009.6	$4,886.8	($877.2)	($47.1)	0.82
				$0.0				
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + Most Likely Participation 50% 0-10-yr Buyout	$15,217.0	$23,970.7	$446,196.8	$400,218.8	$45,978.0	$2,470.0	1.11
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Most Likely Participation 50% 0-10-yr Buyout		$759.5	$14,138.3	$24,634.8	($10,496.5)	($563.9)	0.57
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + Low Participation 25% 0-5-yr Buyout	$15,868.8	$23,318.9	$434,063.3	$378,193.6	$55,869.7	$3,001.4	1.15
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Low Participation 25% 0-5-yr Buyout		$107.7	$2,004.8	$2,609.6	($604.8)	($32.5)	0.77
	SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 + Low Participation 25% 0-10-yr Buyout	$15,596.7	$23,590.9	$439,127.7	$390,348.8	$48,778.9	$2,620.5	1.12
	with increment SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Low Participation 25% 0-10-yr Buyout		$379.8	$7,069.1	$14,764.7	($7,695.6)	($413.4)	0.48

Notes: Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (4.875%, 50-yr)
AAEV = Average Annual Equivalent Value (4.875%, 50-yr)
All damage categories included.
Calculated with risk & uncertainty.
Mii for optimized structural plan by Cost Engineering.

Phase 4 – Second-Added Measures Analysis: Phase 4 of the second-added measures process began with reevaluation of individual detention components. As mentioned, the Mii cost estimates significantly increased from the screening level cost estimates for the detentions. As such, it was necessary to reconfirm the individual viability of the detention elements. Further analysis revealed that the off-line detention elements on Mud Gully and the main stem were no longer incrementally justified while all other components remain viable. Reevaluation of the detentions was conducted at Oct 2007 price levels and at 4.875 percent discount rate.

Phase 4 continued with update of price levels to October 2009 and the current discount rate of 4.375 percent, as well as removal of Mary's detentions as a component of the Federal project. Guidance was provided through the review process which required existing Mary's Detentions to be analyzed under Section 575. In addition, further guidance required the inclusion of the Clear Lake Second Outlet in both the without and with-project condition. The exclusion of the second outlet did not affect plan formulation.

The results of additional analysis in phase 4 are described below. Table 2-10 illustrates the optimization and incremental analysis of the fourth phase of the second-added analysis.

Details of Phase 4 – Second-added Measures Process:

Step 1: Reevaluation of Detention Components with Mii Cost Estimate

- Incremental analysis of detention components due to significant increase in Mii estimates – Main Stem Offline Detention (Clr Crk Det smooth-b), Mud Detention (Mud Det C)

  Measures Justified? No

Step 2: Update Price Levels, Discount Rate and remove Existing Mary's Detentions (analyzed under Section 575), include second outlet and gate in both the without- and with-project conditions.

- Arrive at Recommended Plan – comprised of Upstream Anchor Main Stem Conveyance (SuperCd), Upstream Main Stem Conveyance (C5d) , Mary's Conveyance (MAC2a), Turkey Conveyance (TKC1d), Mud Conveyance, (MUC1b), Main Stem Inline Detention

Table 2-10
Phase 4 – Optimization and Incremental Justification of Second-Added Measures
Clear Creek – Main Stem and Tributaries
Oct 2007 and Oct 2009 price levels and Discount Rates

Formulation Sequence	Plan Description/Measure Added	2020 Expected Annual Damages in thousands	Net Expected Annual Damages Reduced in thousands	PWE Damages Reduced in thousands a	Total Project Cost in thousands b	net excess benefits a-b	AAEV net excess benefits	BCR a/b
	Without project condition, mainstem and tributaries (FY08 Price Levels)	**$39,187.7**						
Optimized Plan (thru Phase 3)	Phase 2 Optimized Structural Plan w/Mii Cost Estimate: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 (FY08 Price levels and 4.875%)	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
Step 1 - Remove Detentions based upon Revised Cost Estimates	Phase 2 Optimized Structural Plan w/Mii Cost Estimate: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 (FY08 Price levels and 4.875%)	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Optimized Stuctural Plan minus Mud Detention (Mud Det C) (FY08 Price Levels and 4.875%)	$17,222.5	$21,965.2	$408,864.8	$339,428.1	$69,436.7	$3,730.3	1.20
	with increment Mud Detention (Mud Det C) (FY08 Price Levels and 4.875%)		$1,246.0	$23,193.7	$36,156.0	-$12,962.2	-$696.4	0.64
	Phase 2 Optimized Structural Plan w/Mii Cost Estimate: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 (FY08 Price levels and 4.875%)	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Optimized Structural Plan minus Mainstem Offline Detention (ClrCrk Det smooth-b) (FY08 Price levels and 4.875%)	$18,195.5	$20,992.2	$390,753.1	$323,270.7	$67,482.4	$3,625.3	1.21
	with increment Mainstem Offline Detention (ClrCrk Det smooth-b) (FY08 Price Levels and 4.875%)		$2,219.0	$41,305.4	$52,313.3	-$11,007.9	-$591.4	0.79
	Phase 2 Optimized Structural Plan w/Mii Cost Estimate: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a+Mud Det C+ClrCrk Det smooth-b+MAD1b1/2 (FY08 Price levels and 4.875%)	$15,976.5	$23,211.2	$432,058.5	$375,584.1	$56,474.5	$3,033.9	1.15
	with increment Optimized Structural Plan minus Mud Detention (Mud Det C) and Mainstem Offline Detention (ClrCrk Det smooth-b) (FY08 Price levels and 4.875%)	**$19,110.8**	**$20,076.9**	**$373,715.5**	**$210,929.2**	**$162,786.4**	**$8,745.3**	**1.77**
	with increment Mud Detention (Mud Det C) and Mainstem Offline Detention (ClrCrk Det smooth-b) (FY08 Price Levels and 4.875%)		$3,134.3	$58,343.0	$164,654.9	-$106,311.9	-$5,711.3	0.35

Formulation Sequence	Plan Description/Measure Added	Average Annual Equivalent Damages in thousands Oct 09 prices @ 4.375%	Average Annual Equivalent Damages Reduced in thousands	PWE Damages Reduced @ 4.375% in thousands a	Total_Project_Cost in thousands (including IDC & O&M) b	net excess benefits a-b	AAEV net excess benefits	BCR a/b
	Without project conditions, mainstem and tributaries (updated to FY10 Price Levels and 4.375%)	**$42,031.0**						
Step 2- Update of Tentatively Recommended Plan	NED Plan: SuperCd+C5d^1+MUC1b+TKC1d+MAC2a	$22,057.0	$19,974.0	$402,887.1	$215,174.5	$187,712.6	$9,306.3	1.87

Notes: Does not include NFIP costs/benefits.
Only FDR features modeled for NED benefit analysis.
PWE = Present worth equivalent (4.875%, 50-yr)
AAEV = Average Annual Equivalent Value (4.875%, 50-yr)
All damage categories included.
Calculated with risk & uncertainty.
Mii for optimized structural plan by Cost Engineering.

Attachment 3
Details of Nonstructural Analysis

Nonstructural Analysis. As previously mentioned, nonstructural measures were investigated early in the first-added measures phase of the study, but with the many changes and updates made over time, in-depth analysis, including the tributaries, was deemed necessary. In addition, nonstructural measures were analyzed as an addition to the optimized structural measures. Nonstructural measures generally work best in frequent, deep flooding events. The flooding that occurs in the Clear Creek watershed is frequent but shallow due to the nature of the floodplain. The final nonstructural analysis was conducted at 2007 price levels and a discount rate of 4.875 percent.

Raising-in-place and relocation were considered initially, however, most of the structures within the floodplain are residential and slab-on-grade foundation. While not impossible to raise slab-on-grade structures, experience has shown the costs to be prohibitive. Costs obtained from the National Flood Proofing Committee show estimates in excess of $100 thousand per structure, just for the physical raising. Raising-in-place is also less desirable as it does not eliminate residual damages to the structures, leaving homes vulnerable to infrequent, but damaging events (i.e. 100-year event would still cause damage). In the event of frequent events, the homeowners may become stranded when their home is surrounded by water.

Wet flood proofing is not appropriate for residential structures but can be used in the case of out-buildings, storage, garages, agricultural-related structures, and structures whose functions are tied to the water. Dry flood proofing may be appropriate for residential structures; however, the property must have adequate space to accommodate a floodwall or berm. Finally, dry flood proofing requires active participation of the homeowner and may actually put them at greater risk. The homeowner may choose to stay behind in order to activate the flood proofing closures and because of the sense that their home is “safe” from the on-coming flood waters because they have flood proofing. Residual risks also remain with flood proofing as the structure and contents still remain in the floodplain. For these reasons, flood proofing was not considered the optimal nonstructural choice for residential properties.

Section 73 of the WRDA of 1974 requires consideration of nonstructural alternatives in flood damage reduction studies. Section 219 of the WRDA of 1999 directs the USACE to calculate benefits for nonstructural flood damage mitigation projects using methods similar to those used in calculating the benefits for structural projects, including similar treatment in calculating the benefits from losses avoided. It further states that in carrying out this directive, the USACE should avoid double-counting of benefits.

Previous USACE guidance directed the use of only the externalized portion of flood damages prevented in calculating benefits for evacuation projects. The guidance was based on the fact that the internalized portion of flood damages is reflected in the reduced market value of the properties used in the calculation of evacuation costs, the cost of buyout of the floodplain. The internalized portion of flood damages includes uninsured losses, flood insurance premiums and deductible as well as agent's fees. Typically, externalized flood damages were estimated by calculating total flood damages using standard depreciated replacement cost techniques as in structural flood control projects and then subtracting the internalized portion of flood damages. The subtraction of the internalized portion of flood damages was intended to remove potential double-counting from the benefit-cost calculation. The following new implementation procedures, which avoid double counting internalized costs, were used in development of the costs and benefits for buyout alternatives on Clear Creek.

Per the implementing guidance associated with Section 219 (a) of WRDA of 1999, flood damage mitigation benefits for evacuation projects were calculated as the total flood damages reduced. No correction was made to remove the internalized portion of flood damages in the benefit calculation.

In accordance with Section 219, the economic analysis for evacuation alternatives utilized comparable flood-free land costs in the valuation of floodplain land. Flood-free land cost is the cost of comparable land without the flood-risk (defined as outside the Federal Insurance Administration (FIA)-designated 100-year floodplain). Additionally, for residential properties under Public Law 91-646, the amount by which the market value of a replacement dwelling (non-floodplain property) exceeds the market value of the displacement dwelling (floodplain property) also is determined. This cost (the market value of the floodplain property, land and structures, plus any additional amount to equal the market value of a comparable replacement dwelling outside the floodplain) is the flood-free property cost. Additional costs were added for demolition and removal of structures and administrative costs.

Buyout alternatives were considered both as stand-alone alternatives and with the optimized structural plan in place (i.e., buyout of the residual floodplain). Buyouts were formulated by flood zone, specifically 50 percent AEP (2-year), 20 percent AEP (5-year) and 10 percent AEP (10-year) floodplain buyouts. Buyout of the 4 percent AEP (25-year) floodplain was not analyzed as experience has proven it to be unjustifiable.

The buyout analysis was further broken down by assuming various levels of participation. Assumptions were made based upon knowledge of the study area and history of participation in previous nonstructural plans in the area. For example, it is reasonable to assume that buyout as a stand-alone measure is more likely to be an “agency-mandated” buyout (since benefits realized from the buyout are required justify the project). Buyout as an addition to a structural plan would be much less likely to be “agency-mandated” (since benefits simply augment the plan and are not required to justify the project.) There are many other variables to take into consideration when determining levels of participation, such as personal preference (i.e. risk aversion of the property owner), time elapsed since the last flood event, and whether the particular owner has suffered losses (new residents may not believe the risk is high, since they have not suffered damages). All of these variables were taken into account when determining the levels of participation.

<u>Nonstructural Buyout as Stand-Alone Project</u>. For the without-project, or stand-alone buyout the levels of participation are assumed to be 75 percent , 85 percent and 95 percent, for the low, most likely and high levels of participation, respectively. The levels of participation for the buyouts with-structural plan in place are assumed to be 25 percent, 50 percent and 75 percent, for the low, most likely and high levels of participation, respectively. Benefits and costs for each level of participation were apportioned accordingly, using the appropriate rate for low-medium-high participation, as there is no way to identify individual structures likely or unlikely to participate.

The buyout analyses were conducted by first removing ancillary structures from consideration. These include barns, sheds and other similar, minimally valued structures. The results of the stand-alone buyout analysis are shown in Table 3-1 for the various levels of participation and flood zones considered. As shown, buyouts of floodplain properties as stand-alone alternatives are proven to be unjustified under all participation rate scenarios and for all flood zones.

TABLE 3-1
ECONOMIC ANALYSIS OF NONSTRUCTURAL (BUYOUT) OPTION AS A STAND-ALONE ALTERNATIVE
(WITHOUT-PROJECT BUYOUT, 2020 CONDITION)
AT VARIOUS LEVELS OF PARTICIPATION AND FLOOD ZONES
Dollar Values in 1,000s, Oct 2007 Price levels, Discount Rate of 4.875%

Plan	50% AEP Floodplain (2-Year) Buyout Level of Participation			20% AEP Floodplain (5-Year) Buyout Level of Participation			10% AEP Floodplain (10-Year) Buyout Level of Participation		
Stand-Alone Buyout	**Low (75%)**	**Most Likely (85%)**	**High (95%)**	**Low (75%)**	**Most Likely (85%)**	**High (95%)**	**Low (75%)**	**Most Likely (85%)**	**High (95%)**
Total Annual Benefits	$97	$110	$122	$2,041	$2,313	$2,586	$5,049	$5,722	$6,395
Total Annual Costs	$795	$811	$828	$3,542	$3,865	$4,187	$10,175	$11,156	$12,137
Net Benefits	-$698	-$702	-$705	-$1,501	-$1,551	-$1,602	-$5,126	-$5,434	-$5,742
B/C Ratio	0.12	0.14	0.15	0.58	0.60	0.62	0.50	0.51	0.53
Number of Structures	approx. 4	approx. 5	approx. 5	approx. 132	approx. 150	approx.168	approx. 412	approx. 467	approx. 522

Notes: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.

100% participation rate for Stand-Alone Buyouts:

0-2 year = 5 structures

0-5 year = 176 structures

0-10 year = 549 structures

Totals do not match numbers found in Table 14 because certain ancillary/support structures were removed from consideration for removal.

Buyout of Residual Floodplain. This alternative consists of all the measures described under the Recommended Plan plus two separate residual floodplain buyout alternatives (namely, 20 percent AEP (5-year) floodplain buyout, and the 10 percent AEP (10-year) floodplain buyout. There were no structures in the residual 50 percent AEP (2-year) floodplain to consider for buyout. The assumption was made that the "most-likely" level of participation would take place, that being 50 percent. As shown, buyouts of the residual floodplain properties are proven to be unjustified under all participation rate scenarios and for all flood zones.

TABLE 3-2
ECONOMIC ANALYSIS OF RESIDUAL FLOODPLAIN BUYOUT
(WITH RECOMMENDED PLAN IN PLACE, 2020 CONDITION)
AT VARIOUS LEVELS OF PARTICIPATION AND FLOOD ZONES
Dollar Values in 1,000s, Oct 2007 Price levels, Discount Rate of 4.875%

Plan	50% AEP Floodplain (2-Year) Buyout Level of Participation			20% AEP Floodplain (5-Year) Buyout Level of Participation			10% AEP Floodplain (10-Year) Buyout Level of Participation		
Buyout of Residual Floodplain (i.e. with GRR Plan in place)	**Low (25%)**	**Most Likely (50%)**	**High (75%)**	**Low (25%)**	**Most Likely (50%)**	**High (75%)**	**Low (25%)**	**Most Likely (50%)**	**High (75%)**
Total Annual Benefits				$108	$215	$323	$380	$760	$1,139
Total Annual Costs				$140	$263	$385	$793	$1,323	$1,854
Net Benefits				-$32	-$47	-$62	-$413	-$564	-$714
B/C Ratio				0.77	0.82	0.84	0.48	0.57	0.61
Number of Structures	0	0	0	approx. 7	approx. 14	approx. 21	approx. 34	approx. 68	approx. 102

100% Participation Rate for Buyout of Residual Floodplain:
2-Year = 0 structures
5-Year = 27 structures
10-Year = 136 structures

Attachment 4
Detailed Tables for Main Stem and Tributaries
For the With-Project 2020 and 2070 Conditions

Details of Distribution of Capital Investment within the With-project Floodplains. Tables 4-1 through 4-6 of this attachment show the detailed distribution of structures by type by flood event for the 2020 with-project condition. For example, Table 4-3 shows the distribution of capital investment on Turkey Creek in the 2020 with-project condition. Tables 4-7 through 4-12 likewise display the distribution of structures by type by flood event; however, the condition is for the 2070 future with-project condition.

TABLE 4-1
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK MAIN STEM
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	16	142	323	559	811	1,382	1,894
Value of Structures	$0	$2,484	$15,824	$34,059	$62,838	$89,607	$156,515	$219,842
Value of Contents	$0	$1,242	$7,912	$17,029	$31,419	$44,804	$78,257	$109,921
Percent of Structures Inundated/Zone	0%			88%	86%	88%	90%	91%
Commercial								
Number of Structures	1	1	8	34	71	85	123	149
Value of Structures	$33	$33	$1,557	$7,103	$11,811	$13,642	$17,247	$18,376
Value of Contents	$0	$0	$396	$3,395	$6,830	$7,456	$9,909	$12,727
Percent of Structures Inundated/Zone	100%	6%	6%	9%	11%	9%	8%	7%
Industrial								
Number of Structures	0	0	1	3	4	8	12	15
Value of Structures	$0	0	0	569	692	1,179	1,738	2,173
Value of Contents	$0	0	0	2,756	3,091	4,589	7,020	9,533
Percent of Structures Inundated/Zone	0%	0%	1%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	4	8	14	17	20	20
Value of Structures	$0	$0	$1,141	$5,732	$6,156	$6,885	$7,740	$7,740
Value of Contents	$0	$0	$372	$813	$1,019	$1,443	$1,900	$1,900
Percent of Structures Inundated/Zone	0%	0%	3%	0%	0%	0%	0%	0%
Total								
Number of Structures	1	17	155	368	648	921	1,537	2,078
Value of Structures	$33	$2,517	$18,521	$47,462	$81,496	$111,312	$183,239	$248,131
Value of Contents	$0	$1,242	$8,679	$23,993	$42,359	$58,292	$97,086	$134,081
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-2

CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT

MUD GULLY

Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition

(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	0	2	137	206	565	895
Value of Structures	$0	$0	$0	$14	$6,952	$10,220	$31,343	$48,383
Value of Contents	$0	$0	$0	$57	$3,425	$5,531	$17,172	$27,763
Percent of Structures Inundated/Zone				100%	99%	97%	96%	96%
Commercial								
Number of Structures	0	0	0	0	2	7	24	39
Value of Structures	$0	$0	$0	$0	$18	$195	$964	$1,300
Value of Contents	$0	$0	$0	$0	$1	$67	$1,538	$1,645
Percent of Structures Inundated/Zone				0%	1%	3%	4%	4%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	2
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$18
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	0	2	139	213	589	936
Value of Structures	$0	$0	$0	$14	$6,969	$10,414	$32,307	$49,700
Value of Contents	$0	$0	$0	$57	$3,426	$5,598	$18,709	$29,408
Percent of Structures Inundated/Zone	n/a	n/a	n/a	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-3

CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
TURKEY CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	0	0	0	2	97	358
Value of Structures	$0	$0	$0	$0	$0	$248	$9,836	$37,051
Value of Contents	$0	$0	$0	$0	$0	$124	$4,918	$18,525
Percent of Structures Inundated/Zone						100%	98%	98%
Commercial								
Number of Structures	0	0	0	0	0	0	1	5
Value of Structures	$0	$0	$0	$0	$0	$0	$193	$356
Value of Contents	$0	$0	$0	$0	$0	$0	$176	$270
Percent of Structures Inundated/Zone						0%	1%	1%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone						0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	1	1
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone						0%	0%	0%
Total								
Number of Structures	0	0	0	0	0	2	99	364
Value of Structures	$0	$0	$0	$0	$0	$248	$10,030	$37,407
Value of Contents	$0	$0	$0	$0	$0	$124	$5,094	$18,795
Percent of Structures Inundated/Zone	n/a	n/a	n/a	n/a	n/a	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-4
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MARY'S CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	1	19	39	82	187	299	445	613
Value of Structures	$95	$2,185	$4,696	$8,237	$19,720	$30,894	$46,702	$66,193
Value of Contents	$48	$1,093	$2,348	$4,119	$9,860	$15,447	$23,351	$33,096
Percent of Structures Inundated/Zone	33%	46%	56%	59%	69%	75%	76%	79%
Commercial								
Number of Structures	2	21	30	54	73	87	114	134
Value of Structures	$1	$142	$327	$1,031	$3,044	$3,469	$4,228	$5,331
Value of Contents	$1	$97	$263	$717	$2,014	$2,305	$2,841	$4,000
Percent of Structures Inundated/Zone	67%	51%	43%	39%	27%	22%	20%	17%
Industrial								
Number of Structures	0	0	0	1	7	8	12	16
Value of Structures	$0	$0	$0	$1,185	$3,705	$4,890	$5,629	$7,294
Value of Contents	$0	$0	$0	$806	$2,520	$3,325	$3,828	$4,960
Percent of Structures Inundated/Zone	0%	0%	0%	1%	3%	2%	2%	2%
Public								
Number of Structures	0	1	1	2	5	6	11	13
Value of Structures	$0	$16	$16	$32	$240	$325	$970	$1,005
Value of Contents	$0	$6	$6	$12	$149	$207	$543	$565
Percent of Structures Inundated/Zone	0%	2%	1%	1%	2%	2%	2%	2%
Total								
Number of Structures	3	41	70	139	272	400	582	776
Value of Structures	$96	$2,343	$5,038	$10,485	$26,709	$39,579	$57,530	$79,823
Value of Contents	$48	$1,195	$2,617	$5,653	$14,543	$21,284	$30,563	$42,622
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-5
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
COWART CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	3	5	9	13	17	32	42
Value of Structures	$0	$66	$139	$319	$1,189	$1,553	$4,329	$6,006
Value of Contents	$0	$33	$69	$160	$594	$776	$2,164	$3,003
Percent of Structures Inundated/Zone		21%	24%	30%	32%	31%	38%	44%
Commercial								
Number of Structures	0	11	14	17	24	32	40	41
Value of Structures	$0	$257	$269	$272	$367	$447	$535	$552
Value of Contents	$0	$171	$179	$182	$188	$243	$302	$314
Percent of Structures Inundated/Zone		79%	67%	57%	59%	58%	48%	43%
Industrial								
Number of Structures	0	0	2	4	4	6	12	13
Value of Structures	$0	$0	$93	$189	$189	$189	$189	$208
Value of Contents	$0	$0	$63	$128	$128	$128	$128	$141
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	14	21	30	41	55	84	96
Value of Structures	$0	$323	$500	$780	$1,745	$2,188	$5,052	$6,766
Value of Contents	$0	$204	$312	$470	$911	$1,147	$2,595	$3,459
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-6
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CHIGGER CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	1	2	5	5	8	19	22
Value of Structures	$0	$253	$753	$1,082	$1,082	$1,532	$4,752	$5,109
Value of Contents	$0	$127	$377	$541	$541	$766	$2,376	$2,555
Percent of Structures Inundated/Zone		50%	67%	83%	83%	80%	86%	88%
Commercial								
Number of Structures	0	1	1	1	1	2	3	3
Value of Structures	$0	$35	$35	$35	$35	$62	$78	$78
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		50%	33%	17%	17%	20%	14%	12%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	2	3	6	6	10	22	25
Value of Structures	$0	$289	$789	$1,117	$1,117	$1,595	$4,830	$5,187
Value of Contents	$0	$127	$377	$541	$541	$766	$2,376	$2,555
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-7

CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CLEAR CREEK MAIN STEM
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	18	167	368	626	885	1,474	2,013
Value of Structures	$0	$2,722	$18,550	$39,503	$70,478	$99,767	$169,261	$237,533
Value of Contents	$0	$1,361	$9,275	$19,752	$35,239	$49,884	$84,630	$118,766
Percent of Structures Inundated/Zone	0%			88%	87%	88%	90%	91%
Commercial								
Number of Structures	1	1	17	38	79	91	131	159
Value of Structures	$33	$33	$1,880	$7,385	$13,204	$15,586	$17,747	$29,781
Value of Contents	$0	$0	$605	$3,489	$7,232	$7,915	$10,294	$64,559
Percent of Structures Inundated/Zone	100%	6%	10%	9%	11%	9%	8%	7%
Industrial								
Number of Structures	0	0	1	3	4	8	12	15
Value of Structures	$0	0	0	569	692	1,179	1,738	2,173
Value of Contents	$0	0	0	2,756	3,091	4,589	7,020	9,533
Percent of Structures Inundated/Zone	0%	0%	1%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	4	11	14	17	19	20
Value of Structures	$0	$0	$1,141	$5,783	$6,156	$6,885	$7,740	$7,740
Value of Contents	$0	$0	$372	$833	$1,019	$1,443	$1,900	$1,900
Percent of Structures Inundated/Zone	0%	0%	2%	0%	0%	0%	0%	0%
Total								
Number of Structures	1	19	189	420	723	1,001	1,636	2,207
Value of Structures	$33	$2,755	$21,571	$53,241	$90,529	$123,417	$196,486	$277,227
Value of Contents	$0	$1,361	$10,252	$26,829	$46,581	$63,831	$103,844	$194,758
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-8

CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MUD GULLY
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	0	19	178	268	791	970
Value of Structures	$0	$0	$0	$341	$8,981	$13,060	$43,086	$51,712
Value of Contents	$0	$0	$0	$558	$4,627	$7,540	$24,291	$29,601
Percent of Structures Inundated/Zone				100%	98%	96%	95%	96%
Commercial								
Number of Structures	0	0	0	0	4	11	37	40
Value of Structures	$0	$0	$0	$0	$40	$461	$1,189	$1,300
Value of Contents	$0	$0	$0	$0	$16	$160	$1,592	$1,646
Percent of Structures Inundated/Zone				0%	2%	4%	4%	4%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	2	2
Value of Structures	$0	$0	$0	$0	$0	$0	$18	$18
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone				0%	0%	0%	0%	0%
Total								
Number of Structures	0	0	0	19	182	279	830	1,012
Value of Structures	$0	$0	$0	$341	$9,021	$13,521	$44,292	$53,029
Value of Contents	$0	$0	$0	$558	$4,643	$7,699	$25,883	$31,246
Percent of Structures Inundated/Zone	n/a	n/a	n/a	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-9

CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT

TURKEY CREEK

Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition

(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	0	0	0	1	13	338	474
Value of Structures	$0	$0	$0	$0	$129	$1,504	$32,335	$44,859
Value of Contents	$0	$0	$0	$0	$64	$752	$16,167	$22,429
Percent of Structures Inundated/Zone					100%	93%	99%	99%
Commercial								
Number of Structures	0	0	0	0	0	1	4	6
Value of Structures	$0	$0	$0	$0	$0	$193	$356	$625
Value of Contents	$0	$0	$0	$0	$0	$176	$270	$514
Percent of Structures Inundated/Zone					0%	7%	1%	1%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone					0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	1	1
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone					0%	0%	0%	0%
Total								
Number of Structures	0	0	0	0	1	14	343	481
Value of Structures	$0	$0	$0	$0	$129	$1,697	$32,691	$45,483
Value of Contents	$0	$0	$0	$0	$64	$928	$16,437	$22,944
Percent of Structures Inundated/Zone	n/a	n/a	n/a	n/a	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-10
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
MARY'S CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	4	32	64	214	291	402	592	862
Value of Structures	$273	$4,196	$6,484	$22,701	$28,922	$40,893	$63,458	$98,027
Value of Contents	$136	$2,098	$3,242	$11,350	$14,461	$20,447	$31,729	$49,014
Percent of Structures Inundated/Zone	44%	58%	58%	70%	74%	76%	78%	82%
Commercial								
Number of Structures	5	22	44	81	90	109	134	157
Value of Structures	$24	$143	$597	$2,428	$3,742	$4,065	$5,331	$6,409
Value of Contents	$17	$97	$442	$1,579	$2,489	$2,738	$4,000	$5,168
Percent of Structures Inundated/Zone	56%	40%	40%	26%	23%	20%	18%	15%
Industrial								
Number of Structures	0	0	0	7	8	10	16	17
Value of Structures	$0	$0	$0	$3,705	$4,890	$5,562	$7,294	$7,886
Value of Contents	$0	$0	$0	$2,520	$3,325	$3,782	$4,960	$5,362
Percent of Structures Inundated/Zone	0%	0%	0%	2%	2%	2%	2%	2%
Public								
Number of Structures	0	1	2	5	6	11	13	19
Value of Structures	$0	$16	$32	$240	$348	$970	$1,005	$1,169
Value of Contents	$0	$6	$12	$149	$189	$543	$565	$625
Percent of Structures Inundated/Zone	0%	2%	2%	2%	2%	2%	2%	2%
Total								
Number of Structures	9	55	110	307	395	532	755	1,055
Value of Structures	$297	$4,355	$7,113	$29,075	$37,902	$51,490	$77,088	$113,490
Value of Contents	$153	$2,201	$3,696	$15,598	$20,465	$27,510	$41,254	$60,169
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-11
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
COWART CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	3	6	9	14	19	34	43
Value of Structures	$0	$66	$144	$319	$1,195	$1,817	$4,688	$6,344
Value of Contents	$0	$33	$72	$160	$598	$908	$2,344	$3,172
Percent of Structures Inundated/Zone		16%	22%	26%	30%	33%	42%	47%
Commercial								
Number of Structures	0	11	14	18	26	32	40	41
Value of Structures	$0	$257	$269	$358	$391	$447	$535	$552
Value of Contents	$0	$171	$179	$182	$205	$243	$302	$314
Percent of Structures Inundated/Zone		58%	52%	53%	55%	55%	49%	45%
Industrial								
Number of Structures	0	5	7	7	7	7	7	8
Value of Structures	$0	$93	$189	$189	$189	$189	$189	$208
Value of Contents	$0	$63	$128	$128	$128	$128	$128	$141
Percent of Structures Inundated/Zone		26%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	19	27	34	47	58	81	92
Value of Structures	$0	$415	$601	$866	$1,775	$2,452	$5,412	$7,104
Value of Contents	$0	$267	$380	$470	$931	$1,279	$2,775	$3,628
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-12
CUMULATIVE DISTRIBUTION OF STRUCTURES BY TYPE BY FLOOD EVENT
CHIGGER CREEK
Cumulative Totals Based on First-Floor Elevations and Recommended Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-year)	20% AEP Floodplain (5-year)	10% AEP Floodplain (10-year)	4% AEP Floodplain (25-year)	2% AEP Floodplain (50-year)	1% AEP Floodplain (100-year)	0.4% AEP Floodplain (250-year)	0.2% AEP Floodplain (500-year)
Residential								
Number of Structures	0	1	2	5	6	10	20	24
Value of Structures	$0	$253	$753	$1,082	$1,339	$2,111	$4,770	$5,612
Value of Contents	$0	$127	$377	$541	$669	$1,055	$2,385	$2,806
Percent of Structures Inundated/Zone		50%	67%	83%	86%	83%	87%	89%
Commercial								
Number of Structures	0	1	1	1	1	2	3	3
Value of Structures	$0	$35	$35	$35	$35	$62	$78	$78
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		50%	33%	17%	14%	17%	13%	11%
Industrial								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Public								
Number of Structures	0	0	0	0	0	0	0	0
Value of Structures	$0	$0	$0	$0	$0	$0	$0	$0
Value of Contents	$0	$0	$0	$0	$0	$0	$0	$0
Percent of Structures Inundated/Zone		0%	0%	0%	0%	0%	0%	0%
Total								
Number of Structures	0	2	3	6	7	12	23	27
Value of Structures	$0	$289	$789	$1,117	$1,374	$2,173	$4,848	$5,690
Value of Contents	$0	$127	$377	$541	$669	$1,055	$2,385	$2,806
Percent of Structures Inundated/Zone	n/a	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Details of Single Occurrence Damages in the With-project Condition. Tables 4-13 through 4-18 of this attachment show the damages expected to accrue from various flood events along the individual streams on Clear Creek. These values represent damages expected for individual events under the with-project near-term hydrologic condition and include structure and content damages as well as other benefit categories. Similarly, Tables 4-19 through 4-24 display the single occurrence damages by event for the main stem and tributaries in the future hydrologic condition.

TABLE 4-13
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
CLEAR CREEK MAIN STEM
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$75.5	$3,116.0	$10,811.5	$20,049.1	$31,538.5	$45,892.2	$74,607.6	$104,272.9
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$1,383.3	$1,656.4
Commercial	$1.0	$30.2	$206.6	$683.5	$1,525.0	$2,418.6	$3,930.3	$5,051.2
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$452.1	$540.9
Damages to Structures, Contents	$76.5	$3,146.2	$11,018.1	$20,732.6	$33,063.5	$48,310.8	$80,373.4	$111,521.4
Postdisaster Recovery Costs	$77.2	$1,117.3	$3,846.7	$6,649.5	$9,839.2	$13,546.7	$20,699.9	$27,091.9
Utilities	$2.9	$42.1	$144.8	$250.3	$370.4	$510.0	$779.3	$1,019.9
Vehicles	$0.1	$57.5	$526.4	$1,284.2	$2,522.7	$4,594.4	$8,745.0	$13,069.8
Roads	$307.6	$530.5	$770.2	$1,018.4	$1,264.2	$1,519.1	$1,938.1	$2,864.3
Total Damages by Event	$464.3	$4,893.6	$16,306.2	$29,935.0	$47,060.1	$68,481.0	$112,535.7	$155,567.3
Percent Distribution by Event								
Residential	16.3%	63.7%	66.3%	67.0%	67.0%	67.0%	66.3%	67.0%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	1.1%
Commercial	0.2%	0.6%	1.3%	2.3%	3.2%	3.5%	3.5%	3.2%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%
Postdisaster Recovery Costs	16.6%	22.8%	23.6%	22.2%	20.9%	19.8%	18.4%	17.4%
Utilities	0.6%	0.9%	0.9%	0.8%	0.8%	0.7%	0.7%	0.7%
Vehicles	0.0%	1.2%	3.2%	4.3%	5.4%	6.7%	7.8%	8.4%
Roads	66.3%	10.8%	4.7%	3.4%	2.7%	2.2%	1.7%	1.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-14
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
MUD GULLY
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$86.8	$572.4	$3,016.0	$11,115.6	$14,695.3	$25,672.9	$39,071.5
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$0.3	$1.7	$31.5	$55.8	$275.0	$769.1
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$0.0	$86.8	$572.7	$3,017.7	$11,147.1	$14,751.0	$25,948.0	$39,840.6
Postdisaster Recovery Costs	$0.0	$0.0	$0.0	$17.5	$1,173.2	$1,707.2	$4,806.5	$7,818.2
Utilities	$0.0	$0.0	$0.0	$0.7	$44.2	$64.3	$181.0	$294.3
Vehicles	$0.0	$0.0	$0.0	$1.2	$56.8	$94.9	$542.7	$1,964.7
Roads	$0.0	$1.4	$13.2	$50.5	$129.3	$193.0	$336.1	$474.6
Total Damages by Event	$0.0	$88.1	$585.9	$3,087.5	$12,550.5	$16,810.4	$31,814.2	$50,392.4
Percent Distribution by Event								
Residential	0.0%	98.4%	97.7%	97.7%	88.6%	87.4%	80.7%	77.5%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.0%	0.1%	0.3%	0.3%	0.9%	1.5%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.0%	0.6%	9.3%	10.2%	15.1%	15.5%
Utilities	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.6%	0.6%
Vehicles	0.0%	0.0%	0.0%	0.0%	0.5%	0.6%	1.7%	3.9%
Roads	0.0%	1.6%	2.3%	1.6%	1.0%	1.1%	1.1%	0.9%
	n/a	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-15
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
TURKEY CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$0.0	$0.0	$39.2	$239.2	$909.3	$8,939.9	$18,523.4
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$0.0	$0.0	$0.0	$1.2	$21.1	$53.0
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
Damages to Structures, Contents	$0.0	$0.0	$0.0	$39.2	$239.2	$910.5	$8,961.0	$18,576.5
Postdisaster Recovery Costs	$0.0	$0.0	$0.0	$2.3	$17.6	$77.2	$2,826.7	$6,523.2
Utilities	$0.0	$0.0	$0.0	$0.1	$0.7	$2.9	$106.4	$245.6
Vehicles	$0.0	$0.0	$0.0	$0.0	$0.0	$0.4	$101.2	$606.3
Roads	$0.0	$0.0	$0.2	$3.8	$10.4	$36.8	$96.4	$145.0
Total Damages by Event	$0.0	$0.0	$0.2	$45.3	$267.9	$1,027.8	$12,091.7	$26,096.6
Percent Distribution by Event								
Residential	0.0%	0.0%	0.0%	86.4%	89.3%	88.5%	73.9%	71.0%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.0%	5.0%	6.6%	7.5%	23.4%	25.0%
Utilities	0.0%	0.0%	0.0%	0.2%	0.2%	0.3%	0.9%	0.9%
Vehicles	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	2.3%
Roads	0.0%	0.0%	100.0%	8.4%	3.9%	3.6%	0.8%	0.6%
	n/a	n/a	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-16
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
MARY'S CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$223.1	$1,032.0	$2,049.3	$6,201.8	$12,169.1	$17,332.8	$26,218.4	$34,357.8
Public	$0.1	$1.5	$2.2	$5.8	$18.7	$31.5	$62.6	$95.0
Commercial	$0.9	$16.5	$35.1	$146.4	$488.8	$725.9	$1,107.2	$1,446.4
Industrial	$0.0	$0.0	$0.7	$68.6	$827.7	$1,391.4	$2,875.3	$4,874.6
Damages to Structures, Contents	$224.2	$1,050.0	$2,087.3	$6,422.5	$13,504.2	$19,481.6	$30,263.5	$40,773.7
Postdisaster Recovery Costs	$150.1	$550.3	$861.1	$2,242.3	$4,168.5	$5,577.1	$8,014.3	$10,261.5
Utilities	$5.7	$20.6	$32.4	$84.4	$156.9	$210.0	$301.7	$386.3
Vehicles	$0.7	$43.2	$134.4	$296.0	$493.9	$748.6	$1,287.0	$1,947.8
Roads	$0.0	$12.6	$64.1	$247.0	$381.6	$431.5	$502.0	$544.2
Total Damages by Event	$380.6	$1,676.6	$3,179.4	$9,292.3	$18,705.2	$26,448.8	$40,368.5	$53,913.5
Percent Distribution by Event								
Residential	58.6%	61.6%	64.5%	66.7%	65.1%	65.5%	64.9%	63.7%
Public	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
Commercial	0.2%	1.0%	1.1%	1.6%	2.6%	2.7%	2.7%	2.7%
Industrial	0.0%	0.0%	0.0%	0.7%	4.4%	5.3%	7.1%	9.0%
Postdisaster Recovery Costs	39.4%	32.8%	27.1%	24.1%	22.3%	21.1%	19.9%	19.0%
Utilities	1.5%	1.2%	1.0%	0.9%	0.8%	0.8%	0.7%	0.7%
Vehicles	0.2%	2.6%	4.2%	3.2%	2.6%	2.8%	3.2%	3.6%
Roads	0.0%	0.8%	2.0%	2.7%	2.0%	1.6%	1.2%	1.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-17
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
COWART CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$40.3	$115.5	$264.2	$489.9	$851.7	$1,727.7	$2,496.5
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$10.6	$34.9	$43.4	$49.8	$57.1	$69.2	$79.1
Industrial	$0.0	$0.9	$11.8	$22.5	$29.6	$35.6	$42.4	$46.7
Damages to Structures, Contents	$0.0	$51.9	$162.2	$330.1	$569.3	$944.4	$1,839.2	$2,622.3
Postdisaster Recovery Costs	$32.5	$222.9	$374.1	$524.3	$665.4	$812.4	$1,023.4	$1,171.0
Utilities	$1.2	$8.4	$14.1	$19.7	$25.0	$30.6	$38.5	$44.1
Vehicles	$0.0	$3.7	$23.5	$48.0	$74.2	$114.7	$197.3	$278.3
Roads	$0.4	$1.5	$4.8	$9.7	$16.7	$27.7	$54.0	$77.0
Total Damages by Event	$34.1	$288.4	$578.6	$931.8	$1,350.6	$1,929.8	$3,152.5	$4,192.7
Percent Distribution by Event								
Residential	0.0%	14.0%	20.0%	28.4%	36.3%	44.1%	54.8%	59.5%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	3.7%	6.0%	4.7%	3.7%	3.0%	2.2%	1.9%
Industrial	0.0%	0.3%	2.0%	2.4%	2.2%	1.8%	1.3%	1.1%
Postdisaster Recovery Costs	95.2%	77.3%	64.7%	56.3%	49.3%	42.1%	32.5%	27.9%
Utilities	3.6%	2.9%	2.4%	2.1%	1.9%	1.6%	1.2%	1.1%
Vehicles	0.0%	1.3%	4.1%	5.1%	5.5%	5.9%	6.3%	6.6%
Roads	1.2%	0.5%	0.8%	1.0%	1.2%	1.4%	1.7%	1.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-18
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2020 CONDITION
CHIGGER CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$6.0	$163.6	$285.7	$465.3	$728.7	$1,167.4	$1,977.4	$2,811.2
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$1.6	$4.4	$5.7	$7.0	$9.3	$12.7	$14.6
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$6.0	$165.2	$290.1	$471.0	$735.7	$1,176.7	$1,990.1	$2,825.8
Postdisaster Recovery Costs	$1.0	$38.8	$60.6	$78.5	$122.5	$199.3	$302.9	$436.5
Utilities	$0.0	$1.5	$2.3	$3.0	$4.6	$7.5	$11.4	$16.4
Vehicles	$0.0	$0.9	$8.1	$20.6	$27.9	$41.9	$75.9	$129.1
Roads	$1.0	$6.6	$10.8	$17.4	$27.0	$42.8	$71.5	$89.8
Total Damages by Event	$8.0	$212.9	$371.8	$590.5	$917.6	$1,468.2	$2,451.8	$3,497.7
Percent Distribution by Event								
Residential	74.5%	76.9%	76.8%	78.8%	79.4%	79.5%	80.6%	80.4%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.7%	1.2%	1.0%	0.8%	0.6%	0.5%	0.4%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	12.0%	18.2%	16.3%	13.3%	13.3%	13.6%	12.4%	12.5%
Utilities	0.5%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%
Vehicles	0.0%	0.4%	2.2%	3.5%	3.0%	2.9%	3.1%	3.7%
Roads	13.0%	3.1%	2.9%	2.9%	2.9%	2.9%	2.9%	2.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-19
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
CLEAR CREEK MAIN STEM
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$129.1	$4,013.8	$12,010.4	$22,479.5	$35,176.2	$49,843.2	$80,360.5	$111,559.0
Public	$0.0	$18.4	$108.1	$309.7	$668.4	$1,006.3	$1,418.2	$1,676.9
Commercial	$0.9	$34.6	$216.0	$819.4	$1,709.8	$2,637.1	$4,236.9	$6,024.5
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$466.1	$556.2
Damages to Structures, Contents	$130.1	$4,066.8	$12,334.5	$23,608.6	$37,554.4	$53,486.6	$86,481.7	$119,816.6
Postdisaster Recovery Costs	$96.1	$1,533.6	$4,187.3	$7,339.7	$10,693.7	$14,434.8	$21,849.4	$28,623.9
Utilities	$3.6	$57.7	$157.6	$276.3	$402.6	$543.4	$822.6	$1,077.6
Vehicles	$0.2	$103.5	$630.3	$1,544.4	$3,048.3	$5,143.6	$9,633.7	$14,318.2
Roads	$338.2	$569.2	$805.8	$1,078.7	$1,335.3	$1,582.7	$2,173.6	$2,961.2
Total Damages by Event	$568.3	$6,330.8	$18,115.5	$33,847.7	$53,034.3	$75,191.1	$120,961.0	$166,797.6
Percent Distribution by Event								
Residential	22.7%	63.4%	66.3%	66.4%	66.3%	66.3%	66.4%	66.9%
Public	0.0%	0.3%	0.6%	0.9%	1.3%	1.3%	1.2%	1.0%
Commercial	0.2%	0.5%	1.2%	2.4%	3.2%	3.5%	3.5%	3.6%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%
Postdisaster Recovery Costs	16.9%	24.2%	23.1%	21.7%	20.2%	19.2%	18.1%	17.2%
Utilities	0.6%	0.9%	0.9%	0.8%	0.8%	0.7%	0.7%	0.6%
Vehicles	0.0%	1.6%	3.5%	4.6%	5.7%	6.8%	8.0%	8.6%
Roads	59.5%	9.0%	4.4%	3.2%	2.5%	2.1%	1.8%	1.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-20
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
MUD GULLY
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$170.0	$1,034.7	$5,905.8	$13,090.2	$16,588.6	$34,073.4	$42,300.4
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$0.4	$5.2	$43.0	$92.2	$598.5	$871.3
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$0.0	$170.0	$1,035.2	$5,911.1	$13,133.2	$16,680.8	$34,671.9	$43,171.7
Postdisaster Recovery Costs	$0.0	$0.0	$0.0	$131.3	$1,462.1	$2,223.8	$6,855.2	$8,439.8
Utilities	$0.0	$0.0	$0.0	$4.9	$55.0	$83.7	$258.1	$317.7
Vehicles	$0.0	$0.0	$0.3	$6.1	$73.4	$142.7	$1,338.2	$2,425.7
Roads	$0.0	$1.7	$18.8	$76.3	$166.4	$241.0	$420.5	$521.4
Total Damages by Event	$0.0	$171.7	$1,054.3	$6,129.7	$14,890.1	$19,372.1	$43,543.9	$54,876.3
Percent Distribution by Event								
Residential	0.0%	99.0%	98.1%	96.3%	87.9%	85.6%	78.3%	77.1%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.0%	0.1%	0.3%	0.5%	1.4%	1.6%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.0%	2.1%	9.8%	11.5%	15.7%	15.4%
Utilities	0.0%	0.0%	0.0%	0.1%	0.4%	0.4%	0.6%	0.6%
Vehicles	0.0%	0.0%	0.0%	0.1%	0.5%	0.7%	3.1%	4.4%
Roads	0.0%	1.0%	1.8%	1.2%	1.1%	1.2%	1.0%	1.0%
	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-21
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
TURKEY CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$0.0	$4.4	$238.0	$440.9	$4,423.1	$17,323.2	$21,368.0
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$0.0	$0.0	$0.0	$0.3	$8.5	$47.3	$75.4
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1
Damages to Structures, Contents	$0.0	$0.0	$4.4	$238.0	$441.3	$4,431.6	$17,370.5	$21,443.5
Postdisaster Recovery Costs	$0.0	$0.0	$0.0	$18.1	$31.6	$1,039.8	$6,187.7	$7,426.3
Utilities	$0.0	$0.0	$0.0	$0.7	$1.2	$39.1	$232.9	$279.6
Vehicles	$0.0	$0.0	$0.0	$0.0	$0.0	$23.6	$509.8	$792.3
Roads	$0.0	$0.0	$2.0	$6.8	$30.2	$72.7	$146.0	$175.3
Total Damages by Event	$0.0	$0.0	$6.5	$263.6	$504.3	$5,606.8	$24,446.9	$30,116.9
Percent Distribution by Event								
Residential	0.0%	0.0%	68.2%	90.3%	87.4%	78.9%	70.9%	71.0%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.3%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	0.0%	0.0%	0.0%	6.9%	6.3%	18.5%	25.3%	24.7%
Utilities	0.0%	0.0%	0.0%	0.3%	0.2%	0.7%	1.0%	0.9%
Vehicles	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	2.1%	2.6%
Roads	0.0%	0.0%	31.8%	2.6%	6.0%	1.3%	0.6%	0.6%
	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-22
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
MARY'S CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$16.2	$678.1	$2,654.3	$6,666.7	$11,007.9	$16,756.2	$26,500.8	$35,049.6
Public	$0.0	$0.1	$1.9	$7.3	$13.8	$28.3	$53.8	$87.0
Commercial	$0.1	$6.0	$66.8	$219.2	$457.0	$740.6	$1,136.8	$1,442.2
Industrial	$0.0	$0.0	$24.3	$211.7	$687.3	$1,279.7	$2,821.7	$4,397.6
Damages to Structures, Contents	$16.2	$684.2	$2,747.3	$7,104.9	$12,165.9	$18,804.9	$30,513.1	$40,976.4
Postdisaster Recovery Costs	$70.0	$405.1	$1,328.5	$2,576.1	$3,848.3	$5,517.0	$8,071.8	$10,476.7
Utilities	$2.5	$15.2	$50.0	$97.0	$144.9	$207.7	$303.9	$394.4
Vehicles	$0.1	$5.1	$50.9	$192.8	$353.5	$617.7	$1,495.9	$2,248.7
Roads	$3.3	$40.6	$151.0	$266.9	$334.6	$384.0	$486.0	$537.8
Total Damages by Event	$92.1	$1,150.2	$4,327.8	$10,237.6	$16,847.3	$25,531.3	$40,870.8	$54,634.0
Percent Distribution by Event								
Residential	17.5%	59.0%	61.3%	65.1%	65.3%	65.6%	64.8%	64.2%
Public	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%
Commercial	0.1%	0.5%	1.5%	2.1%	2.7%	2.9%	2.8%	2.6%
Industrial	0.0%	0.0%	0.6%	2.1%	4.1%	5.0%	6.9%	8.0%
Postdisaster Recovery Costs	76.0%	35.2%	30.7%	25.2%	22.8%	21.6%	19.7%	19.2%
Utilities	2.7%	1.3%	1.2%	0.9%	0.9%	0.8%	0.7%	0.7%
Vehicles	0.1%	0.4%	1.2%	1.9%	2.1%	2.4%	3.7%	4.1%
Roads	3.5%	3.5%	3.5%	2.6%	2.0%	1.5%	1.2%	1.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-23
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
COWART CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$0.0	$47.8	$126.8	$282.7	$542.7	$950.9	$1,839.0	$2,612.0
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$13.7	$35.7	$43.9	$50.5	$58.2	$70.2	$79.9
Industrial	$0.0	$1.5	$12.5	$23.1	$30.4	$36.4	$42.9	$47.2
Damages to Structures, Contents	$0.0	$63.0	$175.0	$349.7	$623.6	$1,045.6	$1,952.0	$2,739.2
Postdisaster Recovery Costs	$49.9	$236.6	$386.2	$535.6	$685.4	$839.2	$1,043.2	$1,191.3
Utilities	$1.9	$8.9	$14.5	$20.2	$25.8	$31.6	$39.3	$44.8
Vehicles	$0.0	$5.2	$25.6	$49.8	$78.6	$122.2	$208.2	$290.5
Roads	$0.5	$1.9	$5.4	$10.6	$18.7	$31.2	$57.9	$80.5
Total Damages by Event	$52.3	$315.6	$606.6	$965.9	$1,432.2	$2,069.8	$3,300.6	$4,346.3
Percent Distribution by Event								
Residential	0.0%	15.2%	20.9%	29.3%	37.9%	45.9%	55.7%	60.1%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	4.3%	5.9%	4.5%	3.5%	2.8%	2.1%	1.8%
Industrial	0.0%	0.5%	2.1%	2.4%	2.1%	1.8%	1.3%	1.1%
Postdisaster Recovery Costs	95.4%	75.0%	63.7%	55.5%	47.9%	40.5%	31.6%	27.4%
Utilities	3.6%	2.8%	2.4%	2.1%	1.8%	1.5%	1.2%	1.0%
Vehicles	0.0%	1.6%	4.2%	5.2%	5.5%	5.9%	6.3%	6.7%
Roads	1.0%	0.6%	0.9%	1.1%	1.3%	1.5%	1.8%	1.9%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

TABLE 4-24
SINGLE OCCURRENCE DAMAGES BY EVENT
WITH-PROJECT 2070 CONDITION
CHIGGER CREEK
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$6.0	$163.6	$285.7	$465.3	$728.7	$1,167.4	$1,977.4	$2,811.2
Public	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$0.0	$1.6	$4.4	$5.7	$7.0	$9.3	$12.7	$14.6
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Damages to Structures, Contents	$6.0	$165.2	$290.1	$471.0	$735.7	$1,176.7	$1,990.1	$2,825.8
Postdisaster Recovery Costs	$1.0	$38.8	$60.6	$78.5	$122.5	$199.3	$302.9	$436.5
Utilities	$0.0	$1.5	$2.3	$3.0	$4.6	$7.5	$11.4	$16.4
Vehicles	$0.0	$0.9	$8.1	$20.6	$27.9	$41.9	$75.9	$129.1
Roads	$1.0	$6.6	$10.8	$17.4	$27.0	$42.8	$71.5	$89.8
Total Damages by Event	$8.0	$212.9	$371.8	$590.5	$917.6	$1,468.2	$2,451.8	$3,497.7
Percent Distribution by Event								
Residential	74.5%	76.9%	76.8%	78.8%	79.4%	79.5%	80.6%	80.4%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial	0.0%	0.7%	1.2%	1.0%	0.8%	0.6%	0.5%	0.4%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Postdisaster Recovery Costs	12.0%	18.2%	16.3%	13.3%	13.3%	13.6%	12.4%	12.5%
Utilities	0.5%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%
Vehicles	0.0%	0.4%	2.2%	3.5%	3.0%	2.9%	3.1%	3.7%
Roads	13.0%	3.1%	2.9%	2.9%	2.9%	2.9%	2.9%	2.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Attachment 5
Details of Cost Calculations

Details of Cost Calculations. Tables 5-1 and 5-2 show the detailed cost schedule for operations and maintenance (O&M) of the Recommended plan at 4.0 percent and 7.0 percent, respectively. Total average annual O&M at 4.0 percent is $10,601,000. Total average annual O&M at 7.0 percent is $718,200.

Table 5-3 details the construction costs, annualized costs and interest during construction (IDC) for the Recommended plan at the current discount rate of 4.0 percent and for the 50-year period of analysis. Total project first cost is $189,135,000, which on an annual basis equates to $8,804,000, at a discount rate of 4.0 percent and 50-year period of analysis. The total annual IDC is $276,000. The total annual cost at 4.0 percent including IDC and O&M is $10,601,000.

Table 5-4 details the construction costs, annualized costs and interest during construction (IDC) for the Recommended plan at the current discount rate of 7.0 percent and for the 50-year period of analysis. Total project first cost is $189,135,000, which on an annual basis equates to $13,705,000, at a discount rate of 7.0 percent and 50-year period of analysis. The total annual IDC is $765,000. The total annual cost at 7.0 percent including IDC and O&M is $15,188,000.

Tables 5-5 and 5-6 detail the construction costs, annualized costs and IDCs for the Modified Authorized Project (including the Second Outlet and Gates) at the discount rates of 4.0 percent and 7.0 percent for the 50-year period of analysis.

TABLE 5-1
DETAILED COST SCHEDULE FOR OPERATIONS & MAINTENANCE
FOR THE RECOMMENDED PLAN
(4.0%, 50-year Period of Analysis)

Project Year	Contract 1 - Mud Conveyance	Contract 2 - Turkey Conveyance	Contract 3 - Mary's Conveyance	Contract 4 - Lower Main Stem Conveyance	Contract 5 - RR Bridge	Contract 6 - Mid-Main Stem Conveyance	Contract 7 Upper Main Stem Conveyance
1	$900	$8,000	$5,800	$311,000	$0	$831,160	$57,600
2	$900	$8,000	$5,800	$311,000	$0	$831,160	$57,600
3	$3,300	$20,100	$17,900	$347,300	$2,500	$867,460	$93,900
4	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
5	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
6	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
7	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
8	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
9	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
10	$29,300	$55,900	$53,800	$1,527,200	$0	$2,034,600	$200,300
11	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
12	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
13	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
14	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
15	$3,300	$20,100	$17,900	$347,300	$2,500	$472,000	$92,300
16	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
17	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
18	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
19	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
20	$29,300	$55,900	$53,800	$1,527,200	$2,400	$2,034,600	$200,300
21	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
22	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
23	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
24	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
25	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
26	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
27	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
28	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
29	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
30	$31,700	$68,000	$65,900	$1,563,500	$2,500	$2,070,900	$236,600
31	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
32	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
33	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
34	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
35	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
36	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
37	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
38	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
39	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
40	$29,300	$55,900	$53,800	$1,230,200	$2,400	$1,635,300	$200,300
41	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
42	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
43	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
44	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
45	$3,300	$20,100	$17,900	$50,300	$2,500	$72,700	$92,300
46	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
47	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
48	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
49	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
50	$29,300	$55,900	$53,800	$1,230,200	$0	$1,635,300	$200,300
Sum	$225,400	$833,100	$723,600	$17,756,800	$44,800	$24,754,280	$2,871,300
Average Annual O&M	$4,104	$16,127	$13,892	$392,439	$882	$575,344	$57,904
Total Average Annual O&M							$1,060,692

TABLE 5-2
DETAILED COST SCHEDULE FOR OPERATIONS & MAINTENANCE
FOR THE RECOMMENDED PLAN
(7.0%, 50-year Period of Analysis)

Project Year	Contract 1 - Mud Conveyance	Contract 2 - Turkey Conveyance	Contract 3 - Mary's Conveyance	Contract 4 - Lower Main Stem Conveyance	Contract 5 - RR Bridge	Contract 6 - Mid-Main Stem Conveyance	Contract 7 Upper Main Stem Conveyance
1	$900	$8,000	$5,800	$311,000	$0	$831,160	$57,600
2	$900	$8,000	$5,800	$311,000	$0	$831,160	$57,600
3	$3,300	$20,100	$17,900	$347,300	$2,500	$867,460	$93,900
4	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
5	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
6	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
7	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
8	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
9	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
10	$29,300	$55,900	$53,800	$1,527,200	$0	$2,034,600	$200,300
11	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
12	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
13	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
14	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
15	$3,300	$20,100	$17,900	$347,300	$2,500	$472,000	$92,300
16	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
17	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
18	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
19	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
20	$29,300	$55,900	$53,800	$1,527,200	$2,400	$2,034,600	$200,300
21	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
22	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
23	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
24	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
25	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
26	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
27	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
28	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
29	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
30	$31,700	$68,000	$65,900	$1,563,500	$2,500	$2,070,900	$236,600
31	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
32	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
33	$3,300	$20,100	$17,900	$347,300	$2,500	$450,300	$58,900
34	$900	$8,000	$5,800	$311,000	$0	$414,000	$22,600
35	$900	$8,000	$5,800	$311,000	$0	$435,700	$56,000
36	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
37	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
38	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
39	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
40	$29,300	$55,900	$53,800	$1,230,200	$2,400	$1,635,300	$200,300
41	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
42	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
43	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
44	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
45	$3,300	$20,100	$17,900	$50,300	$2,500	$72,700	$92,300
46	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
47	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
48	$3,300	$20,100	$17,900	$50,300	$2,500	$51,000	$58,900
49	$900	$8,000	$5,800	$14,000	$0	$14,700	$22,600
50	$29,300	$55,900	$53,800	$1,230,200	$0	$1,635,300	$200,300
Sum	$225,400	$833,100	$723,600	$17,756,800	$44,800	$24,754,280	$2,871,300
Average Annual O&M	$2,458	$10,108	$8,651	$260,431	$552	$398,304	$37,706
Total Average Annual O&M							$718,210

TABLE 5-3
DETAILED CALCULATIONS OF INTEREST DURING CONSTRUCTION
FOR THE RECOMMENDED PLAN
(4.0%, 50-year Period of Analysis)

Contract No.	Measure/Contract Description	First Cost of Construction (FY10)	Construction Duration (months)	Monthly Cost = (a)/(b)	1+ (i/12 months) where i = 4.0%	$(1 + (i/12)^{(months)} - 1$ = $(d)^{(b)} - 1$	total investment cost for applicable period = (e)/i	construction period = (f) * 12	Total with IDC = (c) * (g)	IDC = (h) - (a)
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	
Contract 1	Mud Gully Conveyance	$21,196,000	9	$2,355,111	1.003	0.03040	0.7601	9.1	$21,480,822	$284,822
Contract 2	Turkey Creek Conveyance	$20,636,000	8	$2,579,500	1.003	0.02698	0.6745	8.1	$20,878,365	$242,365
Contract 3	Mary's Creek Conveyance	$20,765,000	11	$1,887,727	1.003	0.03728	0.9321	11.2	$21,114,567	$349,567
Contract 4	Lower Clear Creek Conveyance	$32,864,000	19	$1,729,684	1.003	0.06527	1.6317	19.6	$33,868,794	$1,004,794
Contract 5	BN&SF RR Bridge	$2,459,000	12	$204,917	1.003	0.04074	1.0185	12.2	$2,504,586	$45,586
Contract 6	Mid-Clear Creek Conveyance (Mykawa to Bennie Kate)	$55,306,000	27	$2,048,370	1.003	0.09401	2.3503	28.2	$57,770,517	$2,464,517
Contract 7	Upper Clear Creek Conveyance (Hwy 288 to Mykawa)	$35,909,000	26	$1,381,115	1.003	0.09038	2.2594	27.1	$37,445,883	$1,536,883
	Totals	$189,135,000							$195,063,536	$5,928,536
	* Amortizaton Factor (4.0%, 50-years)	0.046550							0.046550	0.0465502
	= Annualized Costs	$8,804,272							$9,080,247	$275,975

TABLE 5-4
DETAILED CALCULATIONS OF INTEREST DURING CONSTRUCTION
FOR THE RECOMMENDED PLAN
(7.0%, 50-year Period of Analysis)

Contract No.	Measure/Contract Description	First Cost of Construction (FY10)	Construction Duration (months)	Monthly Cost = (a)/(b)	1+ (i/12 months) where i = 7.0%	$(1 + (i/12)^{(months)} - 1$ = $(d)^{(b)} - 1$	total investment cost for applicable period = (e)/i	construction period = (f) * 12	Total with IDC = (c) * (g)	IDC = (h) - (a)
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	
Contract 1	Mud Gully Conveyance	$21,196,000	9	$2,355,111	1.006	0.05374	0.7677	9.2	$21,697,364	$501,364
Contract 2	Turkey Creek Conveyance	$20,636,000	8	$2,579,500	1.006	0.04763	0.6804	8.2	$21,062,270	$426,270
Contract 3	Mary's Creek Conveyance	$20,765,000	11	$1,887,727	1.006	0.06607	0.9439	11.3	$21,381,369	$616,369
Contract 4	Lower Clear Creek Conveyance	$32,864,000	19	$1,729,684	1.006	0.11685	1.6693	20.0	$34,647,747	$1,783,747
Contract 5	BN&SF RR Bridge	$2,459,000	12	$204,917	1.006	0.07229	1.0327	12.4	$2,539,447	$80,447
Contract 6	Mid-Clear Creek Conveyance (Mykawa to Bennie Kate)	$55,306,000	27	$2,048,370	1.006	0.17005	2.4292	29.2	$59,711,247	$4,405,247
Contract 7	Upper Clear Creek Conveyance (Hwy 288 to Mykawa)	$35,909,000	26	$1,381,115	1.006	0.16326	2.3323	28.0	$38,653,761	$2,744,761
	Totals	$189,135,000							$199,693,205	$10,558,205
	* Amortizaton Factor (7.0%, 50-years)	0.072460							0.072460	0.072460
	= Annualized Costs	$13,704,694							$14,469,740	$765,046

TABLE 5-5
DETAILED CALCULATIONS OF INTEREST DURING CONSTRUCTION FOR THE MODIFIED AUTHORIZED PLAN (4.0%, 50-year Period of Analysis)

Contract No.	Measure/Contract Description	First Cost of Construction (FY10)	Construction Duration (months)	Monthly Cost = (a)/(b)	1+ (i/12 months) where i = 4.0%	$(1 + (i/12)^{(months)} - 1$ = $(d)^{(b)} - 1$	total investment cost for applicable period = (e)/i	construction period = (f) * 12	Total with IDC = (c) * (g)	IDC = (h) - (a)
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	
Contract 1	Mud Gully Conveyance	$21,196,000	9	$2,355,111	1.003	0.030	0.760	9.1	$21,480,822	$284,822
Contract 2	Turkey Creek Conveyance	$20,636,000	8	$2,579,500	1.003	0.027	0.674	8.1	$20,878,365	$242,365
Contract 3	Mary's Creek Conveyance	$20,765,000	11	$1,887,727	1.003	0.037	0.932	11.2	$21,114,567	$349,567
Contract 4	Lower Clear Creek Conveyance	$32,864,000	19	$1,729,684	1.003	0.065	1.632	19.6	$33,868,794	$1,004,794
Contract 5	BN&SF RR Bridge	$2,459,000	12	$204,917	1.003	0.041	1.019	12.2	$2,504,586	$45,586
Contract 6	Mid-Clear Creek Conveyance (Mykawa to Bennie Kate)	$55,306,000	27	$2,048,370	1.003	0.094	2.350	28.2	$57,770,517	$2,464,517
Contract 7	Upper Clear Creek Conveyance (Hwy 288 to Mykawa)	$35,909,000	26	$1,381,115	1.003	0.090	2.259	27.1	$37,445,883	$2,464,517
	2nd Outlet and Gates	$37,864,000	26	$1,456,308	1.003	0.090	2.259	27.1	$39,484,556	$1,536,883
	Project Expenditures thru Sept 11	$16,625,000							$16,625,000	
	Totals	$243,624,000							$251,173,092	$8,393,053
	* Amortizaton Factor (4.0%, 50-years)	0.046550							0.046550	0.046550
	= Annualized Costs	$11,340,746							$11,692,158	$390,698

TABLE 5-6
DETAILED CALCULATIONS OF INTEREST DURING CONSTRUCTION FOR THE MODIFIED AUTHORIZED PLAN
(7.0%, 50-year Period of Analysis)

Contract No.	Measure/Contract Description	First Cost of Construction (FY10)	Construction Duration (months)	Monthly Cost = (a)/(b)	1+ (i/12 months) where i = 4.0%	$(1 + (i/12))^{(months)} - 1$ = $(d)^{(b)} - 1$	total investment cost for applicable period = (e)/i	construction period = (f) * 12	Total with IDC = (c) * (g)	IDC = (h) - (a)
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	
Contract 1	Mud Gully Conveyance	$21,196,000	9	$2,355,111	1.006	0.054	0.768	9.213	$21,697,364	$501,364
Contract 2	Turkey Creek Conveyance	$20,636,000	8	$2,579,500	1.006	0.048	0.680	8.165	$21,062,270	$426,270
Contract 3	Mary's Creek Conveyance	$20,765,000	11	$1,887,727	1.006	0.066	0.944	11.327	$21,381,369	$616,369
Contract 4	Lower Clear Creek Conveyance	$32,864,000	19	$1,729,684	1.006	0.117	1.669	20.031	$34,647,747	$1,783,747
Contract 5	BN&SF RR Bridge	$2,459,000	12	$204,917	1.006	0.072	1.033	12.393	$2,539,447	$80,447
Contract 6	Mid-Clear Creek Conveyance (Mykawa to Bennie Kate)	$55,306,000	27	$2,048,370	1.006	0.170	2.429	29.151	$59,711,247	$4,405,247
Contract 7	Upper Clear Creek Conveyance (Hwy 288 to Mykawa)	$35,909,000	26	$1,381,115	1.006	0.163	2.332	27.987	$38,653,761	$2,744,761
	2nd Outlet and Gates	$37,864,000	26	$1,456,308	1.006	0.090	2.259	27.113	$39,484,556	$1,620,556
	Project Expenditures thru Sept 11	$16,625,000							$16,625,000	
	Totals	$243,624,000							$255,802,761	$12,178,761
	* Amortizaton Factor (7.0%, 50-years)	0.072460							0.072460	0.072460
	= Annualized Costs	$17,652,958							$18,535,430	$882,471

Attachment 6
Sensitivity Analyses

Sensitivity Analyses. As a result of in-depth review of the HEC-FDA model results conducted by the Hydrologic Engineering Center (HEC), further analyses were done to investigate the effect of varying uncertainty parameters as follows:

1. Stage-Discharge Rating Curves
2. Residential First-Floor Stage
3. Risk vs. No Risk

1. Stage-discharge rating curve: Further analysis was done to investigate the effect of various levels of uncertainty in stage-discharge on the recommended plan's BCR. Three levels of uncertainty were investigated – low, most-likely and high. The analysis reveals that reducing the stage-discharge uncertainty to a minimum value of 0.3 to 0.5 results in a BCR of 1.9. The "most-likely" value (as presented in the main economic appendix) results in a BCR of 2.1, while the highest stage-discharge uncertainty value results in a BCR of 2.7. As shown in Table 6-1 below, these changes to the stage-discharge uncertainty values do not significantly alter the final results and indicate that a significant change in stage-discharge uncertainty would not jeopardize project feasibility.

Table 6-1
SENSITIVITY IN STAGE-DISCHARGE RATING CURVES
(4.125%, 50-year Period of Analysis, FY09 Price Levels,)
(Thousands of Dollars)

Uncertainty in Stage-Discharge Rating Curve			
NED Average Annual Impacts	**Low (0.3-0.5 ft)**	**Best**	**High (1.5 ft)**
Total Annual Benefits	$17,693.5	$20,307.0	$25,670.2
Total Annual Project Costs	$9,544.2	$9,544.2	$9,544.2
Benefit/Cost Ratio	1.9	2.1	2.7

2. Residential First-Floor Stage: Further analysis was done to investigate the effect of various levels of uncertainty in the residential first floor stage on the recommended plan's BCR. Three levels of uncertainty were investigated – low, most-likely and high. The analysis reveals that reducing the first-floor uncertainty to a minimum of 0.5 feet results in a BCR of 1.8. The "most-likely" value (as presented in the main economic appendix) results in a BCR of 2.1, while the highest level of uncertainty in first floor elevation results in a BCR of 2.5. As shown in Table 6-2 below, these changes to the residential first-floor uncertainty values do not significantly alter the final results and indicate that a significant change in first floor stage would not jeopardize project feasibility.

Table 6-2
SENSITIVITY IN FINISHED FLOOR ELEVATIONS
(4.125%, 50-year Period of Analysis, FY09 Price Levels,)
(Thousands of Dollars)

Uncertainty in Finished Floor Elevations			
NED Average Annual Impacts	**Low (0.5 ft)**	**Best (1.44 ft)**	**High (1.5 ft)**
Total Annual Benefits	$17,600.5	$20,307.0	$24,235.9
Total Annual Project Costs	$9,544.2	$9,544.2	$9,544.2
Benefit/Cost Ratio	1.8	2.1	2.5

3. Risk vs. No Risk: Further analysis was done to investigate the effect of risk vs. no risk on the recommended plan's BCR. This analysis is only reasonable in establishing the relative importance of uncertainty in the study results. This sensitivity simply removes uncertainty from the analytical results, but does not remove the real uncertainties inherent in the data. This is the most dramatic and conservative of all the sensitivity analyses.

   The results of the risk vs. no risk sensitivity are shown in Table 6-3 below. By ignoring uncertainties inherent in the data, the recommended plan remains viable.

Table 6-3
SENSITIVITY ANALYSIS - RISK VS. NO RISK
(4.125%, 50-year Period of Analysis, FY09 Price Levels,)
(Thousands of Dollars)

With & Without Uncertainty		
NED Average Annual Impacts	**w/ Uncertainty (Best)**	**w/o Uncertainty**
Total Annual Benefits	$20,307.0	$12,614.8
Total Annual Project Costs	$9,544.2	$9,544.2
Benefit/Cost Ratio	2.1	1.3

APPENDIX C
Hydrologic Analysis – Without-Project Conditions

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GIS FILES

Filename	Description
A100-BASINS.SHP	Clear Creek Watershed Boundaries
A100-L.SHP	Longest Watershed Path Shapefile
A100-LCA.SHP	Length to Centroid Path Shapefile
A100-LONGEST-1980.SHP	Longest Definable Channel Shapefile (1980 Conditions)
A100-CI-1980.SHP	Channel Improvement Shapefile (1980 Conditions)
A100-LONGEST-2000.SHP	Longest Definable Channel Shapefile (2000 Conditions)
A100-CI-2000.SHP	Channel Improvement Shapefile (2000 Conditions)
A100-DEVELOP-1980.SHP	Development Shapefile (1980 Conditions)
A100-DEVELOP-2000.SHP	Development Shapefile (2000 Conditions)
A100-CENSUS.SHP	Census Tract Shapefile
A100-POLITICAL.SHP	Political Entity Boundaries
A100-PONDING-1980.SHP	Ponding Shapefile (1980 Conditions)
A100-PONDING-2000.SHP	Ponding Shapefile (2000 Conditions)
A100-SOILS.SHP	Hydrologic Soil Group Shapefile
A100-CREEK.SHP	Creek Centerlines
A100-HEC-NODES.SHP	HEC-1 Routing Notes

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HEC-RAS Files

CLEAR CREEK GENERAL REEVALUATION REPORT
HYDROLOGIC ANALYSIS
WITHOUT-PROJECT CONDITIONS

I. INTRODUCTION AND SCOPE

Purpose - This write-up documents hydrologic modeling studies conducted for the Clear Creek General Reevaluation Report (GRR). The write-up describes the development and calibration of a rainfall-runoff model for the Clear Creek watershed and a hydraulic model for the mainstream of Clear Creek. Simulations with the new models to generate flood frequency are also presented. The models and simulations represent without-project conditions, i.e. flood conditions that are expected to occur in the absence of any major flood damage reduction projects. Hydrologic modeling representing a slate of proposed project alternatives will be documented in the future upon completion.

Models - The rainfall-runoff model (HEC-1) and hydraulic model (HEC-RAS) were created using newly acquired data. The HEC-1 model covers the entire watershed of Clear Creek. The HEC-RAS model includes the mainstream of Clear Creek from the Fort Bend County line to the outlet at Galveston Bay. Similar models have been developed in the past for other purposes, but the new models benefit from modern technologies such as Geographic Information Systems software (GIS), Global Positioning System surveying (GPS), and improved modeling software.

Model Simulations – Simulations with the new models were conducted for historical events and also for hypothetical flood frequency events. Two historical floods were simulated including the October 1994 flood and Tropical Storm Allison (June 2001). The results were compared to historical records to verify the accuracy of the new models.

Hypothetical flood frequency events were simulated to develop the stage and flow frequency results needed in the GRR for flood damage computations. The GRR will address flood damages for a 50-year analysis period (2010 to 2060) representing the approximate economic service life of any project that might be proposed. The flood frequency simulations were made for watershed conditions representing both 2010 and 2060 to capture the range of flooding expected over that period.

Flood Sources - Flood damages along Clear Creek and Clear Lake can result from stream flooding events and also from storm tides. The GRR study authority only addresses stream flooding, so the hydrologic analysis is limited to that flood source.

Tributary Modeling - The write-up only documents flood flows for the main stem of Clear Creek. The GRR will consider flood damages for the main stem and also for six major tributaries including Hickory Slough, Marys Creek, Cowart Creek, Chigger Creek, Mud Gully, and Turkey Creek. The original study scope did not include tributaries, so they were not included in the startup surveys. Later, the GRR scope was broadened; so tributary flood frequency results will be required. Flood flows for the tributaries are a byproduct of the mainstream HEC-1 simulations. The corresponding flood stages will be computed with hydraulic models developed in previous flood insurance studies. Neither the flows nor stages for tributaries are presented at this time.

Related Studies and Models – Computer models for the Clear Creek watershed have been developed and updated several times in the last few decades. Some of the earliest models were created for developing the old Authorized Federal Project, for watershed master planning, and for the first flood insurance mapping studies. These models date back to the early 1980's. Dannenbaum Engineering Corporation (DEC) performed most of the Clear Creek hydrologic modeling studies to date working with funding from agencies including Harris County Flood Control District and the Texas Water Development Board.

The Clear Creek Hydraulic Baseline Report was completed in September 1991. Hydrologic and hydraulic models of Clear Creek and its tributaries were updated from the earlier flood insurance models. The computed flood plain and floodway boundaries were incorporated into the updated FEMA FIRM panels (September 22, 1999).

The Clear Creek Regional Flood Control Plan was completed in December 1992. This report analyzed structural and non-structural flood control alternatives for the projected flood control needs of the Clear Creek watershed. A regional plan was selected that would reduce or eliminate flood damages and accommodate continued watershed development. The plan relied on mainstream flood capacity that was to be provided by the old Authorized Federal Project, which is no longer slated for construction.

In 1997 modeling studies were conducted to identify a Sponsor Proposed Alternative that would substitute for the Authorized Federal Project but with less environmental impacts. A plan was identified and presented at a series of public meetings. The Corps of Engineers decided that the new sponsor plan was not sufficiently similar to the original plan to allow construction under the original project authorization.

More recently, following Tropical Storm Allison in June 2001, FEMA and Harris County decided to modernize the flood insurance maps within Harris County. The new Clear Creek GRR HEC-RAS model was transferred to the FEMA contractor along with all the supporting maps and terrain data. Thus, the new FEMA model will be a derivative of the GRR HEC-RAS model. The FEMA analysis will utilize HEC-HMS for rainfall-runoff modeling instead of HEC-1.

Projections and Datum - Mapping and GIS related data for the GRR were referenced to NAD 83 and the State Plane Coordinate System, South Central Zone. Vertical elevations were referenced to NAVD 88 (2000 epoch) where epoch refers to the date of the surveys.

Watershed Description - The Clear Creek watershed is located in the San Jacinto-Brazos Coastal Basin and lies within the counties of Harris, Galveston, Fort Bend, and Brazoria (see Exhibit I.1). As seen in Exhibit I.2, the watershed includes 16 cities and covers approximately 260 square miles. The Clear Creek watershed is about 45 miles long in an east-west direction and varies in width from 2.5 miles at its upstream end to 13.5 miles at its midpoint. The watershed is a flat coastal plain with a maximum ground surface elevation of approximately 70 feet and a minimum elevation of about 5 feet at the outlet.

Stream Gages and Records - Stream gages have been operated along Clear Creek since at least 1946. Gage measurements are important to the GRR hydrologic analysis because they provide a historical record of specific flood flows and stages that can be used to calibrate the hydrologic models. Table I.1 lists locations and record periods for each gage along the mainstream of Clear Creek. The table also shows how each gage was utilized in the hydrologic analysis**.**

TABLE I.1
STREAM GAGES ALONG CLEAR CREEK

Gage ID	Location	Operated By	Record Type	Record Period	How Gage Was Used in the GRR Modeling Analysis			
					Annual Peaks Used for Statistical Frequency Analysis	Recorded Hydrographs Used for HEC-1 Historical Event Simulations	Stage Discharge Measurements Used for HEC-RAS Roughness Calibration	Recorded Stage Used for HEC-RAS Historical Event Flood Profile Simulations
08077000 Clear Creek Near Pearland, TX	Downstream side of State Highway 35 at X/S 185547	USGS	Stage and flow	WY1946-1994	X		X	
08077540 Clear Creek At Friendswood, TX	Downstream side of FM 2351 at X/S 112393	USGS	Stage and flow	WY1995-1997		X (Oct 1994)	X	X (Oct 1994)
08077600 Clear Creek Near Friendswood, TX	Downstream side FM528 at X/S 90072	USGS	Stage only Stage and flow	WY1966-1994 WY1998-2001	X	X (TS Allison - June 2001)	X	X (TS Allison - June 2001)
HCOEM Gages	Eight gages along the Harris Co reach	Harris Co. Office of Emergency Manag.	Stage only	Beginning in 1985				X

II. SPECIAL MODELING ASSUMPTIONS AND OVERVIEW

GRR Approach Versus Master Plan Approach - A conventional drainage master plan would target some future development scenario and then determine the size of drainage features, secondary laterals, and primary laterals necessary to accommodate that design condition. The GRR analysis is fundamentally different. Its objective is to identify the most efficient measures that can be taken to reduce flood damage. It does not presume or attempt to accommodate future, locally constructed channel rectifications since that would be forcing a solution that has not been demonstrated. Thus, the new without-project models do not assume a future condition where primary laterals are rectified. If the opposite assumption were made, mainstream flood damage estimates for future condition would be greater due to the higher flows that would result from widened tributary channels. The HEC-1 models were coded to reflect development trends in the watershed. The impervious percentage of each subbasin was increased and the runoff coefficients were adjusted to show conversion to urban drainage systems. However, the models were not coded to reflect future channel rectification of primary laterals.

Second Outlet Modeling - The Clear Lake Second Outlet is a dredged outlet channel connecting Clear Lake to Galveston Bay. It is technically a project feature (a portion of the old Authorized Federal Project). Thus, the Second Outlet is deliberately excluded from the GRR without-project models. It will be modeled later for the with-project modeling phase. Its effectiveness will be measured both as a stand-alone feature dedicated to flood damage reduction for property around Clear Lake and alternatively as a flow mitigation feature as was originally intended. A goal of the GRR will be to determine which function is the most efficient for reducing flood damage.

Detention Basin Modeling - The new models treat detention basins in one of two ways depending on their function. Detention basins built to mitigate development are represented in the HEC-1 model by adjusting subbasin runoff coefficients to show that the full effects of development are at least partially mitigated. Detention basins built to *reduce* the existing flood risk (not merely mitigate development) are intentionally omitted from the GRR modeling. This approach prevents these locally constructed flood damage reduction features from reducing computed benefits for any future Federal project. This strategy is expressly directed by Federal legislation (Water Resources Development Act of 1996, Section 575). The intent is to avoid penalizing local governments for taking action to reduce existing flood damage.

Predicting the Effects of Detention Policies – Many communities within the Clear Creek watershed have ordinances that are designed to prevent new urban development from creating or worsening flood problems. The ordinances require detention basins to detain increased runoff. The current and future effectiveness of these policies is an important factor in predicting flooding along Clear Creek. A method was developed to reflect detention policies in the GRR HEC-1 modeling. This is described in detail in later sections of this write-up.

Overview of Analysis Procedures - Hydrologic models were developed, calibrated, and used to compute flood frequency along Clear Creek. The individual steps are outlined in Table II.1.

TABLE II.1
OUTLINE OF WITHOUT-PROJECT MODELING ANALYSIS

Initial Model Development

- Obtain basic data (channel cross-section surveys, bridge surveys, digital terrain data, digital orthophotos, population projections, rainfall atlas data, historical rainfall data, stream gage records, etc.)

- Develop HEC-RAS and HEC-1 models. Develop the needed HEC-1 model versions (1994 and 2001 for historical flood simulations and 1980, 2010, and 2060 for flood frequency simulations). Use population projections to estimate urban development conditions for the 2010 and 2060 models.

Calibrate Models

- Calibrate HEC-RAS by adjusting hydraulic roughness values until computed stage-discharge agrees with gage measurements.

- Calibrate/verify HEC-1 by simulating historical events (October 1994 and June 2001 floods). Compare simulated flood hydrographs with hydrographs recorded at stream gages. Also, compute water surface profiles with HEC-RAS using simulated flood peaks from HEC-1 and compare with observed high-water marks.

Flood Frequency Simulations

- Simulate flood frequency events and compare resultant flow frequency to values from independent sources (regression equations and statistical analysis of gage records). Adjust assumed HEC-1 rainfall loss rates if necessary so that simulated peaks are judged to be reasonable in comparison to the other estimates. (This verification process was made with the HEC-1 model representing 1980 conditions. The regression estimates were also based on 1980 conditions, and the statistical analysis results roughly approximate 1980 conditions.)

- Simulate HEC-1 flood frequency events for 2010 and 2060 watershed conditions (eight frequencies each). Compute corresponding flood stages with HEC-RAS. This step defines flood frequency for the beginning and ending of the GRR economic analysis period.

Export 2010 and 2060 Flood Frequency to Economics Model

- Determine uncertainty parameters for the HEC-1 flow frequency results.

- Determine uncertainty parameters for the HEC-RAS stage discharge results.

- Export computed flood flows, stages, and uncertainty parameters into the FDA economics models for computation of expected flood damage over the analysis period (2010-2060).

(End of Analysis)

III. HEC-1 WATERSHED MODELING

Watershed and Subbasin Delineation – A watershed delineation was created representing the current (year 2000) watershed and subbasin boundaries for the Clear Creek watershed. This delineation was used to represent all modeling conditions. Boundaries tend to change slightly as development alters natural drainage patterns, but the changes are rarely significant at the mainstream and major tributary level. The delineation was patterned similar to versions used for previous modeling studies of Clear Creek and reflects both surface topography and also subsurface storm drain patterns. The delineation was not computer generated from digital terrain as is possible with GIS computer processing. The watershed and subbasin boundaries used in this study may be found in Exhibit III.1.

HEC-1 Subbain Unit Hydrograph Method – The Clark unit hydrograph method was used in the Clear Creek HEC-1 model to compute runoff from individual subbasins. Harris County Flood Control District equations were used for estimating the required subbasin runoff coefficients TC and R. The equations are described in Appendix A. The equations utilize the following subbasin characteristics:

Drainage Area (A)
Watershed Length (L)
Watershed Length to Centroid (L_{ca})
Channel Slope (S)
Watershed Slope (S_o)
Percent Land Urbanization (DLU)
Percent Channel Improvement (DCI)
Percent Channel Conveyance (DCC)
Percent Ponding (DPP)

Flood Hydrograph Routing and Routing Steps - Hydrograph routing in the HEC-1 model was performed using the Modified Puls routing method. The required storage-outflow data for each reach were determined with HEC-RAS using multi-pass analysis so that the final storage-outflow routing data and final computed flood profiles were consistent. The number of routing steps for each routing reach was based on reach travel time divided by the HEC-1 computation interval (15-minutes). The storage-outflow routing data derived from the calibrated HEC-RAS model represent current (year 2000) conditions. However, the same routing data were judged to be sufficiently representative for all without-project conditions.

Storage-outflow data for routing reaches along tributaries were borrowed from previous flood insurance models since new HEC-RAS modeling was only available for the mainstream. It should be noted that the storage-routing data for all tributaries including Armand Bayou were not changed for the future condition models i.e., no future channel rectifications were assumed.

Subbasin Rainfall Loss Potential - The initial/constant loss rate methodology was utilized for this study. This method assumes that the first rainfall increments are absorbed or otherwise abstracted up to a certain “initial rainfall loss” value specified in inches. All additional rainfall in excess of this initial loss will become direct runoff except for a "constant loss" specified in inches per hour.

Loss rates are dependent upon the predominant soil types within the watershed. To determine the soil types within the Clear Creek watershed, Soil Conservation Service (SCS) soil data for Harris, Galveston, Brazoria, and Fort Bend counties were compiled. Exhibit III.2 displays the various SCS hydrologic soil group categories for the Clear Creek watershed. As seen in the exhibit, the predominant hydrologic soil group is Type "D". This soil group has the highest runoff potential of the four SCS soil groups (A, B, C or D).

Relatively small loss rates were assumed for the HEC-1 flood flow frequency simulations to reflect the impermeable nature of the soils. An initial loss of 0.5 inches and a constant loss rate of 0.1 inches per hour were used. The suitability of these values for flood flow simulations was verified by comparing the HEC-1 results with flood flow frequency from independent methods. Loss rates for historical simulations were set at values that most closely matched runoff volumes recorded at flow gages during the actual events.

HEC-1 Modeling Versions - Versions of the HEC-1 model were developed to represent different watershed conditions. A primary product of the modeling analysis was flood flow frequency for 2010 and 2060. Therefore HEC-1 model versions were needed representing those two conditions. Other versions were needed for calibration purposes. Table III.1 lists all of the HEC-1 model versions created and describes their purpose in the analysis.

Creating HEC-1 Modeling Versions - The HEC-1 model versions (1980, 1994, 2001, 2010, and 2060) were created by changing the subbasin runoff coefficients TC and R (and imperviousness) to represent each watershed condition. The values needed for each condition were computed with subbasin parameters representing each year. The subbasin parameters in the TC and R equations can be divided into two groups as follows:

- Development-Independent Parameters:
    - Drainage Area (A)
    - Watershed Length (L)
    - Watershed Length to Centroid (L_{ca})
    - Channel Slope (S)
    - Watershed Slope (S_o)

- Development-Dependent Parameters:
    - Percent Land Urbanization (DLU)
    - Percent Channel Improvement (DCI)
    - Percent Channel Conveyance (DCC)
    - Percent Ponding (DPP)

The development-independent parameters were set based on aerial photos, previous studies, and survey data. Their values are the same for all model versions (see Appendix B).

The development-dependent parameters were estimated using the methods outlined in Table III.2 and described below. Their values are different for each model version.

TABLE III.1
HEC-1 MODELING VERSIONS
(Without-Project Conditions)

HEC-1 Version (Watershed Conditions Representing):	Purpose in Analysis
1994	Historical simulations to simulate the October 1994 flood event. Comparisons of recorded and simulated hydrographs confirm the accuracy of the HEC-1 modeling. Computed peak flows also used in HEC-RAS to simulate historical flood profile for comparison with historical high water marks.
2001	Historical simulations to simulate the June 2001 (T.S. Allison) flood event. Comparisons of recorded and simulated hydrographs confirm the accuracy of the HEC-1 modeling. Computed peak flows also used in HEC-RAS to simulate historical flood profile for comparison with historical high water marks.
1980	Flood frequency simulations to compute 1980 flow frequency for comparison with independent estimates (statistical frequency analysis and regression equation methods). The comparison reveals the accuracy of the HEC-1 flood frequency modeling and the assumed rainfall loss rate.
2010	Flood frequency simulations to compute flow frequency for flood damage calculations. (Represents the beginning of the economic analysis period.)
2060	Flood frequency simulations to compute flow frequency for flood damage calculations. (Represents the end of the economic analysis period.)
2060 Uncontrolled	Flood frequency simulations to compute flow frequency for 2060 conditions assuming no watershed development detention requirements. These results compared to the other 2060 case show the impact of existing detention policies on flow frequency.

TABLE III.2
DERIVATION OF DEVELOPMENT-DEPENDENT SUBBASIN PARAMETERS
(Without-Project Conditions)

HEC-1 Model Version:	DLU (Percent Land Urbanization)	DCI (Percent Channel Improvement)	DCC (Percent Channel Conveyance)	DPP (Percent Ponding)
1980	Measured from 1980 aerial photos	Measured from 1980 aerial photos	Taken from 1991 Hydraulic Baseline Report	Measured from 1984 aerial photos
1994	Interpolated between 1980 and 2000 measured values	Interpolated between 1980 and 2000 measured values	Interpolated between 1980 and 2010	Interpolated between 1980 and 2000 measured values
2001	Interpolated between 2000 measured values and 2010	Interpolated between 2000 measured values and 2010	Interpolated between 1980 and 2010	Interpolated between 2000 measured values and 2010
2010	Based on census tract population projections for 2010	Interpolated between 2000 and 2060 values based on subbasin DLU	Interpolated between 2000 and 2060 based on subbasin DLU. (DCC for 2000 assumed same as 1980.)	Based on measured 2000 ponding values reduced proportionally by additional development
2060	Based on census tract population projections for 2060	DCI set equal to DLU. Values for subbasins adjacent to mainstream were weighted based on lateral and mainstream length.	Weighted average between the lateral (improved) and the main channel (unimproved). Lateral value is based on DLU table.	Based on measured 2000 ponding values reduced proportionally by additional development

Projecting 2010 and 2060 Urbanization (DLU) Using Population Trends – The first development-dependent subbasin parameter, DLU, was measured for 1980 and 2000. Values for 2010 and 2060 were projected based on population trends using the following steps:

- Map the urban development for year 2000:
  Development for year 2000 was mapped (see Exhibit III.3) using aerial photos from that year. Developed area within the watershed was delineating as 100% developed or 50% developed. Areas designated as 100% development include dense commercial/industrial areas, and dense residential subdivisions. Areas designated as 50% developed included residential subdivisions with large lots or light industrial areas.

- Determine year-2000 development acreage for census tracts:
  The amount of developed area within each census tract covering the watershed was determined by overlaying the development map onto the census tract map and computing the weighted developed area falling within each tract (see Exhibit III.4).

- Determine year-2000 "population/development area" ratio for census tracts:
  Year-2000 population counts were coupled with the development area acreage within each census tract to compute the population/developed area ratio.

- Project development for each census tract for 2010 and 2060:
  It was assumed that the "population/developed area" ratio for each census tract would remain constant in the future. Thus, the amount of development for each tract could be projected for 2010 and 2060 conditions based upon census projections for those years.

- Determine 2010 and 2060 development for each subbasin:
  The development levels for each subbasin were then obtained by overlaying the census tract map with the subbasin map to compute the weighted development in each subbasin.

Results of Development Projections – The urban development projections provided development percentages for each subbasin (see Appendix C). The development percentages for the entire basin (based on the weighted subbasin values) are shown in Table III.3.

TABLE III.3
CLEAR CREEK URBAN DEVELOPMENT PERCENTAGES

Year	Corresponding Clear Creek Watershed Urban Development	Source
1980	25%	Measured from 1980 aerial photos
2000	35%	Measured from 2000 aerial photos
2010	42%	Based on census tract population projections for 2010
2060	69%	Based on census tract population projections for 2060

Determining Remaining Development-Dependent Subbasin Parameters – The remaining development-dependent subbasin parameters were determined as described in Table III.2 and detailed below for each parameter. (See Appendix C for listings of the derived 2010 and 2060 parameters for each subbasin.)

- Percent Channel Improvement (DCI) - The main channel of Clear Creek, Armand Bayou, and their major tributaries were assumed to not have future channel improvements beyond current (year 2000) conditions. However, the minor lateral channels of the watershed were assumed to have drainage improvements that pace development. Thus, 2060 DCI values for subbasins on minor lateral channels were set equal to the subbasin's development percentage (DLU). Subbasins along the mainstream of Clear Creek had their 2060 DCI values predicted by taking a weighted average between the predicted lateral channel improvements (equal to subbasin DLU) and the existing main channel DCI. The future condition DCI values were constrained to never be lower than the 2000 value. Year-2010 values for DCI were interpolated between year-2000 values and 2060 projected values based upon each subbasin's DLU.

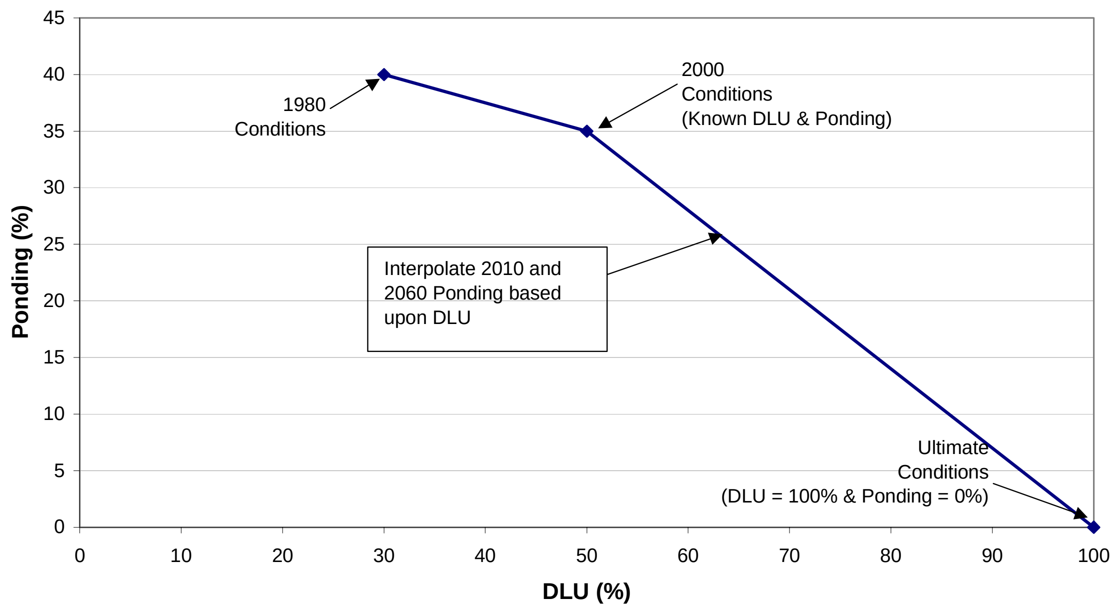
- Channel Conveyance (DCC) – Year-2060 channel conveyance was also predicted based upon each subbasin's urbanization percentage. The conveyance percentage of Clear Creek and its tributaries was known for current conditions and assumed to be static. Year-2060 channel conveyance on minor lateral channels was assumed to increase by the following relationship.

Urbanization %	Conveyance % (Never Less Than Current (2000) Conveyance)
< 18%	Year-1980 Conveyance
18%	35% Conveyance (Approximate 2-year capacity)
25%	37% Conveyance
50%	66% Conveyance (Approximate 10-year capacity)
100%	100% Conveyance

A weighted average between the lateral conveyance and the main channel conveyance was determined for all subbasins. Year-2010 values for DCC were interpolated between year-2000 values and 2060 projected values based upon each subbasin's DLU.

- Ponding Percentage (DPP) - Ponding percentages of each subbasin were reduced according to the amount of development that is projected for future conditions. Since a subbasin that is fully developed (DLU = 100%) will have 0% ponding, and the year-2000 ponding and DLU percentage are known for each subbasin, the 2010 and 2060 ponding percentage can be interpolated between these two points.

Figure III.1
Example of the Ponding vs. Development Relationship



Subbasin Control Factors - Beginning in the 1980's some jurisdictional entities began to require storm water detention for new development projects. Thus, development after that period will have less flow impacts than indicated by the development-dependent subbasin parameters. The parameters discussed in the previous sections are "uncontrolled", meaning they do not reflect the effects of detention ordinances. A method was developed to adjust the uncontrolled parameters to incorporate detention ordinances.

A Control Factor (CF) was derived for each of the four development-dependent subbasin parameters. The Control Factors allow only a fraction of the maximum increase in a parameter to occur. For example, a subbasin with a DCI control factor of 0.2 would allow only 20% of the "uncontrolled" increase in DCI between 1980 and 2060 conditions to occur, as seen below:

FIGURE III.2
CONTROL FACTOR EXAMPLE

2000 DCI	2060 "Uncontrolled" DCI	Control Factor	2060 "Controlled" DCI
20%	80%	0.2	32%

2060 "Controlled" DCI = ((2060 "Uncontrolled" DCI - 2000 DCI) x Control Factor) + 2000 DCI
= ((80% - 20%) x 0.2) + 20%
= 32%

Control factors were applied to each subbasin in the Clear Creek watershed. These factors were estimated by considering the relative stringency of the detention ordinances of each entity within the Clear Creek watershed. This ranking was used to postulate a Control Factor for DLU, DCI, DCC and DPP by entity. Using GIS, weighted Control Factors were determined for each subbasin based upon the amount of each entity falling within the subbasin.

Many residents along Clear Creek feel that runoff control ordinances have been ineffective and that rapid development in the watershed has led to a noticeable increase in flooding. On the other hand, plots of the recorded annual flood peaks for stream gages along the creek do not reveal a pattern of dramatic flow increases. Annual flood peak trends in the most recent historic period are not much different from those earlier in the record. Thus, impacts to date have been relatively moderate so as to be obscured by normal climactic fluctuations. Test modeling runs using the Control Factor approach produced results consistent with this trend, i.e. flows increase with development but runoff controls buffer impacts so that residual effects are moderate.

It should be noted that Control Factors to account for residual impacts are a planning tool and not a measurement of an entity’s runoff control criteria effectiveness. Control Factors were based upon conjecture and not upon fact. Modeling tests and experiments were conducted to help determine the Control Factors but the values were mostly based on judgment. Potential limitations for current policies in at least some areas are listed in Table III.4. Control Factors for each subbasin are listed in Appendix C.

TABLE III.4
POTENTIAL LIMITATIONS FOR LOCAL DETENTION POLICIES

a. Flow increases can occur from land use changes other than residential, commercial, or industrial development. Some examples include conversions from forest to pasture, from rice farming acreage to pasture, or simply grading an area to improve drainage. Some vacant sites may have been graded to remove natural prairie pothole features to avoid possible future wetland regulation issues. Flow increases from these conversions may not be covered by detention policies.

b. Small developments (like single homes) are frequently exempted from detention requirements. Given sufficient numbers, this could result in an impact. Some jurisdictions are already substantially developed so detention is not required for the few remaining vacant lots.

c. Some areas of the Clear Creek watershed that were formerly used for rice farming have unusually low runoff rates due to the ponding effects of agricultural levees. As these areas develop, conventional engineering computations for detention requirements may not recognize this and accordingly overestimate the pre-development flow. Thus, the detention requirements are underestimated since a much larger detention basin would be needed to control runoff to the original (unusually low) rates.

d. The correction of drainage problems in established, developed areas may be considered a maintenance issue rather than new construction. Thus, detention is not required. An example of this would be the emergency deepening and widening of a lateral following a severe flood. This would result in increased flow for downstream areas.

e. Requirements for some jurisdictions are not codified because it was envisioned that a basin-wide drainage district would be formed to unify and strengthen requirements. Also, in the absence of a basin-wide authority, the administration and interpretation of existing detention policies is vulnerable to local politics.

f. Parking lots or recreation areas may be accepted for meeting detention requirements. However, the nuisance effects might eventually lead to drainage modifications that would diminish the detention function.

g. Required detention volume may sometimes be created by "leveeing off" flood plain area so that, in effect, the detention volume is robbed from the floodplain volume. Also, placement of fill in the floodplain is not regulated in some jurisdictions. These actions deplete floodplain storage volume, which generally increases downstream flows.

h. Maintenance of private detention facilities (i.e. sediment removal, outlet works repair, etc.) over the long term (decades) may be uncertain. Also, some private facilities may not be protected from future conversion to other uses.

HEC-1 Historical Flood Simulations - A historical event simulation is generated by applying a measured or estimated rainfall pattern for a particular rainfall event to a watershed's hydrologic model. The resultant runoff hydrographs are compared to measured stream gage data and/or compared to measured highwater marks by placing the resultant peak flows in HEC-RAS. This verification process was completed for Clear Creek using the June 2001 and October 1994 events.

Rainfall for Historical Simulations - Nexrain Corporation was contracted to develop rainfall data, in a HEC-1 format, for Clear Creek. Nexrain Corporation developed data for the June 2001 (Tropical Storm Allison) and the October 1994 events. Nexrain based their rainfall upon 15-minute NEXRAD radar rainfall estimates that have a data resolution of approximately 2 km x 2 km. The raw radar rainfall data was calibrated to measured values using rainfall gages from three sources: the Harris County Office of Emergency Management (HCOEM), the City of Houston, and the National Weather Service (NWS). Sixty (60) gages were used to calibrate the 1994 storm event, while one hundred fifty six (156) gages were used to calibrate the 2001 event. Calibration of the raw NEXRAD rainfall data was required to mitigate the effects of ground-based objects and other factors that might skew the results of the raw radar rainfall data.

As a final product, Nexrain developed a basin average rainfall distribution for each of the drainage basins in the Without-Project conditions HEC-1 models for Clear Creek. The October 1994 event data has a time increment of 30 minutes and spans from October 15, 1994 (12:00 AM) to October 19, 1994 (12:00 AM). The June 2001 event data has a time increment of 30 minutes and spans from June 5, 2001 (12:00 AM) to June 10, 2001 (12:00 AM). The rainfall data for the 1994 and 2001 historical events may be found in Appendix D.

Comparison of Nexrain Rainfall with Gage Data - Nexrain's 1994 event rainfall data was compared with other rainfall data collected by the City of Pearland (COP) for this event. Table III.5 compares the COP gages with the Nexrain adjusted basin rainfall data (basin average) that corresponds to each gage. It should be noted that the COP gages were not used in the Nexrain calibration since they are not a uniform increment temporal gages. The COP gage data was collected by hand at irregular intervals, making it unusable in Nexrain's calibration process; however, the overall depth of rainfall collected by these gages should be comparable with the Nexrain values.

As seen in Table III.5, some significant differences exist between the Nexrain rainfall data and the COP data. It is understood that this table is comparing point rainfall data with average basin rainfall depths; however, significant differences are present in enough locations that the accuracy of the Nexrain's 1994 rainfall data should be questioned. The accuracy is not questioned due to methods used by Nexrain, but is questioned due to the limited number of time series rainfall gages available to calibrate the NEXRAD radar rainfall data. This may have contributed to an underprediction of the 1994 event rainfall.

Table III.5
1994 EVENT RAINFALL COMPARISON

Gage Data		*NEXRAIN Data*			
Rain Gage ID	Total Rainfall (Inches) (10/17 - 10/18/94) **(1)**	Associated Drainage Basin	NEXRAIN Basin Total Rainfall (in) (10/15 - 10/18/94) **(2)**	Difference (Inches) **(2)-(1)**	% Difference
COP-1	27.03	A100A2	10.254	-16.776	-62.1%
COP-2	27.09	A100B5	14.808	-12.282	-45.3%
COP-3	22.08	A100C	14.732	-7.348	-33.3%
COP-4	21.02	A100E1	12.381	-8.639	-41.1%
COP-5	21.04	A100E1	12.381	-8.659	-41.2%
COP-6	22.07	A100E2	10.673	-11.397	-51.6%
COP-7	19.07	A100E2	10.673	-8.397	-44.0%
CPWW-1	13.1	A100E1	12.381	-0.719	-5.5%
CPWW-2	13.7	A100E2	10.673	-3.027	-22.1%
HCFCD #140	13.94	A119B	10.629	-3.311	-23.8%
HCFCD #180	10.71	A100D	13.33	2.62	24.5%

As seen in Table III.6, a similar comparison was made for Nexrain's 2001 event data. The 2001 Nexrain rainfall data was compared to HCFCD gages within the Clear Creek watershed. During the June 2001 event at least seventeen (17) temporal rain gages were present within the Clear Creek watershed, as opposed to approximately four (4) for the 1994 event. The increased number of rainfall gages during the 2001 event allowed for a better calibration of the raw radar rainfall data, as supported by Table III.6. Again, it should be noted that Table III.6 is comparing a point rainfall depth (HCFCD gage data) with a basin average depth (Nexrain basin total rainfall).

Table III.6
2001 EVENT RAINFALL COMPARISON

Gage Data		*NEXRAIN Data*			
Rain Gage ID	Total Rainfall (Inches) (6/5 - 6/10/01) **(1)**	Associated Drainage Basin	NEXRAIN Basin Total Rainfall (in) (6/5 - 6/10/01) **(2)**	Difference (Inches) **(2)-(1)**	% Difference
HCFCD #100	10.67	A100M	14.095	3.425	32.1%
HCFCD #105	19.53	MA100E	18.062	-1.468	-7.5%
HCFCD #110	19.21	A100J	17.566	-1.644	-8.6%
HCFCD #115	28.66	CW100D	18.415	-10.245	-35.7%
HCFCD #120	13.7	A100H	17.26	3.56	26.0%
HCFCD #125	19.72	CH100C1	18.706	-1.014	-5.1%
HCFCD #130	21.5	A100I	18.92	-2.58	-12.0%
HCFCD #140	18.9	A119B	18.849	-0.051	-0.3%
HCFCD #150	16.14	A120B	18.904	2.764	17.1%
HCFCD #160	17.12	A100E2	18.335	1.215	7.1%
HCFCD #180	22.48	A100D	20.978	-1.502	-6.7%
HCFCD #190	13.81	A100B4	15.299	1.489	10.8%
HCFCD #210	18.19	B100E	17.619	-0.571	-3.1%
HCFCD #220	19.65	B111A	19.91	0.26	1.3%
HCFCD #230	20.2	B106B	20.628	0.428	2.1%
HCFCD #240	19.02	B100A	21.187	2.167	11.4%
HCFCD #250	18.66	B104G1	19.402	0.742	4.0%

Historical Event Watershed Parameters – Watershed parameters for the 1994 and 2001 development conditions were created for the 1994 and 2001 historical simulations. Only the development-dependent watershed parameters (DLU, DCI, DCC & DPP) had to be created as outlined in Table III.2. The historical simulation hydrologic models reflect 1% exceedance event R-values**.**

Historical Event Simulation Verification – To verify the accuracy of the study's hydrologic and hydraulic models, a calibration was performed. The results from the historical event simulations were compared with measured stream gage data, as well as highwater marks. If necessary, modifications would be made to the study's hydrologic and hydraulic models until their results adequately matched measured values.

There were two steps in the historical event calibration: loss rate verification and peak flow verification. Loss rate parameters were verified based upon a comparison of the measured hydrograph volume versus the simulated hydrograph volume at a common location. Simulated loss rates would be modified, if necessary, to match measured runoff volume. The peak flow and hydrograph shape of the simulated event was verified against a measured hydrograph

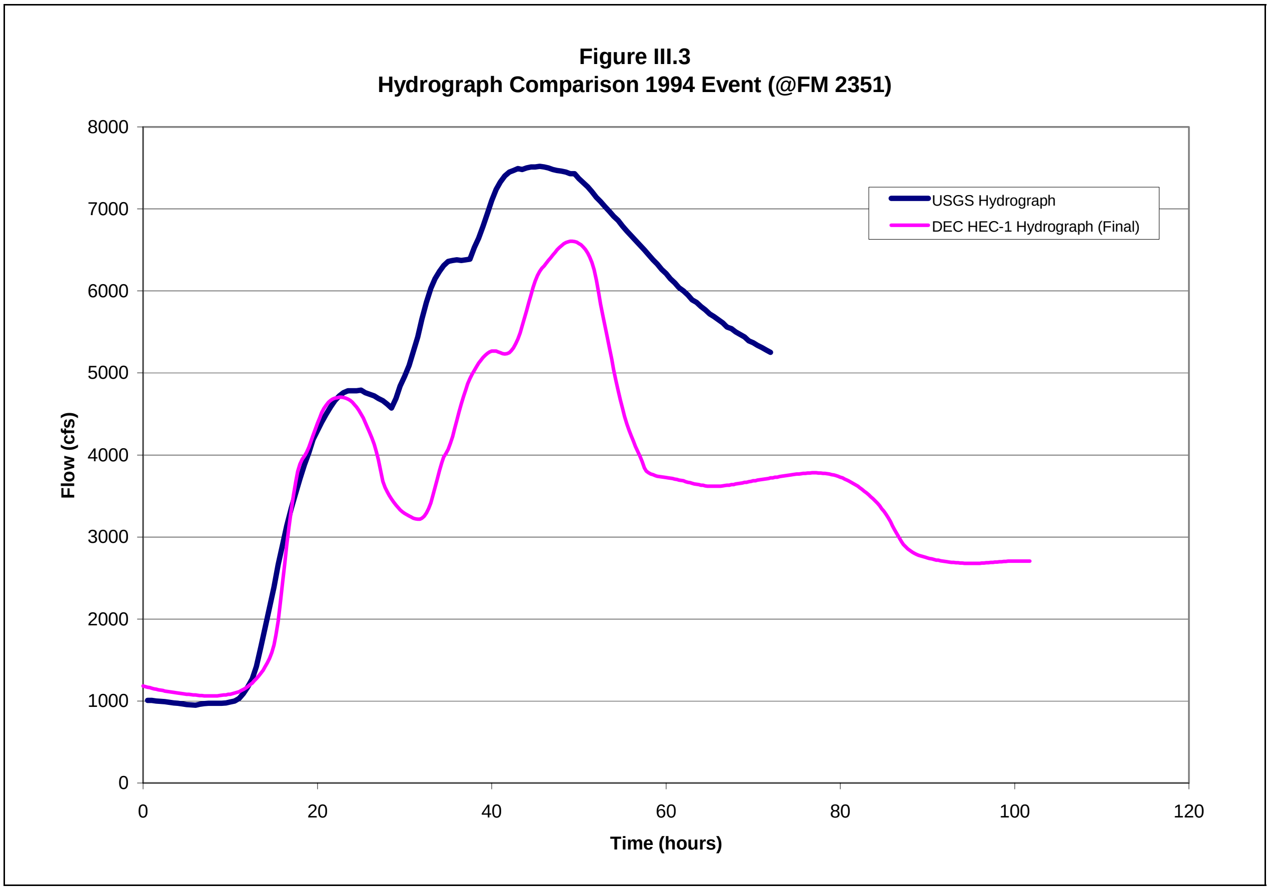
(Stream Gage). This comparison was used to verify the accuracy of the HEC-RAS routing data (n-values).

The 1994 condition watershed parameters and the 1994 event rainfall were used to develop a HEC-1 simulation for the 1994 storm event. The hydrograph from a measured USGS stream gage was compared with the HEC-1 model's simulated hydrograph at the same location. As seen in Table III.7, the simulated 1994 event hydrograph at FM 2351 had approximately 24% less volume than the measured USGS hydrograph (08077540) at the same location. In addition, the peak of the simulated hydrograph (6607 cfs) was approximately 12% lower than the measured hydrograph's peak flow of 7520 cfs. Figure III.3 displays this relationship.

Table III.7
1994 EVENT HYDROGRAPH VOLUME COMPARISON

Start Time:	10/17/1994	12:00 AM
End Time:	10/20/1994	12:00 AM

1.	USGS Volume (ac-ft) =	29281
2.	DEC HEC-1 Volume w/ Nexrain Data (ac-ft) =	22184
% Difference (1-2) =		-24.2%

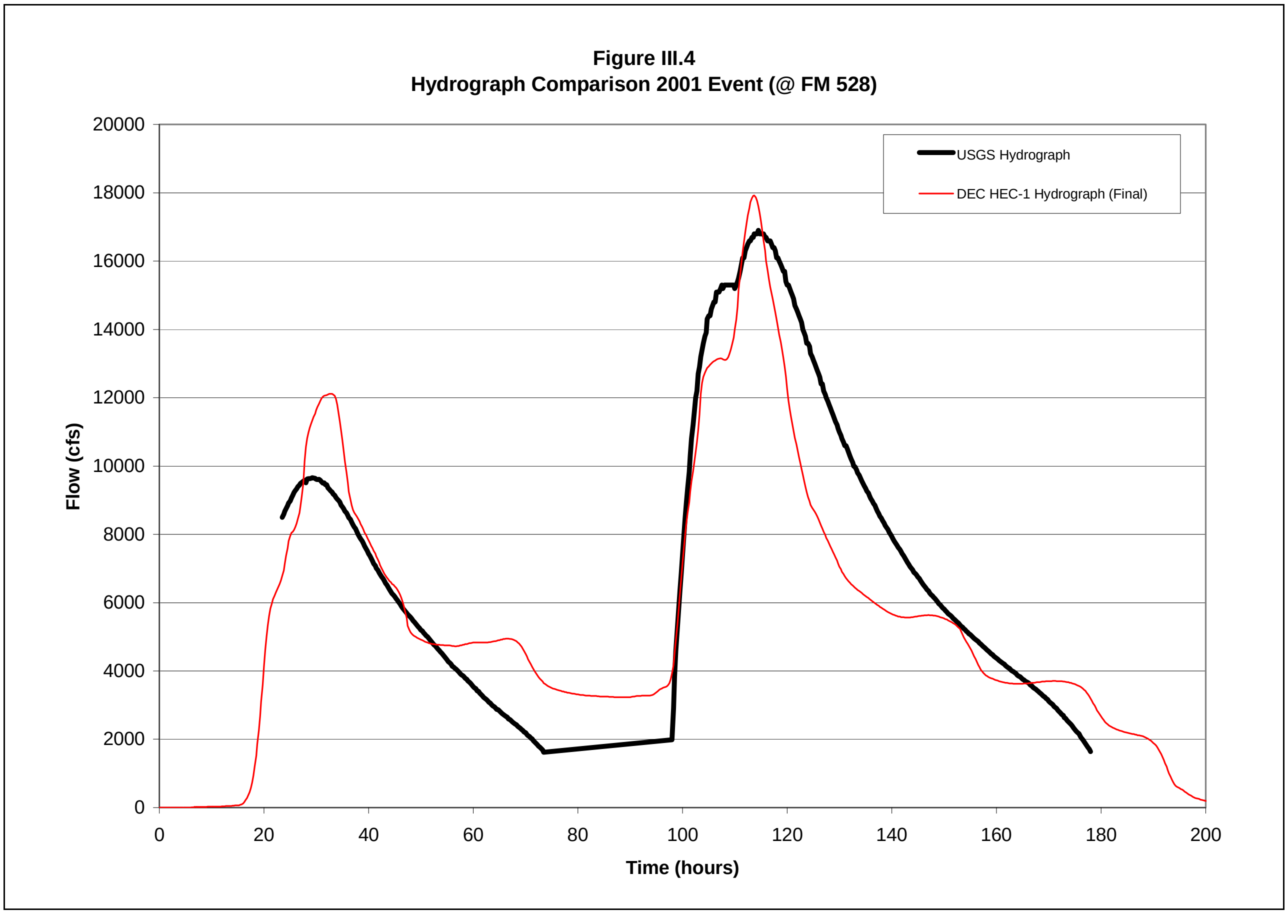


A similar comparison was made at FM 528 for the June 2001 rainfall event. When the simulated runoff hydrograph was compared with the measured USGS hydrograph (08077600) at this location, the two hydrographs had very similar volumes. The simulated hydrograph had a runoff volume that was only 2.4% less than the measured hydrograph at FM 528. The peak flows of the hydrographs also matched well. The simulated hydrograph peak (17781 cfs) was only 5% higher than the measured hydrograph's peak flow of 16900 cfs. The simulated and measured hydrograph may be seen in Figure III.4.

Table III.8
2001 EVENT HYDROGRAPH VOLUME COMPARISON

Start Time:	06/05/2001	11:30 PM
End Time:	06/12/2001	10:00 AM

1.	USGS Volume (ac-ft) =	86764
2.	DEC HEC-1 Volume-Final Model (ac-ft) =	84724
% Difference (1-2) =		-2.4%



Conclusions from Historical Event Simulation Verification – The results of the historical event simulation verification show that the simulated 2001 event matches much better with measured stream gage data than the simulated 1994 event. This discontinuity in the results of the historical simulations is most likely the result of inaccurate rainfall data for the 1994 event. As previously mentioned, only four (4) temporal rainfall gages located within the Clear Creek watershed were available to calibrate the NEXRAD rainfall data for the 1994 event, while at least seventeen (17) temporal gages were available for calibration of 2001 rainfall event.

Based upon the previously mentioned factors, much more weight was placed on results of the June 2001 historical simulation. The results of the June 2001 event historical event simulation verification show that the hydrologic models used in this study accurately represent watershed conditions. No modification to the models is warranted based upon the results of the historical simulation.

HEC-1 Flood Frequency Simulations - Flood flow frequency is generated with HEC-1 by simulating rainfall events associated with specific exceedance frequencies. The rainfall aerial distribution pattern is assumed uniform over the basin and a unique temporal distribution is generated by HEC-1. These synthetic rainstorms are referred to as “hypothetical events.” Peak flood flows resulting from hypothetical event simulations are assumed to have the same frequency as the applied rainfall event. Thus, the resultant peak flows define flow frequency at each computation node in the model. In reality, rainstorms occur in an infinite array of temporal and aerial patterns and occur coincidentally with a varying range of antecedent moisture conditions in the watershed. Thus, hypothetical event simulations do not capture the true complexity of the real-world flood spectrum, and the "same frequency" assumption is empirical. The process is verified by comparing results with flow frequency estimates from independent methods. This verification process was accomplished for Clear Creek using two independent methods as will be described in a subsequent paragraph.

Rainfall for Flood Frequency Simulations - Eight hypothetical rainfall events were compiled using rainfall frequency publications TP-40 (USWB, 1961) and NWS-35 (NOAA, 1977). The adopted storm duration was 24 hours and the computation interval was set at 15 minutes. Hypothetical storm with longer durations can be simulated, but for moderate sized basins like Clear Creek the 24-hour duration is adequate. Table III.9 shows the rainfall depth values that were coded into the HEC-1 simulations for each frequency.

TABLE III.9
POINT RAINFALL DEPTHS
FOR HEC-1 FLOOD FREQUENCY SIMULATIONS
FROM TP-40 AND NWS-35

Percent Chance Exceedance	Depth in inches for rainfall duration of:						
	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
50	1.2	2.4	2.9	3.2	3.8	4.4	5.2
20	1.4	2.9	3.7	4.1	5.0	6.0	7.0
10	1.5	3.4	4.3	4.8	5.9	7.2	8.6
4	1.7	3.9	4.9	5.6	6.9	8.5	9.9
2	1.8	4.3	5.6	6.3	7.8	9.6	11.4
1	2.0	4.7	6.2	7.1	8.7	10.8	13.0
0.4	2.2	5.1	6.8	8.2	10.0	12.5	15.0
0.2	2.4	5.4	7.2	9.0	11.0	13.8	16.4

Note:
o Values for 0.4 and 0.2 percent chance exceedance are extrapolated.

o The durations shown are those required for the HEC-1 automatic event generation procedure with a computation interval of 15-minutes. The 15-minute values are from NWS-35.

Comparison of TP-40 Rainfall with Newer Sources - The TP-40 rainfall atlas was compiled over 40 years ago. A newer rainfall frequency atlas was recently prepared for Texas by the USGS. Rainfall from the new atlas is shown for comparison purposes in the following table.

TABLE III.10
USGS POINT RAINFALL DEPTHS
FOR COMPARISON WITH TP-40

Percent Chance Exceedance	Depth in inches for rainfall duration of:						
	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
50	1.1	2.0	2.6	2.7	3.2	3.8	4.5
20	1.4	2.6	3.4	3.7	4.5	5.3	6.3
10	1.5	3.0	3.9	4.3	5.4	6.4	7.7
4	1.7	3.5	4.7	5.3	6.9	8.2	9.7
2	1.9	3.9	5.3	6.1	8.2	9.8	11.6
1	2.0	4.4	6.0	7.1	9.8	11.7	13.2
0.4	2.3	5	7	8.5	12.4	14.7	16.1
0.2	2.5	5.6	7.9	9.8	14.7	17.5	18.4

Note: The USGS depths are based on annual series analysis which results in smaller depths for the 50% chance exceedance in comparison to TP-40.

The depths from the newer atlas are similar to the TP-40 values although depths for specific durations are sometimes larger or smaller. A decision was made to use the TP-40 values for the following reasons:

- The HEC-1 hypothetical event generation process includes an adjustment for storm area size. The HEC-1 internal adjustment factors are those specified in TP-40. The USGS has only published new reduction factors for the 24-hour depth. Consistent adjustments for the other durations are not available.

- Rainfall depths from the newer source for the Clear Creek area show no major differences overall in comparison to the TP-40 values.

- The adopted rainfall depths for the flood frequency simulations are not critical to the process since some rainfall infiltration losses must be assumed. A higher or lower assumed loss would counteract the rainfall depth differences between the two sources. The final computed flood flow frequency is compared with independent methods to insure that the adopted rainfall values and losses, together, result in reasonable flood frequency peaks.

Annual Series Adjustment to Rainfall - TP-40 rainfall values are based on partial series analysis of historic rainfall data considering all high values in the gage record. The desired flow frequency estimates were needed in annual series form, which considers only annual maximum values. The adjustment factors in Table III.11 are applied to convert the rainfall depths into annual series equivalents. No adjustment is needed for frequencies beyond the 10-percent event. The HEC-1 program automatically performs this adjustment in the hypothetical event generation process.

TABLE III.11
PARTIAL SERIES TO ANNUAL SERIES
RAINFALL ADJUSTMENT FACTORS
FROM TP-40

Percent Chance Exceedance	Conversion Factor
50	0.88
20	0.96
10	0.99

Depth-Area Adjustment to Rainfall - Rainfall atlas values generally represent depths that can be expected over a small area. When used to represent rain depths over large watershed areas, the depths must be reduced. For a given frequency, the appropriate depth is less for a large area than for a smaller area. The HEC-1 program automatically performs this adjustment in the hypothetical event simulation process based on the adjustment criteria in TP-40. Area reduction factors are a function of storm area size and duration. The JD record in HEC-1 allows hypothetical event simulations corresponding to a range of area sizes to be executed in parallel. The appropriate flow at each stream node is interpolated from the resulting array of flows based on the contributing basin area at that node. An inherent assumption is that the storm size is equal to the total basin size at each node.

The USGS published area reduction factors for only the 24-hour duration. The following Table compares resultant rainfall from both sources for this duration for 4 locations. As seen in Table III.12, the USGS rainfall criteria actually results in less applied rainfall than TP-40 after the area adjustment factor is applied (when compared for the 24-hour depth for the 1 percent event).

TABLE III.12
COMPARISON OF AREA ADJUSTED RAINFALL
FOR FOUR LOCATIONS
(24-HOUR DURATION AND 1% EXCEEDANCE EVENT)

Location:	Basin Area Sqmi	TP-40 Atlas (Used In HEC-1 Simulations)			USGS Atlas (For Comparison Only)			Ratio Tp-40/ Usgs
		DEPTH (In.)	AREA REDUCTION FACTOR	ADJ DEPTH (In.)	DEPTH (In.)	AREA REDUCTION FACTOR	ADJ DEPTH (In.)	
Near headwaters at Fort Bend Co. Line	6.3	13.0	0.99	**12.9**	13.2	0.90	**11.9**	1.1
USGS gage 08077000 Clear Cr. near Pearland at SH35	36.0	13.0	0.96	**12.5**	13.2	0.83	**11.0**	1.1
USGS gage 08077600 Clear Cr. near Friendswood at FM528	120.2	13.0	0.93	**12.1**	13.2	0.76	**10.0**	1.2
Outlet at Galveston Bay	258.5	13.0	0.91	**11.8**	13.2	0.71	**9.4**	1.3

HEC-1 Flood Frequency Simulation Results – Tables showing the computed flood frequency results are included in Appendix E. Results are shown for 1980, 2010, 2060, and 2060 uncontrolled. A brief summary of flows is included in Table III.13.

The modeling results predict a measurable flow increase resulting from increased development. For instance, flow increases (from 1980) for the 50 percent exceedance event averaged 6 percent to 2010 and 22 percent to 2060. With no runoff controls the increase to 2060 averaged 41 percent. For the 1 percent exceedance event, the average increases were about half those described for the 50 percent event.

TABLE III.13
COMPUTED FLOW FREQUENCY SUMMARY
FOR FOUR LOCATIONS

Location:	Watershed Condition	Peak Flow (CFS) for Percent Chance Exceedance							
		50	20	10	4	2	1	.4	.2
Near headwaters at Fort Bend Co. Line	1980	268	475	656	793	906	1,058	1,247	1,295
	2010	269	477	659	794	907	1,060	1,248	1,296
	2060	285	497	681	818	906	1,058	1,240	1,282
	2060UC	333	554	744	884	976	1,099	1,383	1,617
USGS gage 08077000 Clear Cr. near Pearland at SH35	1980	1,036	1,506	1,909	2,439	3,022	3,681	4,561	5,271
	2010	1,198	1,686	2,224	2,834	3,407	4,008	5,005	5,628
	2060	1,219	1,818	2,360	2,940	3,531	4,087	5,138	5,727
	2060UC	1,326	2010	2,628	3,263	3,842	4,478	5,465	6,298
USGS gage 08077600 Clear Cr. near Friendswood at FM528	1980	5,352	8,347	10,775	12,679	14,365	16,328	18,837	20,503
	2010	5,604	8,570	11,006	12,858	14,554	16,532	18,996	20,629
	2060	6,383	9,632	11,817	13,507	15,350	17,394	19,918	22,053
	2060UC	7,081	10,579	12,802	14,487	16,705	19,106	22,372	24,925
Outlet at Galveston Bay	1980	8,220	13,824	20,576	25,340	31,665	37,546	44,482	49,805
	2010	8,509	14,508	21,317	26,544	32,628	38,313	45,253	50,753
	2060	8,673	17,617	24,523	31,406	36,542	41,978	49,584	54,692
	2060UC	9,671	20,732	27,314	34,199	39,582	45,393	53,493	58,782

Notes: This summary is excerpted from Appendix E.
Computed flows are not directly comparable to other studies due to the unique assumptions of the GRR.

HEC-1 Flood Frequency Verification with Independent Methods - The HEC-1 flood frequency results were compared with values determined with other methods to insure that the modeling results were reasonable. The comparisons were made for 1980 watershed conditions, so HEC-1 simulations were conducted to generate flood flow frequency for that condition. The independent methods used were 1) USGS regression equations and 2) statistical analysis of recorded flood peaks. These are described in the following paragraphs and the resultant comparisons are illustrated in Figures III.5 through III.8. The comparisons were based on 1980 conditions because development patterns for that period are well documented and because that period is more representative of the stream gage records used in the statistical analysis. Values were computed at four specific locations along Clear Creek including: the upstream limits of the study near the Fort Bend County line, at State Highway 35, at FM528, and the mouth of Clear Creek at Galveston Bay.

Flood Frequency Computed with Regression Equations - The USGS publishes regression equations for computing flood flow frequency for streams as a function of independent variables that characterize the contributing basin. They provide a simple method to estimate flood peaks, but only within certain statistical limits of accuracy. There are two sets of equations that are relevant to the Clear Creek study area. Both methods were utilized so two sets of values were generated. The methods used were as follows:

- WRI 80-17, “Technique for Estimating the Magnitude and Frequency of Floods in the Houston, Texas Metropolitan Area"

- WRIR 96-4307, “Regional Equations for Estimation of Peak-Streamflow Frequency for Natural Basins in Texas"

The latter method is for undeveloped basins, so the resultant flood frequency values must be adjusted for urbanization effects. The adjustment was made using the regression formulas in the following USGS publication.

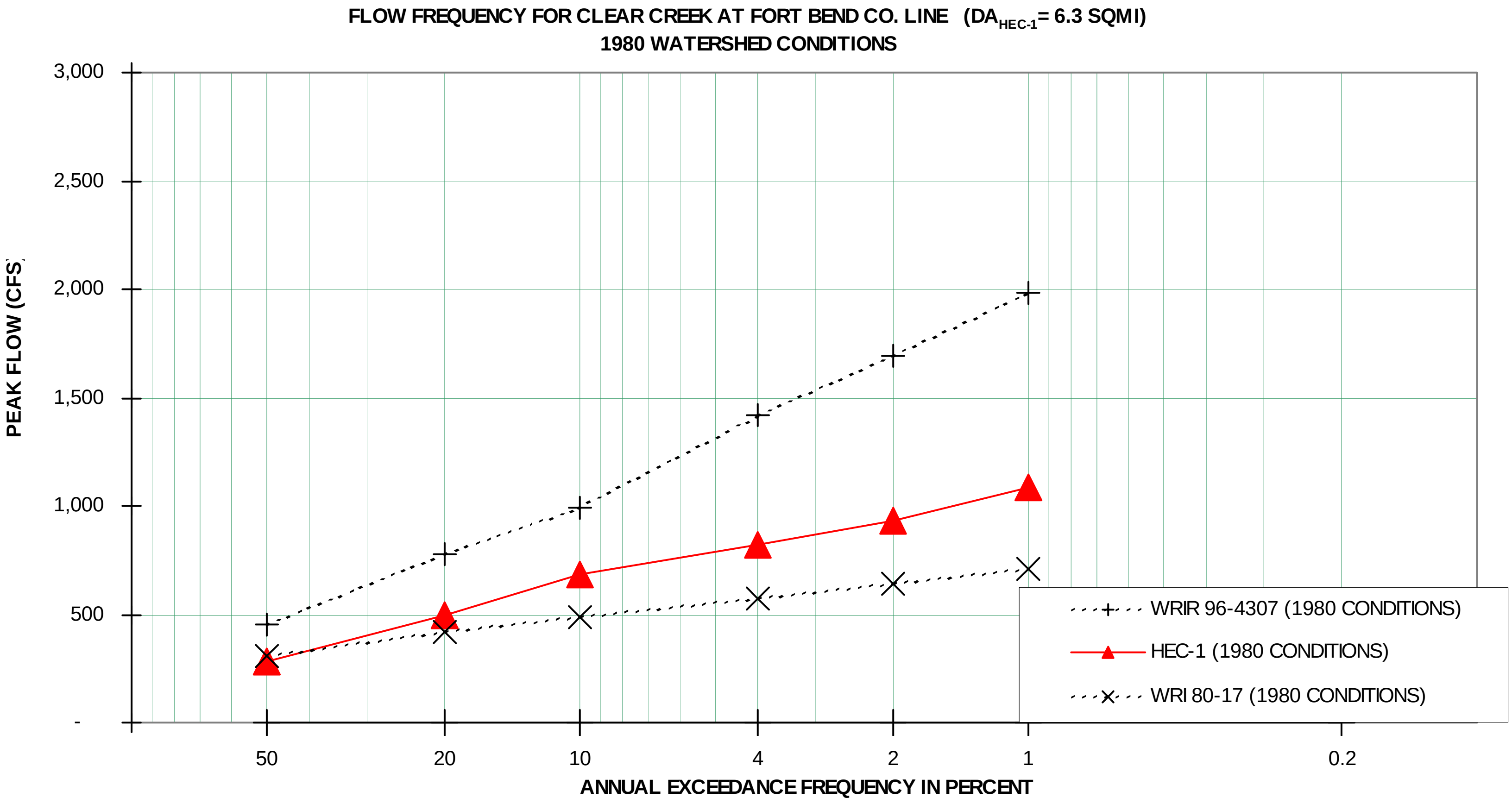
- Water-Supply Paper 2207, “Flood Characteristics of Urban Watersheds in the United States"

Backup data for the regression computations are included in Appendix F along with tables showing computed flood peaks. Resultant flood frequency is shown graphically on Figures III.5 through III.8 for four locations along Clear Creek.

Flood Frequency Computed with Statistical Analysis - Flood frequency estimates were made using statistical analysis of annual maximum flood peaks at two gage sites along Clear Creek. The gages at State Highway 35 and at FM 528 are the only two gages that have significant records to justify statistical analysis. The gage records are not strictly homogenous since there have been development changes in the watershed that influence the magnitude of flood flows. Theoretically, the recorded flood peaks used in the statistical analysis should represent consistent hydrologic conditions. It is sometimes helpful to use only a segment of the gage record before or after development or to otherwise adjust the record to remove the effects. However, analysis results using segments of the gage records for the Clear Creek gages did not show a clear pattern of development effects. Thus, a decision was made to include the entire, available records for both gages and qualify the results as being only estimates. This was deemed adequate since the results were only needed for comparison purposes. Gage records for the two gages are shown in Appendix F. Resultant flood frequency is shown graphically on Figures III.6 and III.7.

Gage records used in the analysis are listed in Appendix F. Peak flows for the Friendswood gage were estimated from stages for water years 1966 – 94 since only stages were reported for that period. The flows were estimated using the latest available gage rating from the USGS. Ideally historic ratings would have been used, but these were not generally available, and there have been no significant channel modifications affecting this gage.

FIGURE III.5



FLOW FREQUENCY FOR CLEAR CREEK AT FORT BEND CO. LINE (DA HEC-1 = 6.3 SQMI)
1980 WATERSHED CONDITIONS
PEAK FLOW (CFS)
3,000
2,500
2,000
1,500
1,000
500
-
50
20
10
4
2
1
0.2
ANNUAL EXCEEDANCE FREQUENCY IN PERCENT
WRIR 96-4307 (1980 CONDITIONS)
HEC-1 (1980 CONDITIONS)
WRI 80-17 (1980 CONDITIONS)

FIGURE III.6

FLOW FREQUENCY FOR CLEAR CREEK AT STATE HW35 (DA$_{HEC-1}$= 36.0 SQMI)
GAGE = CLEAR CREEK NR PEARLAND 08077000
1980 WATERSHED CONDITIONS

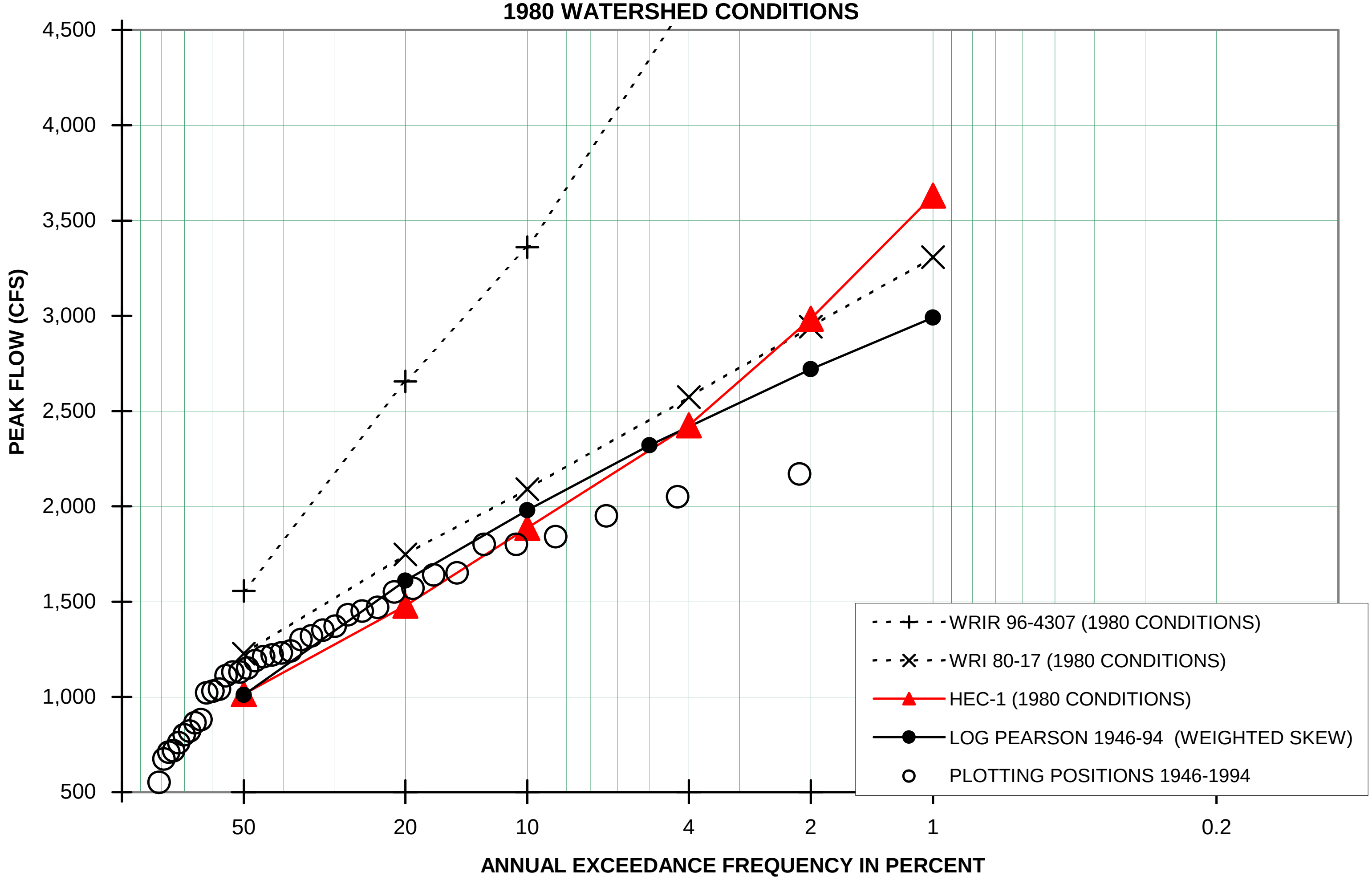
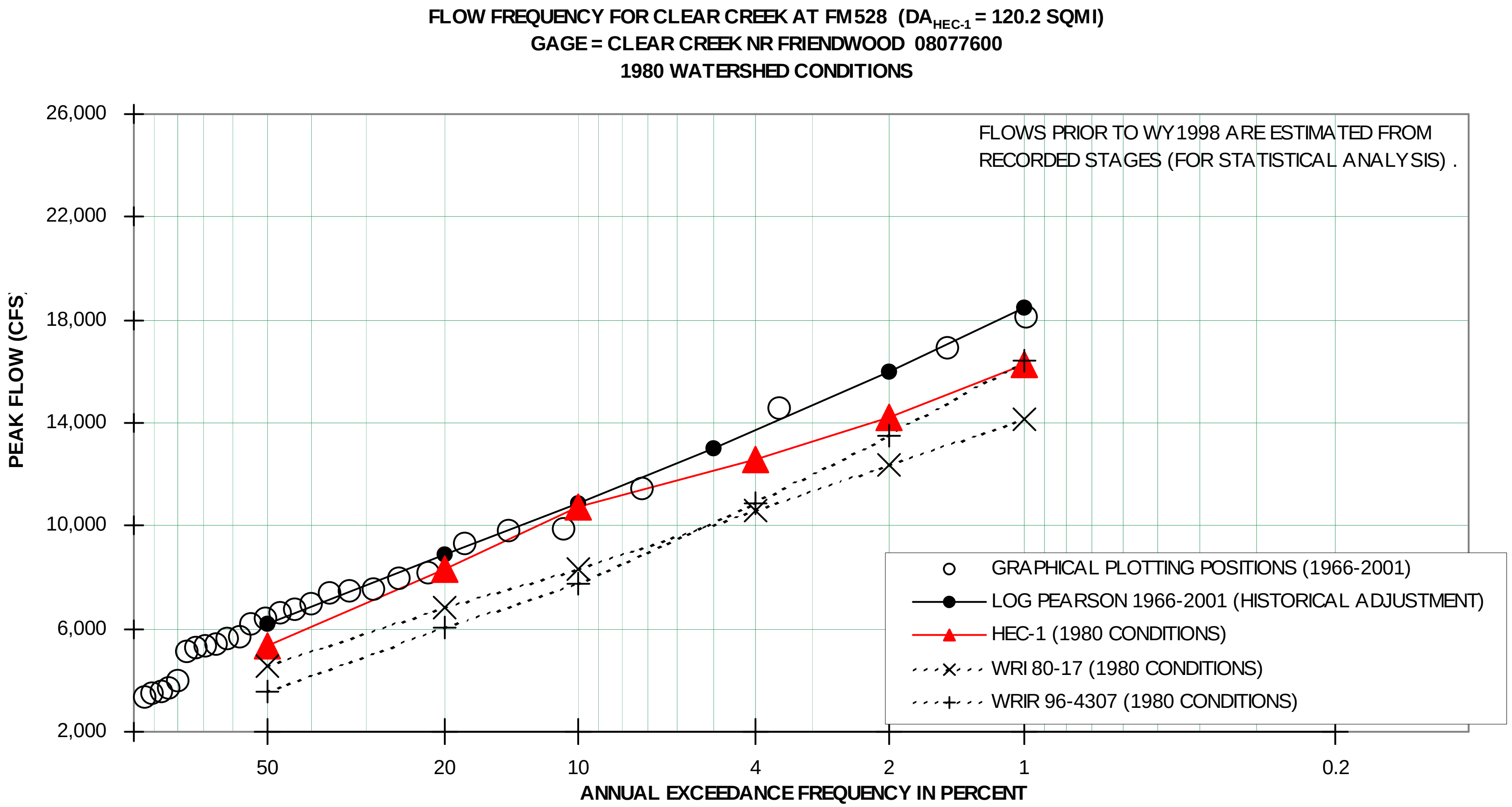
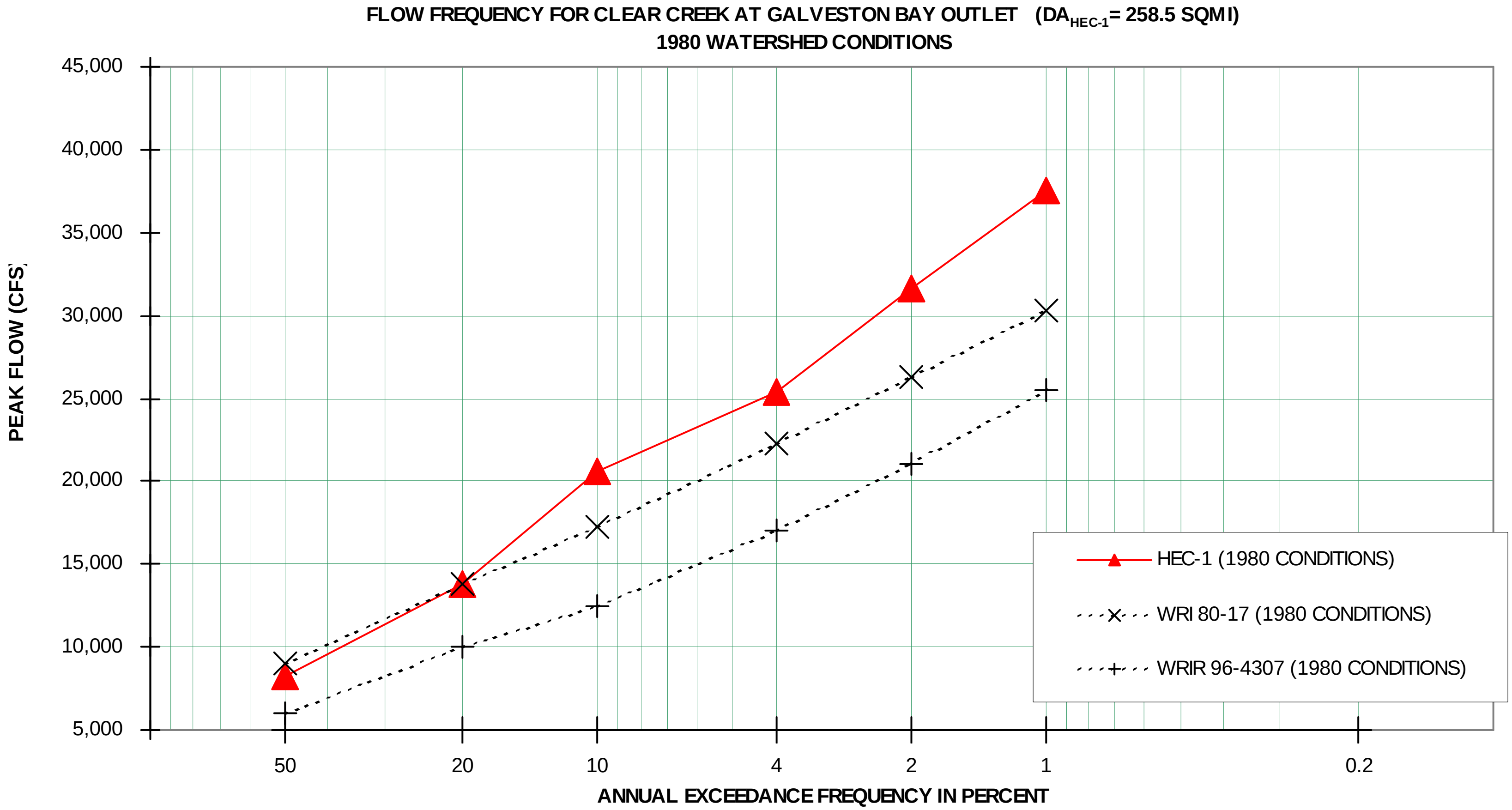


FIGURE III.7



FLOW FREQUENCY FOR CLEAR CREEK AT FM528 (DA HEC-1 = 120.2 SQMI)
GAGE = CLEAR CREEK NR FRIENDWOOD 08077600
1980 WATERSHED CONDITIONS
FLOWS PRIOR TO WY1998 ARE ESTIMATED FROM RECORDED STAGES (FOR STATISTICAL ANALYSIS) .
PEAK FLOW (CFS)
26,000
22,000
18,000
14,000
10,000
6,000
2,000
50
20
10
4
2
1
0.2
ANNUAL EXCEEDANCE FREQUENCY IN PERCENT
GRAPHICAL PLOTTING POSITIONS (1966-2001)
LOG PEARSON 1966-2001 (HISTORICAL ADJUSTMENT)
HEC-1 (1980 CONDITIONS)
WRI 80-17 (1980 CONDITIONS)
WRIR 96-4307 (1980 CONDITIONS)

FIGURE III.8



FLOW FREQUENCY FOR CLEAR CREEK AT GALVESTON BAY OUTLET (DA HEC-1 = 258.5 SQMI)
1980 WATERSHED CONDITIONS
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
PEAK FLOW (CFS)
50
20
10
4
2
1
0.2
ANNUAL EXCEEDANCE FREQUENCY IN PERCENT
HEC-1 (1980 CONDITIONS)
WRI 80-17 (1980 CONDITIONS)
WRIR 96-4307 (1980 CONDITIONS)

The statistical analysis was conducted using the computer program HEC-FFA which employs analysis procedures recommended in WRC Bulletin 17B. A generalized skew value of 0.06 with a mean squared error of 0.350 was used based on map values presented in USGS WRI 96-4117.

A historic period of 201 years was specified for the largest three floods in the record for the Friendswood gage. There is no specific observer accounts to justify this, however the adjustment was judged to be appropriate. Rainfall for these three events is known to have been extreme (greater than 1% exceedance). Without the adjustment the 16,900 cfs flood peak for Tropical storm Allison would equate to about a 10% exceedance event. With the adjustment the Allison flood computes to be closer to a 2% to 1% exceedance event, which is more consistent with the observed rainfall severity (11.5 inches in 24-hours in the Friendswood area).

Conclusions from HEC-1 Flood Flow Frequency Verification With Independent Methods – The flow frequency comparisons (Figures III-5 through III.8) provide an independent measure of the accuracy of the HEC-1 flood frequency simulations. All of the methods tend to agree for the more frequent events like the 50 percent exceedance event. The methods diverge for the rare events. This is to be expected since the larger events require a long historical period to become statistically represented in the gage record. The HEC-1 results fit the statistical estimates well and also agree closely with the WRI 80-17 regression method. That regression equation is likely the better of the two used since it was developed specifically for the Houston area and because it considers urban development effects. The other regression method is newer, but it was developed regionally and it requires additional adjustment for urbanization.

IV. HEC-RAS HYDRAULIC MODELING

Data Sources, Projections, and Datum - Topographic data for hydraulic modeling were obtained from several sources as shown in Table IV.1.

TABLE IV.1
SOURCE OF TOPOGRAPHIC DATA
FOR HYDRAULIC MODELING

Data Type	Coverage/Description	Spacing/ Resolution (Feet)	Date of Flight/ Survey
Field surveyed channel cross sections	Clear Lake Outlet Reach	700	2000
	Clear Lake Reach	2,000	2000
	Galveston County – Harris County Reach	400	1985 & 2000
	Brazoria County – Harris County Reach	700	2000
Photogrammetric digital terrain data	Entire watershed	100	Feb 2000
	Floodplain area	50	Feb 2000
Digital orthophotos	Entire watershed (monochrome)	1	Feb 2000
	Entire watershed –DOQQ's (color IR)	3	1995

Horizontal projections were referenced to NAD 83 and the State Plane Coordinate system, South Central Zone. Vertical elevations were referenced to NAVD 88. Cross sections surveyed in 1985 were originally surveyed to a different datum but were converted to NAD 83 / NAVD 88 and also adjusted for subsidence.

The surveyed channel cross sections and the digital terrain data covering the Clear Creek floodplain area were the source of all hydraulic modeling sections. The digital terrain data were prepared by the mapping contractor (Atlantic Technology) to Class 1 1990 ASPRS Standards for a 2-foot contour map. Terrain elevations were generated conventionally with aerial photogrammetry. The elevations of over fifty field-surveyed points were compared to the digital terrain values as an independent quality control test. The resultant root mean square error was 1.16 feet.

Ground control points, bridge data (opening geometry, pier dimensions, low chord and top of roadway elevations), and channel cross sections were obtained by field surveys by John Chance Land Surveyors, Inc. Nineteen survey monuments were established along the creek and are documented in a digital report that show a location map and photo for each monument.

Creating the ARC-VIEW TIN - The GIS software ARC-VIEW was used for creating the HEC-RAS model using a software extension known as GEO-RAS developed by the Corps' Hydrologic Engineering Center (HEC). GEO-RAS enables HEC-RAS cross sections, reach lengths, and roughness values to be extracted from GIS data. Cross sections were extracted from a TIN, which is a digital representation of terrain. The TIN was created within ARC-VIEW from Microstation files provided by the mapping contractor containing mass point and break line layers.

Cross Sections - The cross section alignment layout was created by drawing sections in ARC-VIEW. Sections were drawn left to right looking downstream and extended the full width of the TIN, which covered a preliminary floodplain plus a 2,000-foot buffer. Sections were generally drawn through each surveyed channel section so that the Clear Creek channel detail would be captured accurately. A total of 357 sections were included in the final layout. Exhibit IV.1 shows the cross section layout theme from ARC-VIEW.

Filtering Cross Section Coordinates - After the initial creation of the HEC-RAS file, it was necessary to reduce the number of coordinates at each cross section. The GEO-RAS creation process generally resulted in sections exceeding the 500-point limit. A filter tool in HEC-RAS eliminates unnecessary coordinates from the section according to user specified tolerances. Filtering was minimized so that the section would maintain a high density of coordinates. The filtering tool in version 3.2 of HEC-RAS did not specifically preserve roughness boundaries, therefore it was desirable to maintain as many coordinates as possible so that roughness boundaries (described below) were not distorted excessively.

Bridge Crossings - There are nineteen bridge crossings coded in the HEC-RAS model as listed in Table IV.2.

TABLE IV.2
BRIDGES CODED IN THE CLEAR CREEK
HEC-RAS MODEL

Bridge Crossing	Downstream Cross Section	Comment
Almeda School Rd.	234420.7	
SH288	223445.1	
Cullen Blvd.	211227.4	
Stone Rd.	205888.3	Timber bridge
Mykawa Rd.	189432.4	
AT&SF RR	189373.4	
SH35	185547.5	08077000 Clear Creek nr Pearland gage (WY1946 -1994)
Bennie Kate	170703.4	Timber bridge
Country Club Dr.	160052.5	
Dixie Farm Rd	143346.3	
FM2351	112393.5	08077540 Clear Creek at Friendswood gage (WY1995-1997)
Whispering Pines	95406.35	
FM528	90072.02	08077600 Clear Creek nr Friendswood gage (WY1966-94, 1998-2000)
W Bay Area Blvd.	73892.70	
Interstate 45	55615.42	
SH3	46279.31	
MKT-RR	46214.15	
FM270	37212.22	
SH146	3054.182	

Manning's Overbank Roughness Values - Hydraulic roughness values (Manning's n) were based on field observations of channel and overbank vegetation cover and also based on aerial photography. A special GIS map was created to define roughness patterns (Exhibit IV.2). GEO-RAS captures roughness boundary stations at each cross section and imports the corresponding values and boundaries into the HEC-RAS file during the creation process. Three main overbank roughness classes were delineated as shown in Table IV.3. For the reach from section 54018.04 near Interstate 45 to section 152591.1 upstream of Dixie Farm Road, Overbank roughness values were coded to vary with stage. Overbank roughness values were all coded with two decimals and channel and oxbow values were coded with three decimals so that they could be distinguished in the model more easily.

TABLE IV.3
MANNING'S "n" ROUGHNESS

Overbank Class	Initial Roughness	Roughness from Calibration
Dense vegetation	0.12	0.12 - 0.24
Dense urban development	0.15	0.15
Sparse vegetation or development	0.07	0.07 – 0.10

Manning's Roughness for Channel Areas - Channel roughness classes were also delineated on the GIS roughness map so that the appropriate values would be transferred to the HEC-RAS model. The channel polygons were delineated to capture just the immediate low bank areas that are either submerged with water or barren of vegetation due to frequent submergence. These areas were the easiest to distinguish on the digital orthophotos. Roughness values assigned to these channel polygons varied from 0.025 to 0.041. All oxbow cutoff polygons were coded with 0.042 roughness values.

Calibration of Roughness Values - Figures IV.1 through IV.3 show comparisons of gage rating curves with HEC-RAS computed values. The model calibrates closely to the gage data, but it was necessary to vary overbank roughness values with stage to match the gage data over the full range of flows. The gage measurements and gage ratings were adjusted to the GRR datum (NAVD88, 2000 epoch). The required datum adjustment was determined by running an instrument level from the gage reference monument to monuments established for the GRR surveys. Datum adjustments are shown in the following table.

TABLE IV.4
DATUM ADJUSTMENTS FOR USGS GAGE DATA

CLEAR CREEK NR FRIENDSWOOD (08077600)

Location: Downstream side of bridge at FM528 (HEC-RAS Section: 90072)

Distance to gage datum below BM "CCDD GPS No 30":	25.245	Feet
Elevation of CCDD GPS No 30 NAVD88 (2000 epoch):	25.130	Feet
Gage datum NAVD88 (2000 epoch):	**-0.115**	Feet

CLEAR CREEK AT FRIENDSWOOD (08077540)

Location: Downstream side of bridge at FM2351 (HEC-RAS Section: 112393)

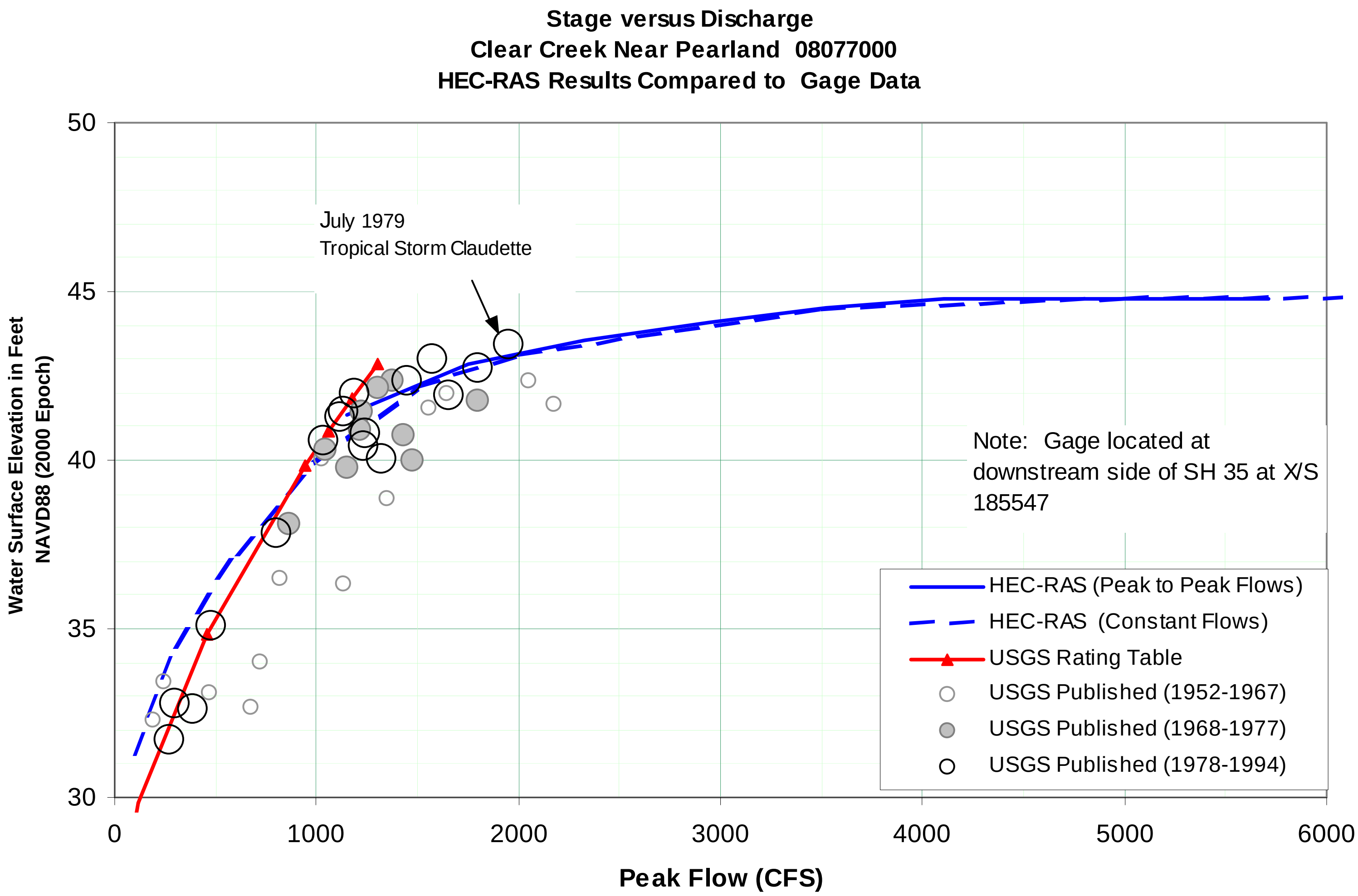
	<Oct 1996	>Oct 1996	
Distance to gage datum below BM "CCDD GPS No 3":	25.937	29.037	Feet
Elevation of CCDD GPS No 3 NAVD88 (2000 epoch):	28.97	28.97	Feet
Gage datum NAVD88 (2000 epoch):	**3.033**	**-0.067**	Feet

CLEAR CREEK NR PEARLAND (08077000)

Location: Downstream side State Highway 35 (HEC-RAS Section: 185547)

Distance to gage datum below benchmark "RM4"	19.44	Feet
Elevation of RM4 NAVD88 (2000 epoch):	44.29	Feet
Gage datum NAVD88 (2000 epoch):	**24.85**	Feet

FIGURE IV.1



Stage versus Discharge
Clear Creek Near Pearland 08077000
HEC-RAS Results Compared to Gage Data
Water Surface Elevation in Feet
NAVD88 (2000 Epoch)
Peak Flow (CFS)
50
45
40
35
30
0
1000
2000
3000
4000
5000
6000
July 1979
Tropical Storm Claudette
Note: Gage located at downstream side of SH 35 at X/S 185547
HEC-RAS (Peak to Peak Flows)
HEC-RAS (Constant Flows)
USGS Rating Table
USGS Published (1952-1967)
USGS Published (1968-1977)
USGS Published (1978-1994)

FIGURE IV.2

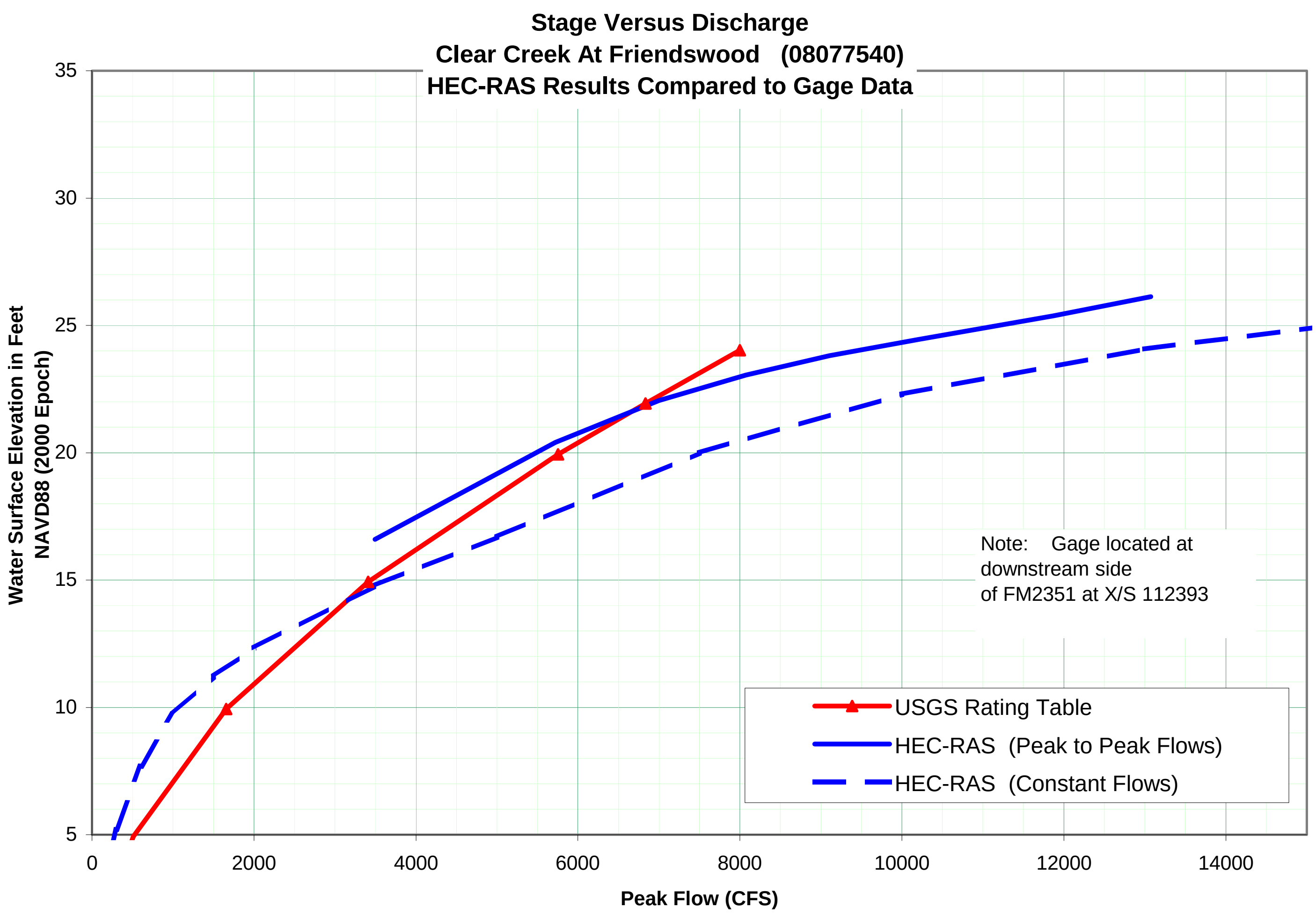
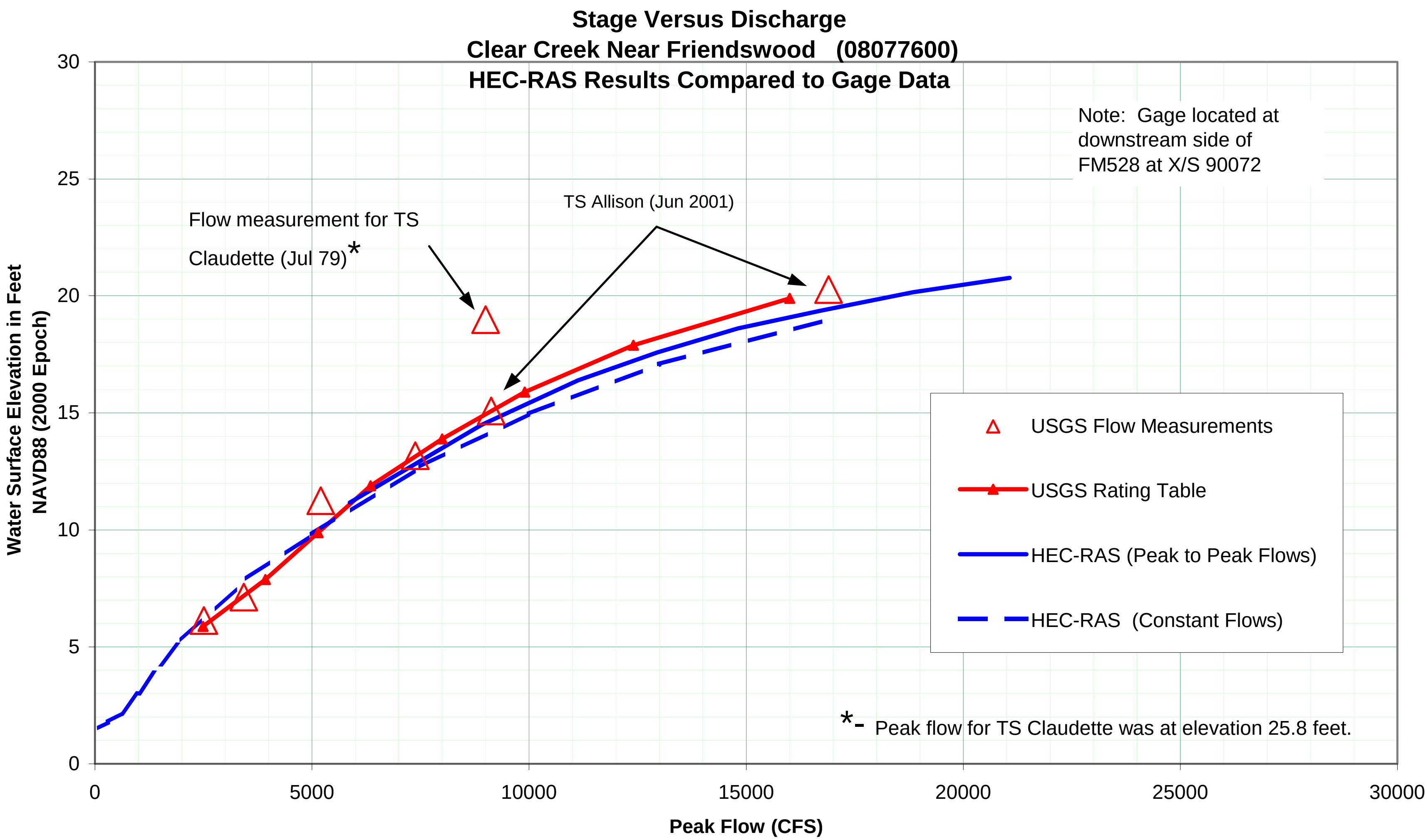

Stage Versus Discharge
Clear Creek At Friendswood (08077540)
HEC-RAS Results Compared to Gage Data
Water Surface Elevation in Feet
NAVD88 (2000 Epoch)
35
30
25
20
15
10
5
0
2000
4000
6000
8000
10000
12000
14000
Peak Flow (CFS)
Note: Gage located at
downstream side
of FM2351 at X/S 112393
USGS Rating Table
HEC-RAS (Peak to Peak Flows)
HEC-RAS (Constant Flows)

FIGURE IV.3


Stage Versus Discharge
Clear Creek Near Friendswood (08077600)
HEC-RAS Results Compared to Gage Data
Note: Gage located at downstream side of FM528 at X/S 90072
Flow measurement for TS Claudette (Jul 79)*
TS Allison (Jun 2001)
USGS Flow Measurements
USGS Rating Table
HEC-RAS (Peak to Peak Flows)
HEC-RAS (Constant Flows)
*- Peak flow for TS Claudette was at elevation 25.8 feet.
Water Surface Elevation in Feet NAVD88 (2000 Epoch)
Peak Flow (CFS)
0
5
10
15
20
25
30
0
5000
10000
15000
20000
25000
30000

Starting Conditions – The flood frequency profiles for all conditions were computed assuming a starting water surface elevation of +1.45 feet at Galveston Bay. Conditions for real flood events depend on astronomical tides and wind or storm induced variations, all of which vary through the duration of a runoff event. Coincident probability studies show that a +1.45 feet starting condition yields accurate stage-frequency estimates in Clear Lake for rainfall-runoff events with nominal coincident tide conditions.

Insertion of HEC-1 Flows – Exhibit IV.3 shows the flood flow frequency flow values in profile view along Clear Creek. The cross sections from the HEC-RAS steady flow data file are shown along with tributary locations. This exhibit is helpful in illustrating how flows change along the creek and the flow increments associated with each tributary.

HEC-RAS Historical Floods Simulations - Flood profiles were simulated for the October 1994 flood and the June 2001 (T.S. Allison) flood using peak flows resulting from the HEC-1 historical flood simulations. The computed flood profiles are compared to high watermarks and gage data in Exhibits IV.4 and IV.5. High watermarks for the T.S. Allison flood are documented in Table IV.5.

HEC-RAS Flood Flow Frequency Simulations – Exhibit IV.6 shows a comparison of 2010, 2060, and 2060 uncontrolled flood profiles for the 1 percent chance exceedance event. Exhibit IV.7 shows a digitally plotted floodplain for the 2010 flood (1 percent chance exceedance).

Development Impacts on Hydraulics - Residential and commercial development along Clear Creek tends to restrict flood capacity as property on the fringe of the floodplain is raised with fill for new construction. Federal flood insurance regulations generally permit this process allowing up to a one-foot increase in the one-percent exceedance flood elevation. Fill in the floodplain also tends to increase peak flow rates by reducing the buffering effects of floodplain storage volume. Some communities have more strict regulations, which reduce these impacts.

The modeling for the GRR takes into effect the hydrologic impacts of future development but does not include the hydraulic impacts described in the preceding paragraph. These hydraulic impacts are realized mostly for rare events and flood damages are compounded more heavily by frequent events. Still, there are some future condition flood damage increases which have not been captured in the analysis.

TABLE IV.5
HIGH WATER MARKS FOR TROPICAL STORM ALLISON (JUNE 2001)

RAS Sec	Location	Elev (ft) NAVD88 2000epoch Jun 6	Jun 9	Comments
53599	Private road d/s of I-45 on south side		10.5	Surveyed by HCFCD 10.88 /78adj CC04 9.97/78adj 9.55 NAVD88/2000 Correction= 9.97-9.55=0.42
	I-45			
55615	North bank/Downstream		10.8	Surveyed by HCFCD 11.24 /78adj
55615	South bank/Downstream	8.7		16.5" below low chord *elev. 9.93ft
55615	South bank/Downstream		11.1	Surveyed by HCFCD 11.48 /78adj
55861	South bank/Upstream		11.4	Orange paint on side of embankment
55861	Midspan/Upstream (HCFCD Gage #109)	7.78	11.1	HCFCD readings were 8.2 and 11.5
	Clear Creek Village			
56115	Residence - Lafayette Ln.		11.8	12" below floor. Floor from DTM=12.8
	Bay Area Blvd.			
73998	South bank/Upstream		16.2	7" above low chord *elev.15.6 ft*
	Friendswood Forest			
87139	Residence - Leisure		19.9	Approx. 36" above slab.
90082	**FM528**		20.34	USGS Gage 8077600 = 20.46 - 0.12
	Friendswood Link			
95406	Residence - Minglewood		21.9	35" above floor. Floor = 19.0'
99945	Residence - Royal Parkway		21.8	12" above floor. Floor=20.8'
101605	Residence - Clearview *Friendswood*		21.9	
103109	Residence - Whittier Oaks		24.3	6" above floor.
104949	Residence - Pennystone Ct.		24.5	Equal to threshold.
	Off 2351			
108589	Residence - Wandering Trail		23.4	
110331	Residence - Wandering Trail		25.4	Approx. 12" above floor.
110479	Residence - Wandering Trail		25.4	
	Imperial Estates			
109262	Residence - Imperial Dr.	22.0	25.2	On 6/6/01: 9" above floor, On 6/9/01 48" above floor
110368	Residence - Imperial Drive		25.1	27" above floor
	FM2351 (1776 Memorial Park)			
112394	South bank-Downstream		25.1	24" above low chord *elev. 23.1 ft*
112394	North bank/Downstream	22.1		12" below low chord *elev. 23.1ft*
112703	**Residence - Cherry Tree Ln.**		25.9	13" above floor.
	Dixie Farm Rd.			6/6/01: 6" over oxbow
143346	South bank/Downstream	32.0	31.3	6/9/01: 9" below low chord *elev. 32 ft*
	Sleepy Hollow			
152375	Residence - Rip Van Winkle		34.2	12" above floor.
	Green Tee Terrace			
159022	Residence - Green Tee		38.5	
160053	Residence - Country Club Rd.	36.8		Lift Plant, 6/6/01:water was 12" over oxbow
183604	**Residence - Robinson Dr.**		43.4	
	SH 35 (Pearland)			
185548	South side/Downstream	43.0	42.9	6/6/01:14"below low chord *elev. 44.2 ft* 6/9/01:16" below low chord *elev. 44.2 ft*
185606	South side/Upstream	43.0	43.0	6/6/01:15" below low chord *elev. 44.2 ft* 6/9/01:14" below low chord *elev. 44.2 ft* Commercial Businesses on southside/downstream:flooded on 6/6/01
	Mykawa			
189526	South bank/Upstream	44.9	45.8	6/6/01:18" below low chord *elev. 46.4 ft* 6/9/01:7" below low chord *elev.46.4 ft*
205888	Stone Rd.	47.6		6" below low chord *elev. 48.1 ft*
211278	Cullen Blvd. (FM 865)	49.3		21" below low chord *elev. 51 ft*
223445	SH 288	53.4		peak equal to low chord *elev. 53.4 ft*
234421	Old Airline Rd.(Almeda School)	56.9	59.5	1st pk 18" below low chord *elev. 58.4 ft* 2nd pk reported by dd4 to be 18" over lowspot on road 58.0+1.5=59.5

Marks from Dannenbaum

Location	Elev	Comment
14000	4.76	
30139	5.74	
42050	8.21	League City
57171	10.02	League City
65855	13.71	League City
89314	19.60	League City
95406	22.40	Friendswood
100234	23.20	Friendswood
101082	21.15	Friendswood
107933	25.02	Friendswood
112796	25.70	Friendswood
143346	32.98	Friendswood
150467	33.88	Friendswood
151242	34.34	Pearland
151941	34.86	Pearland
153192	35.78	Pearland
158159	37.37	Houston
160052	38.37	Houston
167361	40.59	Pearland
178408	42.35	Pearland
185547	44.96	Houston
189373	44.88	Houston
192943	45.90	Brookside Village
197996	47.45	Brookside Village
199968	50.27	Brookside Village
211227	51.89	Brookside Village
223445	54.69	Pearland

V. RISK AND UNCERTAINTY PARAMETERS

Export of Flood Frequency Results for Flood Damage Computations - The HEC-RAS flood frequency profiles for 2010 and 2060 were exported to the Flood Damage Analysis (FDA) program for computation of flood damages. FDA extracts both flow frequency and stage discharge data from the HEC-RAS export file. The export file is a standard table option on the summary profile table menu in HEC-RAS. The table must have a WSP extension and the cross sections in the table must appear in order starting from the downstream end. Additional keyboard input is required to define the error functions for each of these data sets so that damages can be computed using "risk and uncertainty" methods. The following paragraphs describe the derivation of the error functions.

Derivation of Discharge Uncertainty - The uncertainty of flow frequency results can be derived using two approaches. When the flow frequency values are thought to fit a log Pearson III distribution, the uncertainty can be derived analytically from the mean, standard deviation, skew, and representative record length. Conversely, the order statistics approach is preferred for deriving uncertainty when the log Pearson distribution is not applicable. The Clear Creek flow frequency values are influenced by development, so the order statistics method was adopted. FDA performs the derivations, but an equivalent record length is required. Equivalent record length was selected using guidance from Table 4-5 of EM 1110-2-1619. A value of 30 years was selected for 2010 conditions since the flow data were estimated with rainfall-runoff modeling calibrated at short-record gages within the watershed. A shorter length of 25 years was used for 2060 conditions since development projections and detention policy effectiveness introduce additional uncertainty for the distant future.

Derivation of Stage Uncertainty - The uncertainty of computed flood stages can be attributed to the natural variability of the stream and to hydraulic modeling inaccuracies. Guidance is provided in EM 1110-2-1619 for estimating and combining both components.

Natural variations include such factors as seasonal vegetation changes, debris constrictions, and unsteady flow effects. Equation 5-5 from EM 1110-2-1619 was used to compute the standard deviation of stage uncertainty due these natural effects. Values were computed for several reaches along the creek with results ranging from 0.3 to 0.5 feet as shown in Table V.1. Figure 5-3 of the EM was used to estimate upper bounds. Upper bound values and adopted values for natural variations are also shown in Table V.1.

Hydraulic modeling inaccuracies include errors in estimating roughness values, errors in cross section topography, and errors in defining effective flow area. Minimum values were estimated from Table 5-2 of the EM. The cross sections for the Clear Creek hydraulic model were based on field surveys for the mainstream channel and on digital terrain data (equivalent to a 2-foot contour map) for the overbank portions. Manning's reliability were judged to be good since both stream gages and high-water marks were used to set roughness values (as described in other sections of this report). As an additional measure of modeling uncertainty, a series of tests were conducted to determine the sensitivity of the model to the roughness coefficient, Manning's n. The adopted roughness values were multiplied by 1.25 and by 0.75 and the resultant profile differences were tabulated. Taking the stage difference between the upper and lower roughness values to be reasonable bounds, the standard deviation was then estimated as the difference divided by 4. Table V.2 shows the resultant modeling uncertainty values and the adopted values.

Combined stage uncertainty was determined by combining the natural variability and the modeling uncertainty into one value using equation 5-6 from the EM. Final values ranged from 1.0 to 1.1 feet so for simplification a standard deviation value of 1 foot was used for the entire study reach as shown on Table V.3.

TABLE V.1
STAGE UNCERTAINTY DUE TO NATURAL VARIATIONS

Computed with Equation 5-5 EM1110-2-1619

Location:	I bed	A basin (mi^2)	H range (ft)	$Q_{1\%}$ (cfs)	$S_{natural}$ (ft)
Outlet at Galveston Bay	4	258.5	5	37,884	0.3
FM 528	4	120.2	20	16,172	0.5
SH 35	4	36.0	16	3,568	0.5
Almeda School Road	4	6.3	9	1,082	0.4

Upper Bound From Figure 5-3 EM1110-2-1619

Location:	Stream Slope (ft/ft)	Upper Bound $S_{natural}$ (ft)
Outlet at Galveston Bay	0.00018	2.3
FM 528	0.00024	2.2
SH 35	0.00022	2.1
Almeda School Road	0.00034	2.0

Adopted Values (Natural Variation)

Location:	Adopted $S_{natural}$ (ft)
Outlet at Galveston Bay	0.3
FM 528	0.5
SH 35	0.5
Almeda School Road	0.4

TABLE V.2
STAGE UNCERTAINTY
DUE TO MODELING LIMITATIONS (TABLE 5-2 EM1110-2-1619)
AND FROM ROUGHNESS SENSITIVITY TESTING

Location:	Model Limitations From EM	Roughness Sensitivity From HEC-RAS Testing		Adopted S_{model} (ft)
	S_{model} Min (ft)	Prof Diff (ft)	S_{rough} (ft)	
Outlet at Galveston Bay	0.5	1.7	0.4	0.5
FM 528	0.4	3.0	0.8	0.5
SH 35	0.5	1.5	0.4	0.5
Almeda School Road	0.5	0.5	0.1	0.4

Notes:
1. Prof Diff is the HEC-RAS profile difference that results when Manning's n multiplied by 1.25 and 0.75
2. S_{rough} is profile difference divided by 4.

TABLE V.3
STAGE UNCERTAINTY
COMBINED TOTAL
FROM EQUATION 5-6 EM1110-2-1619

Location:	$S_{natural}$ (ft)	S_{model} (ft)	S_{total} (ft)
Outlet at Galveston Bay	0.3	0.5	1.0
FM 528	0.5	0.5	1.1
SH 35	0.5	0.5	1.1
Almeda School Road	0.4	0.4	1.0

Notes:
1. An S_{total} of 1.0 foot was adopted for the entire study reach to simplify input.

VI. CONCLUSIONS

HEC-RAS and HEC-1 models representing Clear Creek and the Clear Creek watershed were developed, calibrated, and used to compute flood frequency for the Clear Creek GRR. The models were verified with available data in the form of gage rating curves, observed historical hydrographs, and observed high water marks. The flood flow frequency results were compared with flow frequency estimates from statistical analysis and also regression equation methods. In all cases the model results were judged to be reasonable.

VII. LIST OF REFERENCES

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APPENDIX D
Clear Creek Watershed Flood Risk Management Habitat Assessments Using Habitat Evaluation Procedures (HEP)

ERDC/EL TR-SWWRP-10-X

ERDC Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

System-Wide Water Resources Program

Clear Creek Watershed Flood Risk Management Habitat Assessments Using Habitat Evaluation Procedures (HEP)

Analyses, Results and Documentation

Kelly A. Burks-Copes and Antisa C. Webb

July 2010

ERDC/EL TR-SWWRP-08-X
July 2010

Clear Creek Watershed Flood Risk Management Habitat Assessments Using Habitat Evaluation Procedures (HEP)

Analyses, Results and Documentation

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Draft report

Prepared for U.S. Army Corps of Engineers

Under System-Wide Water Resources Program - Habitat Based Ecological Response Models

Monitored by Environmental Laboratory
U.S. Army Engineer Research and Development Center
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Abstract: Over the last 100 years, the cumulative effects of urban development along the Clear Creek (southern Texas) has led to substantial increases in flooding directly attributed to both the narrowing of the floodplain and the construction of buildings and infrastructure in the region's flood-prone areas. In 1999, the USACE Galveston District initiated a feasibility study to revise past efforts and formulate new solutions to address the Clear Creek problems, and contacted the U.S. Army Engineer Research and Development Center's Environmental Laboratory (ERDC-EL) in 2003 to assist in these endeavors. The District is preparing an Environmental Impact Statement (EIS), as required under the tenets of the National Environmental Policy Act (NEPA), to evaluate the impacts of proposed flood risk management measures in the watershed. As part of the process, a multi-agency evaluation team was established to (1) identify environmental issues and concerns; (2) evaluate the significance of fish and wildlife resources and select resources; (3) recommend and review environmental studies; (4) evaluate potential impacts; and (5) recommend and evaluate potential mitigation measures. Between 2003 and 2008, this team designed, calibrated, and applied a landscape-level community-based index model for the system's floodplain forests using standard Habitat Evaluation Procedures (HEP). Five individual conveyance (with inline detention) management measures were combined to generate the National Economic Development (NED) plan (including mitigation). One hundred and one floodplain forest Average Annual Habitat Units (AAHUs) were lost due to the proposed flood risk management measures. Twelve individual mitigation plans were evaluated to offset the impacts detailed in the NED plan. The outputs for the various mitigation scenarios ranged from 9-180 AAHUs for the forests communities. The results of both the impact and mitigation assessments are provided herein. The intent of this document is to provide details of the HEP application (for both the impact and the mitigation assessments) for the Clear Creek project. Readers interested in the scientific basis upon which the models were developed should refer to our second report entitled, "Floodplain Forest Community Index Model for the Clear Creek Watershed, Texas" (Burks-Copes and Webb 2010).

Contents

Figures and Tables

Figures

Tables

Preface

This report provides the documentation to support a Habitat Evaluation Procedures application evaluating the effects of both flood risk management activities and proposed mitigation plans to address flooding issues in the Clear Creek Watershed south of Houston, Texas.

The work described herein was conducted at the request of the U.S. Army Engineer District, Galveston, Texas. This report was prepared by Ms. Kelly A. Burks-Copes and Ms. Antisa C. Webb, U.S. Army Engineer Research and Development Center's Environmental Laboratory (ERDC-EL), Vicksburg, Mississippi. At the time of this report, Ms. Burks-Copes and Ms. Webb were ecologists in the Ecological Resources Branch.

Many people contributed to the overall success of the production of the model documentation. The authors wish to thank the following people for their hard work and persistence during the intensive months over which the project was assessed: Ms. Jennifer Emerson (Bowhead Information Technology Services), Ms. Andrea Catanzaro and Mr. Seth Jones (Galveston District). We also thank Dr. Andrew Casper (ERDC), Ms. Elizabeth Brandreth (Philadelphia District), Richard Stiehl (Independent consultant, Arizona), Mr. Tom Cuba (Delta Seven, Inc., Florida), Mr. Bradford Wilcox (Texas A&M, Texas), and Mr. William Espey (Espey Consultants, Inc., Texas) for their comprehensive review of the report.

This report was prepared under the general supervision of Ms. Antisa C. Webb, Chief, Ecological Resources Branch and Dr. Edmond Russo, Chief, Ecosystem Evaluation and Engineering Division. At the time of publication of this report, Dr. Beth Fleming was Director of EL.

This report should be cited as follows:

Burks-Copes, K. A., and A.C. Webb. 2010. Clear Creek Watershed Flood Risk Management Habitat Assessments Using Habitat Evaluation Procedures (HEP): Analyses, Results and Documentation. Draft Report. U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS.

1 Introduction

Background

Over the last 100 years, the cumulative effects of rapid urban development along the Clear Creek (southern Texas) has led to substantial increases in flooding directly attributed to both the narrowing of the floodplain and the construction of buildings and infrastructure in the region's flood-prone areas (U.S. Army Corps of Engineers (USACE) 1999; 2002, 2010) (Figure 1 and Figure 2).

Figure 1. Flooding in the Clear Creek study area just after Tropical Storm Allison in June of 2001 (photo of Green Tee Terrace provided by Galveston District).

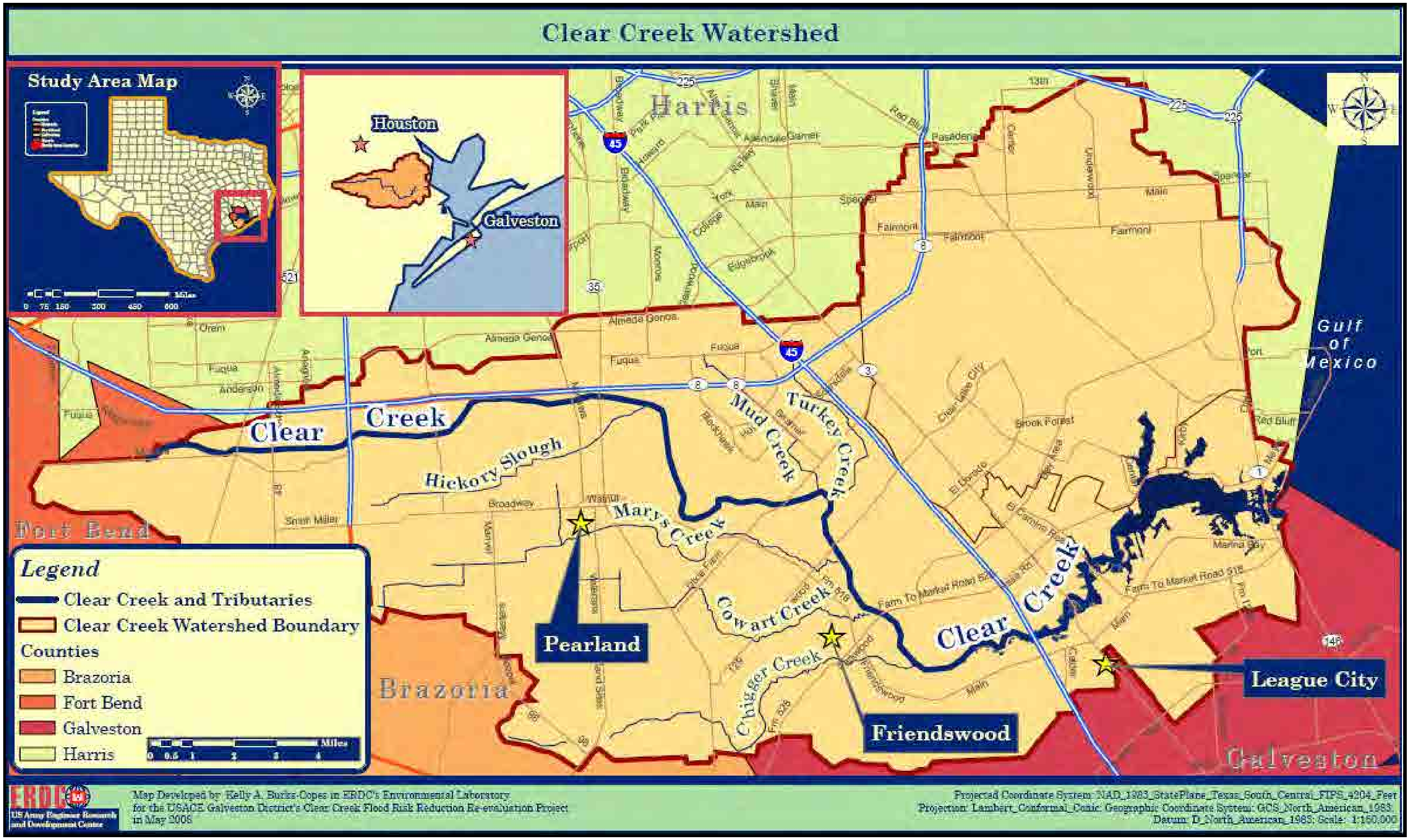

Figure 2. Study location – Clear Creek watershed.

In 1999, the USACE Galveston District initiated a feasibility study to revise past efforts and formulate new solutions to address the Clear Creek problems, and contacted the U.S. Army Engineer Research and Development Center's Environmental Laboratory (ERDC-EL) in 2003 to assist in these endeavors. The Clear Creek study documentation identified and recommended effective, affordable and environmentally sensitive flood risk management features throughout the Clear Creek Watershed (USACE 2010). The goal was to provide the necessary engineering, economic and environmental plans in a timely manner to establish viable projects that would be acceptable to the public, local sponsors and USACE.

The District is preparing an Environmental Impact Statement (EIS), as required under the tenets of the National Environmental Policy Act (NEPA), to evaluate the impacts of proposed flood control measures in the watershed (USACE 2010). As part of the process, a multi-agency evaluation team was established to (1) identify environmental issues and concerns; (2) evaluate the significance of fish and wildlife resources and select resources; (3) recommend and review environmental studies; (4) evaluate potential impacts; and (5) recommend and evaluate potential mitigation measures.

USACE headquarters promulgated standard policies and guidance to formulate single-purpose studies under a specific paradigm referred to as the "Six Planning Steps" (Yoe and Orth 1996; USACE 2000). These steps can be outlined as follows:

> Step 1. Identifying Problems and Opportunities. The study team identifies problems and opportunities, objectives and constraints in the study area. The study team also enumerates the resource, legal, and policy constraints in this step as well.
>
> Step 2. Inventorying and Forecasting Resources. The study team develops qualitative and quantitative descriptions of resources relevant to the problems and opportunities under consideration for the study.
>
> Step 3. Formulating Alternative Plans. The study team formulates all reasonable alternatives and screens or reduces these to a manageable set of intensively scrutinized potential designs. These

alternatives incorporate issues identified in earlier steps, and are bounded by constraints identified during scoping.

Step 4. Evaluating Alternative Plans. The study team then assesses the effects of the screened alternatives.

Step 5. Comparing Alternative Plans. All alternatives, including the "No Action Plan," are then compared based on ecological, hydrological, and economic effectiveness and efficiency.

Step 6. Selecting the Recommended Plan. The study team then selects plans that maximize benefits and minimize costs (consistent with the Federal objective).

Early in the process, a multi-agency Ecosystem Assessment Team (E-Team) was convened. Representatives from the Galveston District, U. S. Fish and Wildlife Service (USFWS), U. S. Environmental Protection Agency (USEPA), National Marine Fisheries Service (NMFS), and National Resources Conservation Service (NRCS), Texas Commission on Environmental Quality (TCEQ), the Texas General Land Office (TGLO), the Texas Parks and Wildlife Department (TPWD), the Galveston Bay National Estuary Program (GBNEP), the Harris County Flood Control District (HCFCD), Brazoria County Drainage District No. 4 (BCDD), and Galveston County actively participated in the assessment process. Scientists from the U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL) facilitated the ecological evaluations undertaken by the E-Team. The planning process is described in great detail in the various Clear Creek planning and NEPA documents (USACE 1999; 2002, 2010). For purposes of this report, we will focus predominantly on the ecological evaluations supporting these activities.

Coupling Conceptual Modeling and Index Modeling

Conceptual models are proving to be an innovative approach to organize, communicate, and facilitate analysis of natural resources at the landscape scale (Harwell et al. 1999, Turner et al. 2001, Henderson and O'Neil 2004, Davis et al. 2005, Ogden et al 2005, Watzin et al. 2005, Alvarez-Rogel et al. 2006). By definition a conceptual model is a representation of relationships among natural forces, factors, and human activities believed to impact, influence or lead to an interim or final ecological condition

(Harwell et al. 1999, Henderson and O'Neil 2004). In most instances these models are presented as qualitative or descriptive narratives and illustrated by influence diagrams that depict the causal relationships among natural forces and human activities that produce changes in systems (Harwell et al. 1999, Turner et al. 2001, Ogden et al. 2005, Alvarez-Rogel et al. 2006). No doubt, conceptual models provide a forum in which individuals of multiple disciplines representing various agencies and outside interests can efficiently and effectively characterize the system and predict its response to potential alternatives in a descriptive manner. In theory and practice, conceptual models have proved an invaluable tool to focus stakeholders on developing ecosystem restoration goals in terms of drivers and stressors. These in turn are translated into essential ecosystem characteristics that can be established as targets for modeling activities.

For purposes of this study, a systematic framework was developed that coupled the traditional USACE planning process with an index modeling approach derived from a sound conceptual understanding of ecological principles and ecological risk assessment that characterized ecosystem integrity[1] across spatial and temporal scales, organizational hierarchy, and ecosystem types, yet adapted to the project's specific environmental goals. Ideally, the development of conceptual models involves a close linkage with community-index modeling, and produces quantitative assessment of systematic ecological responses to planning scenarios (Figure 3).

[1] We prescribe to the Society of Ecological Restoration's (2004) definition of ecosystem integrity here, which has been defined as "the state or condition of an ecosystem that displays the biodiversity characteristics of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning." We expand upon this definition by including Dale and Beyeler (2001) descriptions which refer to "system wholeness, including the presence of appropriate species, populations, and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes."

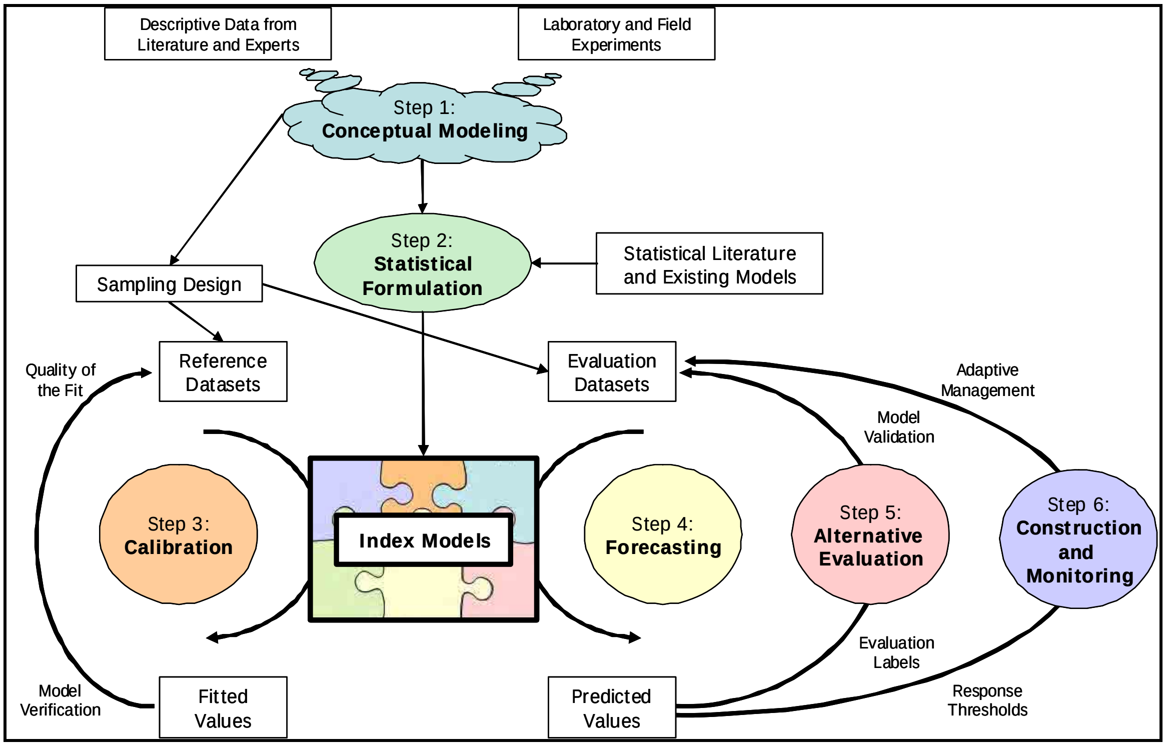

Figure 3. Overview of the successive steps (1-6) of the community-based index model building and application process for ecosystem restoration, where two data sets (one for calibration and one for alternative evaluations) are used (adapted from Guisan and Zimmerman 2000).

Under this modeling paradigm, conceptual modeling led to the choice of an appropriate scale for conducting the analysis and to the selection of ecologically meaningful explanatory variables for the subsequent environmental (index) model. The model was calibrated using reference-based conditions and modified when the application dictated a necessary change. Note that the same model used to evaluate alternatives should be used in the future to monitor the restored ecosystem and generate response thresholds to trigger adaptive management under the indicated feedback mechanism.

Several advantages of this approach were readily apparent. First, it provided a logically consistent ordering of relations among planning steps. Second, the relationships among environmental factors were supported by formal logical expressions (mathematical algorithms in the model), couched in terms of ecosystem structure and functions, and quantified in terms of habitat suitability. Key to this approach was the utilization of expert knowledge in a transparent fashion as well as the characterization of communities across the system in a quantifiable manner with minimal expense and within a limited timeframe.

Using HEP to Assess the Ecosystem Response

To evaluate the ecological impacts of proposed flood risk management plans, and to assess the veracity of proposed mitigation plans formulated to offset these potential impacts, the District and its stakeholders needed an assessment methodology that could capture the complex ecosystem process and patterns operating at both the local and landscape levels across multiple ecosystems (Figure 4).

Figure 4. At stake are the dwindling floodplain forests situated along the Clear Creek channel and its tributaries.

In 1980, the USFWS published quantifiable procedures to assess planning initiatives as they relate to change of fish and wildlife habitats (USFWS 1980a,b,and c). These procedures, referred to collectively as Habitat Evaluation Procedures and known widely as HEP, use a habitat-based approach to assess ecosystems and provide a mechanism for quantifying changes in habitat quality and quantity over time under proposed alternative scenarios. Habitat Suitability Indices (HSIs) are simple mathematical algorithms that generate a unitless index derived as a function of one or more environmental variables that characterize or typify the site conditions (i.e., vegetative cover and composition, hydrologic regime, disturbance, etc.) and are deployed in the HEP framework to quantify the outcomes of impact or mitigation scenarios. These tools have been applied many times over the course of the last 30 years (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown et al. 2000, Store and Jokimaki 2003, Shifley et al. 2006, Van der Lee et al. 2006 and others). The Clear Creek study team made the decision to assess ecosystem impacts and mitigation using HEP and two[1] community-based functional HSI models (Burks-Copes and Webb 2010) therein. The remainder of this document focuses on the E-Team's HEP assessment methodology and results.

Planning Model Certification

The USACE Planning Models Improvement Program (PMIP) was established to review, improve, and validate analytical tools and models for USACE Civil Works business programs. In May of 2005, the PMIP developed Engineering Circular (EC) 1105-2-407, Planning Models Improvement Program: Model Certification (USACE 2005). This EC requires the use of certified models for all planning activities. It tasks the Planning Centers of Expertise to evaluate the technical soundness of all planning models based on theory and computational correctness. EC 1105-2-407 defines planning models as,

> *" . . . any models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making."*

Clearly, the community-based HSI model developed for the study must be either certified or approved for one-time use. The Galveston District initiated this review in 2009 and is awaiting a memo from the USACE Eco-PCX granting one-time-use approval.[2] Information necessary to facilitate

[1] It is important to note that a third model was initially developed under this effort to evaluate tidal marshes within the Clear Creek watershed. However, further investigation of the problems and opportunities surrounding both the proposed flood control plans and their subsequent mitigation requirements indicated tidal marsh would not be affected.

[2] For a detailed copy of the independent model review report and the District's response for issue resolution contact the District.

model certification/one-time-use approval is outlined in Table 2 of the EC 1105-2-407 (pages 9-11).

For purposes of model certification, it is important to note that the model must be formally certified or approved for one-time-use, but the methodology under which it is applied (i.e., HEP) does not require certification as it is considered part of the application process. HEP in particular has been specifically addressed in the EC:

> "*The Habitat Evaluation Procedures (HEP) is an established approach to assessment of natural resources, developed by the US Fish and Wildlife Service in conjunction with other agencies. The HEP approach has been well documented and is approved for use in Corps projects as an assessment framework that combines resource quality and quantity over time, and is appropriate throughout the United States*." (refer to Attachment 3, page 22, of the EC)

The authors used the newly developed **Habitat Evaluation and Assessment Tools** (**HEAT**) (Burks-Copes et al. 2010) to automate the calculation of habitat units for the study. This software is not a "shortcut" to HEP modeling, or a model in and of itself, but rather a series of computer-based programming modules that accept the input of mathematical details and data comprising the index model, and through their applications in the HEP or the Hydrogeomorphic Wetland Assessment (HGM) processes, calculates the outputs in responses to parameterized alternative conditions. The **HEAT** software contains two separate programming modules – one used for HEP applications referred to as the **EXpert Habitat Evaluation Procedures** (**EXHEP**) module, and a second used in HGM applications referred to as the **EXpert Hydrogeomorphic Approach to Wetland Assessments** (**EXHGM**) modules. The authors used the **EXHEP** module to calculate outputs for the MRGBER study. The developers of the **HEAT** tool (including both the **EXHEP** and **EXHGM** modules themselves) are currently pursuing certification through a separate initiative, and hope to have this tool through the process in the next year barring unforeseen financial and institutional problems.

The authors used **IWR Planning Suite**[1] to run the cost analyses for the restoration plans in the study which was certified in 2008.

Report Objectives and Structure

Between 2003 and 2008, the E-Team designed, calibrated, and applied a landscape-level community-based index model for the system's floodplain forests using field and spatial data gathered from watershed reference sample sites (Burks-Copes and Webb 2010) . Five individual conveyance/detention measures were combined to generate the National Economic Development (NED) plan (including mitigation). Twelve individual mitigation plans were evaluated to offset the impacts detailed in the NED plan. The intent of this document is to detail the HEP application and present the findings of that assessment. The objectives of this report are to:

1. Briefly characterize the habitat community affected by the proposed flood risk management plans;
2. Describe the methods used to assess the proposed NED plan (and the subsequent mitigation plans therein);
3. Present the HEP results for both evaluations; and
4. Present the cost analysis that will facilitate the District's selection of recommended mitigation to complete the NED plan.

This report is organized in the following manner. *Chapter 1* provides the background, objectives, and organization of the document. *Chapter 2* is devoted to describing the technical merits and requirements of HEP. A brief characterization of the relevant community is provided including a discussion of data handling techniques, decisions made by the E-Team in the utilization of data in the analysis, and the derivation of baseline Habitat Units (HUs) for the models. *Chapter 3* documents the baseline analyses of the watershed. *Chapter 4* provides details regarding the "No Action" plan, also known as the Without-project (WOP) Condition, and *Chapter 5* documents the impacts of the NED plan (i.e., the With-project (WP) Condition). *Chapter 6* details the evaluation of the proposed mitigation plans and documents the cost analyses of these alternatives. *Chapter 7* summarizes the findings of the previous chapters and offers conclusions.

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[1] http://www.pmcl.com/iwrplan/

Appendices A through *C* serve as general information for the reader [e.g., a list of commonly used acronyms in this report, a glossary of terms, and tables of variables associated with the study's community model]. *Appendix D* has been included to facilitate review of this document. A separate report has been developed by ERDC-EL presenting the community-based HSI model (Burks-Copes and Webb 2010) developed for this study. The model's characteristics, limiting factors (i.e., variables and habitat suitability indices), supporting mathematical equations, and significant literature references are documented therein.

2 Methods

The protection and restoration of ecosystems must focus on the preservation and/or recovery of specific system attributes that promote human welfare independent of human use. Such “non-use” benefits can arise from the mere existence and/or maintenance of nationally or regionally rare and unique ecosystems. Indeed, the public is likely to view the protection of endangered species and their associated habitats, as an important goal of ecosystem restoration and management. There is no doubt the determination of restoration and management success based on ecosystem processes is complex. Yet, federal law requires USACE Districts evaluate the effects of proposed flood risk management measures at levels used to justify the project. To facilitate efficiency, evaluation methodologies need be no more elaborate than required to demonstrate that the anticipated ecological impacts are justified and can be offset with mitigation effectively. To ensure effectiveness, these methods must include the ecosystem elements necessary for linking impacts to ecosystem integrity response. To guarantee plan completeness, the scope of the method or tool should fit the ecological and social dimensions of environmental problems targeted by ecosystem impacts and mitigation. To assure plan acceptance, the models and other decision-support methods have to comply with institutional constraints and influential public opinion (both technically and politically). The main problem addressed in the search for appropriate decision-support methods, is how to evaluate the relative impacts of non-monetary environmental services and their compensation through mitigation. Once non-monetary services are characterized in fundable measures, they can be compared to other proposed projects, and independent estimates of monetized service benefits and costs in a public forum. With key stakeholders involved, the monetized opportunity costs incurred by impacts and mitigation of non-monetary service values can be weighed against the opportunity costs among other inputs.

Types of Ecosystem Evaluation Methodologies

USACE planning studies depend on non-monetary evaluation methodologies to quantify inherent ecological processes, structure, dynamics and the functions ecosystems carry out in nature. These processes depend on particular attributes that correspond to physical features of an ecological setting (e.g., the density of tree canopy over a section of stream bank, permeability of soils which form the bank and complexity of surface relief along the bank). It should be noted that these attributes can be measured, counted or described in a standardized way. The attributes of interest in landscape-scale analyses of ecologically important processes typically have an inherent sense of quantity that affects the manner in which they influence the ecosystem. For example, dense tree canopy is indicative of forest age, health, vigor, water availability and nutrient cycling at any given location. Several evaluation techniques have been developed to capture or quantify ecosystem health and function.

The HEP Process

The HEP methodology is an environmental accounting process developed to appraise habitat suitability for fish and wildlife species in response to potential change (USFWS 1980a-c). HEP is an objective, quantifiable, reliable and well-documented process used nationwide to generate environmental outputs for all levels of proposed projects and monitoring operations in the natural resources arena. HEP provides an impartial look at environmental effects, and delivers measurable products to the decision-maker for comparative analysis.

HSI models have played an important role in the characterization of ecosystem conditions nationwide. They represent a logical and relatively straightforward process for assessing change to fish and wildlife habitat (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown et al. 2000, Kapustka 2005). The controlled and economical means of accounting for habitat conditions makes HEP a decision-support process that is superior to techniques that rely heavily upon professional judgment and superficial surveys (Williams 1988, Kapustka 2005). They have proven to be invaluable tools in the development and evaluation of restoration alternatives (Williams 1988, Brown et al. 2000, Store and Kangas 2001, Kapustka 2003, Store and Jokimaki 2003, Gillenwater et al. 2006, Schluter et al. 2006, Shifley et al. 2006), managing refuges and nature preserves (Brown et al. 2000, Ortigosa et al. 2000, Store and Kangas 2001, Felix et al. 2004, Ray and Burgman 2006, Van der Lee et al. 2006) and others), and mitigating the effects of human activities on wildlife species [Burgman et al. 2001, National Research Council (NRC)

2001, Van Lonkhuyzen et al. 2004]. These modeling approaches emphasize usability. Efforts are made during model development to ensure that they are biologically valid and operationally robust. Most HSI models are constructed largely as working versions rather than as final, definitive models (VanHorne and Wiens 1991). Simplicity is implicitly valued over comprehensiveness, perhaps because the models need to be useful to field managers with little training or experience in this arena. The model structure is therefore simple, and the functions incorporated in the models are relatively easy to understand. The functions included in models are often based on published and unpublished information that indicates they are responsive to species density through direct or indirect effects on life requisites. The general approach of HSI modeling is valid, in that the suitability of habitat to a species is likely to exhibit strong thresholds below which the habitat is usually unsuitable and above which further changes in habitat features make little difference. And as such, most HSI models should be seen as quantitative expressions of the best understanding of the relations between easily measured environmental variables and habitat quality. Habitat suitability models then, are a compromise between ecological realism and limited data and time (Radeloff et al. 1999, Vospernik et al. 2007).

In HEP, a Suitability Index (SI) is a mathematical relationship that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type. These suitability relationships are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges from 0.0 to 1.0, where an SI = 0.0 represents a variable that is extremely limiting, and an SI = 1.0 represents a variable in abundance (not limiting) for the species or community. In HEP, a Habitat Suitability Index (HSI) model is a quantitative estimate of habitat conditions for an evaluation species or community. HSI models combine the SIs of measurable variables into a formula depicting the limiting characteristics of the site for the species/community on a scale of 0.0 (unsuitable) to 1.0 (optimal).

Community HSI models in HEP

Existing community-based HSI models offer more promise than species-based HSI models because they are more efficient in capturing those habitat measures necessary for restoring ecosystem integrity and can be compared across a wide range of ecosystems for prioritization purposes

(Stakhiv et al. 2001). Community-based HSI models indicate relative ecosystem value more inclusively than species-based models because they link habitat more broadly to ecosystem components or functions. Community-based HSI models can also be deployed in the traditional HEP methodology. The community-based HSI models rely on field measured habitat parameters (just as the species-based HSI models do). These parameters are integrated into a series of predictive suitability indices – quantifying the suitability of the community in terms of physical, chemical and biological processes relative to other communities from a regional perspective within a reference domain. Community-based HSI models are, by definition, scaled from zero to one. An index of "1" indicates that a community is operating at the highest sustainable level, the level equivalent to a community under reference standard conditions in a reference domain. An index of "0" indicates the community does not operate at a measurable level and will not recover the capacity to operate through natural processes. Community models can often be broken into specific components, such as biota (diversity and structure), water and landscapes. Some examples of variables within these components include presence/absence of canopy architecture, species richness, flooding frequency, flooding duration, patchiness, corridor widths and lengths. The results of the index-based assessments are multiplied by the affected area (in acres) to calculate HUs. In the HEP process, species are often selected on the basis of their ecological, recreational, spiritual or economic value. In other instances, species are chosen for their representative value (i.e., one species can "represent" a group or guild of species, which have similar habitat requirements). Most of these species can be described using single or multiple habitat models and a single HSI mathematical formula. In some studies, several cover types are included in an HSI model to reflect the complex interdependencies critical to the species' or community's existence. Regardless of the number of cover types incorporated within an HSI model, any HSI model based on the existence of a single life requisite requirement (e.g. food, water, cover or reproduction) uses a single formula to describe the relationship between quality and carrying capacity for the site.

Most communities are examined inaccurately by using the single formula model approach described above. In these instances, a more detailed model can emphasize critical life requisites, increase limiting factor sensitivity and improve the predictive power of the analysis. Multiple habitats and HSI formulas are often necessary to calculate the habitat suitability of these comprehensive HSI models. This second type of HSI model is used to capture the juxtaposition of habitats, essential dependencies and performance requirements such as reproduction, roosting needs, escape cover demands or winter cover that describe the sensitivity of a species or community. Multiple Formula Models require more extensive processing to evaluate habitat conditions.

Habitat units in HEP

HSI models can be tailored to a particular situation or application and adapted to meet the level of effort desired by the user. Thus, a single model (or a series of inter-related models) can be adapted to reflect a site's response to a particular design at any scale (e.g., species, community, ecosystem, regional and/or global dimensions). Several agencies and organizations have adapted the basic HEP methodology for their specific needs in this manner (Inglis et al. 2006, Gillenwater et al. 2006, and Ahmadi-Nedushan et al. 2006). HEP combines both the habitat quality (HSI) and quantity of a site (measured in acres) to generate a measure of change referred to as Habitat Units (HUs). Once the HSI and habitat quantities have been determined, the HU values can be derived with the following equation: HU = HSI x Area (acres). Under the HEP methodology, one HU is equivalent to one acre of optimal habitat for a given species or community.

Capturing changes over time in HEP applications

In studies spanning several years, Target Years (TYs) must be identified early in the process. Target Years are units of time measurement used in HEP that allow users to anticipate and identify significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be at least a TY = 1 and a TY = X2. TY1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TYX2 designates the ending target year or the span of the project's life. A new target year must be assigned for each year the user intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses, and between the baseline and future analyses. In studies focused on long-term effects, HUs generated for indicator species/communities are estimated for several TYs to reflect the life of the project. In such analyses, future habitat conditions are estimated for both without-project (e.g., No Action Plan) and with-project conditions. Projected long-term effects of the project are reported in terms of Average Annual Habitat Units (AAHUs) values. Based on the AAHU outcomes, alternative designs can be formulated and trade-off analyses can be simulated to promote environmental optimization.

Applying HEP to the Clear Creek Study: 12 Steps

Twelve steps were completed in the assessment of the study's proposed flood risk management (and mitigation) designs using HEP. Briefly, they included:

1. Building a multi-disciplinary evaluation team.
2. Defining the project.
3. Mapping the site's Cover Types (CTs).
4. Selecting, modifying and/or developing index model(s).
5. Collect data.
6. Performing data management and statistical analyses.
7. Calculating baseline conditions.
8. Setting goals and objectives, and defining project life and Target Years (TYs).
9. Generating Without-project (WOP) conditions and calculating outputs.
10. Generating With-project (WP) conditions and calculating outputs.
11. Performing trade-offs.
12. Reporting the results of the analyses.

The following sections provide the details of the Clear Creek application plan formulation process and the application of the HEP techniques to the study's plans.

Step 1: The Clear Creek Ecosystem Evaluation Team

In HEP, a multi-agency interdisciplinary team is formed to lead both the model selection/development phase of the project and to establish the baseline and future conditions of the site(s). Participants often include representatives from USACE, USEPA, USFWS, NRCS, state fish and game offices, and other federal, state, and local governments as well as tribes as is deemed necessary. The technical expertise necessary to support planning efforts should include, but is not restricted to, representatives from botany, soils, hydrology, and wildlife ecology disciplines. The E-Team should also include individuals who were responsible for project design and management [i.e., engineers, project managers, NEPA consultants, cost-share sponsors, university professors, etc.].

The Clear Creek multidisciplinary ecosystem evaluation team (E-Team) was convened in 2003 to develop the community index models and conduct the HEP evaluations for the study. The multi-disciplinary, multi-agency team included various interests and technical expertise. A complete list of Clear Creek's E-Team members can be found in Table 1 below.

Table 1. The Clear Creek study's E-Team members.

E-Team Members	Agency	Phone	Email Address
Catanzaro, Andrea	USACE	409-766-6346	Andrea.Catanzaro@usace.army.mil
Easley, Greg	TCEQ	512-239-4539	geasley@tceq.state.tx.us
Jeff DallaRosa	TCEQ – GBNEP	281 486-1242	jdallaro@tceq.state.tx.us
Heinly, Bob	USACE	409-766-3992	Robert.W.Heinly@.usace.army.mil
Hunt, Shane	Bureau of Reclamation, Sacramento, CA (formerly with USACE–Galveston TX)	559-487-5138	shunt@mp.usbr.gov
Jones, Seth	USACE	409-766-3068	Seth.W.Jones@usace.army.mil
Labay, Andrew	PBS&J	512-342-3382	aalabay@pbsj.com
Murphy, Carolyn	USACE	409-766-3044	Carolyn.E.Murphy@usace.army.mil
Rosen, David	Lee Community College, Baytown, TX (formerly with USFWS)	281-427-5611	
Belton, Moni	USFWS	281-286-8288	moni_belton@fws.gov
Phil Glass	USFWS* (retired)		
Rund, Natalie	USACE	409-766-6384	Natalie.A.Rund@usace.army.mil
Gerald Dunaway	USACE* (retired)	409-740-1386	gmdun@sbcglobal.net
Jake Walsdorf	USACE	409-766-3827	Jacob.C.Walsdorf@usace.army.mil
Sarah Xie-DeSoto	USACE	409-766-3172	Sarah.H.Xie-DeSoto@usace.army.mil
Carol Hollaway	USACE/IWR	409-744-1120	Carol.a.hollaway@usace.arny.mil

(Continued)

Table 1. Concluded.

E-Team Members	Agency	Phone	Email Address
Garry McMahon	Port of Houston Authority, Houston, TX (formerly with TxGLO)	713-670-2594	gmcmahan@poha.com
Schubert, Jamie	TPWD	281-534-0135	William.schubert@tpwd.state.tx.us
Woody Woodrow	TPWD		Jarrett.Woodrow@tpwd.state.tx.us
Seidensticker, Eddie	NRCS	281-383-4285	Eddie.Seidensticker@tx.usda.gov
Swafford, Rusty	NMFS	409-766-3699	Rusty.Swafford@noaa.gov
Taylor, Ralph	HCFCD (Retired)		
David Randolph	HCFCD	713-684-4199	dlr@hcrcd.co.harris.tx.us
Jennifer Dyke	HCFCD	7136844167	Jennifer.dyke@hcfcd.org
Glen Laird	HCFCD	713-684-4199	dlr@hcrcd.co.harris.tx.us
Catherine Elliott	HCFCD	713-684-4061	Catherine.Elliott@hcfcd.co.harris.tx.us
Steve Fitzgerald	HCFCD	713-684-4060	sdf@hcrcd.co.harris.tx.us

It is important to note that attrition and turnover over the course of the study led to many changes in this original roster. We have attempted to include both the names of original participants as well as replacements and additions here as well.

Step 2: Defining the Clear Creek Project

The following sections (*Lead District*, *Project Location*, etc.) were developed by the District and used to define the overall project. For further details regarding this information, refer to the study's planning and NEPA reports (USACE 1999; 2002, 2010)

Lead District

The Clear Creek study falls under the purview of the U.S. Army Corps of Engineers, Galveston District, Galveston, TX (Figure 5).[1]

[1] http://www.swg.usace.army.mil/ (APR 2008).

Figure 5. Galveston District boundaries.

The District is one of four districts that make up the USACE Southwestern Division.[1]. The Galveston District is an operating component of the Southwestern Division, responsible for providing support along an arc of the Texas Gulf Coast, approximately 150 miles in width, extending from the Texas-Louisiana border on the northeast, to the Mexican border on the southwest. With its rich heritage in Texas history, the District performs its civil works mission throughout the Texas gulf coast, contributing to the area's metropolitan and rural life, congenial mixture of industry and natural environment, abundant wildlife, and coastal attractions. The District serves the vital Texas petrochemical refining industry, plus commercial and sports fishing. Waterborne commerce on the 1,000 miles

[1] http://www.swd.usace.army.mil/ (APR 2008).

of deep and shallow draft channels totals 300 millions tons annually. The District was established in 1880 to conduct river and harbor improvements along the Texas Gulf Coast, including construction of jetties to make Galveston Channel navigable. The District is almost entirely coastal in nature, encompassing the entire Texas coast from Louisiana to Mexico - 50,000 square miles. Its length, measured along the coast is about 400 miles and it extends inland about 150 miles, including the major metropolitan area of the fourth largest city in the U.S. – Houston, TX. With its 370 dedicated professionals and an annual budget of $200 million, the District works to carry out its missions of navigation, flood control and hurricane-flood protection, while its regulatory office works to protect the nation's wetlands and navigation channels. In addition, the District has a major real estate responsibility including acquisition of real estate for the National Park Service's Big Thicket Preserve in East Texas. The project manager for the Clear Creek study was Mr. Bob Heinly (CESWG-PE-PL), and the study manager/planner/lead biologist was Ms. Andrea Catanzaro (CESWG-PE-RB).

Project Location

The Clear Creek watershed is located south of the City of Houston and includes parts of Harris, Galveston, Brazoria, and Fort Bend Counties (Figure 6).

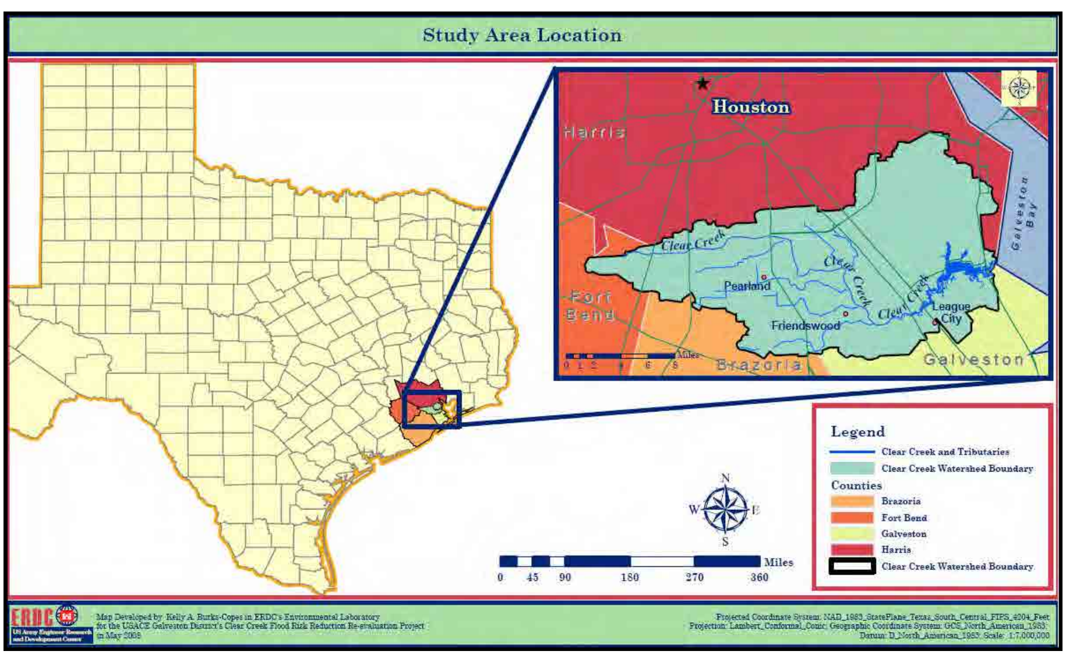

Figure 6. Clear Creek study area location.

The Clear Creek watershed covers approximately 250 square miles and is partly inclusive of the City of Houston. There are an additional 16 cities that are at least partially within the watershed including Pearland, Friendswood, and League City. Clear Creek flows from west to east and drains into western Galveston Bay at Seabrook. Armand and Taylor Bayous are two of the larger tributaries (i.e., identified as separate subwatersheds) flowing into Clear Lake from the north.

The watershed is approximately 45 miles long and is relatively flat - exemplifying the Gulf Coast Plains (Figure 7). Elevations vary from less than 5 feet above mean sea level (msl) near Clear Lake to approximately 75 feet above msl at the western end.

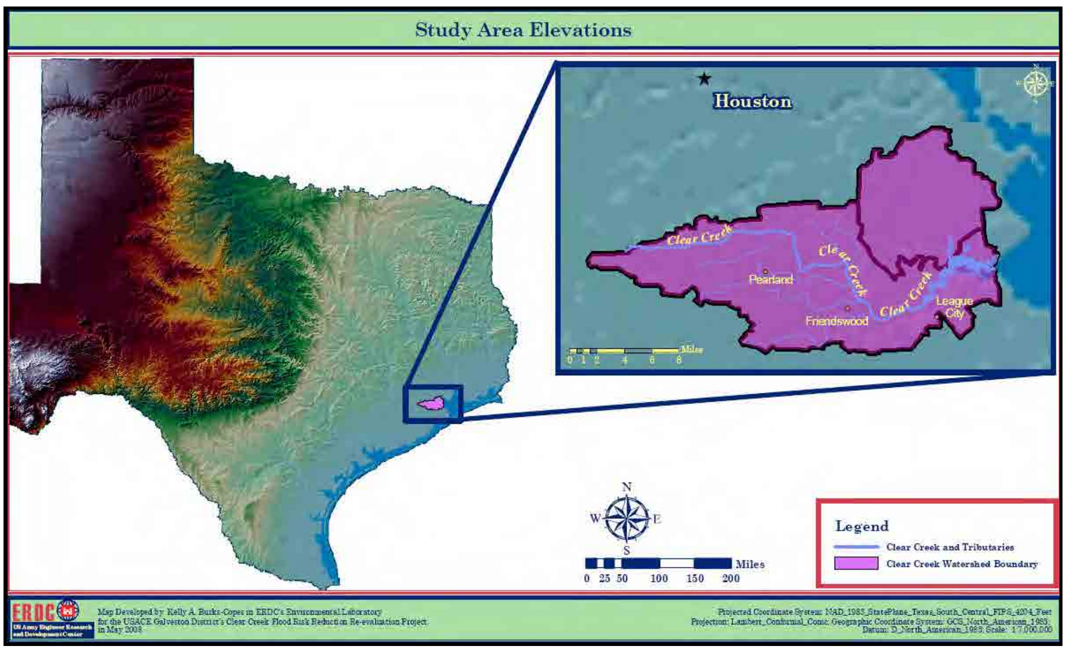

Figure 7. Clear Creek study area elevations.

The floodplain is much wider and shallower in the upstream extents. It narrows and deepens as it moves downstream into Clear Lake. The only significant irregularities in the slope are the valleys cut by the creek and its tributaries.

The Clear Creek Watershed encompasses approximately 166,900 acres – 49 percent (81,650 acres) held in Harris County alone (Figure 8).

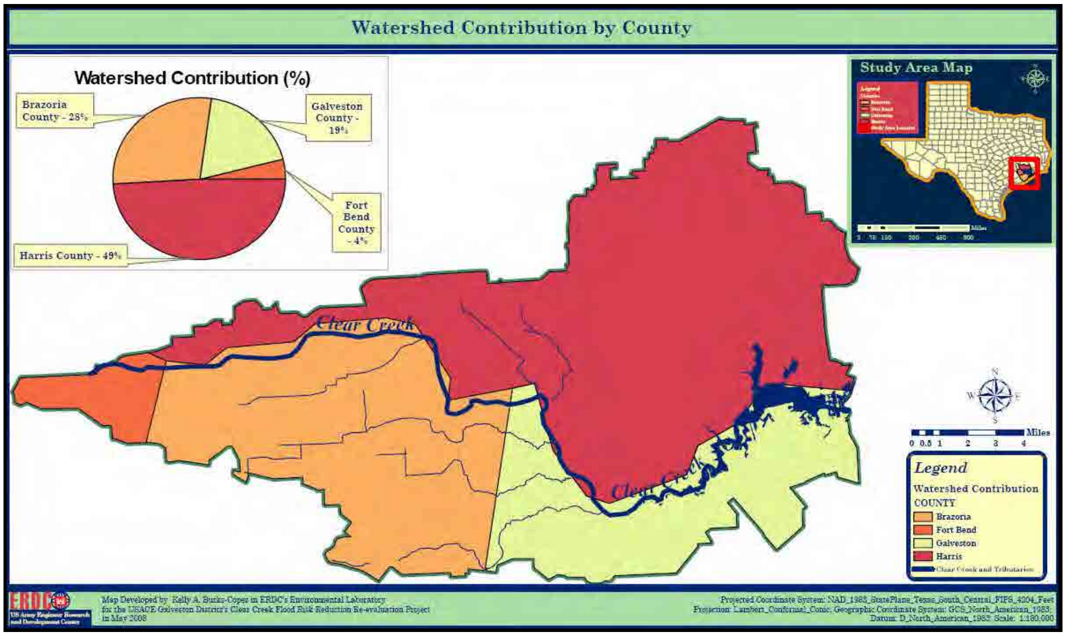

Figure 8. Distribution of acreages across the four counties in the Clear Creek Watershed.

Brazoria and Galveston Counties contribute another 28 and 19 percent (47,468 and 31,771 acres). The remaining four percent comes from the Fort Bend County at the western end of the watershed (6,010 acres). A myriad of land covers/land uses have been identified within the watershed (Figure 9).

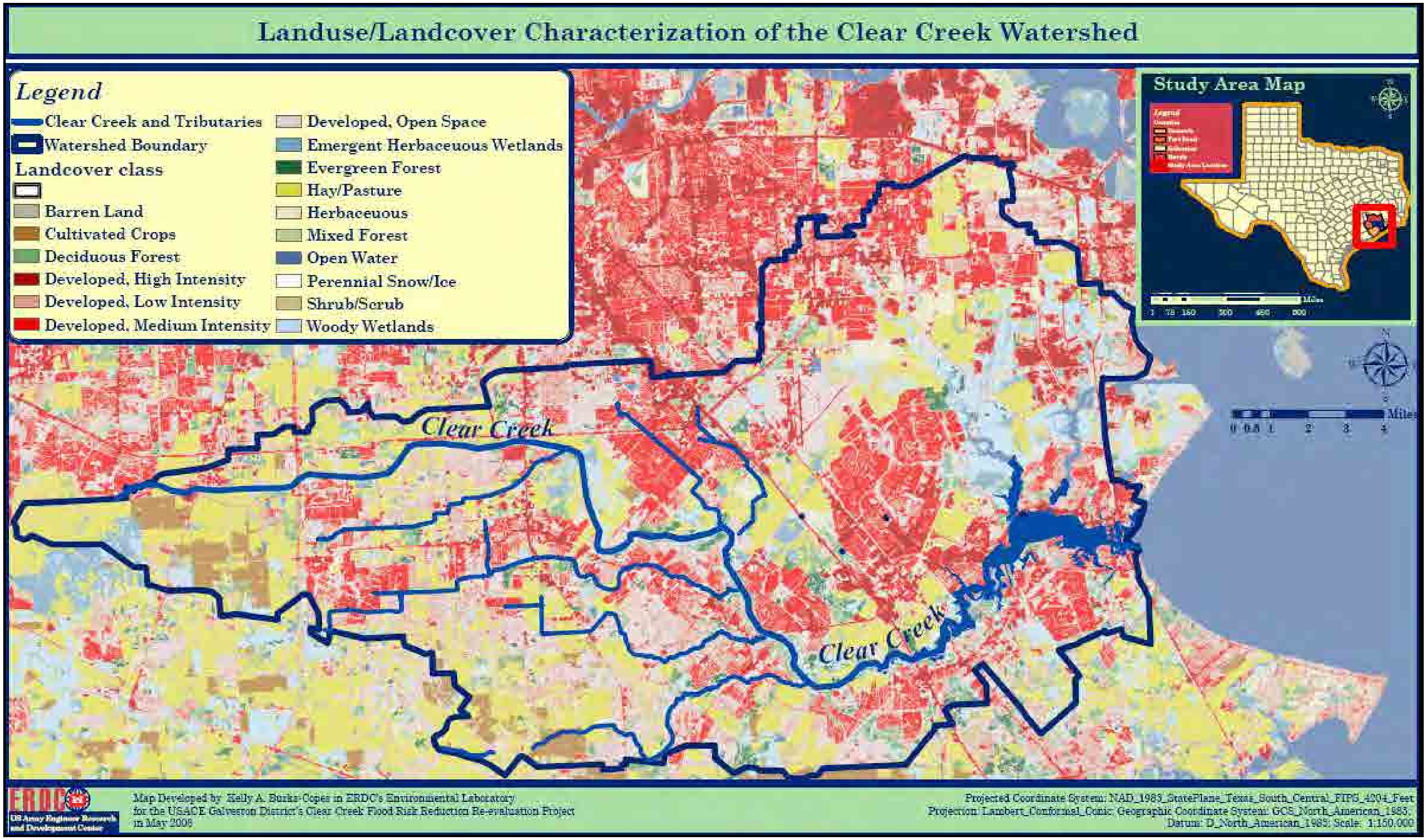

Figure 9. Landuse/landcover (LULC) classes present in the Clear Creek Watershed.[1]

[1] This information was extracted from the National Land Cover Data website: (http://www.mrlc.gov/multizone_download.php?zone=10 (APR 2008).

For purposes of the this analysis, the District chose to take a floodplain-level approach toward flood risk management planning, and as such, made the decision to focus all activities inside the 500-year floodplain (Figure 10).

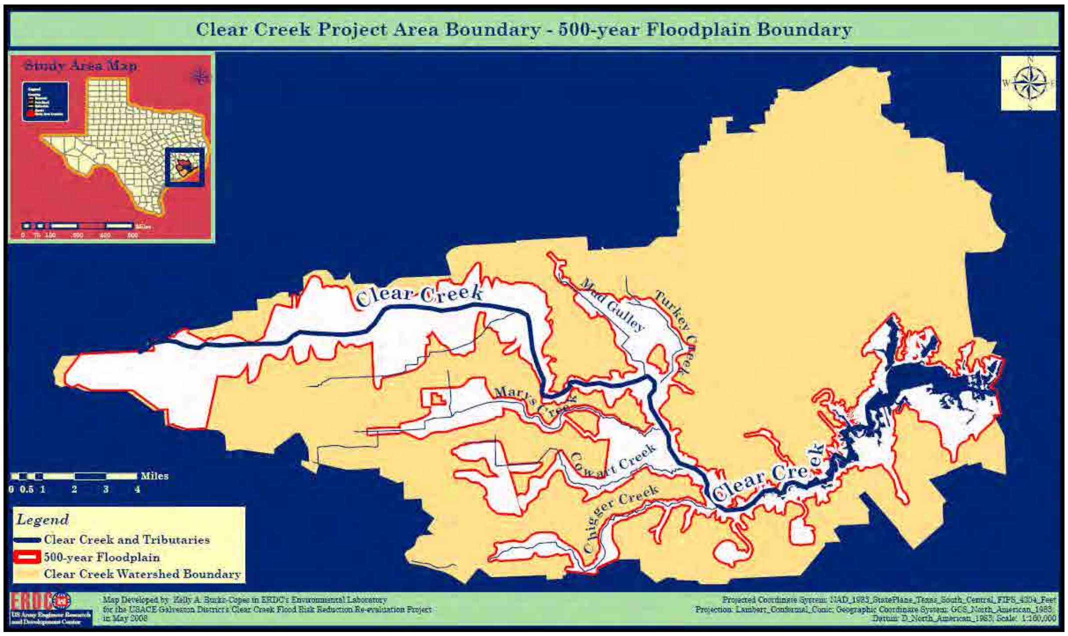

Figure 10. 500-year floodplain delineation defines the boundaries of the Clear Creek study.

It is important to note that the community HSI model was intentionally developed with an emphasis on evaluating landscape-level functions, and as such was designed for applications at the "alternative" level rather than at the feature, action, or treatment level.[1] It is the collective and/or cascading effects of the combination of management measures (comprised of features, actions, and/or treatments) that together formulate an alternative that the model was designed to assess (Figure 11).

[1] For working definitions of these terms, please refer to *Appendix B Glossary* in this report.

Figure 11. By definition, the Clear Creek Floodplain forest community model was designed to assess alternatives, not individual features, actions or treatments. The components of an alternative that may or may not be separable actions that can be taken to affect environmental variables and produce environmental outputs are often referred to as "management measures" in USACE planning studies. As such, management measures are typically made up of one or more features, activities or treatments at a site.

Only applications at this scale can comprehensively address watershed-level planning activities where critical landscape level processes must be measured via patch dynamic-sensitive metrics. Because the E-Team was concerned with the potential masking of impacts when operating at this scale, the decision was made to break the system down into smaller, more manageable units or "ecological reaches" that could still be said to function at the landscape scale, but that could be assessed somewhat independently with a greater degree of resolution. The District used criteria such as degree of human disturbance, land use, stream morphology (stream width, bank characteristics, sinuosity, and water depth) as well as past channelization activities to delineate unique reach settings across the watershed. All told, seven individual "ecological reaches" were defined (Figure 12).

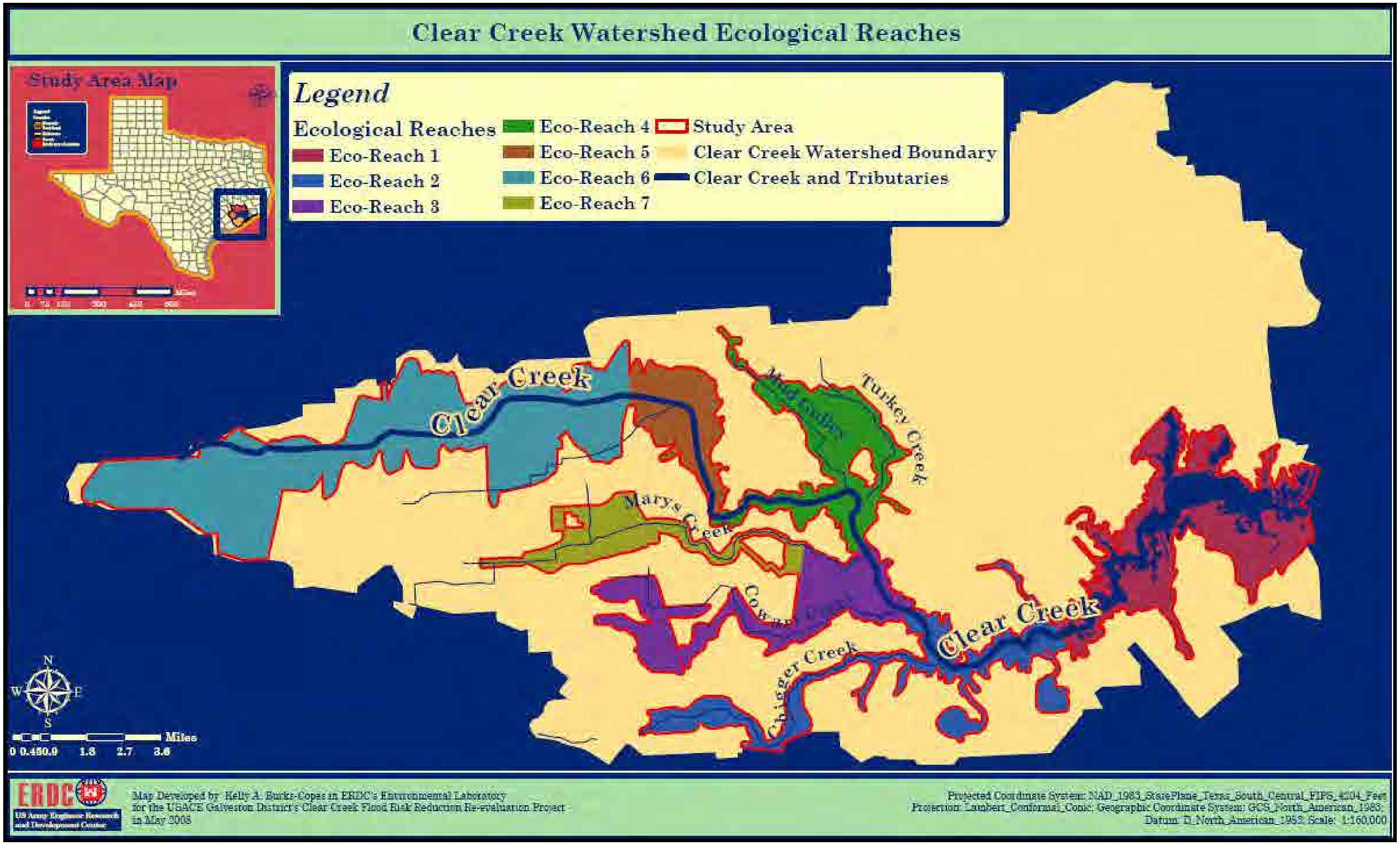

Figure 12. Reaches delineated for the baseline assessment of the Clear Creek watershed.

Eco Eco-Reach 1: Clear Lake from its mouth at Galveston Bay upstream to I-45

The lower two-thirds of Eco-Reach 1 (ER 1) includes the relatively broad, shallow, open-water area known as Clear Lake, which covers about 2 square miles. Farther upstream, the creek narrows to about 180 feet in width with a meandering channel. This reach is moderately developed with more than 60 percent of the adjacent land made up of urban development and pasture, mostly in the lower two-thirds of Clear Lake. Shores are gently sloped throughout much of the reach. The remaining undeveloped areas of riparian corridor along Clear Creek occur mostly in the upstream portion, and these areas are typically forested with small areas of tidal fringe marsh occurring intermittently within small cove-like features. The waterway remains relatively unaltered by channelization except for a very short section connecting Clear Lake to Galveston Bay. Important tributaries include Taylor Lake and Armand Bayou. The entire reach is tidally influenced, and vegetation must be able to tolerate exposure to saltier estuarine waters. ER1 includes 490 acres of floodplain forest and 255 acres of tidal marsh. These two types of land cover made up about 9 percent of the study area in ER 1. Areas of tidal marsh are populated by *Spartina*, *Juncus*, *Sagittaria*, and in some cases the submerged aquatic *Ruppia*. Some floodplain forest is located along the upper portion of this reach and in the Armand Bayou portion of the reach. Willow oak is common in these forest areas.

Eco-Reach 2: Clear Creek Tidal from I-45 Upstream to FM 528

Chigger Creek is about 10 miles long and Clear Creek is about 8 miles long in Eco-Reach 2 (ER2). ER 2 has experienced low to moderate development. Almost 50 percent of land cover in the study area is pasture followed by floodplain forest (27 percent) and urban development (19 percent). Clear Creek is about 180 feet wide just upstream of I-45, narrowing to around 90 feet in width at FM 528. Creek banks are gently sloped throughout, and some small areas of tidal marsh are still present in the lower 0.5 mile of the reach, totaling only 2 percent of the land cover in this reach. Clear Creek has not been channelized in ER 2 and retains its natural meanders and much of its riparian forest. The local drainage district performs some light clearing and snagging of trees along the water’s edge.

Clear Creek is tidally influenced in this Eco-Reach, and there is some exposure to estuarine waters in the lower 5 miles of this reach. Eco-Reaches upstream of ER 2 are considered perennially fresh and should rarely, if ever, be exposed to salty estuarine waters. Chigger Creek is as an intermittent stream with perennial pools for much of its length. Floodplain forest is found along the lower 3 miles of Chigger Creek. This reach of Clear Creek includes the healthiest and most-extensive stands of floodplain forest in the study area, with 1,095 acres of floodplain forest. Willow oak and cedar elm are common (Figure 13).

Figure 13. Tidally influenced marsh on the north bank of Clear Creek upstream of I-45 aptly illustrates the unique ecosystem setting in Eco-Reach 2.

Eco-Reach 3: Clear Creek from FM 528 Upstream to FM 2351 for a Distance of about 4 miles, and Cowarts Creek

Eco-Reach 3 (ER 3) includes the mainstem of Clear Creek and its tributary, Cowarts Creek. This reach has a high degree of development, with more than 90 percent of the adjacent land as pasture and urban development. Clear Creek begins to narrow considerably, ranging from 90 feet wide downstream to less than 30 feet wide at FM 2351. Stream banks steepen considerably in the upstream portion of the reach. Clear Creek has not been channelized and retains its natural meanders in this reach; however, a series of high-flow bypasses have been constructed at various locations in an effort to alleviate impacts of high-velocity flows during flooding. Development has reduced the floodplain forest to a comparatively narrow corridor within this reach. As a result of development, some clearing and snagging of trees along the edge of the creek has been performed by the local drainage district within the reach. Cowarts Creek, about 6.4 miles long, is the primary tributary to this reach of Clear Creek and is considered an intermittent stream with perennial pools (TCEQ, 2008a). Floodplain forests in this reach include green ash, American elm, sugar hackberry, water oak, and water hickory. The only floodplain forest on Cowarts Creek consists of a small patch near its confluence with Clear Creek (Figure 14).

Figure 14. Clear Creek at Imperial Estates (downstream view) represents "typical" conditions along Eco-Reach 3.

Eco-Reach 4: Clear Creek from FM 2351 upstream to Country Club Drive

Eco-Reach 4 (ER4) includes about 8 miles of Clear Creek and two tributaries, Mud Gully and Turkey Creek. This reach has experienced a moderate to high degree of development with around 75 percent of the land converted to urban development or pasture. Clear Creek is relatively narrow, about 15 feet wide at the upstream limit, and has considerable meanders in this reach. Stream banks are naturally steep and nearly vertical. Bank slope has increased primarily due to erosion downstream of Dixie Farm Road and human alterations of the channel. The upstream portion of this reach from Dixie Farm Road to Country Club Drive has been shaped into a trapezoidal channel by flood control activities dating back to the 1940s. Past alterations combined with maintenance activities, including routine mowing, vegetation removal, and channel reshaping by the local drainage districts have left this portion of the creek a relatively straight, grass-lined, low-flow channel with steep slopes bordered by remnant fragmented riparian forest.

Channelization of the upstream portion of the reach also cut off many of the natural channel meanders when excavated material was mounded along the north bank. A series of forested oxbow lakes formed in the cutoff portions of the channel. While the oxbows join the creek via culverts, the water elevation at low flow in the rectified channel is too low for water exchange with oxbows except under heavy rainfall conditions. Under high-flow conditions, oxbows may fill to a level where they drain into the creek, or the flooding creek may force water through the culverts into the oxbows. With 1,053 acres of floodplain forest, this reach of Clear Creek has the second-largest area of floodplain forest, about 24 percent of the land cover.

The tributaries of Mud Gully and Turkey Creek have also been altered extensively as a result of past flood control activities, especially in the upstream areas. Each of the creeks is about 3 miles long, and both are considered perennial streams by the TCEQ (2006). Turkey Creek has been previously channelized and straightened in the upper half, and although some natural sinuosity I the lower half of the channel remains, little nature forested riparian habitat exists. Mud Gully has a few relatively small patches of floodplain forest along its channel near its confluence with Clear Creek (Figure 15).

Figure 15. Mud Gully downstream of Sagedowne Boulevard typifies conditions in Eco-Reach 4.

Eco-Reach 5: Clear Creek from Country Club Road upstream to SH 35

Eco-Reach 5 is a 6-mile reach of Clear Creek that has experienced low to moderate development with about 75 percent of the adjacent land covered with tallgrass prairie (including remnant prairie) and, to a lesser extent, pasture. Clear Creek ranges from approximately 15 to 20 feet in width. It has been extensively altered since the 1940s into a trapezoidal-shaped channel by past flood control activities. Continued maintenance activities over the last 10 years, including routine mowing, vegetation removal, and channel reshaping by the local drainage districts, have kept this portion of Clear Creek a relatively straight, steep-sided, grass-lined, low-flow channel with virtually no woody vegetation near the water's edge except in a few isolated locations. The floodplain forest remaining within this reach occurs mostly outside the low-flow channel and is somewhat fragmented.

Figure 16. Sites on Clear Creek between Country Club Road and SH 35 offer examples of typical ecosystem conditions along Eco-Reach 5.

Eco-Reach 6: Clear Creek from SH 35 upstream to just past SH 288

Eco-Reach 6 (ER6) of Clear Creek has a low to moderate degree of development with coastal prairie (including remnant prairie) making up about 79 percent of the land cover and, to a lesser extent, pasture (Figure 17). The main channel of Clear Creek is very narrow, seldom exceeding 15 feet in width at low flow. Much of this reach of Clear Creek has been shaped into a trapezoidal channel by past flood control activities back to the 1940s. Channel maintenance activities (e.g., reshaping, mowing, tree removal, etc.) from approximately 1 mile downstream of Cullen Boulevard to SH 35, have kept this section relatively straight with virtually no woody vegetation along the low flow channel or its side slopes. The upstream portion of the creek in the vicinity of Tom Bass Park has not been maintained for many years allowing forested riparian habitat to return to the edges of the low-flow channel. Hickory Slough is a very small tributary (less than 8 feet wide) to Clear Creek within ER 6.

Figure 17. Sites on Clear Creek between Country Club Road and SH 35 offer insight into conditions along Eco-Reach 6.

Eco-Reach 7: Mary's Creek from its confluence with Clear Creek near Winding

Road and Sunset Meadows Road Habitat along Mary's Creek consists of a few small, isolated patches of remnant riparian forest in Brazoria County. This Eco-Reach has less floodplain forest than any other reach in the study area as a result of the extensive urban and agricultural development, totaling 83 percent of the Eco- Reach area. Floodplain forest covered about 85 acres, or 3 percent of the study area. Urbanized areas and oldfields, haylands, and pasture cover 41 and 42 percent, respectively, of the Eco- Reach. Much of the middle and upper reaches of Mary's Creek has been modified into a trapezoidal channel, concrete lined in some reaches. Riparian trees and shrubs have been removed along much of the creek (Figure 18).

Figure 18. Sites on Mary's Creek downstream of Harkey Road, Pearland, Texas Mary's Creek downstream of Veteran's Road illustrate conditions along Eco-Reach 7.

Vegetative Communities of Concern

Watershed vegetation at any given time is determined by a variety of factors, including climate, topography, soils, proximity to bedrock, drainage, occurrence of fire, and human activities. Because of the temporal and spatial variability of these factors and the sensitivity of different forms of vegetation to these factors, the watershed vegetation has been a changing mosaic of different types. The pre-settlement vegetation in southeast Texas was predominantly prairie and forest in nature (Figure 19 and Figure 20).

Figure 19. Classic examples of floodplain forests can still be found along the main Clear Creek channel and its many tributaries (photo taken in April 2004).

Figure 20. Classic example of the wet coastal prairie community in the Clear Creek watershed (photo taken in April 2004).

The forested communities are shaped by the frequency and duration of flooding, by nutrient and sediment deposition, and by the permeability of the soil. Overbank river flooding is the primary source of water for forested wetlands. On floodplains with distinctive wetland character, flooding occurs in most years and the flooding persists for at least several weeks at a time. The wet coastal prairies, located along the coastal plain of southwestern Louisiana and south central Texas, are the southernmost tip of the tallgrass prairie ecosystem so prevalent in the Midwest. Detailed characterizations of the floodplain forest community is offered in Burks-Copes and Webb 2010 and references listed therein.

Threats to These Communities

While a significant portion of the river's banks are lined by a narrow system of relictual floodplain forest communities along its course, suburban development within the watershed has reestablsiehd a river system that has lost much of its ecological and hydrological integrity (Figure 21).

Figure 21. Fragmentation and urban encroachment is a common problem for the riparian communities situated along Clear Creek (Clear Creek Channel between Telephone Rd and Mykawa Road).

Forested wetlands are perhaps the most rapidly disappearing wetland type in the United States (Moulton, Dahl, and Dall 1997; Wagner 2004; Jacob, Moulton, and López 2004; and TPWD 2007). Agriculture and silviculture (pine plantations) are the major continuing threats to these wetlands. The character of a forested wetland is destroyed if all of the trees are cut down, even if the hydrology is not otherwise altered, and the wetland may require a hundred or more years to recover. Many forested wetlands can be logged on a sustainable basis and still retain their major ecological functions.

Another major threat is the construction of dams and reservoirs on the rivers that supply water to these wetlands (Moulton, Dahl and Dall 1997; Wagner 2004; Jacob, Moulton and López 2004; and TPWD 2007). In addition to the clearing or drowning of forested wetlands within reservoir floodpools, there is a long-term threat that results from the flood-control function of most dams. Once annual flooding is removed, the wetlands begin to dry out and become more susceptible to development pressures. Since the mid-1950s, forested wetlands on the Texas coast have decreased in area by about 11 percent, a net loss of more than 96,000 acres (Moulton, Dahl, and Dall 1997; Wagner 2004; Jacob, Moulton, and López 2004; and TPWD 2007).

Because the proposed flood risk management activities were likely to impact vegetative communities along the streams, the impact analyses (and associated mitigation planning) focused on the floodplain forests lining their banks.

Step 3: Mapping the Applicable Cover Types

To quantify the community's habitat conditions, the HEP process requires the study area be divided into manageable sections and quantified in terms of acres. This process, referred to as "cover typing," allows the user to define the differences between vegetative covers (e.g., prairie, forest, marsh, etc.) hydrology and soils characteristics, and clearly delineate these distinctions on a map. The final classification system, based primarily upon dominant vegetation cover, captures "natural" settings as well as common land-use practices in a specific and orderly fashion that accommodates the USACE plan formulation process.

In the Clear Creek Watershed study, nine unique habitat types were (i.e., cover types or CTs) were identified and mapped across the entire project study area (Table 2).

Table 2. Cover types identified and mapped for the Clear Creek watershed.

No.	Code	Cover Type (and Land Use) Description
1	AGCROP	Farms and Croplands
2	FOREST	Floodplain Forest
3	NEWFOREST	Newly Developed Floodplain Forest
4	NEWMARSH	Newly Developed Tidal Marsh
5	OPENWATER	Open Bodies of Water Deeper than 1-3m
6	PASTURES	Old Fields, Haylands and Pastures
7	PRAIRIE	Wet Coastal Prairie
8	TIDALMARSH	Tidal Marsh
9	URBAN	Existing Residential, Industrial and Transportation Avenues

Cover types identified as “NEW” refer to newly developed areas proposed in conjunction with construction of proposed alternatives. The existing cover types were subsequently mapped using a Geographic Information System (and ground-truthed during the 2003-2004 field seasons) (Figure 22). For details regarding the total baseline acreages and quality of these CTs, refer to *Chapter 3* of this report.

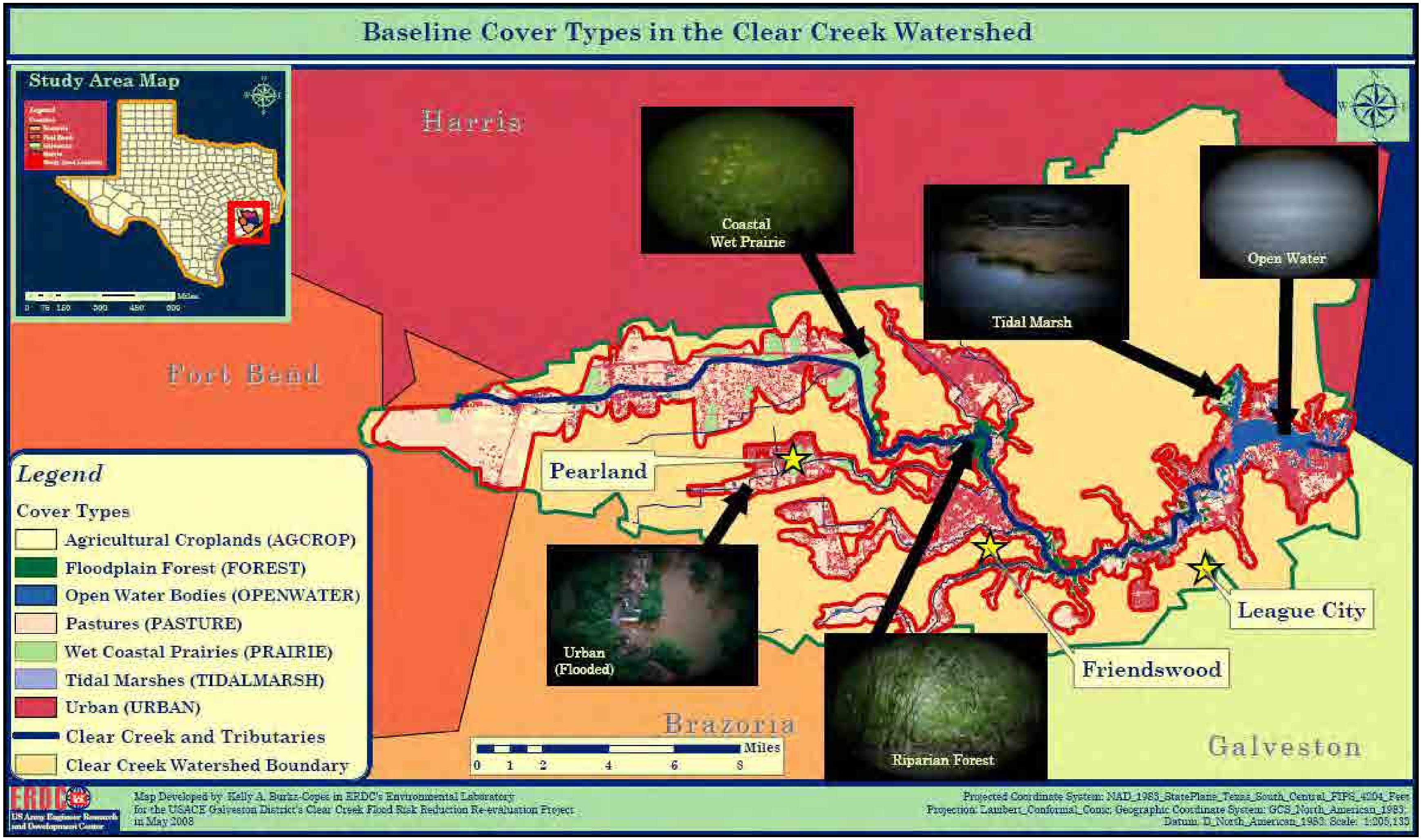

Figure 22. Baseline cover type map for the project study area.

Step 4: Developing Models for the Study

Community assessment was identified as a priority for the District's upcoming feasibility study. However, few HSI community models were published and available for application. ERDC-EL proposed a strategy to the District to develop a community model for the Clear Creek watershed study. The strategy entailed five steps:

1. Compile all available information that could be used to characterize the communities of concern.
2. Convene an expert panel in a workshop setting to examine this material and generate a list of significant resources and common characteristics (land cover classes, topography, hydrology, physical processes) of the system that could be combined in a meaningful manner to "model" the communities. In the workshop, it was important to outline study goals and objectives and then identify the desired model endpoints (e.g., outputs of the model). It was also critical for the participants to identify the limiting factors present in the project area relative to the model endpoints and habitat requirements .The outcome of the workshop was a series of mathematical formulas that were identified as functional components (e.g., Hydrology, Vegetative Structure, Diversity, Connectivity, Disturbance, etc.) which were comprised of variables that were:

    a. biologically, ecologically, or functionally meaningful for the subject,
    b. easily measured or estimated,
    c. able to have scores assigned for past and future conditions,
    d. related to an action that could be taken or a change expected to occur,
    e. were influenced by planning and management actions, and
    f. independent from other variables in each model.

3. Develop both a field and a spatial data collection protocol (using Geographic Information Systems or GIS) and in turn, use these strategies to collect all necessary data and apply these data to the model in both the "reference" setting and on the proposed project area

4. Present the model results to an E-Team and revise/recalibrate the model based on their experiences, any additional and relevant regional data, and application directives.
5. Submit the model to both internal ERDC-EL/District review and then request review from the E-Team members that participated in the original workshop, as well as solicit review from independent regional experts who were not included in the model development and application process.

A series of ten workshops were held over the course of five years (2003-2008) to develop models and characterize baseline conditions of the study area prior to plan formulation and alternative assessment for the flood risk study. Several federal state and local agencies, as well as local and regional experts from the stakeholder organizations, and private consultants, participated in the model workshops. One community-based index model was developed under this paradigm for the system's floodplain forests. Over the course of several workshops, the E-Team was able to devise three model components (i.e., Soils and Hydrology, Biotic Integrity and Structure, and Spatial Context) to characterize the key functional aspects of the system necessary to model the ecosystem integrity in Clear Creek's Floodplain forest communities. A flow diagram best illustrates the model's component relationships (Figure 23).

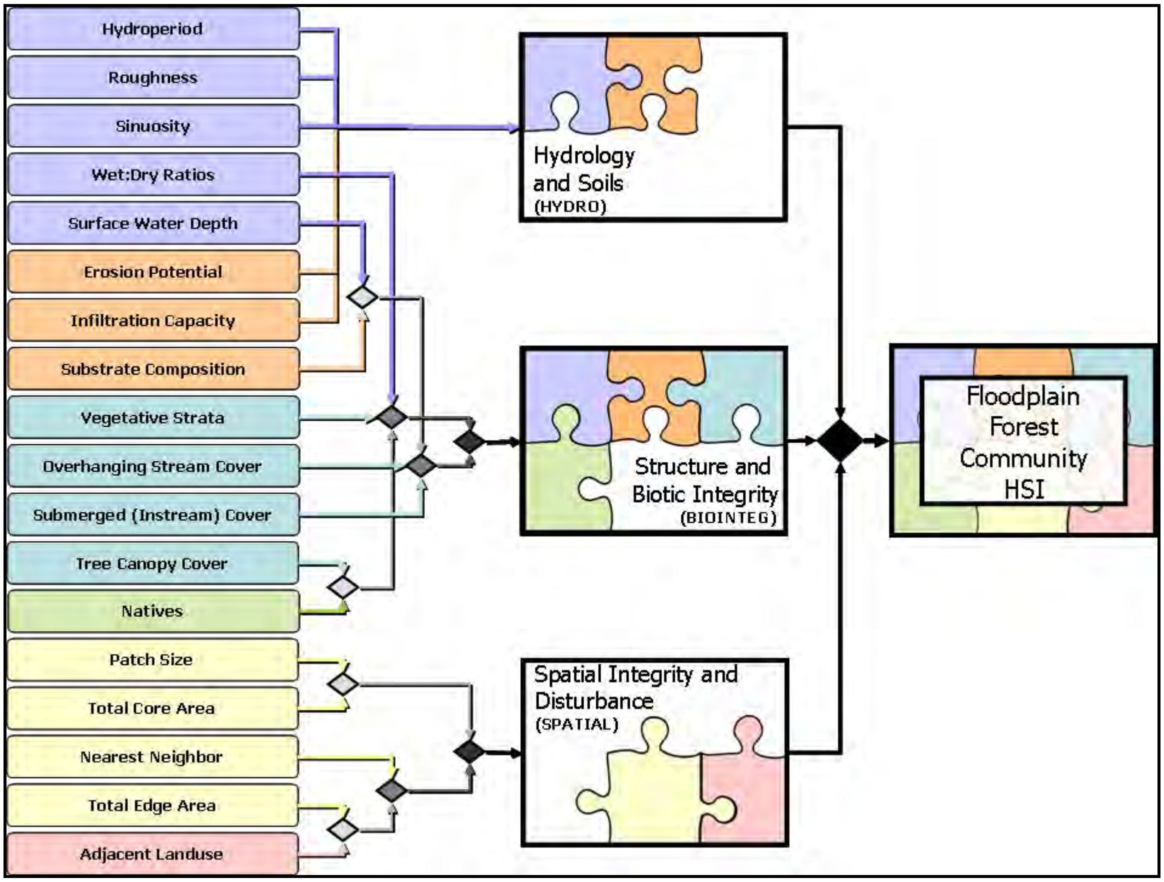

Figure 23. Flow diagram depicting combinations of model components and variables to form the Floodplain forest community index model in the Clear Creek study.

Variables were selected as indicators of functionality, and have been color coded here to correlate their use in specific model components (i.e., purple = hydrologic parameters, orange = soil characteristics, etc.). In essence, this diagram attempts to emulate the standard diagramming protocol adopted by the USFWS in their publications for species HSI models in the late 1980's and early 1990's. Each colored line represents the normalization of a variable (converting the raw data to a scale of 0-1 using suitability index curves). Once the scores are normalized, they are combined in a meaningful manner mathematically to characterize the existing reference conditions found in the watershed. These in turn can be used to capture the effects of change under proposed design scenarios (refer to the section below). Diamonds indicate weightings or merging of indices prior to full component calculation. The three components (i.e., ***HYDRO, BIOINTEG***, and ***SPATIAL***) are combined using a second formula to produce the final HSI result.

After successfully diagramming the relationships between the model components and the variables therein, the E-Team used their extensive natural resources expertise to translate these flow diagrams into mathematical algorithms that would capture the functional capacity of each community in a quantifiable manner. It is important to note that this process was iterative and adaptive. Over the course of several years, the E-Team tested (verified) both the accuracy of the model to predict the suitability of known reference-based conditions[1] as well as test their utility in distinguishing amongst proposed restoration initiatives (Figure 24). With this information in hand, ERDC-EL used a systematic, scientifically-based, statistical protocol to calibrate the community models. Modifications to the original algorithms were incorporated into the system as indicated, and the final formulas were made ready for the Clear Creek application (Table 3). Further descriptions of the community-based index model and its calibration and verification can be found in Burks-Copes and Webb (2010). A general list and description of the model components and their associated variables has been included in *Appendix C* of this report.

[1] ERDC-EL assisted the Galveston District in locating a series of 28 floodplain forest sample sites across the entire study area that were considered both reference standard (optimal) or sub-optimal and representing the range of conditions existing within the reference domain.

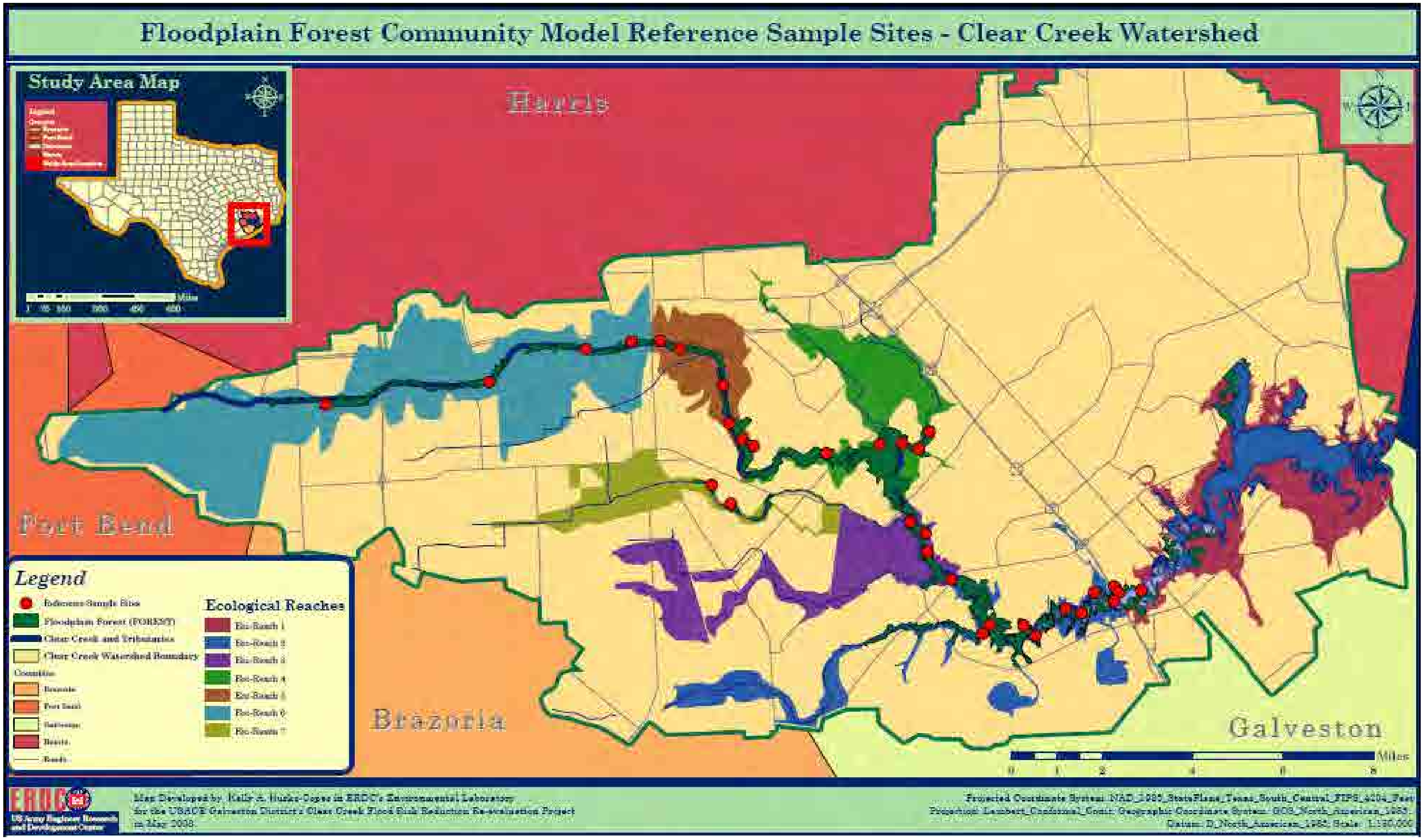

Figure 24. Floodplain forest reference sites in the Clear Creek watershed.

Table 3. Index formulas for the Clear Creek Floodplain forest community model.

Model Component	Variable Description	Variable Code	Formulas
Soils and Hydrology (HYDRO)	Hydroperiod	ALTERHYDRO	$$\frac{V_{ALTERHYDRO} + V_{ROUGHNESS} + V_{IMPERVIOUS} + V_{SINUOSITY} + V_{EROSION}}{5}$$
	Roughness	ROUGHNESS	
	Infiltration Capacity	IMPERVIOUS	
	Sinuosity	SINUOSITY	
	Erosion Potential	EROSION	
Structure and Biotic Integrity (BIOINTEG)	Tree Canopy Cover	CANTREE	$$\frac{\left[\frac{\left(V_{CANTREE} \times V_{NATIVE}\right)^{1/2} + V_{VEGSTRATA} + V_{AREAWETDRY}}{3}\right] + \left[V_{OVRHDCOV} \times V_{INSTRMCOV} \times \left(\frac{V_{SUBSTRATE} + V_{WATERDEPTH}}{2}\right)\right]^{1/3}}{2}$$
	Natives	NATIVE	
	Vegetative Strata	VEGSTRATA	
	Wet::Dry Ratios	AREAWETDRY	
	Overhanging Stream Cover	OVRHDCOV	
	Submerged (Instream)	INSTRMCOV	
	Substrate Composition	SUBSTRATE	
	Surface Water Depth	WATERDEPTH	
Spatial Integrity and Disturbance (SPATIAL)	Patch Size	PATCHSIZE	$$\left\{\left(V_{PATCHSIZE} \times V_{CORE}\right)^{1/2} \times \left[\frac{V_{NEIGHBOR} + \left(V_{EDGE} \times V_{ADJLANDUSE}\right)^{1/2}}{2}\right]\right\}^{1/2}$$
	Total Core Area	CORE	
	Nearest Neighbor	NEIGHBOR	
	Total Edge Area	EDGE	
	Adjacent Landuse	ADJLANDUSE	
Overall Habitat Suitability Index (HSI):			$$\frac{V_{HYDRO} + V_{BIOINTEG} + V_{SPATIAL}}{3}$$

Step 5: Data collection

Baseline characterization of the Clear Creek watershed necessitated the collection of hydrologic, floristic, and spatially-explicit data system-wide. To the greatest extent possible, underlying stressors in the region were also identified. In particular, land-use activities, physical habitat alterations, and indicator species were described in detail. Some of this information was geographically-based and were assessed using documented protocols in a GIS environment. As part of the basic site characterization efforts, historical data on landscape-scale habitat conditions, land-use characteristics, and ownership patterns were collected as well. Site- and landscape-level data were collected and analyzed between 2000 and 2008. Refer to Burks-Copes and Webb 2010 for details on sampling protocols used in this effort.

Step 6: Data management and statistical analysis

Baseline data were subject to straightforward statistical analysis. Means, modes and standard deviations were derived for the variables sampled in the field and generated through GIS exercises. Some limits to the assessment's data should be acknowledged. In some instances, variables were sampled incorrectly, recorded incorrectly or not measured in certain settings, and the data was either discarded or corrections were made several weeks after sampling was concluded. Where parameters were discarded or absent, extrapolations were made from regional means. When data management problems arose, ERDC-EL consulted with the E-Team prior to data handling, and solutions were devised with their full knowledge and consent. Detailed notes and minutes were taken during these meetings and phone conversations to provide documentation for the assessment. For minutes/notes recorded at these meetings, contact Mrs. Andrea Catanzaro at the District office.

Step 7: Calculate Baseline Conditions

Once the baseline inventory was completed, the variable means, modes and the acreages were calculated. The baseline conditions in terms of units (HUs) were generated by multiplication. Below the mathematical protocol used to generate the units in HEP is described

Calculating SIs in the Baseline HEP Analysis

The means/mode values for each variable were applied to the SI graphs as dictated by the models' documentation (Burks-Copes and Webb 2010). A new SI graph was developed for each variable (per model) based on reference standards and reference site findings. The mean for each variable (per model) was then "scored" on SI graphs, while providing a comparison of the baseline conditions to that of reference optimum. The basic mathematical premise is fairly straightforward and easy to complete. For example, if the average core size is 10 acres, the value "10" was entered into the "X-axis" on the SI curve below, and the resultant SI score (Y-axis) was determined (SI = 0.75) (Figure 25).

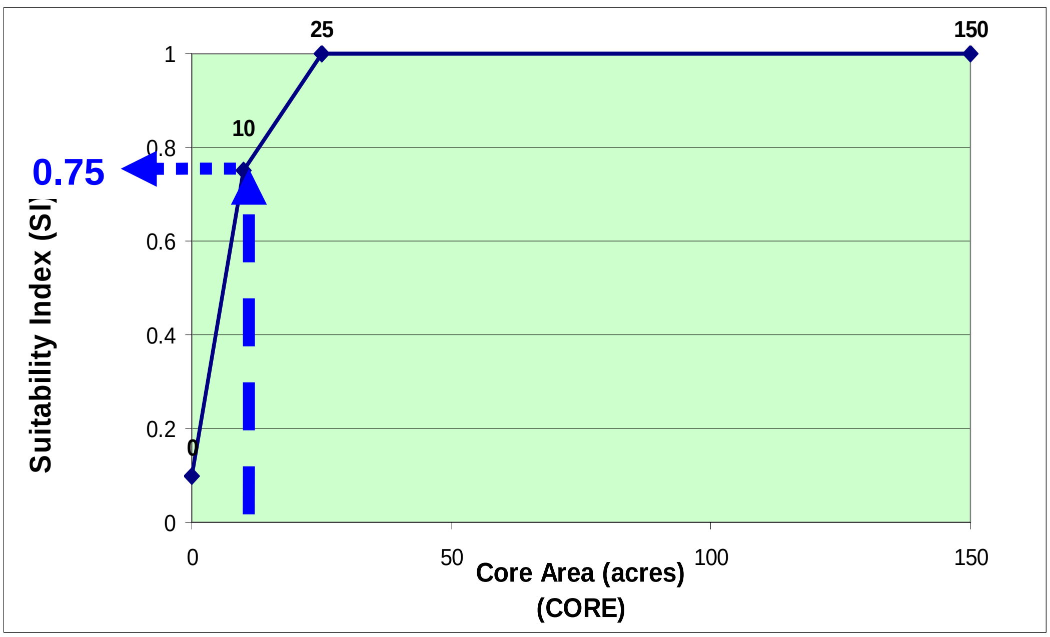

Figure 25. Example Suitability Index (SI) curve.

The process was repeated for every variable in each community's CT for each of the component (aka life requisite) formulas for each of the models. The individual Life Requisite Suitability Index (LRSI) scores were entered into the HSI formulas (Table 3 above) on a CT-by-CT basis, and individual CT HSIs were generated.

Calculating HSIs in the Baseline HEP Analysis

The Relative Area (RA) of the CT was applied to each answer (CT HSI) from the previous step and then combined with the answers from the remaining associated CTs in an additive fashion. The model HSI formulas were considered to be the sum of the CT HSIs with RAs applied, or arithmetically speaking:

$$\mathbf{HSI_{Model}} = \sum (\mathbf{CT\ HSI\ x\ RA})_{\mathbf{X}} \tag{1}$$

where :

CT HSI = Results of the CT HSI calculation,
X = Number of CTs associated with the model, and
RA = Relative area of each CT.

Calculating HUs in the Baseline HEP Analysis

The final step was to multiply the HSI results (per model) against the habitat acres (i.e., CT acres associated with the model). The final results, referred to as HUs, quantified the quality and quantity of the baseline ecosystem conditions per community.

Step 8: Clear Creek's Goals, Objectives, Project Life, and Target Years

In an attempt to generate quantifiable objectives for the study, the District began the process of establishing specific flood risk management goals, and developed a series of performance measures to assess the success of the mitigation designs. The process is ongoing and iterative, and is subject to change as lessons from the review process are incorporated into the overriding planning process.

Project Goals

The primary goal of the study was to provide the necessary engineering, economic and environmental plans in a timely manner to establish viable projects that would be acceptable to the public, local sponsors and USACE (USACE 1999; 2002, 2010). The Clear Creek study's objectives included:

1. Reduce flood risk for economic, social, and environmental purposes along Clear Creek and its tributaries;
2. Improve fish and wildlife resources of Clear Creek and its tributaries for the purpose of attracting more and varied species of fish and wildlife;
3. Preserve and protect natural and cultural resources for public education and historical appreciation purposes;

4. Develop opportunities for recreation in Clear Creek and its tributaries;
5. Facilitate stabilization of the stream banks of Clear Creek and its tributaries; and
6. Improve the quantity and quality of habitat on Clear Creek and its tributaries.

The proposed mitigation efforts would be designed to mimic historic, natural conditions that harvest water, trap sediments, facilitate water absorption, and provide water to vegetation. Existing vegetation communities would be restored and rehabilitated with supplemental plantings, invasive species control, and other best management practices and strategies (aka restoration/rehabilitation). With the restoration of the vegetation communities, habitat structure should improve and there should be an increase in the number and diversity of wildlife species in the area. This approach to restoration, focusing on the community functions and processes via the habitat and vegetation structure, will eventually lead to more natural ecosystems, as these are signs of a healthy ecosystem and a successful ecosystem restoration.

Selection of a Project Life and TYs

Given these goals and objectives, the District designated a "Project Life" of 50 years for the Clear Creek study, and asked the E-Team to develop a series of TYs within this 50-year setting to guide the projections of both without-project and with-project activities. Five TYs were defined by the E-Team:

1. TY = "**0**" refers to the baseline condition, or the 2000 calendar year;
2. TY = "**1**" refers to the last year of construction and planting activities, or the 2020 calendar year;
3. TY = "**11**" was chosen to capture 10 full years of vegetative growth under the proposed with-project conditions (e.g., the 2030 calendar year);
4. TY = "**36**" was selected to capture 25 full years of vegetative growth under the with-project conditions (e.g., the 2055 calendar year); and
5. TY = "**51**" was selected to capture 15 full years of vegetative growth under the with-project conditions (e.g., the 2070 calendar year).

Step 9: WOP Conditions for the Clear Creek Study

To develop plans for a community or region, it becomes necessary to predict both the short-term and long-term future conditions of the environment (USACE 2000). Forecasting is undertaken to identify patterns in natural systems and human behavior, and to discover relationships among variables and systems, so that the timing, nature and magnitude of change in future conditions can be estimated. A judgment-based method, supported by the scientific and professional expertise of the evaluation team, is often relied upon to forecast the impacts and evaluate the effectiveness of proposed mitigation plans, rate project performance, and determine many other important aspects of both WOP and WP conditions.

The WOP condition is universally regarded as a vital and important element of the evaluation (USACE 2000). No single element is more critical to the planning process than the prediction of the most likely future conditions anticipated for the study area if no action is taken as a result of the study. It is important to note that by definition the “No Action Alternative” in NEPA is the WOP condition that describes the future that society would have to forego if action was taken. Conversely, the WOP condition is the result when no action is taken. When formulating plans, NEPA regulations require that the No Action Alternative be considered – this requires that any action taken be more “in the public interest” than doing nothing. The WOP condition becomes the default recommendation.

The WOP descriptions must adequately describe the future (USACE 2000). Significant variables, elements, trends, systems and processes must be sufficiently described to support good decision-making. WOP descriptions must be rational. Forecasts must be based on appropriate methods, and professional standards must be applied to the use of those methods. Accuracy is an important element of a rational scenario. All future scenarios should be based on the assumption of rational behavior by future decision-makers. A good scenario must pass the test of making common sense. WOP conditions are not “before-and-after” comparisons. “Before-and-after” comparisons can overlook the causality that is important to effective plan evaluation. Conditions that concentrate on causality of existing conditions, and focus too narrowly on how existing conditions might change, fail to be future-oriented. WOP conditions are not mere extensions of existing conditions, and should be oriented toward comparing alternative future scenarios. There should never be deliberately misleading information in a scenario, nor should any important information ever be deliberately withheld. An honest scenario would point out weaknesses and soft spots in the analysis, identifying the implications of these “faults.” Honesty also implies a sincere effort to convey the full implications of the scenario. Honesty requires that significant differences in the future scenario are completely described as alternate WOP conditions. The WOP condition must be inclusive in the sense that it is subjected to rigorous review and comment as part of the public participation process (and throughout the coordination and review process). Because the WOP condition occupies such a critical role in the planning process, it is essential that it be developed in the “open,” and subjected to the scrutiny of all project stakeholders, before the project proceeds too far. In some cases, this will simply mean that data/information receive an unbiased thorough technical review. In other cases, where judgmental or technological changes are being considered, the review and coordination may have a structured part in the public participation process.

Most federal agencies use annualization as a means to display benefits and costs, and ecosystem restoration analyses should provide data that can be directly compared to the traditional benefit: cost analyses typically portrayed in standard evaluations of this nature. Federal projects are evaluated over a period of time that is referred to as the “life of the project” and is defined as that period of time between the times that the project becomes operational and the end of the project life as dictated by the construction effort or lead agency. However, in many cases, gains or losses in wildlife habitat may occur before the project becomes operational and these changes should be considered in the assessment. Examples of such changes include construction impacts, implementation and compensation plans and/or other land-use impacts. Ecosystem restoration analyses incorporate these changes into evaluations by using a “period of analysis” that includes pre-start impacts. However, if no pre-start changes are evident, then the “life of the project” and the “period of analysis” are the same.

In HEP, HUs are annualized by summing HUs across all years in the period of analysis and dividing the total (cumulative HUs) by the number of years in the life of the project. In this manner, pre-start changes can be considered in the analysis. The results of this calculation are referred to as Average Annual Habitat Units (AAHUs), and can be expressed mathematically in the following fashion:

Annualized Units =

$$\sum \text{Cumulative Units} \div \text{Number of years in the life of the project}$$

where:

$$\text{Cumulative Units} = \sum (T_2 - T_1)\left[\frac{(A_1 I_1 + A_2 I_2)}{3} + \frac{(A_2 I_1 + A_1 I_2)}{6}\right] \qquad (2)$$

and where:

T_1 = First Target Year time interval
T_2 = Second Target Year time interval
A_1 = Ecosystem area at beginning of T_1
A_2 = Ecosystem area at end of T_2
I_1 = Index score at beginning of T_1
I_2 = Index score at end of T_2

For those interested in the derivation of the annualization formula, cumulative units are computed by summing the area under a plot of units versus time (pers. comm. Adrian Farmer, USGS, June 18, 2007). This is equivalent to mathematical integration of the unit relationship over time, or

$$Cumulative\_Units = \int_0^T U \, dt \qquad (3)$$

But U = A x I
where:
A= Area area
I= Quality index.

Also, over any time interval of length T (=$T_2 - T_1$) within which A and I either change linearly or not at all, the values of A and I are given by:

$A = A_1 + m_1 t$

$I = I_1 + m_2 t$

where :

t= time

A_1= the area at the beginning of the time interval

I_1= the quality index at the beginning of the time interval

m_1= the rate of change of area with time

m_2= the rate of change of quality with time.

Thus,

$$\begin{aligned}\int_0^T U\ dt &\equiv \int_0^T (A_1 + m_1 t)(I_1 + m_2 t)\ dt \\ &\equiv \int_0^T A_1 I_1\ dt + \int_0^T m_1 I_1 t\ dt + \int_0^T m_2 A_1 t\ dt + \int_0^T m_1 m_2 t^2\ dt \\ &\equiv A_1 I_1 T + \frac{m_1 I_1 T^2}{2} + \frac{m_2 A_1 T^2}{2} + \frac{m_1 m_2 T^3}{3}\end{aligned} \tag{4}$$

Substitute the following equations for the slopes, m_1 and m_2

$$\begin{aligned} m_1 &= \frac{A_2 - A_1}{T} \\ m_2 &= \frac{I_2 - I_1}{T}\end{aligned} \tag{5}$$

into the above formula to generate the following:

$$\int_0^T U\ dt \equiv A_1 I_1 T + \frac{(A_2 - A_1) I_1 T}{2} + \frac{(I_2 - I_1) A_1 T}{2} + \frac{(A_2 - A_1)(I_2 - I_1) T}{3} \tag{6}$$

Collecting terms, substituting $(T_2 - T_1)$ for T, and simplifying yields:

$$\int_0^T U\ dt \equiv (T_2 - T_1)\left[\left(\frac{A_1 I_1 + A_2 I_2}{3}\right) + \left(\frac{A_2 I_1 + A_1 I_2}{6}\right)\right] \tag{7}$$

This formula is applied to the time intervals between TYs. The formula was developed to calculate cumulative HUs when either HSIs or areas (or both) change over a time interval. The rate of change of HUs may be linear (either HSIs or areas change over the time interval) – the formula will work in either case. The shaded area in the curve below represents the cumulative HUs for all years in the period of analysis, and is calculated by summing the products of HSIs and areas of available communities for all years in the period of analysis (Figure 26).

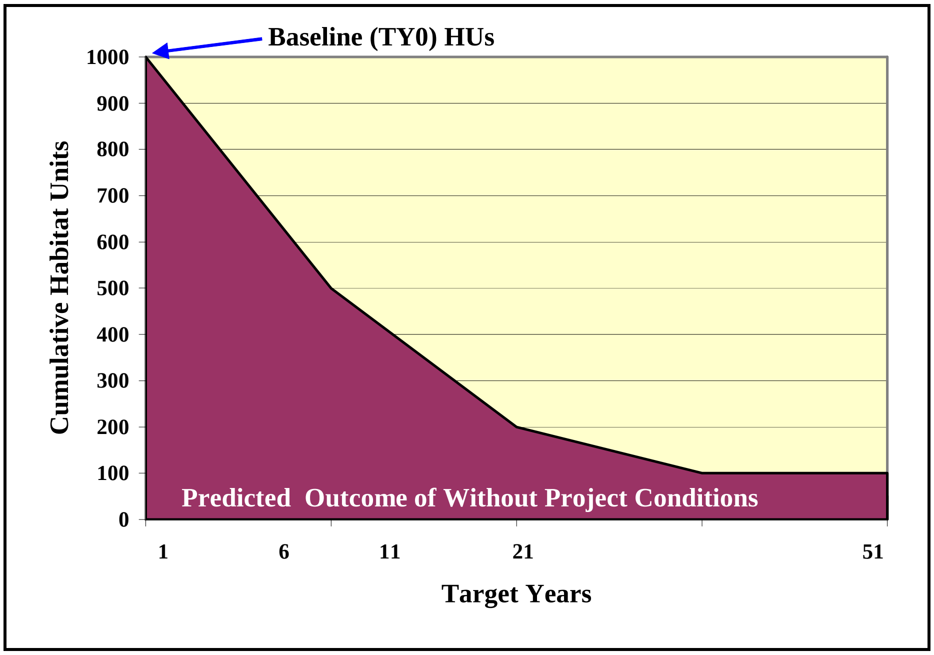

Figure 26. Example of cumulative HU availability under a without-project scenario

The assumptions that went into the projection of future conditions at the Clear Creek study under the "No Action Alternatives" for the proposed pilot studies are reported in *Chapter 4* of this report. Results, in terms of annualized units as well as expectations of change in terms of qualities and acres for the study are fully documented therein.

Step 10: WP Conditions for the Clear Creek study

Between 2004 and the present, the E Team participated in several workshops to present and modify alternatives designs developed by independent teams for the NED plan (including multiple mitigation scenarios). These independent teams were responsible for developing draft alternative matrices, generating acreage and quality trends (by variable and cover type) for the affected ecosystems and developing documentation (maps and verbal descriptions) for the proposals. The E-Team reviewed these and standardized the proposed trends to some extent, and suggested additional alternatives where reasonable. Alternatives were dropped from the analysis if their approaches were too costly, if their designs were incongruous with the overall "avoidance/minimization/mitigation concept," if their constructed footprints were impossible to achieve because of conflicting relationships or if the results were thought to biologically unproductive. Various design and operation/maintenance activities were discussed in detail, and the outcomes of each were incorporated into the forecasting. The results of this effort are presented in *Chapters 5* and *6* of this report.

Step 11: Tradeoffs in the Clear Creek Study – Not Applicable

It is important to note that tradeoffs were not necessary for this study – only a single technique (HEP) and a single community-based model were used to evaluate the NED plan's impacts. In other words, forest impacts (measured in AAHUs with the floodplain forest model) were mitigated with forest restoration/rehabilitation benefits (again measured in AAHUs with the floodplain forest model). The mitigation plans were evaluated and compared on this premise (full mitigation of all community impacts in-kind), and on the basis of cost effectiveness/incremental effectiveness (refer to the *Cost Analysis* section below and the final results presented in *Chapter 6*).

Step 12: Reporting the Results of the Analyses

The success of any evaluation lies in the planner's ability to discuss the assessment strategies and findings to the public. Reporting simply refers to communicating the methodologies and results of the habitat assessment in a clear and concise manner to the reader. Underlying the HEP process is the concept of "repeatability." To assure that the assessment is reasonable and reliable, the reader should be able to follow the descriptions of the approach and the application, and repeat the analyses just as the planner did. To assure the repeatability aspects of the assessments, the planner is advised to document, to the fullest extent, the evaluation in its entirety. This is done most often through an assessment report medium. Typically, depending on the type of planning effort undertaken, there are a series of approximately six to seven chapters provided in every assessment report:

Introduction, *Methods*, *Baseline Results*, *Without-project Results*, *and With-Project Results* (for both the impacts and the mitigation analyses), and *Summary/Conclusions*. In addition, the report typically carries a *References* section and an appendix documenting the models used in the assessment. Further reporting of the assessment results can include, but is not limited to, the production of interactive graphics (maps, graphs, tables, etc.) that visually depict the conditions (both without- and with-project) of the study area under evaluation. In HEP, it is important to document the results of habitat units, quality (indices) and quantity (acres). In addition, any factors that significantly affect the outcome of the study (e.g., minutes of team meetings, data extrapolations, etc.) should be presented.

Introduction to the Cost Analysis Process

Between 1986 and 1987, the Headquarters' Office of USACE provided policy directing Districts to perform a type of cost analysis referred to as Incremental Cost Analysis (ICA) for all feasibility-level studies. The required ICA is, in effect, a combination of both a Cost Effectiveness Analysis (CEA) and ICA. Together, the CEA/ICA evaluations combine the environmental outputs of various alternative designs with their associated costs, and systematically compare each alternative on the basis of productivity. Cost effectiveness analyses focus on the identification of the least cost alternatives and the elimination of the economically irrational alternatives (e.g., alternative designs which are inefficient and ineffective). By definition, inefficient alternative designs produce similar environmental returns at greater expense. Ineffective alternative designs result in reduced levels of output for the same or greater costs. The incremental cost analysis is employed to reveal and interpret changes in costs for increasing levels of environmental outputs.

In 1990, USACE issued Engineer Regulation 1105-2-100 (USACE 1990) directing planners, economists, and resource managers to conduct CEA/ICA for all recommended mitigation plans. Later, in 1991, USACE produced Policy Guidance Letter Number 24 that extended the use of cost analysis to projects that restored fish and wildlife habitat resources (USACE 1991). In the USACE EC 1105-2-210, the incorporation of cost analysis was declared “fundamental” to project formulation and evaluation (USACE 1995). To facilitate the inclusion of these basic economic concepts into the decision-making process, USACE published two reports detailing the procedures to complete both incremental and cost effective analysis (Orth 1994; Robinson, Hansen, and Orth 1995). Based on these reports, there were nine steps that should be completed to evaluate alternative designs based on CEA/ICA. These were as follows:

1. Formulate all possible combinations of alternative designs by:
   a. Displaying all outputs and costs.
   b. Identifying filters, which restrict the combination of alternative designs.
   c. Calculating outputs and costs of combinations.
2. Complete a CEA by:
   a. Eliminating economically inefficient alternative designs.
   b. Eliminating economically ineffective alternative designs.
3. Develop an incremental cost curve by:
   a. Calculating the average costs.
   b. Recalculating average costs for additional outputs.
4. Complete an ICA by:
   a. Calculating incremental costs.
   b. Comparing successive outputs and incremental costs.

In the ICA terminology, an alternative design is considered the with-project condition (i.e., “Build A Dam,” “Develop a Wetland,” “Restore the Riparian Zone,” “Management Plan A,” etc.). Under an alternative design, a series of scales (i.e., variations) can be defined which are modifications or derivations of the initial with-project conditions (i.e., “Develop 10 acres of Low Quality Wetlands,” “Develop 1,000 acres of High Quality Wetlands”, etc.). Often, these scales are based on differences in intensity of similar treatments and, therefore, can be “lumped” under an alternative design class or category. During the first steps of CEA/ICA, all possible combinations of alternative designs and their scales are formed. As a general rule, intra-scale combinations (i.e., combinations of variations within a single alternative design) are not allowed - these activities would occupy the same space and time.

In most instances, CEA/ICA results are displayed in tables, scatter plots, and/or bar charts. These illustrative products assist decision-makers in the progressive comparisons of alternative design costs, and the increasing levels of environmental outputs. Before a user makes a decision based upon the outputs generated by the CEA/ICA, he or she must determine whether cost thresholds exist that limit production of the next level of environmental output (i.e., cost affordability). In addition, factors such as curve anomalies (i.e., abrupt changes in the incremental curve), output targets, and output thresholds can influence the selection of alternative design.

It is important to note that benefit-cost analysis was used to refine and hone the final NED plan. An integral part of the NED plan is inclusion of recommended mitigation. CEA/ICA was used to compare/contrast the various mitigation scenarios and ultimately facilitated the selection of the recommended mitigation plan(s) for the NED plan. *Chapter 6* of this report details the CEA/ICA analyses conducted for the Clear Creek study's mitigation plans. Specifics on cost generation for the proposed alternative mitigation designs, as well as the cost-benefit analysis for the NED plan can be found in the feasibility report (USACE 2010).

3 Baseline Analysis and Results

The baseline conditions for the Clear Creek watershed were determined on a landscape-level scale on the ecological reaches (refer back to Figure 12 on page 1). Below we present details regarding both the quantity (acreage) and quality (variables) data used in the assessment to characterize the baseline condition of the watershed at this scale.[1]

Acreage Inputs

For the baseline analysis, the 41,566 acres were mapped and classified (aka cover typed) inside the study area boundaries. These in turn were divided amongst the eco-reaches for the analysis (Table 4 and Figure 27).

Table 4. Baseline acres classified and assigned to the seven eco-reaches in the Clear Creek study.

Code	Description	Baseline Acres (TY0)							Total Project Area
		Eco-Reach 1	Eco-Reach 2	Eco-Reach 3	Eco-Reach 4	Eco-Reach 5	Eco-Reach 6	Eco-Reach 7	
AGCROP	Farms and Croplands	1	97	34	2	28	1,305	12	1,479
FOREST	Floodplain Forest	490	1,095	253	1,053	337	489	85	3,802
OPENWATER	Open Bodies of Water Deeper than 1-3m	2,900	66	20	17	11	180	25	3,219
PASTURES	Old Fields, Haylands and Pastures	2,260	1,997	2,522	1,521	692	8,378	1,120	18,490
PRAIRIE	Prairie	103	33	0	26	1,094	1,077	314	2,647
TIDALMARSH	Tidal Marsh	255	64	0	0	0	0	0	319
URBAN	Existing Residential, Industrial and Transportation Avenues	2,653	763	1,869	1,753	601	2,871	1,090	11,600
	TOTALS:	8,662	4,115	4,698	4,372	2,763	14,300	2,646	41,556

[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

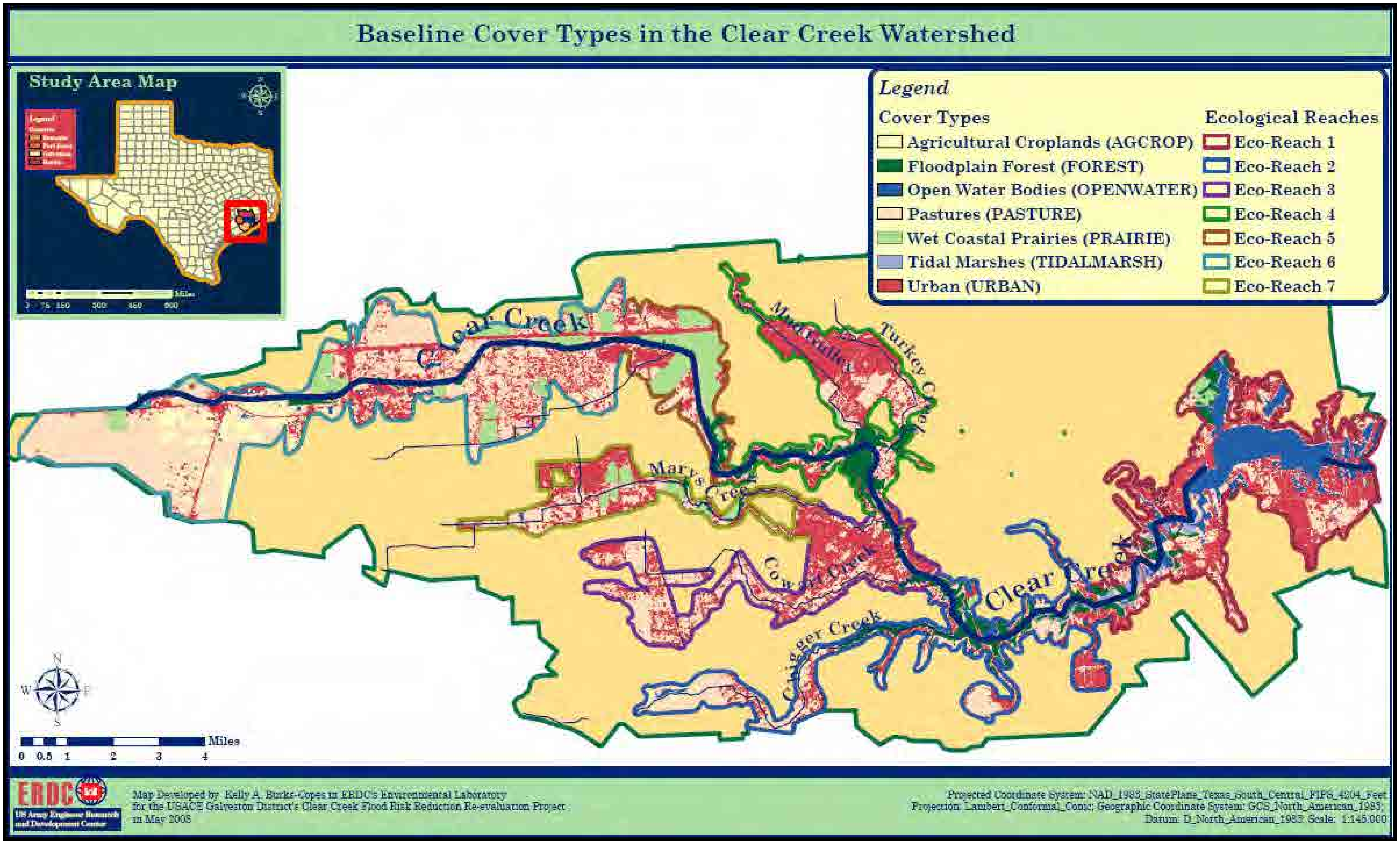

Figure 27. Map of the baseline cover types for the Clear Creek study.

Variable Data Inputs

Field data was collected in 2003 and GIS coverages (based on 2000 imagery) were compiled and analyzed on a reach-by-reach basis over the course of the next several years. Data for each variable per cover type within each community (floodplain forest and wet coastal prairie) were recorded and the variable means/modes were calculated to generate watershed baseline HSIs on a reach-by-reach basis. Eighteen floodplain forest variables and fifteen wet coastal prairie variables were measured across the seven eco-reaches following the prescribed sampling protocols detailed in Burks-Copes and Webb 2010. The means for each variable are summarized in Table 5 below.

Table 5. Baseline data for the floodplain forest communities across reaches.

Reach	ADJLANDUSE	ALTERHYDRO	AREAWETDRY	CANTREE	CORE	EDGE	EROSION	IMPERVIOUS	INSTRMCOV	NATIVE	NEIGHBOR	OVRHDCOV	PATCHSIZE	ROUGHNESS	SINUOUSITY	SUBSTRATE	VEGSTRATA	WATERDEPTH
1	2	5	30	60	0	40	3	30	65	50	10	30	45	0	2	1	6	2
2	2	5	10	70	10	13	3	40	25	75	35	60	15	0	2	1	7	3
3	3	3	0	45	0	24	4	55	0	40	0	40	25	0	2	1	5	4
4	3	1	5	65	40	31	2	40	5	60	0	60	52	0	2	1	7	4
5	3	1	20	75	5	65	3	40	5	60	30	20	65	0	1	1	6	4
6	3	1	5	75	0	70	3	30	5	70	55	30	70	0	1	1	6	4
7	3	1	0	65	0	20	3	50	15	65	23	45	20	0	1	1	6	3

Baseline Outputs - Indices and Units

The results of the baseline HEP assessment for the reaches are summarized below. HSIs capture the quality of the acreage within the reach. Units (i.e., HUs) take this quality and apply it to the governing area through multiplication (Quality X Quantity = Units). Both HSIs and HUs are reported for each reach. Interpretations of these findings can be generalized in the following manner (Table 6).

Table 6. Interpretation of HSI scores resulting from HEP assessments.

HSI Score	Interpretation
0.0	Not-suitable - the community does not perform to a measurable level and will not recover through natural processes
Above 0.0 to 0.19	Extremely low or very poor relative functionality (i.e., in relation to the reference standards found in the model's domain) - the community functionality can be measured, but it cannot be recovered through natural processes
0.2 to 0 .29	Low or poor relative functionality
0.3 to 0.39	Fair to moderately low relative functionality
0.4 to 0 .49	Moderate relative functionality
0.5 to 0.59	Moderately high relative functionality
0.6 to .79	High or good relative functionality
0.8 to0.99	Very high or excellent relative functionality
1.0	Optimum relative functionality - the community performs functions at the highest level - the same level as reference standard settings

In the majority of instances, the individual component indices (aka Life Requisite Suitability Indices or LRSIs) and composite HSIs scored higher than moderate values (>0.5) indicating a "moderately high" level of relative functionality in the watershed (Table 7 and Figure 28). In five out of seven of the reaches, the limiting or driving factor was the Spatial Integrity/Disturbance component, which regularly scored lower than 0.4. The highest functioning reach was Eco-Reach 2 (HSI = 0.84). This was to be expected – the last vestiges of healthy floodplain forest are found in this area. Impacts in this reach will likely incur significant levels of mitigation. Not surprisingly, Reach 3 and 7 generated the lowest HSI scores (HSI = 0.47 and 0.48 respectively). The overall lack of floodplain forest in these reaches, and the overwhelming urban encroachment they are experiencing offer incite into the lack of functioning forested communities in that tributary.

Table 7. Baseline tabular results for the floodplain forest community.

Reach Name	LRSI Code	LRSI Score	Habitat Suitability Index (HSI)	Applicable Acres	Baseline Habitat Units (HUs)
Eco-Reach 1	BIOINTEG	0.87	0.67	490	328
	HYDRO	0.88			
	SPATIAL	0.25			
Eco-Reach 2	BIOINTEG	0.87	0.84	1,095	920
	HYDRO	0.87			
	SPATIAL	0.78			
Eco-Reach 3	BIOINTEG	0.26	0.47	253	119
	HYDRO	0.62			
	SPATIAL	0.53			
Eco-Reach 4	BIOINTEG	0.67	0.74	1,053	781
	HYDRO	0.58			
	SPATIAL	0.97			
Eco-Reach 5	BIOINTEG	0.70	0.62	337	209
	HYDRO	0.66			
	SPATIAL	0.50			
Eco-Reach 6	BIOINTEG	0.66	0.56	489	275
	HYDRO	0.68			
	SPATIAL	0.34			
Eco-Reach 7	BIOINTEG	0.78	0.48	85	41
	HYDRO	0.53			
	SPATIAL	0.14			

At baseline, 3,802 acres of floodplain forests were associated with the model across the entire project area (Table 7 and Figure 29). Eco-Reaches 2 and 4 held the largest numbers of forested acres (1,095 and 1,053 acres respectively). Eco-Reach 7 has the smallest forested holdings (just 85 acres).

Overall, the watershed generated 2,683 habitat units across all ecological reaches. The baseline HUs within the Eco-Reaches ranged from 41 units in Eco-Reach 7 to 920 units in Eco-Reach 2 (Table 7 and Figure 30). In HEP, the maximum HSI score possible is 1.0. Given the total number of applicable floodplain forest acres at baseline (i.e., 3,802 acres), one can derive the optimal conditions and outputs by multiplying the quantity and quality to generate the highest possible outcome (3,082 acres x 1.0 HSI = 3,802 units). By comparing the actual situation to this optimum, the E-Team can determine at what level the ecosystem is functioning. In this case, the watershed is operating at approximately 71 percent of its potential habitat suitability (i.e., total habitat outputs across all reaches÷ possible outputs). Using this same approach, the E-team considered the operational functionality of the seven reaches. The individual performances ranged from 47 percent (Eco-Reach 3) to 84 percent in Eco-Reach 2. Clearly, there are opportunities for improvements (i.e., Eco-Reaches 3, 5, 6 and 7 are prime candidates for mitigation activities), and any flood risk management activities proposed in Eco-Reaches 1, 2, and 4 will likely incur the most impacts (i.e., they have more to lose).

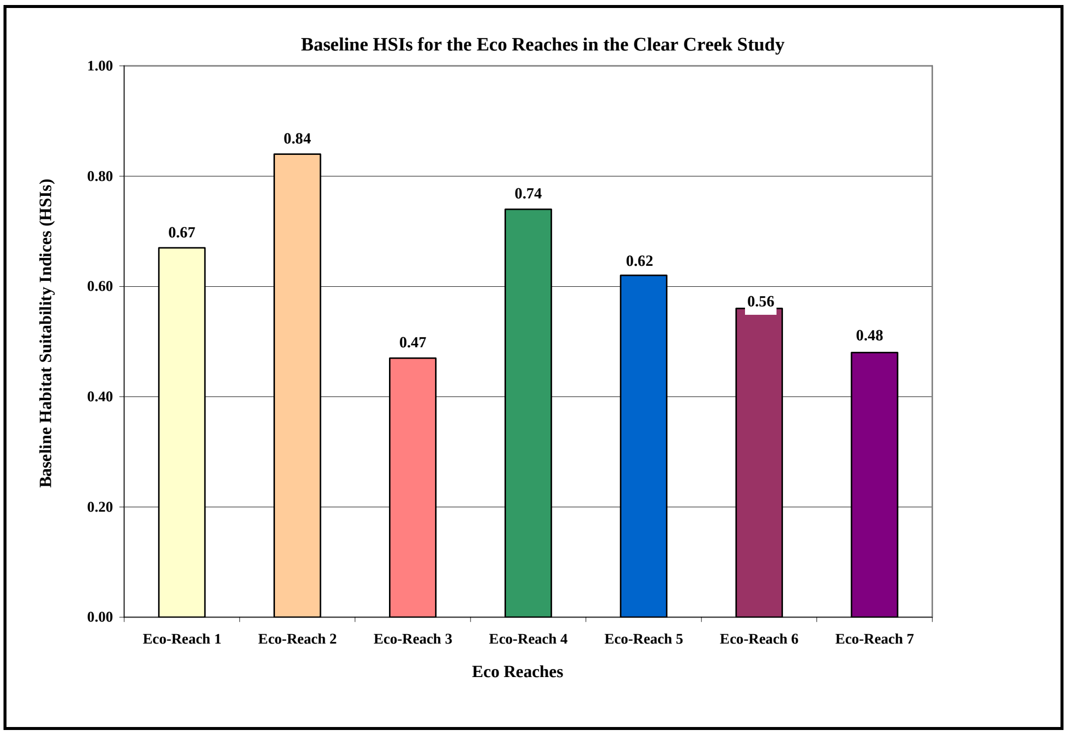

Figure 28. Baseline HSI results for the Clear Creek study's floodplain forest community.

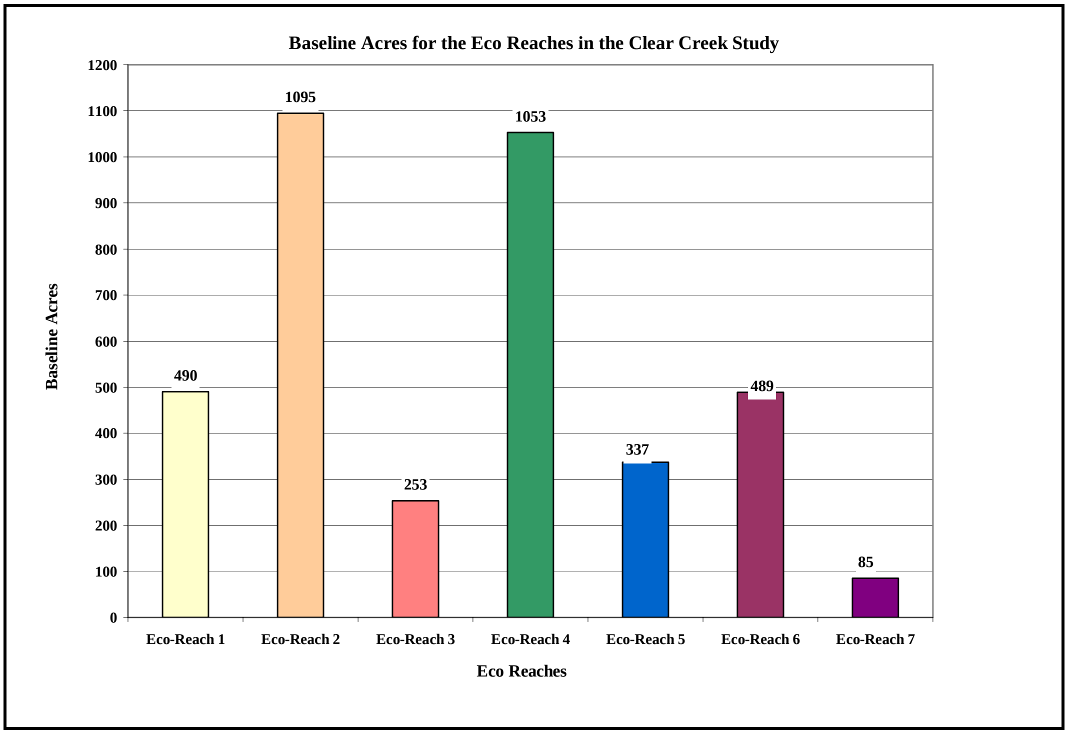

Figure 29. Baseline acre distributions for the Clear Creek study's floodplain forest community.

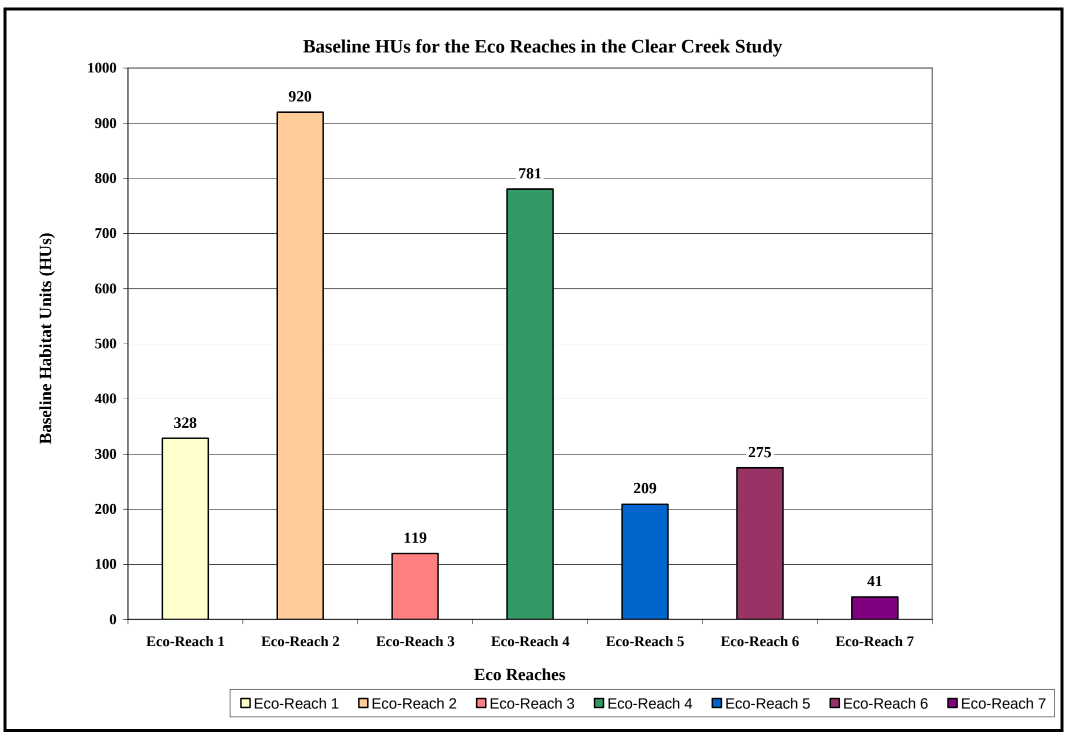

Figure 30. Baseline HU results for the Clear Creek study's floodplain forest community

The implications of these findings are rather straightforward. First, the results support the conceptual premise surrounding the model and indicate its representative capabilities. In other words, scientific literature characterizing the state of the community along the Texas coast point to an overall decline in ecosystem integrity (i.e., health, biodiversity, stability, sustainability, naturalness, etc.) – a finding the model can now quantify (less than optimal HSI values in all reaches). Furthermore, the results indicate an opportunity to both incur and redress impacts. There is a high likelihood that any flood risk management measures taken in Reaches 1, 2 and 4 will induce impacts to forests, and should therefore be avoided. On the other hand, there is great potential to restore forested communities in the remaining reaches, thereby meeting the demand for mitigation by implementing appropriate and sustainable activities targeting these sub-functional communities.

4 Without-project (WOP) Analysis and Results

It was the general consensus of the E-Team, that the future without-project conditions of the study area were certain to reflect losses in community function (i.e., quality) and presence (i.e., quantity) when faced with the pressures of increasing population growth and flooding. The E-Team addressed these issues in several workshops over the course of the study, and developed trends to capture both the losses of quantity and quality to generate a “No Action” scenario for the study. Numerous assumptions were used to support the projected values - these are presented below.[1]

Predicted WOP Acreage Trends (Quantity)

Given the study’s location and the projected growth trends for the area, forecasting suggested initial development would focus on privately held vacant and agricultural parcels.[2] Agricultural lands, pastures, wet coastal prairies, and floodplain forests near urban centers were thought to be especially vulnerable to residential conversion over the next 50 years. As privately held lands were converted to commercial and industrial park uses, adjacent publicly-owned areas (forests currently considered prime candidates for preservation, creation and restoration activities) would come under increased development pressure. Real estate values would rise in response to market demand. In order to maximize development acreages in areas adjacent to Clear Creek, conventional, engineered solutions for bank protection and erosion control would likely be implemented. Over the next ~40 years, the projected population growth trends of the major cities within the watershed are staggering (Table 8).[3]

1 Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

2 For more details regarding future WOP trends, refer to USACE 2010, Section 4.9.2.

3 Population growth projections provided by the Texas Water Development Board (http://www.twdb.state.tx.us/data/popwaterdemand/2002%20Projections/populationh.htm) for the cities of Pearland, Friendswood, and League City were used as the basis for projecting populations.

Table 8. Projected population growth trends for some cities in the Clear Creek watershed.

County	City	1990	2000	2010	2020	2030	2040	2050
Brazoria	Pearland	17,234	29,480	39,464	49,742	61,929	73,332	86,834
Harris	Friendswood	7,835	11,337	17,089	26,504	38,491	57,649	77,708
Harris	League City	133	207	237	275	298	327	358

In an effort to capture these significant land use changes in the Clear Creek study area, the E-Team developed a table projecting acreages per cover type on a TY basis for each Eco-Reach (Table 9).[1]

Table 9. WOP acre projections for Clear Creek watershed eco-reaches.

Eco-Reach 1						
		Calendar Year and Target Year				
		2000	2020	2030	2055	2070
Code	Description	TY0	TY1	TY11	TY36	TY51
AGCROP	Farms and Croplands	1	1	1	1	1
FOREST	Floodplain Forest	490	420	389	311	264
OPENWATER	Open Bodies of Water Deeper than 1-3m	2,900	2,626	2,545	2,338	2,214
PASTURES	Old Fields, Haylands and Pastures	2,260	1,834	1,684	1,314	1,092
PRAIRIE	Prairie	103	93	88	73	64
TIDALMARSH	Tidal Marsh	255	215	199	159	135
URBAN	Existing Residential, Industrial and Transportation Avenues	2,653	3,473	3,756	4,466	4,892
	TOTALS:	8,662	8,662	8,662	8,662	8,662
Eco-Reach 2						
		Calendar Year and Target Year				
		2000	2020	2030	2055	2070
Code	Description	TY0	TY1	TY11	TY36	TY51
AGCROP	Farms and Croplands	97	94	92	86	83
FOREST	Floodplain Forest	1,095	941	869	689	581
OPENWATER	Open Bodies of Water Deeper than 1-3m	66	62	60	56	53
PASTURES	Old Fields, Haylands and Pastures	1,997	1,814	1,716	1,470	1,323
PRAIRIE	Prairie	33	28	26	20	17
TIDALMARSH	Tidal Marsh	64	55	51	42	36
URBAN	Existing Residential, Industrial and Transportation Avenues	763	1,121	1,301	1,752	2,022
	TOTALS:	4,115	4,115	4,115	4,115	4,115

(Continued)

[1] One note to the reader - although baseline conditions for Eco-Reach 1 were assessed early-on in the process, the District determined that flood risk management in that section of the watershed was not productive or feasible, and therefore the decision was made to focus planning efforts on critical river sections upstream. As such, the authors elected to omit the Eco-Reach 1 results from this document as they had no bearing on the NED plan and its recommended mitigation options.

Table 9. (Continued).

Code	Description	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
Eco-Reach 3						
		Calendar Year and Target Year				
AGCROP	Farms and Croplands	34	31	29	25	22
FOREST	Floodplain Forest	253	206	196	171	156
OPENWATER	Open Bodies of Water Deeper than 1-3m	20	17	16	14	12
PASTURES	Old Fields, Haylands and Pastures	2,522	2,196	2,069	1,747	1,555
PRAIRIE	Prairie	0	0	0	0	0
TIDALMARSH	Tidal Marsh	0	0	0	0	0
URBAN	Existing Residential, Industrial and Transportation Avenues	1,869	2,248	2,388	2,741	2,953
	TOTALS:	4,698	4,698	4,698	4,698	4,698
Eco-Reach 4						
		Calendar Year and Target Year				
Code	Description	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	Farms and Croplands	2	2	2	2	2
FOREST	Floodplain Forest	1,053	931	852	655	536
OPENWATER	Open Bodies of Water Deeper than 1-3m	17	15	14	12	10
PASTURES	Old Fields, Haylands and Pastures	1,521	1,370	1,271	1,019	871
PRAIRIE	Prairie	26	24	23	20	18
TIDALMARSH	Tidal Marsh	0	0	0	0	0
URBAN	Existing Residential, Industrial and Transportation Avenues	1,753	2,030	2,210	2,664	2,935
	TOTALS:	4,372	4,372	4,372	4,372	4,372
Eco-Reach 5						
		Calendar Year and Target Year				
Code	Description	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	Farms and Croplands	28	25	24	21	20
FOREST	Floodplain Forest	337	309	295	258	236
OPENWATER	Open Bodies of Water Deeper than 1-3m	11	10	10	8	7
PASTURES	Old Fields, Haylands and Pastures	692	625	592	511	463
PRAIRIE	Prairie	1,094	988	941	826	755
TIDALMARSH	Tidal Marsh	0	0	0	0	0
URBAN	Existing Residential, Industrial and Transportation Avenues	601	806	901	1139	1282
	TOTALS:	2,763	2,763	2,763	2,763	2,763

(Continued)

Table 9. (Concluded).

Eco-Reach 6						
		Calendar Year and Target Year				
		2000	2020	2030	2055	2070
Code	Description	TY0	TY1	TY11	TY36	TY51
AGCROP	Farms and Croplands	1,305	1,219	1,166	1,032	951
FOREST	Floodplain Forest	489	448	426	368	334
OPENWATER	Open Bodies of Water Deeper than 1-3m	180	163	154	132	119
PASTURES	Old Fields, Haylands and Pastures	8,378	7,814	7,527	6,811	6,381
PRAIRIE	Prairie	1,077	982	928	792	711
TIDALMARSH	Tidal Marsh	0	0	0	0	0
URBAN	Existing Residential, Industrial and Transportation Avenues	2,871	3,674	4,099	5,165	5,804
	TOTALS:	14,300	14,300	14,300	14,300	14,300
Eco-Reach 7						
		Calendar Year and Target Year				
		2000	2020	2030	2055	2070
Code	Description	TY0	TY1	TY11	TY36	TY51
AGCROP	Farms and Croplands	12	10	9	6	4
FOREST	Floodplain Forest	85	71	65	51	43
OPENWATER	Open Bodies of Water Deeper than 1-3m	25	20	18	11	7
PASTURES	Old Fields, Haylands and Pastures	1,120	900	796	540	385
PRAIRIE	Prairie	314	256	228	156	113
TIDALMARSH	Tidal Marsh	0	0	0	0	0
URBAN	Existing Residential, Industrial and Transportation Avenues	1,090	1,389	1,530	1,882	2,094
	TOTALS:	2,646	2,646	2,646	2,646	2,646

As these tables indicate, urban areas (residential, commercial, industrial and infrastructure such as roads) would increase in coverage, while over 1,650 acres of surrounding natural vegetative communities (e.g., floodplain forests) would be eliminated. The existing narrow band of riparian habitat supported by current hydrologic regime would decline over time in response to altered hydroregime. The loss of terrestrial and wetland communities that serve as habitat for a myriad of wildlife species is significant. Interestingly, the floodplain forest communities will not be the only "losers" under this scenario. The majority of the agricultural croplands, pastures and prairies would be consumed in the wave of urban growth (more than 6,815 acres lost).

Predicted WOP Variable Trends (Quality)

Future conditions under the "No Action" alternative were based on the development assumptions used in the rainfall and hydraulic analyses of engineering study (USACE 2010). The "No Action" alternative assumes the Clear Creek's current configuration will be maintained, and that no locally constructed channel rectifications would occur. Future forecasts were based on urban development trends (percent land urbanization) within the watershed's subbasins, and assumed that as population increased the area would be converted to an urban drainage system with increasing impervious percentages and associated runoff. Year-2000 population counts were coupled with the development area acreage within census tracts to compute the population/developed area ratio, and Census tract population projections from years 2010 and 2060 were used to estimate weighted future urban development conditions (percent land urbanization) within each subbasin.

As a direct result of growth, it was assumed that impervious cover would increase, thereby reducing both available areas for native vegetative communities and infiltration of runoff. Increased runoff associated with the predicted urban development would cause increased flows resulting in increases in water elevation sufficient to cause flooding in many areas. It was further assumed that urban development would occur along the edge of the creek's banks (in those areas permitting such activities) resulting in the loss of native riparian vegetation communities. Continued urban encroachment was assumed to cause extensive losses of native riparian vegetation, and the environmental value (i.e., ecosystem function) associated with the remaining relictual communities was assumed to continue to decline. Within these remaining patches, we would expect to see riparian vegetation removed from within and along streams (clearing and snagging practices are common in this area, and thus we assumed this activity would continue). This loss of vegetative cover will lead to reduced friction and improved flow. However, the result of these actions will yield a highly fragmented landscape (i.e., smaller patches, less core area, more edge, greater distances between patches, etc.) and the forests buffering functions would therefore be lost entirely. As the stabilizing function of native riparian plans is lost, and as further development occurs, artificial bank stabilization measures (namely armoring) would likely be employed to reduce potential erosion. With the disappearance and declining quality of the native vegetation, we would also expect to see a decline in community-dependent species of wildlife. Water quality (temperature, dissolved oxygen, turbidity and salinity) too will degrade significantly in the absence of the riparian vegetative community, as the shading and sediment stabilizing effects of trees and associated vegetation in and adjacent to the creek disappear. Noxious and/or exotic species will likely be introduced and proliferate rapidly into homogenous stands of undesirable vegetation choking out the native remnants in the forests. As the stabilizing function of native remnants (Table 10- Table 16).

Table 10. WOP variable projections for Eco-Reach 1.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	5	2	2	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	30	30	30	40	45
	ROUGHNESS	0.11	0.070	0.07	0.07	0.07
	SINUOSITY	1.55	1.55	1.55	1.55	1.55
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	20	45	50	60	65
Structure and Biotic Integrity (BIOINTEG)	CANTREE	60	60	60	60	60
	INSTRMCOV	65	40	40	40	40
	NATIVE	50	45	40	30	25
	OVRHDCOV	30	20	20	20	20
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	2	6	6	8	9
	AREAWETDRY	30	24	20	15	10
	CORE	0	0	0	0	0
	EDGE	40	35	35	25	20
	NEIGHBOR	100	115	125	155	175
	PATCHSIZE	45	40	35	25	20

Table 11. WOP variable projections for Eco-Reach 2.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	5	2	2	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	40	40	45	55	65
	ROUGHNESS	0.1	0.070	0.07	0.07	0.07
	SINUOSITY	1.57	1.57	1.57	1.57	1.57
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	30	55	60	70	75
Structure and Biotic Integrity (BIOINTEG)	CANTREE	70	70	70	70	70
	INSTRMCOV	25	15	15	15	15
	NATIVE	75	70	65	50	40
	OVRHDCOV	60	35	35	35	35
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	2	7	7	8	8
	AREAWETDRY	10	10	9	7	6
	CORE	10	10	10	5	5
	EDGE	135	125	115	90	75
	NEIGHBOR	35	35	35	45	50
	PATCHSIZE	155	140	130	100	85

Table 12. WOP variable projections for Eco-Reach 3.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	3	2	2	1	1
	EROSION	4	4	4	5	5
	IMPERVIOUS	55	70	70	80	90
	ROUGHNESS	0.11	0.070	0.07	0.07	0.07
	SINUOSITY	1.64	1.64	1.64	1.64	1.64
	SUBSTRATE	1	1.00	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	45	45	45	45	45
	INSTRMCOV	0	0	0	0	0
	NATIVE	40	35	35	25	20
	OVRHDCOV	40	25	25	25	25
	VEGSTRATA	5	5	5	5	5
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	0	0	0	0	0
	CORE	0	0	0	0	0
	EDGE	240	195	185	165	150
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	255	205	195	170	150

Table 13. WOP variable projections for Eco-Reach 4.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	2	2	1	1
	EROSION	2	4	4	5	5
	IMPERVIOUS	40	40	45	55	65
	ROUGHNESS	0.11	0.070	0.07	0.07	0.07
	SINUOSITY	1.74	1.74	1.74	1.74	1.74
	SUBSTRATE	1	1.00	1	1	1
	WATERDEPTH	45	70	75	85	90
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	65	65
	INSTRMCOV	5	5	5	5	5
	NATIVE	60	55	50	40	35
	OVRHDCOV	60	35	35	35	35
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	5	4	2	1
	CORE	40	34	30	25	20
	EDGE	310	265	245	190	160
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	525	450	415	325	270

Table 14. WOP variable projections for Eco-Reach 5.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.11	0.110	0.11	0.11	0.11
	SINUOSITY	1.23	1.23	1.23	1.23	1.23
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	70	75	85	90
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	75	75
	INSTRMCOV	5	5	5	5	5
	NATIVE	60	55	55	45	40
	OVRHDCOV	20	10	10	10	10
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	20	18	17	15	13
	CORE	5	5	5	5	5
	EDGE	65	55	55	45	40
	NEIGHBOR	30	30	30	40	45
	PATCHSIZE	65	55	55	45	40

Table 15. WOP variable projections for Eco-Reach 6.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	30	30	30	40	45
	ROUGHNESS	0.11	0.070	0.07	0.07	0.07
	SINUOSITY	1.16	1.16	1.16	1.16	1.16
	SUBSTRATE	1	1.00	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	75	75
	INSTRMCOV	5	5	5	5	5
	NATIVE	70	65	60	50	45
	OVRHDCOV	30	20	20	20	20
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	5	5	4	3	3
	CORE	0	0	0	0	0
	EDGE	70	60	55	45	40
	NEIGHBOR	55	65	70	80	90
	PATCHSIZE	70	60	55	45	40

Table 16. WOP variable projections for Eco-Reach 7.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	50	60	65	75	85
	ROUGHNESS	0.11	0.070	0.07	0.07	0.07
	SINUOSITY	1.2	1.20	1.2	1.2	1.2
	SUBSTRATE	1	1.00	1	1	1
	WATERDEPTH	35	60	65	75	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	65	65
	INSTRMCOV	15	10	10	10	10
	NATIVE	65	60	55	45	40
	OVRHDCOV	45	25	25	25	25
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	1	1	1	1	1
	CORE	0	0	0	0	0
	EDGE	20	20	20	15	15
	NEIGHBOR	235	285	305	375	425
	PATCHSIZE	20	20	20	15	15

WOP Results

The changes predicted above led to considerable declines in projected community functionality across the watershed. Below we detail these in terms of declines in quantity and quality captured in annualized outputs.[1]

WOP Quality

Based on the findings, the final HSI scores for the study indicate a dramatic loss in functionality over the 50-year life-of-the-project (Table 17).

Table 17. Projected WOP results for the Clear Creek study under the WOP scenario.

Reach	Final WOP HSI	WOP TY 51 Acres	Net Change in HSIs	Net Change in Acres
Eco-Reach 1	0.49	264	-0.2	-226
Eco-Reach 2	0.61	581	-0.2	-514
Eco-Reach 3	0.35	156	-0.1	-97
Eco-Reach 4	0.61	536	-0.1	-517
Eco-Reach 5	0.52	236	-0.1	-101
Eco-Reach 6	0.47	334	-0.1	-155
Eco-Reach 7	0.37	43	-0.1	-42

Under the current forecasted without-project condition, urban encroachment and flooding ensues, and the ecosystem functionality of the remnant communities plummet (final HSI scores ranged 0.35 to 0.61 across the eco-reaches). These results indicate the communities will either cease to exist entirely, or remain as fragmented pockets that have lost a great deal of functionality. By 2070 (TY51), the baseline HSI scores fell approximately 20 percent (from HSI = 0.68 on average to HSI = 0.49 on average). The loss in function and suitability was quite dramatic as was the case in Eco-Reach 1 and 2's floodplain forests (HSI dropped by 0.2 points in both cases). In the end, most of the reach scores hovered near the HSI midpoint (average HSI = 0.48, moderate functionality), which suggests wildlife would abandon the area, and vegetative communities would decline well beyond the level from which they could recover on their own. When reviewed across time, and against one another, these changes are readily apparent (Figure 31).

[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

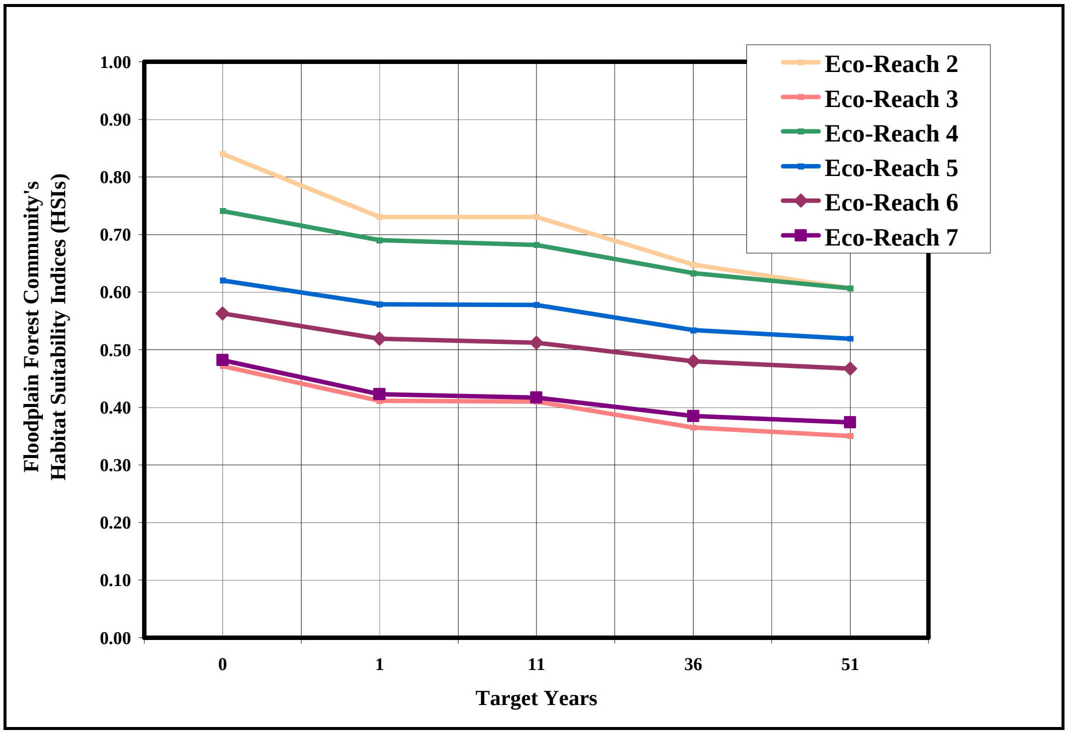

Figure 31. Cumulative changes in HSI values under the WOP scenario.

WOP Quantity

At baseline, 3,802 acres were associated with the floodplain forest model. By 2070 (TY51), this number plummets to 2,150 (a 43 percent reduction in available habitat) (Table 18 and Figure 32).

Table 18. Predicted losses for the Clear Creek study area under the WOP scenario.

Code	Calendar Years and Target Years					Net Change
	2000	2020	2030	2055	2070	
	TY0	TY1	TY11	TY36	TY51	
AGCROP	1,479	1,382	1,323	1,173	1,083	-396
FOREST	3,802	3,326	3,092	2,503	2,150	-1,652
OPENWATER	3,219	2,913	2,817	2,571	2,422	-797
PASTURES	18,490	16,553	15,655	13,412	12,070	-6,420
PRAIRIE	2,647	2,371	2,234	1,887	1,678	-969
TIDALMARSH	319	270	250	201	171	-148
URBAN	11,600	14,741	16,185	19,809	21,982	10,382
TOTALS:	41,556	41,556	41,556	41,556	41,556	

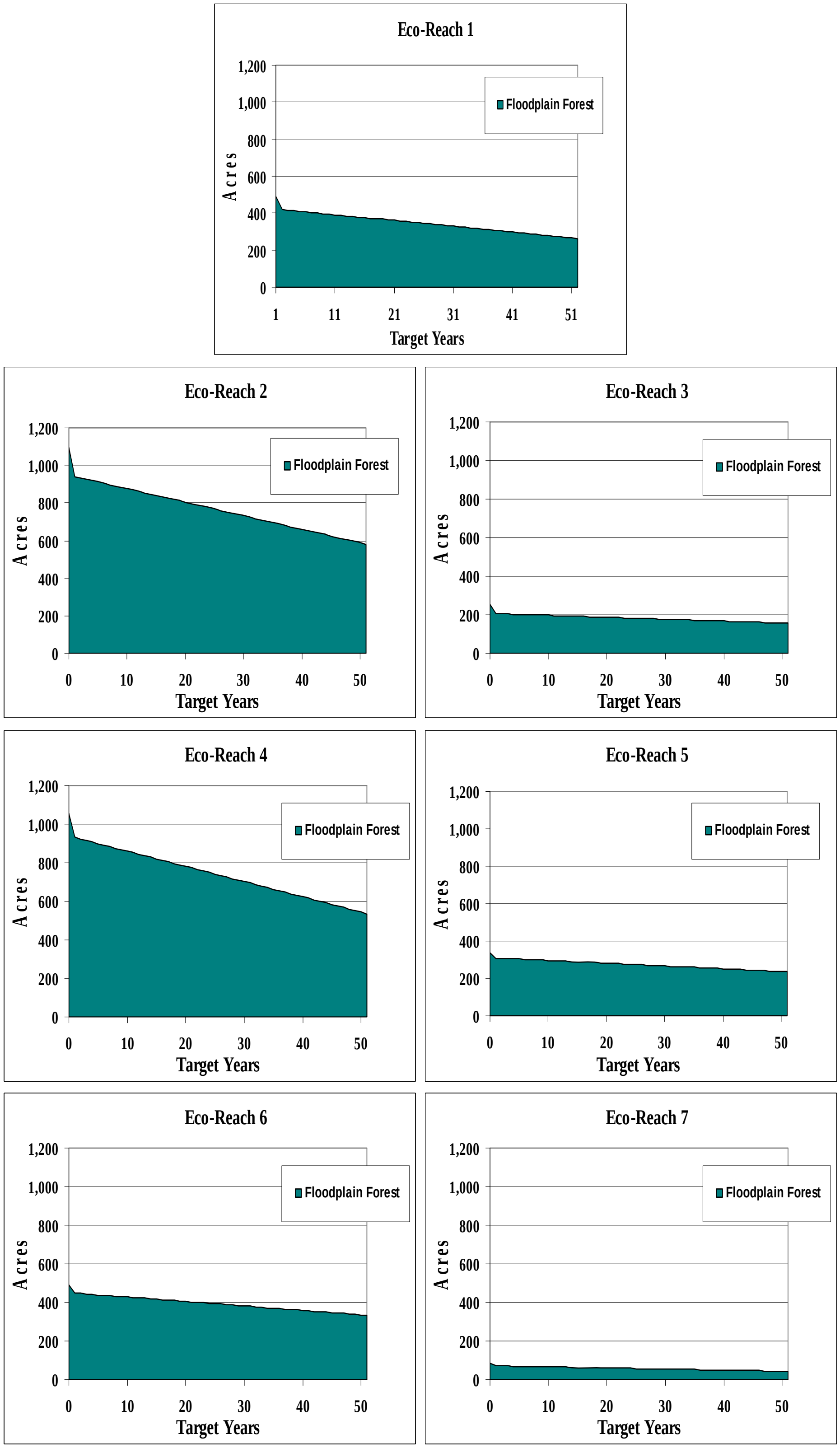

Figure 32. Predicted cumulative losses of habitat for eco-reaches in the Clear Creek watershed under the WOP scenario.

WOP Outputs (Quality x Quantity)

When the loss of quality described above is combined with the resultant loss in wetland acreage across the study area, the projected future conditions are disastrous (Figure 33).

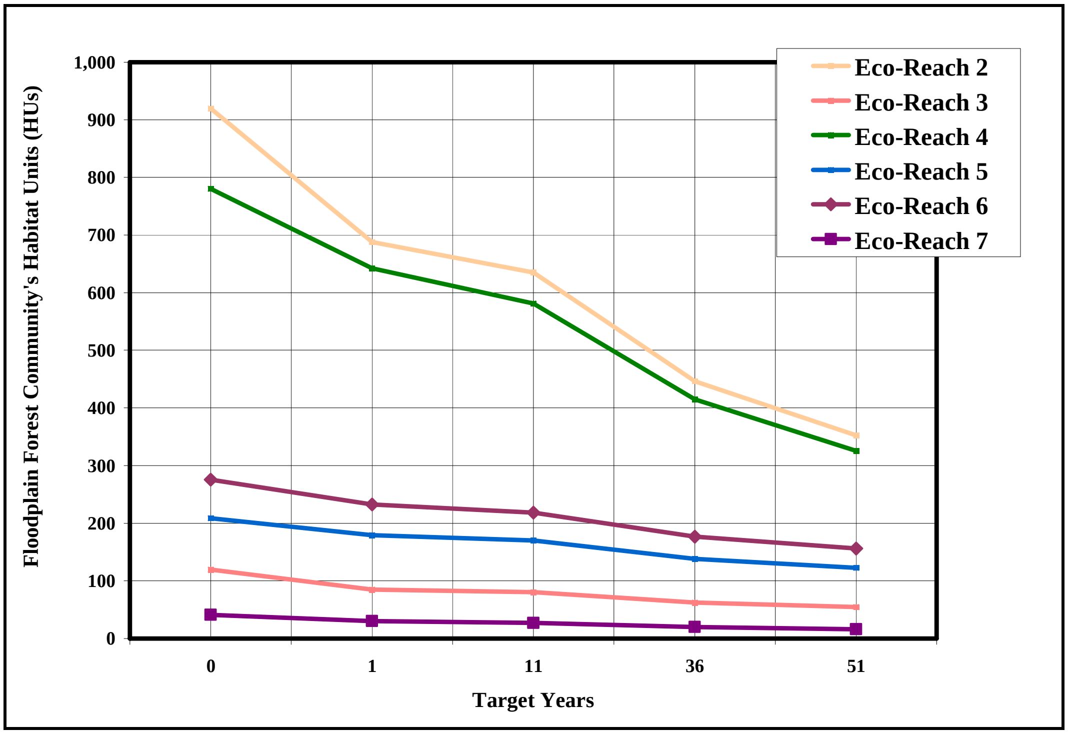

Figure 33. Cumulative changes in HUs under the WOP scenario.

Clearly, by 2070 (TY51) 57 percent of the forest community's baseline functionality is lost (Table 19).

Table 19. Predicted losses for the Clear Creek study under the WOP scenario.

Reach	Baseline Hus	TY 51 WOP HUs	Net Change in HUs	Percent Loss of HUs	WOP AAHUs
Eco-Reach 1	328	130	-198	60	193
Eco-Reach 2	920	353	-567	62	527
Eco-Reach 3	119	55	-65	54	70
Eco-Reach 4	780	325	-455	58	486
Eco-Reach 5	209	122	-86	41	152
Eco-Reach 6	275	156	-119	43	195
Eco-Reach 7	41	16	-25	61	23
TOTALS	2,673	1,158	-1,515	57	1,646

5 With-project (WP) Analysis and Results

For reasons detailed in the District's planning documentation (USACE 2010), the District's Project Delivery Team (PDT) implemented a proactive strategy to formulate flood risk management features, measures, and alternatives – an approach specifically tailored to focus on flood-prone areas (identified by stakeholders and the public).[1] A series of 72 structural and non-structural features were combined to generate 24 measures that addressed the four planning criteria (i.e., completeness, efficiency, effectiveness, and acceptability). Three sizes of each of these measures were then carried forward into detailed hydraulic, economic, and environmental analyses. Each measure was evaluated on a stand alone basis for its potential impact to the entire watershed and its capability for reduction of flood damages (Figure 34).

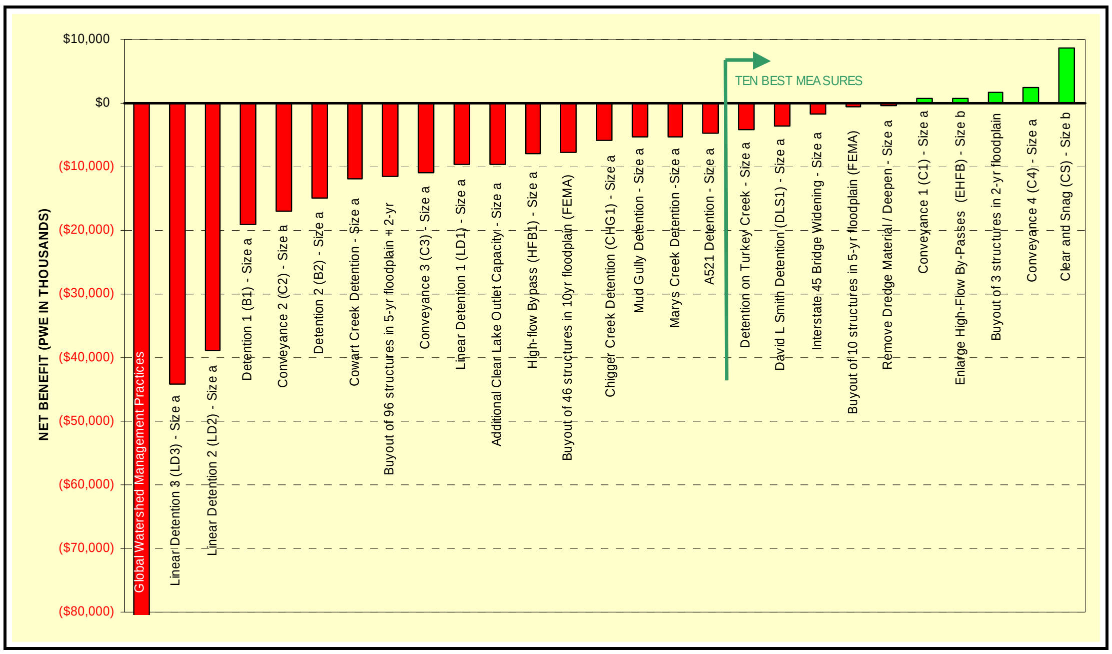

Figure 34. "First-added" results of the WP planning process on the Clear Creek study – the top 10 measures were carried forward into the "second-added" analysis.[2]

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[1] The WP analyses generated the NED plan (aka the General Reevaluation Plan, or GRP Alternative). All other plans (Sponsor's Alternative, the Authorized Plan, Non-Structural Plan) have not been analyzed with the HSI models to date.

[2] Graphic from USACE 2010.

Detailed descriptions of each measure as well as determinations of costs, net excess benefits, and Benefit-Cost Ratios (BCRs) for each of these measures can be found in the *First Added Notebook* (USACE 2010). The team then concentrated on the more successful measures from the first-added analysis - refining them, modifying their designs where appropriate, and testing combinations of these measures to produce the most effective NED Plan. To form these combinations, the decision was made to begin with upstream measures that would reduce damages in the "hardest hit" reaches, then incrementally add productive downstream measures in a "systems" approach to produce the final plan accepted NED plan. Although preliminary (iterative) HEP analyses were performed throughout the process, the authors present only the HEP assessment of the final NED plan here.[1]

NED Plan Components - Conveyance

It is important to grasp the iterative process that eventually led to the NED plan presented herein. The "second added" analysis focused predominantly on conveyance measures - detention was not considered initially due to its poor performance in the first added analysis. Thus five "conveyance" type measures were drafted as a preliminary NED plan and presented to sponsors for consideration (Figure 35):

1. Clear Creek Mainstem-Upstream Conveyance (*Super C*);
2. Clear Creek Mainstem-Downstream Conveyance [*C5(d)*];
3. Turkey Creek Conveyance (*TKC1d*);
4. Mary's Creek Conveyance (*MaC2a*); and
5. Mud Gulley Conveyance (*MudG1b*).

A synopsis of these measures is provided in the sections below. Refer to the *Predicted WP Acreage Trends (Quantity)* and the *Predicted WP Variable Trends (Quality)* sections below that to review the analysis assumptions that went into the HEP assessment of impacts for these measures.[2]

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[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

[2] For further details regarding these designs, refer to USACE 2010 (Section 4.9.3).

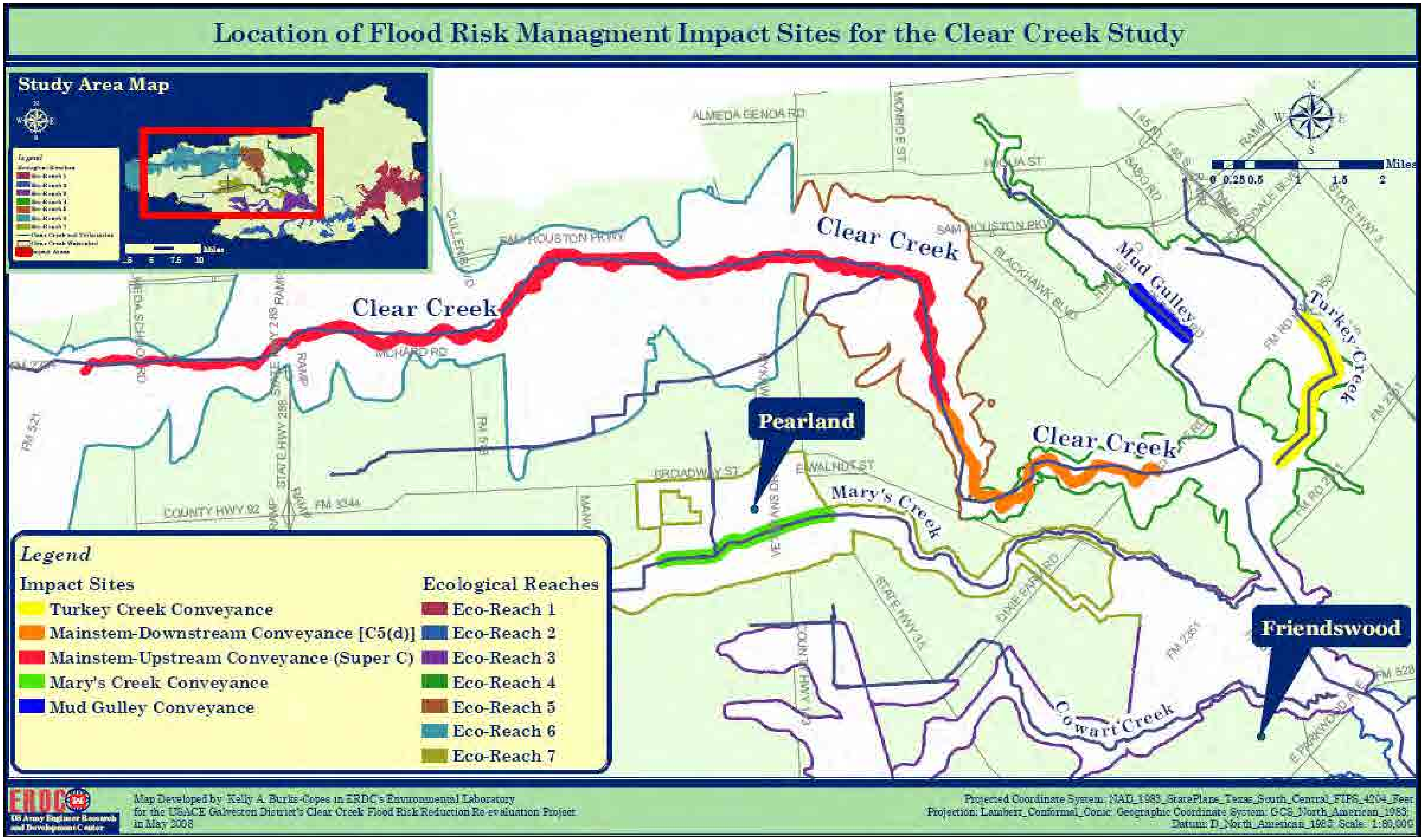

Figure 35. Final proposed NED plan for the Clear Creek study .

1 - Clear Creek Mainstem-Upstream Conveyance (*Super C*)

The *Super C* measure was designed to provide conveyance improvement on Clear Creek's mainstem (upstream) running from State Highway (SH) 288 to 4,000 feet downstream of Bennie Kate Road, in Harris and Brazoria Counties, Texas (Eco-Reaches 5 and 6) (refer to Figure 38 on the next page). The measure involved the construction of 10.8 miles of 240-foot-wide high flow channel. The high flow channel would be reestablished by constructing a shallow, wide flood bench that, generally, straddled the existing channel. The existing channel would be preserved to convey low flows. The 240-foot-wide flood bench would have a total bottom width of 200 feet with 20-foot-wide side slopes on either side (Figure 36).

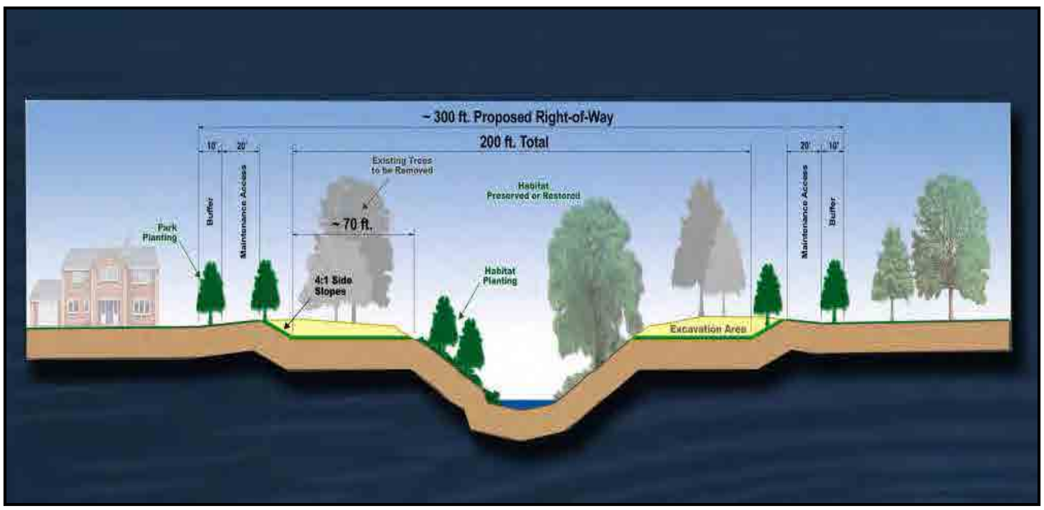

Figure 36. Illustration depicting on-the-ground designs for the Clear Creek *Mainstem-Upstream Conveyance* measure (*Super C*).

The bench would be designed with 1:4 (V:H) side slopes. The bench areas would be grassy, park-like areas that would be routinely mowed. Trees would be planted on the side slopes at a density of 14 trees per acre. An additional 25 feet of right-of-way (ROW) would be required outside of and on both sides of the high flow bench. This ROW would be used to construct several 15-foot-wide backslope drains to prevent erosion caused from sheet flows into the high flow channel. The remaining 10 feet of the ROW on each side would become a buffer that preserved, restored and rehabilitated existing floodplain forest or reestablished/restored existing floodplain forest where the land was undeveloped pasture or cropland. One hundred and eighty-six acres of floodplain forest would be lost with the implementation of this design.

In-line Detention – One Final Modification to the Clear Creek Mainstem-Upstream Conveyance (*Super C*)

As a final adjustment to the suit of measures that when combined formed the NED plan, “in-line” detention was added to the *Super C* measure (Figure 37). In essence, this additional feature was designed to provide detention for approximately 485 acre feet of water within limited segments of the currently proposed footprint of the Clear Creek Conveyance measure (detailed above). This measure would consist of deepening the high flow channel in areas where the high flow channel diverges from the low flow channel.

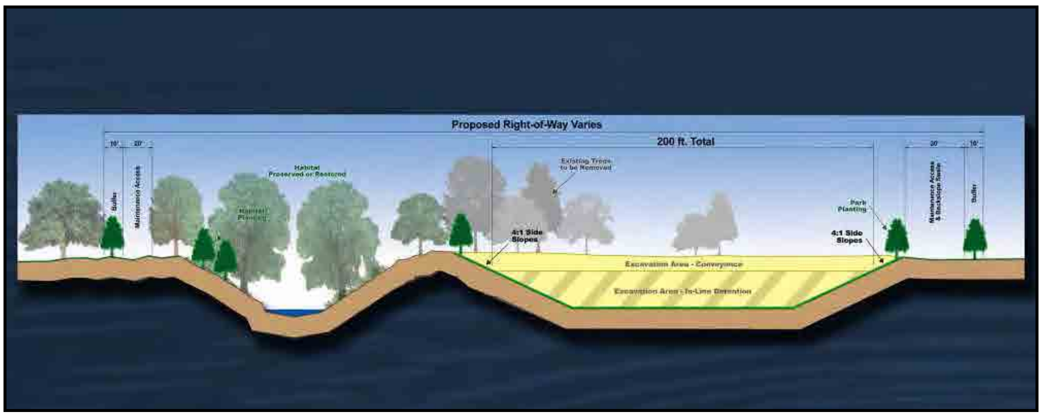

Figure 37. Illustration depicting “in-line” detention utilized in the *Clear Creek Mainstem-Upstream Conveyance* measure (*Super C*).

This would allow for additional storage with no impact to the low flow channel itself. The width of the high flow channel would remain the same as described above. The only change would be depth of excavation. Approximately 8 additional feet of excavation would be performed in the divergent high flow to reestablish storage. Gravity flow would be utilized to return temporarily stored waters to the low flow channel.

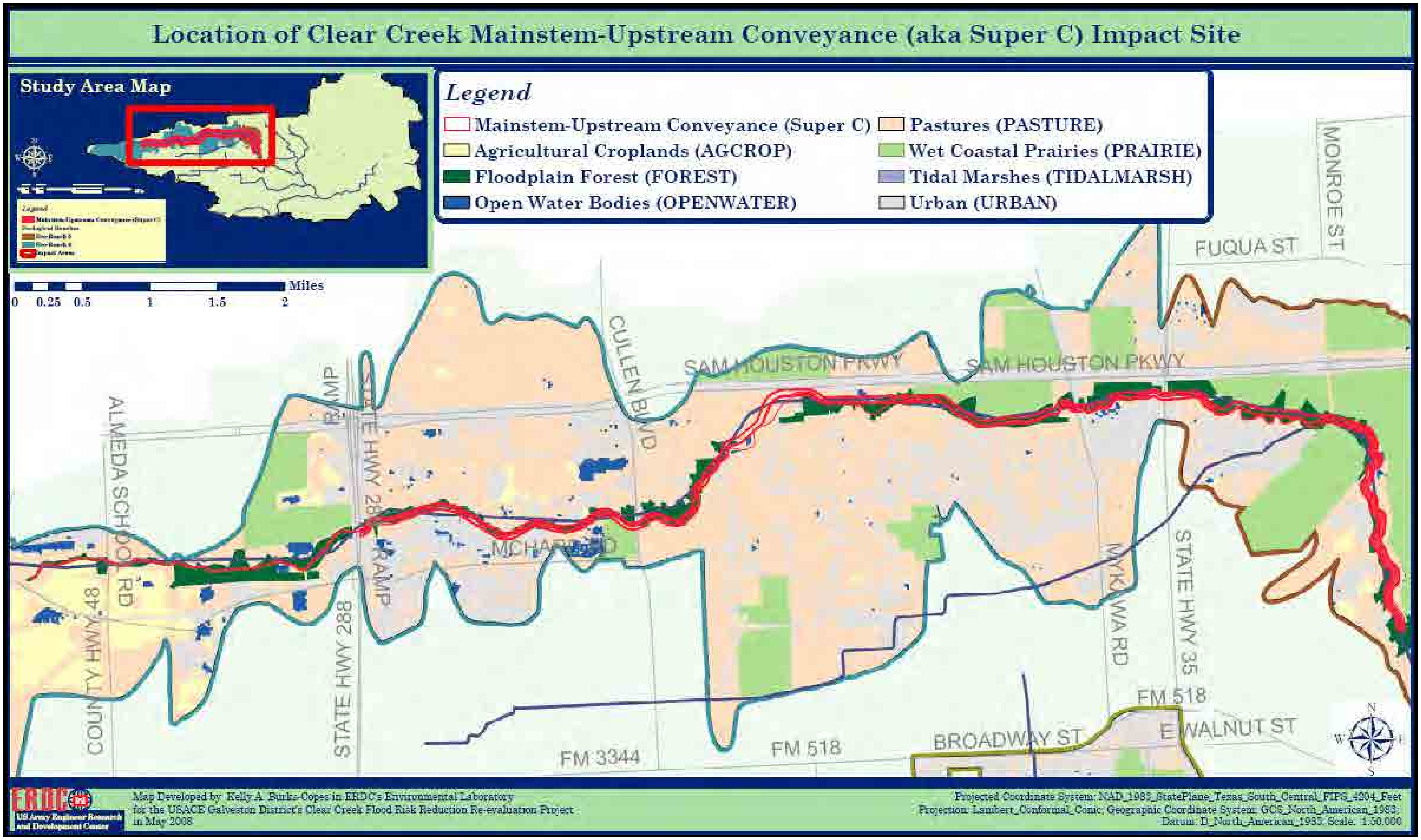

Figure 38. Cover type map of the Clear Creek Mainstem-Upstream Conveyance (*Super C*) measure.

2 - Clear Creek Mainstem-Downstream Conveyance [*C5(d)*]

The *C5(d)* measure was designed to provide conveyance improvement on the Clear Creek mainstem from a point approximately 4,000 feet downstream of Bennie Kate Road downstream to Dixie Farm Road, in Harris and Brazoria Counties, Texas (Eco-Reaches 4 and 5) (refer to Figure 40 on the next page). The conveyance feature involved the construction of 4.4 miles of 130-foot-wide high flow channel. The high flow channel would be reestablished by constructing a shallow, wide flood bench that straddles the existing channel. The existing channel would be preserved to convey low flows. The 130-foot-wide flood bench would have a total bottom width of 90 feet with approximately 20-foot-wide side slopes on either side (Figure 39).

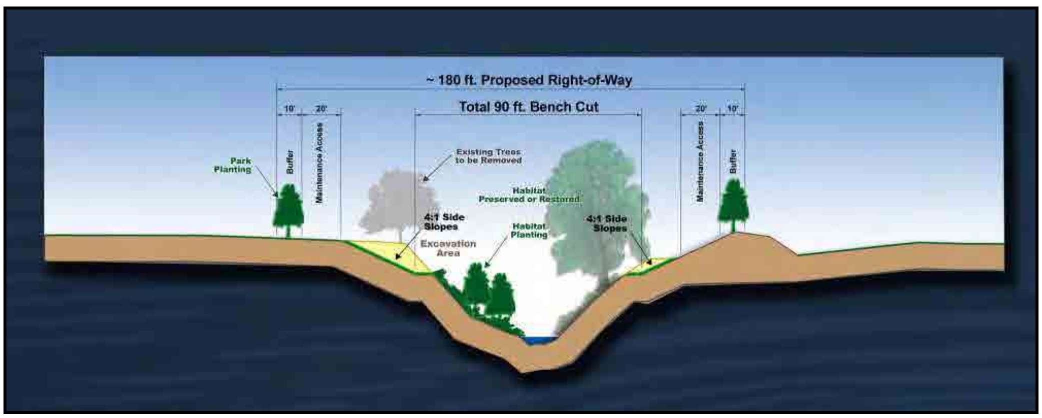

Figure 39. Illustration depicting on-the-ground designs for the Clear Creek *Mainstem-Downstream Conveyance* measure [*C5(d)*].

The channel would be designed with 1:4 (V:H) side slopes. The bench areas would be grassy, park like areas that are routinely mowed. Trees would be planted on the side slopes at a density of 14 trees per acre. An additional 25 feet of ROW would be required outside of and on both sides of the high flow bench. This ROW would be used to construct several 15-foot-wide backslope drains to prevent erosion caused from sheet flows into the high flow channel. The remaining 10 feet of the ROW on each side would become a buffer that preserved existing floodplain forest or reestablished/restored existing floodplain forest where the land was undeveloped pasture or cropland. Seventy-two acres of floodplain forest would be lost with the implementation of this design.

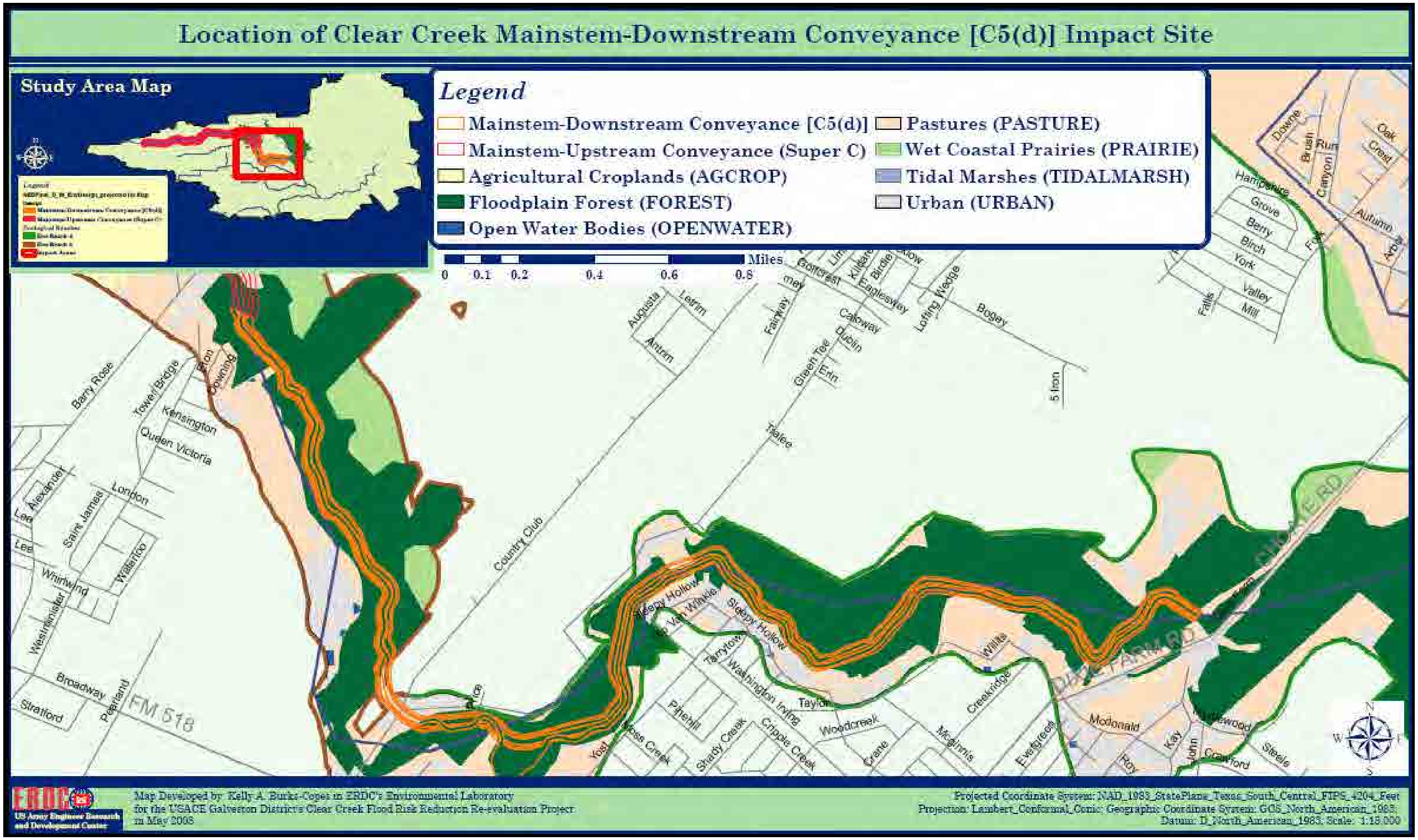

Figure 40. Cover type map of the Clear Creek Mainstem-Downstream Conveyance [*C5(d)*] measure.

3 - Turkey Creek Conveyance (*TKC1d*)

The *TKC1d* measure was designed to provide conveyance improvement through the construction of a 2.4-mile earthen, grass-lined channel on Turkey Creek from Dixie Farm Road to its confluence with Clear Creek, in Harris County, Texas (Eco-Reach 4) (refer to Figure 42 on the next page). The channel bottom width from Dixie Farm Road to 2,000 feet downstream of Well School would be 20 feet wide. The remaining length of the proposed channel would have a bottom width of 25 feet to its confluence with Clear Creek (Figure 41).

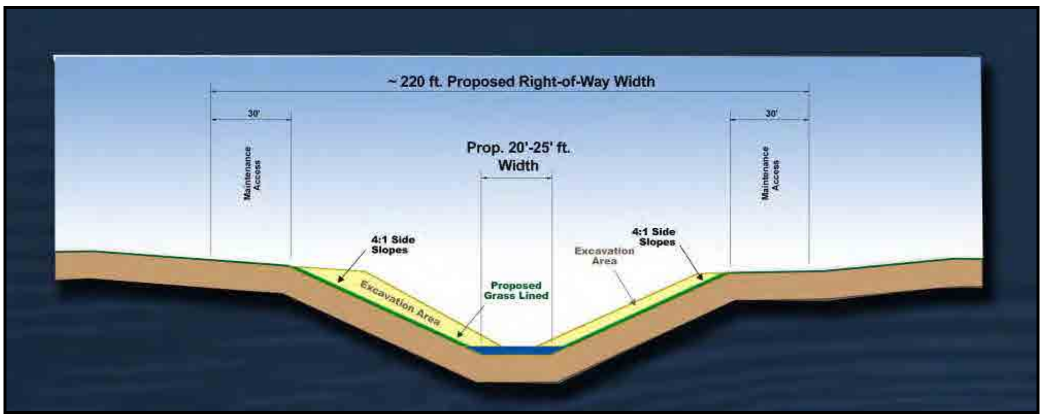

Figure 41. Illustration depicting on-the-ground designs for the Turkey Creek Conveyance measure (*TKC1d*).

The channel be designed with 1:4 (V:H) side slopes. An additional 60 feet of ROW would be required outside of the high flow bench (30-foot ROW on each side). This ROW would be used to construct several 15-foot-wide maintenance ROWs and 15-foot-wide backslope drains on each side of the channel to prevent erosion caused from sheet flows into the high flow channel. Twenty acres of floodplain forest would be lost with the implementation of this design.

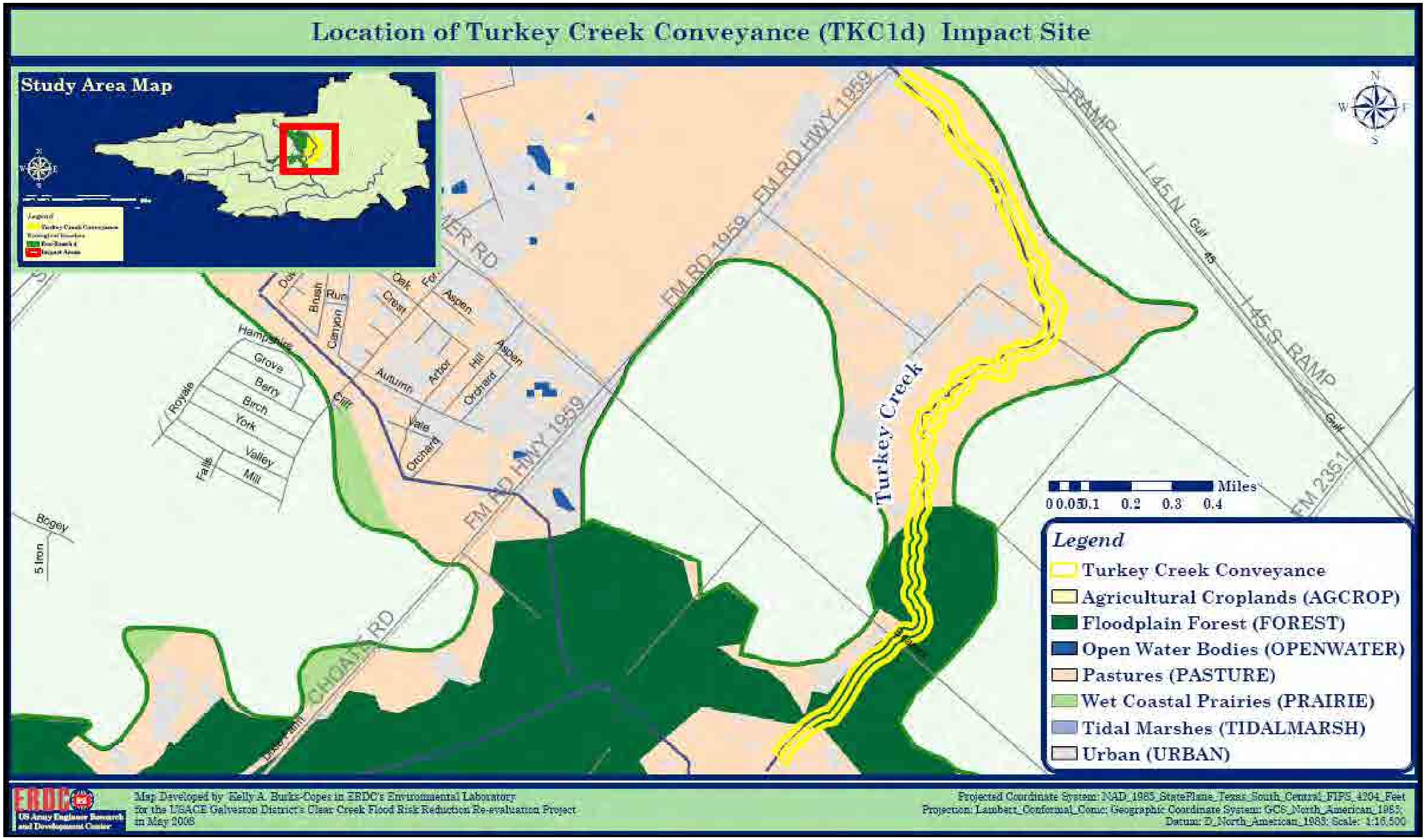

Figure 42. Cover type map of the Turkey Creek Conveyance (*TKC1d*) measure.

4 - Mary's Creek Conveyance (*MaC2a*)

The *Mac2a* measure was designed to provide conveyance improvement through the construction of a 2.1-mile earthen, grass-lined channel on Mary's Creek from Harkey Road to State Highway 35, in Brazoria County, Texas (Eco-Reach 4) (refer to Figure 44 on the next page). The channel bottom cut will be 15 feet wide from Harkey Road to 3,940 feet upstream of McClean Road, 27.5 feet wide from 3,940 feet upstream of McClean Road to 100 feet downstream of McClean Road, and 35 feet wide from 100 feet downstream of McClean Road to State Highway 35 (Figure 43).

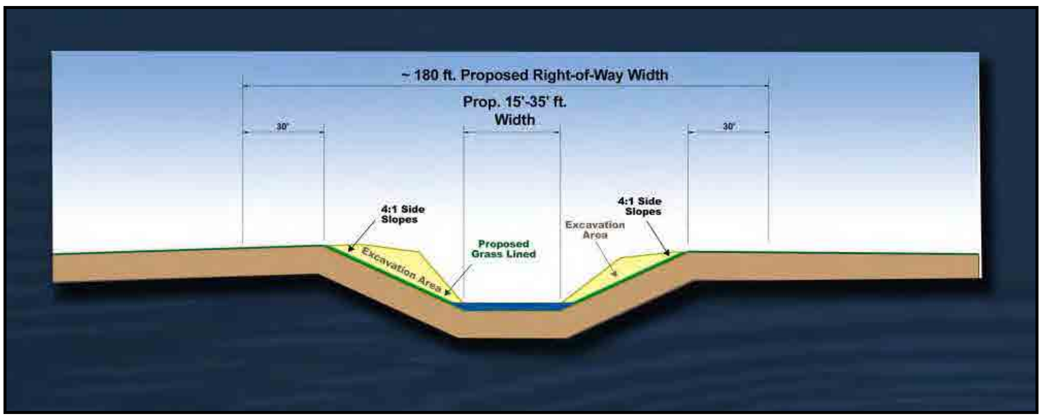

Figure 43. Illustration depicting on-the-ground designs for the Mary's Creek Conveyance measure (*MaC2a*).

The channel be designed with 1:4 (V:H) side slopes. A 30-foot ROW will be required outside and on both sides of the channel. This ROW will be used to construct several 15-foot-wide maintenance ROWs and 15-foot-wide backslope drains on each side of the channel to prevent erosion caused from sheet flows into the high flow channel.

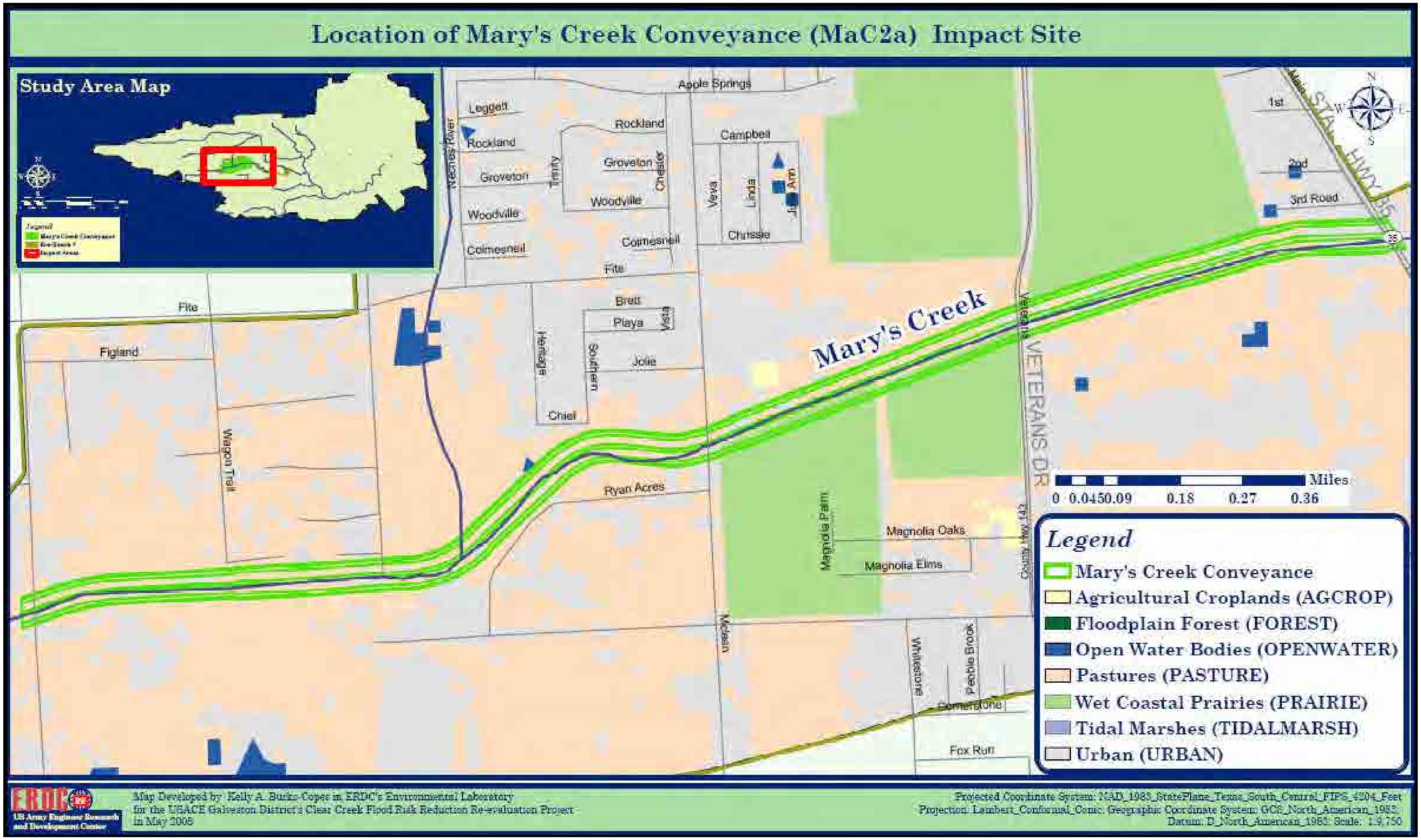

Figure 44. Cover type map of the Mary's Creek Conveyance (*MaC2a*) measure.

5 - Mud Gulley Conveyance (*MudG1b*)

The *MudG1b* measure was designed to provide conveyance improvement through the construction of a 0.8-mile concrete-lined channel on Mary's Creek from Sagedown to Astoria (southwest of the intersection of Beltway * and I-45) in Houston, Harris county, Texas (Eco-Reach 7) (refer to Figure 46 on the next page). The channel bottom cut will be 15 feet wide from Harkey Road to 3,940 feet upstream of McClean Road, 27.5 feet wide from 3,940 feet upstream of McClean Road to 100 feet downstream of McClean Road, and 35 feet wide from 100 feet downstream of McClean Road to State Highway 35 (Figure 45).

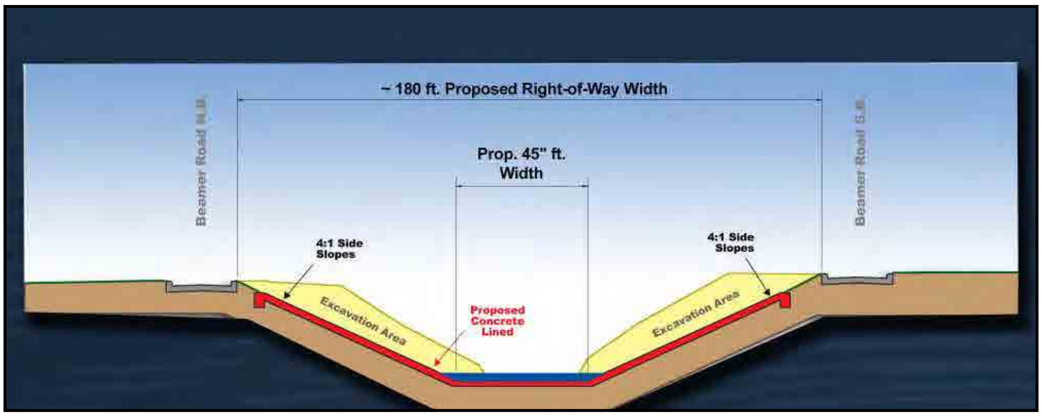

Figure 45. Illustration depicting on-the-ground designs for the Mud Gulley Conveyance measure (*MudG1b*).

The channel be designed with 1:4 (V:H) side slopes. A 30-foot ROW will be required outside and on both sides of the channel. This ROW will be used to construct several 15-foot-wide maintenance ROWs and 15-foot-wide backslope drains on each side of the channel to prevent erosion caused from sheet flows into the high flow channel. No impacts were anticipated with the implementation of this design.

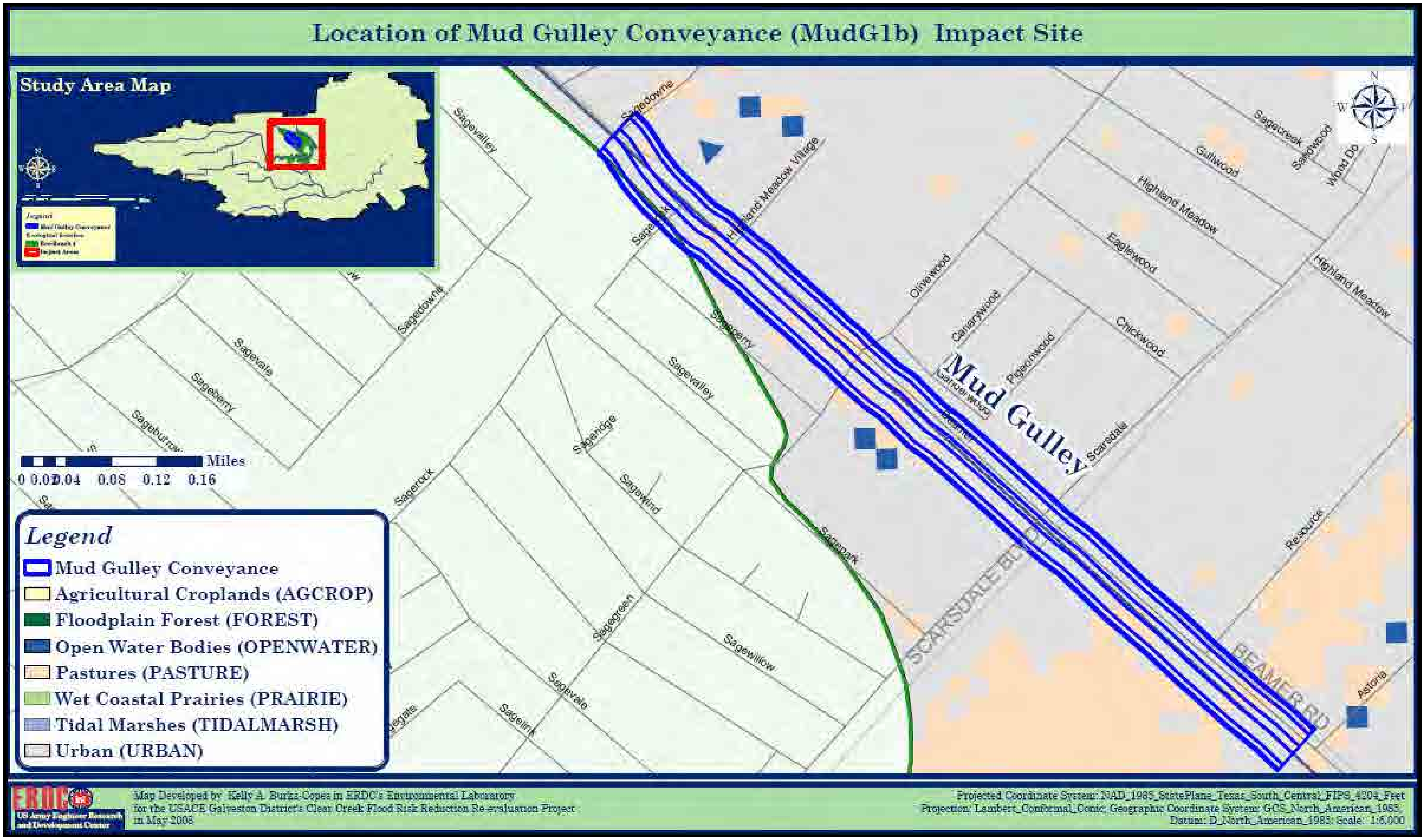

Figure 46. Cover type map of the Mud Gulley Conveyance (*MudG1b*) measure.

To summarize, the proposed 698-acre NED footprint would include 542 acres of direct impacts (lands converted to flood risk management features) and an additional 156 acres of on-site mitigation via avoidance, minimization and restoration/rehabilitation features (Table 20).

Table 20. Summary of the measures incorporated into the final NED plan and the conversion of habitats (floodplain forest/wet coastal prairies) and other landscape features to construct the plan.

		Footprints (Acres)	FOREST (Floodplain Forest)			PRAIRIE[2]	AGCROP	OPENWATER	PASTURES	URBAN
Total NED Footprint		698[1]	Impacted	Preserved, Restored, and Rehabilitated	Reestablished Floodplain Forest (NEWFOREST)	Coastal Prairies	Farms and Croplands	Open Bodies of Water Deeper than 1-3m	Old Fields, Haylands and Pastures	Existing Residential, Industrial and Transportation
1 Mainstem-Upstream Conveyance (*Super C*)		432	-186	88	33	-3	0	-1	-71	-15
	Corridor	122	0	88	33	0	0	1	25	8
	Bench/right-of-ways	310	-186	0	0	-3	0	-2	-96	-23
2 Mainstem-Downstream Conveyance [*C5(d)*]		109	-72	34	0	0	0	0	-2	-1
	Corridor	34	0	34	0	0	0	0	0	0
	Bench/ right-of-ways	75	-72	0	0	0	0	0	-2	-1
3 Turkey Creek Conveyance (*TKC1d*)		68	-20	0	0	0	0	-1	-43	-4
4 Mary's Creek Conveyance (Ma*C2a*)		63	0	0	0	-5	0	0	-45	-13
5 Mud Gully Conveyance (*MudG1b*)		26	0	0	0	0	0	0	-5	-21

[1] Blue values indicate combinations of features to generate the final footprints (in acres) per management measure.

[2] While these few acres were lost within the impact footprint, it was assumed that they were relatively non-functioning scrubby fringe prairie patches that have been severely modified by local drainage activities. As such, the E-Team made the assumption that these losses would be more than compensated for with the proposed forest community mitigation activities.

Predicted WP Acreage Trends (Quantity)

In order to complete the HEP assessment of the NED plan, individual measures were assessed independently (per Eco-Reach), and their cumulative effects were combined to generate an estimate of total impacts and the subsequent requirements for mitigation in terms of AAHUs. The first step was to develop acreage projections over the life of the project for each plan. It should be noted that two measures [i.e., Mud Gulley Conveyance (*MudG1b*) and Mary's Creek Conveyance (*MaC2a*)] avoided impacts to the existing floodplain forest community, and as such have been omitted from the following sections. The remainder of the plans and their expected landuse trends are detailed below (Table 21 - Table 25). In this manner, the E-Team was able to capture the localized affects of the various measures, yet maintain the landscape-level trends experienced across the affected eco-reaches (including the omnipresent urban encroachment).[1]

> *One note here – the creation of new forest community on agricultural croplands (or any other cover type in the list) warranted the addition to the cover type classification scheme. In those instances where active restoration or creation was undertaken to address on-site mitigation activities, the acreages were tracked in categories using the "NEW" naming convention (see below – Super C in Eco-Reach 5 for example tracks the development of new floodplain forest).*

[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

Table 21. WP acre projections for Mainstem-Upstream Conveyance (*Super C*) – Eco-Reach 5.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2010 TY0	2030 TY0	2055 TY0	2070 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	28	25	24	21	20	28	25	24	21	20
FOREST	337	309	295	258	236	337	256	245	217	200
NEWFOREST	0	0	0	0	0	0	11	11	11	11
OPENWATER	11	10	10	8	7	11	10	10	8	7
PASTURES	692	625	592	511	463	692	585	552	471	423
PRAIRIE	1,094	988	941	826	755	1,094	985	938	823	752
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	601	806	901	1,139	1,282	601	780	872	1,101	1,239
FCPROJECT	0	0	0	0	0	0	111	111	111	111
TOTALS:	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763

Table 22. WP acre projections for Mainstem-Upstream Conveyance (*Super C*) – Eco-Reach 6.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2010 TY0	2030 TY0	2055 TY0	2070 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	1,305	1,219	1,166	1,032	951	1,305	1,219	1,166	1,032	951
FOREST	489	448	426	368	334	489	330	317	283	263
NEWFOREST	0	0	0	0	0	0	22	22	22	22
OPENWATER	180	163	154	132	119	180	161	152	130	117
PASTURES	8,378	7,814	7,527	6,811	6,381	8,378	7,740	7,453	6,737	6,307
PRAIRIE	1,077	982	928	792	711	1,077	982	928	792	711
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	2,871	3,674	4,099	5,165	5,804	2,871	3,647	4,063	5,105	5,730
FCPROJECT	0	0	0	0	0	0	199	199	199	199
TOTALS:	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300

Table 23. WP acre projections for Mainstem-Downstream Conveyance [*C5(d)*] – Eco-Reach 4.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2020 TY0	2030 TY0	2055 TY0	2070 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	2	2	2	2	2	2	2	2	2	2
FOREST	1,053	931	852	655	536	1,053	885	812	630	520
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	17	15	14	12	10	17	15	14	12	10
PASTURES	1,521	1,370	1,271	1,019	871	1,521	1,368	1,269	1,017	869
PRAIRIE	26	24	23	20	18	26	24	23	20	18
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,753	2,030	2,210	2,664	2,935	1,753	2,023	2,197	2,636	2,898
FCPROJECT	0	0	0	0	0	0	55	55	55	55
TOTALS:	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372

Table 24. WP acre projections for Mainstem-Downstream Conveyance [*C5(d)*] – Eco-Reach 5.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000	2020	2030	2055	2070	2000	2020	2030	2055	2070
	TY0	TY0	TY0	TY0	TY0	TY0	TY1	TY11	TY36	TY51
AGCROP	28	25	24	21	20	28	25	24	21	20
FOREST	337	309	295	258	236	337	291	278	244	224
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	11	10	10	8	7	11	10	10	8	7
PASTURES	692	625	592	511	463	692	625	592	511	463
PRAIRIE	1,094	988	941	826	755	1,094	988	941	826	755
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	601	806	901	1,139	1,282	601	804	898	1,133	1,274
FCPROJECT	0	0	0	0	0	0	20	20	20	20
TOTALS:	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763

Table 25. WP acre projections for Turkey Creek Conveyance (*TKC1d*) – Eco-Reach 4.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000	2020	2030	2055	2070	2000	2020	2030	2055	2070
	TY0	TY0	TY0	TY0	TY0	TY0	TY1	TY11	TY36	TY51
AGCROP	2	2	2	2	2	2	2	2	2	2
FOREST	1,053	931	852	655	536	1,053	913	836	643	526
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	17	15	14	12	10	17	14	13	11	9
PASTURES	1,521	1,370	1,271	1,019	871	1,521	1,331	1,232	980	832
PRAIRIE	26	24	23	20	18	26	24	23	20	18
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,753	2,030	2,210	2,664	2,935	1,753	2,020	2,198	2,648	2,917
FCPROJECT	0	0	0	0	0	0	68	68	68	68
TOTALS:	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372

Just as they did in the WOP conditions, these tables indicate urban encroachment will continue to change the face of the Clear Creek watershed over the next 50 years regardless of the implementation of the NED plan. This time however, the NED plan's individual measures will play a role in shaping the landscape.

Predicted WP Variable Trends (Quality)

Rather than presenting copious amounts of tables documenting variable projections here, the authors chose to provide a brief synopsis of general WP trends (and the E-Team assumptions supporting these trends).[1]

[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

Generally speaking, the E-Team surmised that the hydrologic parameters (hydroregime, sinuosity, substrates, roughness, etc.) would not be greatly affected by the proposed WP scenario – the system was already stressed and would continue as such. However, water depth would increase as a matter of design. The impacts were more acutely experienced in the vegetative and spatial arenas. The E-team assumed that fragmentation of the habitat incurred by the NED plan when it converted forest into channelized features in conjunction with the ongoing urban growth scenario, would lead to constrictions in core areas and increases in overall edges. Urban encroachment would continue to affect patch sizes, distances between patches, and impervious surfaces – the WP scenario would simply exacerbate the problems to some extent. Increased edge would make the communities more susceptible to disease and incursions of non-native species and exotics would lead to increased competition and a general loss of the native-based, functioning communities. The incidental loss of overhanging vegetation as the channels were constructed, and the general loss of species diversity as critical core areas disappeared would lead to the loss of vegetative structure and spatial complexity critical to ecosystem support and function.

On-site restoration activities, on the other hand, were expected to counteract these trends to some degree. Detailed (native) planting schemes and intensive 30+ year maintenance plans were predicted to generate highly functioning systems in 40 years or less. These areas contributed to the overall spatial complexity of the systems adding patches, expanding core areas, and increasing the overall connectivity of the landscape mosaic (Table 26 - Table 32).

Table 26. FOREST cover type WP variable projections for Mainstem-Upstream Conveyance (Super C) – Eco-Reach 6.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	3	3	5	6
	IMPERVIOUS	30	40	40	45	45
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.16	1.16	1.16	1.16	1.16
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	40	70	75	85	90
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	75	75
	INSTRMCOV	5	5	5	5	5
	NATIVE	70	60	60	50	45
	OVRHDCOV	30	30	30	40	45
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	5	8	8	9	11
	CORE	0	1	0	0	0
	EDGE	70	5	5	5	5
	NEIGHBOR	55	25	25	30	30
	PATCHSIZE	70	5	5	5	5

Table 27. NEWFOREST cover type WP variable projections for Mainstem-Upstream Conveyance (Super C) – Eco-Reach 6.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	0	1	1	1	1
	EROSION	0	3	3	5	6
	IMPERVIOUS	0	40	40	45	45
	ROUGHNESS	0	0.11	0.11	0.11	0.11
	SINUOSITY	0	1.16	1.16	1.16	1.16
	SUBSTRATE	0	1	1	1	1
	WATERDEPTH	0	70	75	85	90
Structure and Biotic Integrity (BIOINTEG)	CANTREE	0	5	30	70	75
	INSTRMCOV	0	5	10	25	35
	NATIVE	0	100	100	100	100
	OVRHDCOV	0	60	60	65	70
	VEGSTRATA	0	2	3	5	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	0	7	7	8	8
	AREAWETDRY	0	8	8	9	11
	CORE	0	1	0	0	0
	EDGE	0	5	5	5	5
	NEIGHBOR	0	25	25	30	30
	PATCHSIZE	0	5	5	5	5

Table 28. FOREST cover type WP variable projections for Mainstem-Upstream Conveyance (Super C) – Eco-Reach 5.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	3	3	5	6
	IMPERVIOUS	40	45	45	55	60
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.23	1.23	1.23	1.23	1.23
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	75	80	90	95
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	75	75
	INSTRMCOV	5	5	5	5	5
	NATIVE	60	60	60	50	45
	OVRHDCOV	20	20	20	30	35
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	20	18	18	16	14
	CORE	5	5	5	5	5
	EDGE	65	20	20	20	20
	NEIGHBOR	30	20	20	20	20
	PATCHSIZE	65	25	25	25	25

Table 29. NEWFOREST cover type WP variable projections for Mainstem-Upstream Conveyance (Super C) – Eco-Reach 5.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	0	1	1	1	1
	EROSION	0	3	3	5	6
	IMPERVIOUS	0	45	45	55	60
	ROUGHNESS	0	0.11	0.11	0.11	0.11
	SINUOSITY	0	1.23	1.23	1.23	1.23
	SUBSTRATE	0	1	1	1	1
	WATERDEPTH	0	75	80	90	95
Structure and Biotic Integrity (BIOINTEG)	CANTREE	0	5	30	70	75
	INSTRMCOV	0	5	10	25	35
	NATIVE	0	100	100	100	100
	OVRHDCOV	0	60	60	65	70
	VEGSTRATA	0	2	3	5	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	0	7	7	8	8
	AREAWETDRY	0	18	18	16	14
	CORE	0	5	5	5	5
	EDGE	0	20	20	20	20
	NEIGHBOR	0	20	20	20	20
	PATCHSIZE	0	25	25	25	25

Table 30. FOREST cover type WP variable projections for Mainstem-Downstream Conveyance [C5(d)] – Eco-Reach4.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	2	1	1	1	1
	IMPERVIOUS	40	45	50	60	70
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.74	1.74	1.74	1.74	1.74
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	60	60	60	60
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	70	75
	INSTRMCOV	5	10	10	25	40
	NATIVE	60	55	50	40	35
	OVRHDCOV	60	60	60	60	60
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	3	3	3	3
	CORE	40	30	30	20	15
	EDGE	310	65	60	45	40
	NEIGHBOR	0	5	5	5	5
	PATCHSIZE	525	95	85	70	60

Table 31. FOREST cover type WP variable projections for Mainstem-Downstream Conveyance [C5(d)] – Eco-Reach 5.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	2	2	2	2
	EROSION	3	2	2	2	2
	IMPERVIOUS	40	45	45	55	60
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.23	1.23	1.23	1.23	1.23
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	50	50	50	50
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	75	75
	INSTRMCOV	5	10	10	15	20
	NATIVE	60	55	55	45	40
	OVRHDCOV	20	20	20	25	25
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	20	18	17	15	13
	CORE	5	0	0	0	0
	EDGE	65	45	45	35	30
	NEIGHBOR	30	30	30	40	45
	PATCHSIZE	65	50	50	40	35

Table 32. FOREST cover type WP variable projections for Turkey Creek (TCK1d) – Eco-Reach 4.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	2	2	1	1
	EROSION	2	4	4	5	5
	IMPERVIOUS	40	35	35	25	20
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.74	1.74	1.74	1.74	1.74
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	70	75	85	90
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	65	65
	INSTRMCOV	5	5	5	5	5
	NATIVE	60	55	50	40	35
	OVRHDCOV	60	35	35	35	35
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	3	3	2	2
	CORE	40	30	30	20	15
	EDGE	310	110	100	80	65
	NEIGHBOR	0	50	55	65	75
	PATCHSIZE	525	175	160	125	105

WP Results for the Proposed NED Plan

The changes predicted above under the proposed NED plan resulted in quantifiable impacts to the floodplain forest community within the watershed (Table 33).

Table 33. Final results (Net AAHUs) of the proposed NED plan (impacts and mitigation).

Measure Description	Code	Eco-Reach 4	Eco-Reach 5	Eco-Reach 6	SUM of Net AAHUs Across Reaches
		Floodplain Forest	Floodplain Forest	Floodplain Forest	TOTALS
Mainstem-Upstream Conveyance	MS_US Conveyance		-22	-42	-64
Mainstem-Downstream Conveyance	MS_DS Conveyance	2	3		5
Turkey Creek Conveyance	TkC Conveyance	-47			-47
SUM of Net AAHUs Across Reaches		-45	-19	-42	-106

The proposed flood risk management and mitigation measures were analyzed as stand alone features to determine the ecological gains or losses attributed to each on an individual basis. This also allowed decision-makers to better determine which flood risk management measures were worth implementing or dropping from consideration due to disproportionate ecological losses requiring added mitigation. System-wide affects of flood risk management measures were determined from combining the gains and losses of stand alone measures to allow the team to make decisions regarding the best performing measure or combinations of measures with respect to ecological gains and losses. Mitigation measures were then assessed in a similar fashion. Where two or more flood risk management or mitigation measures were proposed for implementation within a particular ecological reach, the E-Team agreed to cumulatively remunerate the results of the measures to account for the system effects of the measure(s) on that reach using multiplicative factors.

A total of 106 AAHUs were lost in the floodplain forest community due to the combined proposed management measures. The greatest forest losses were experienced in Eco-Reaches 4 and 6 (i.e., 45 AAHUs and 42 AAHUs were lost respectively). The more significant impacts were felt under the Clear Creek Mainstem-Upstream Conveyance (*Super C*) management measure which generated a total loss of 64 AAHUs across Reaches 5 and 6. (Figure 47).

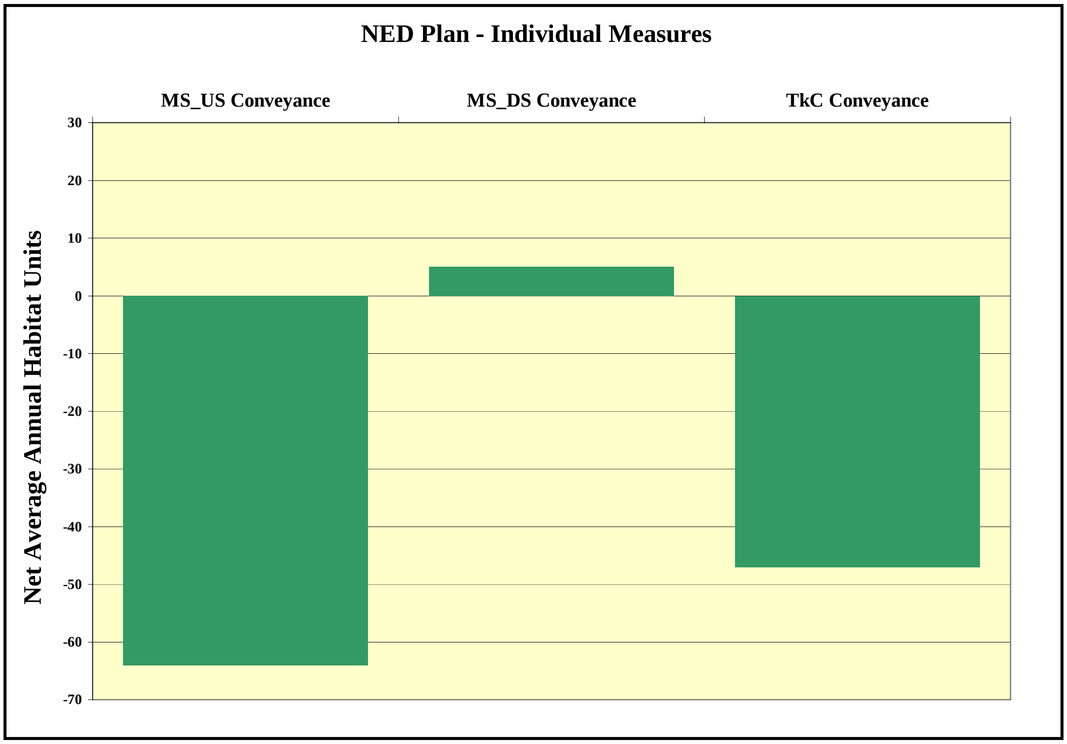

Figure 47. Results of the proposed NED plan arrayed across individual components (i.e., measures).

Based on these findings, additional mitigation of 106 AAHUs of floodplain forest must be acquired to fully compensate for the losses incurred under the proposed NED plan. Refer to *Chapter 6* for details regarding the mitigation options under consideration.

6 Mitigation Analysis and Results

In light of the potential impacts likely to be incurred as a direct result of implementing the proposed NED plan, the E-Team began an iterative plan formulation process to develop, evaluate and compare potential mitigation activities across the watershed. Below, we briefly describe the final set of mitigation alternatives that evolved out of this iterative formulation process. The benefits gained with the implementation of these plans are detailed here in terms of acres, quality, and ultimately AAHUs.[1]

Mitigation Measures Under Consideration

Twenty-seven mitigation measures were initially conceived and assessed with HEP at a screening-level.[2] Where possible, the E-Team devised strategies to preserve, restore, and reestablish both communities at the same locale, thereby addressing concerns of lost spatial heterogeneity and complexity while taking advantage of the cost-savings of restoring both communities in the fewest possible locations. The E-Team culled measures that did not meet the in-kind mitigation requirements, did not address the spatial connectivity and complexity requirements, and/or refined plans to optimize outputs where possible. In some instances, proposed measures incorporated non-structural "buy-outs" of flood-prone structures, with the expectation of providing potential ancillary flood risk management benefits. However, these measures were dropped from consideration or modified to remove the non-structural or "buy-out" component as they provided relatively minor economic benefits to flood risk management and would likely receive unfavorable public reception as stand-alone mitigation measures. Some measures offered less than full compensation to offset the community's losses, but generated reasonable amounts of benefits to partially mitigate losses in the region. Because these options might serve as partial fulfillment of the mitigation requirements, and could be combined with additional measures to fully meet the demand for replacement of function, these measures were retained and included in the final comparative array. The final array included 10 management

[1] Details of the plan formulation process and the final selection of a recommended mitigation plan can be found the study's planning documentation (USACE 2010).

[2] Contact the District to obtain the results of these initial screening-level analyses.

measures, spanned 4 reaches, and offered a range of AAHU outputs at varying degrees of costs sufficient to offset losses and move forward into cost effective and incremental cost caparisons (Figure 48).

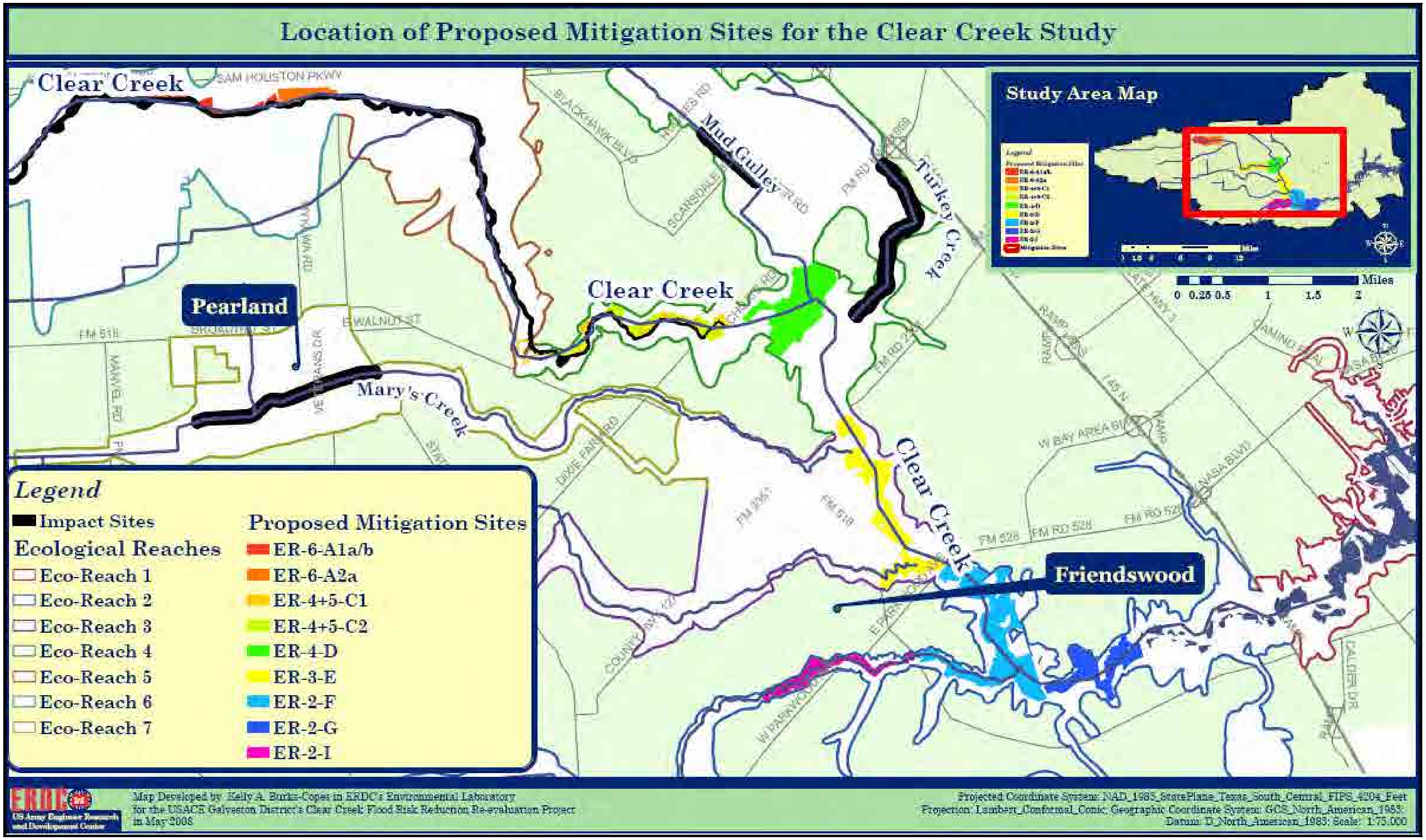

Figure 48. Proposed locations for the various mitigation measures proposed to offset losses incurred by the proffered NED plan for the Clear Creek study.

Eco-Reach (ER)-6-A1a and ER-6-A1b

The *A1* measure, located in Eco-Reach 6, proposed the preservation of 20 existing acres of floodplain forest (Figure 49). Intensive O&M (including reconnaissance, removal and foliar applications (e.g., cut-tumped method with application of herbicides) to control invasive, noxious, and exotic species) would be performed annually for 35 years. The *A1a* vs. *A1b* increments of this mitigation measure was formulated to quantify the two optional desired states: 1) and 20% wet core area (*A1a*) versus 2) a 30% wet core area (*A1b*). The measure would require the purchase of vacant land south of Beltway 8 west of Mykawa.

ER-6-A2a

The *A2a* measure (also in Eco-Reach 6) proposed the preservation of 29 existing acres of floodplain forest, and the conversion of 9 acres of urban areas and pasturelands to newly planted floodplain forest, with at least 20% of the area restored to a hydric or wetland interior (Wet:Dry Ratio of the floodplain forest would be 20%) (Figure 50). Intensive O&M (including reconnaissance, removal and foliar applications to control invasive, noxious, and exotic species) would be performed annually for 35 years. The measure would require the purchase of vacant land south of Beltway 8 east of Mykawa.

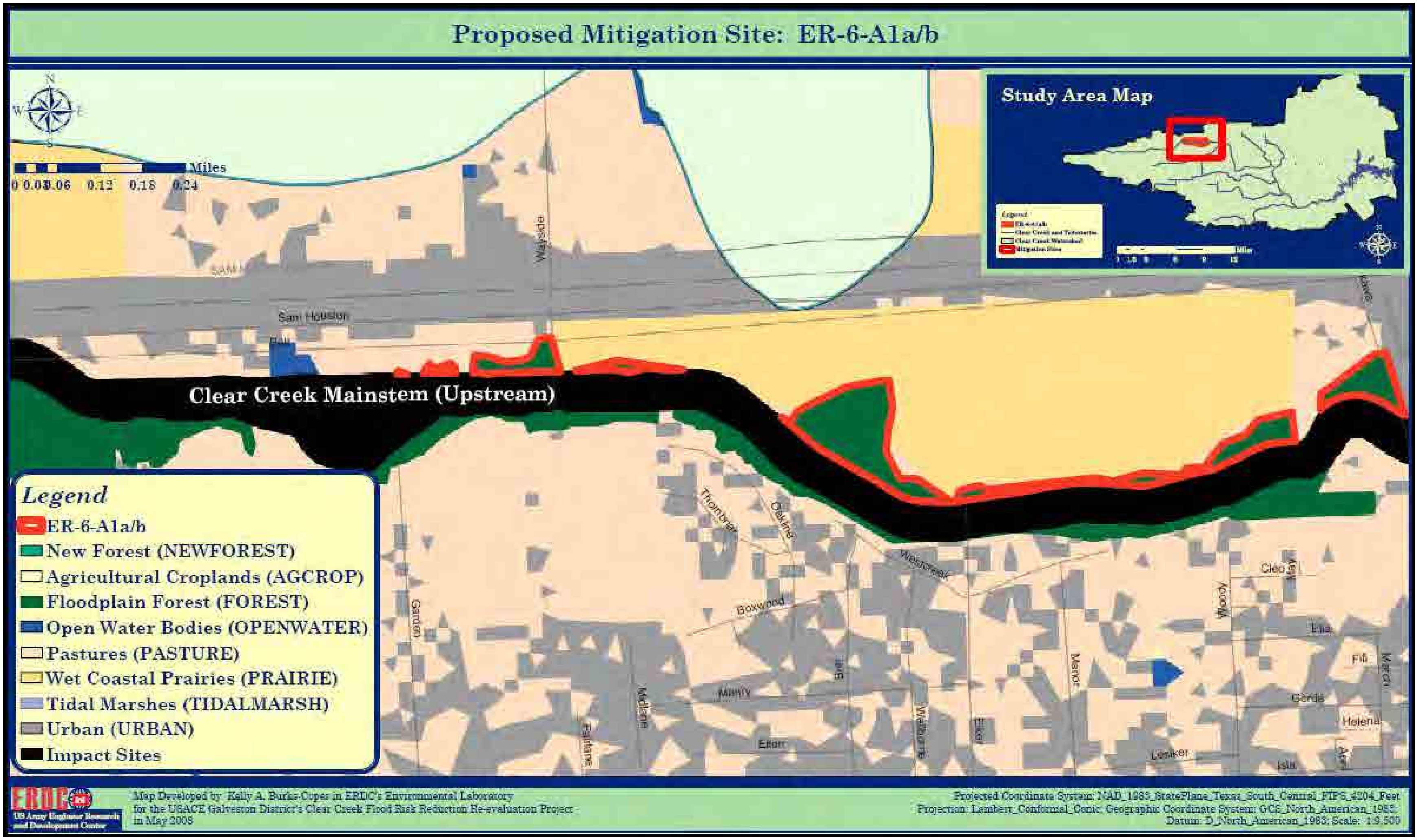

Figure 49. Cover type map of the ER-6-A1a and ER-6-A1b mitigation measures.

Figure 50. Cover type map of the ER-6-A2a mitigation measure.

ER-4-C1 and ER-5-C1

The *C1* measure's footprint spanned two reaches (ER 4 and 5) and offered the restoration of the low flow channel to mimic the 1955 sinuosity regime of the Clear Creek mainstem by reconnecting thirteen remnant oxbows scattered throughout the system between Country Club Drive and Dixie Farm Road that were cut off as a result of past channelization activities (Figure 51). This would be accomplished by modifying portions of the existing conveyance feature, diverting water into the oxbows under low flow conditions, and maintaining high flow conditions to guarantee flood protection for the area. Dredged material stock piled along the north bank of the creek would be removed, and the existing cleared overbank areas along the channel would be densely planted to restore the existing floodplain forest to a desired state (based on data collections by TPWD and USFWS in 2005 within the study area). Approximately 31 acres of floodplain forest would be restored.

ER-4-C2 and ER-5-C2

The *C2* measure was a modification of the *C1* measure involving the addition of 31 acres of floodplain forest restoration via a reconnection of oxbows, and the additional preservation of 67 acres and restoration of 5 acres of floodplain forest (Figure 52).

ER-4-D

The *D* measure proposed the preservation and restoration of 272 acres of existing floodplain forest including the riparian corridor along Clear Creek in Eco-Reach 4. This measure required the purchase of vacant land around the confluence of Clear Creek and Mud Gully adjacent to, and east of, Dixie Farm Road and Choate Parks Road (Figure 53).

ER-3-E

The *E* measure proposed the preservation and restoration of 241 acres of existing floodplain forest including the riparian corridor along Clear Creek in Eco-Reach 3. This measure required the purchase of vacant land along Clear Creek between FM 2351 and FM 528 (Parkwood) (Figure 54).

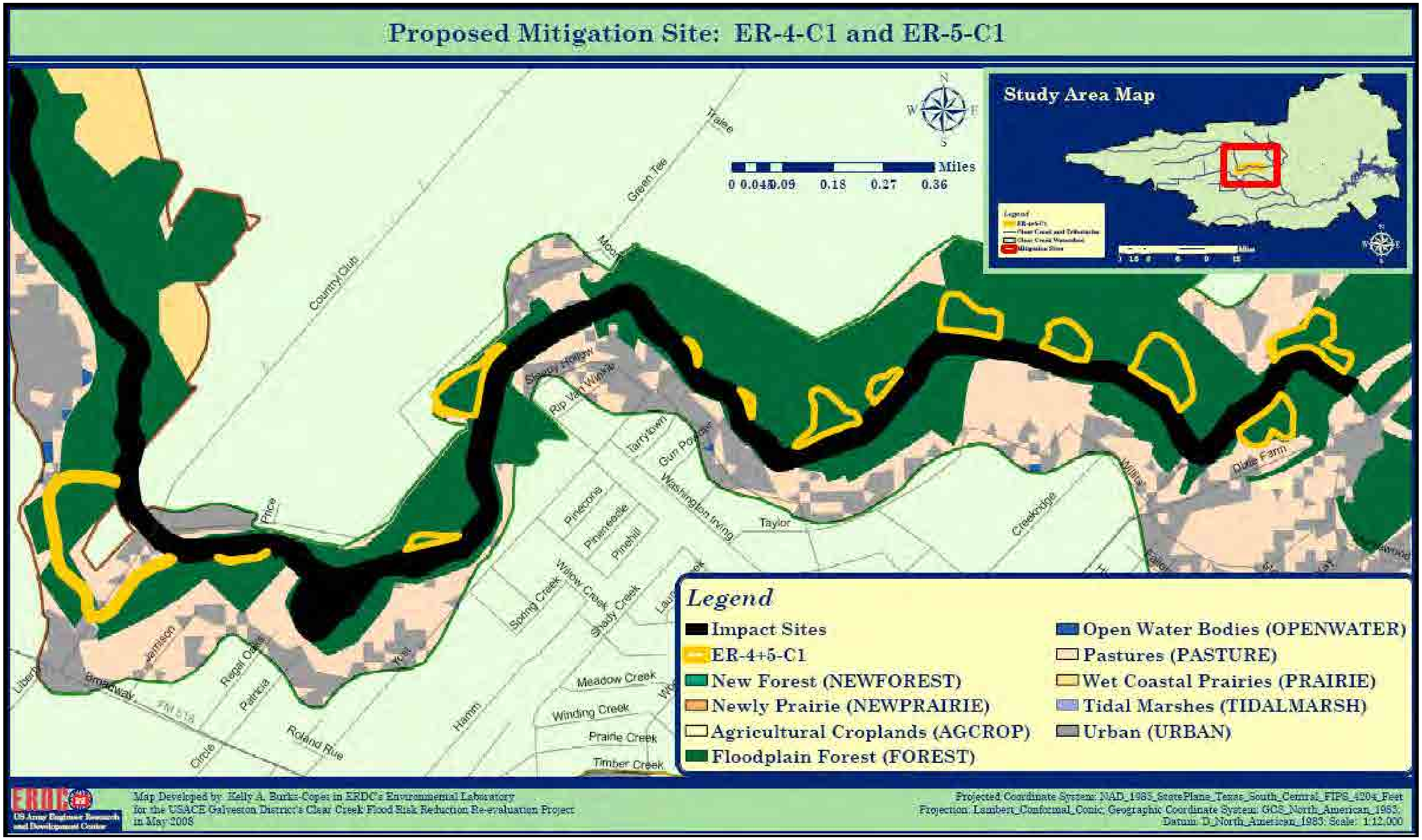

Figure 51. Cover type map of the ER-4-C1 and ER-5-C1 mitigation measure.

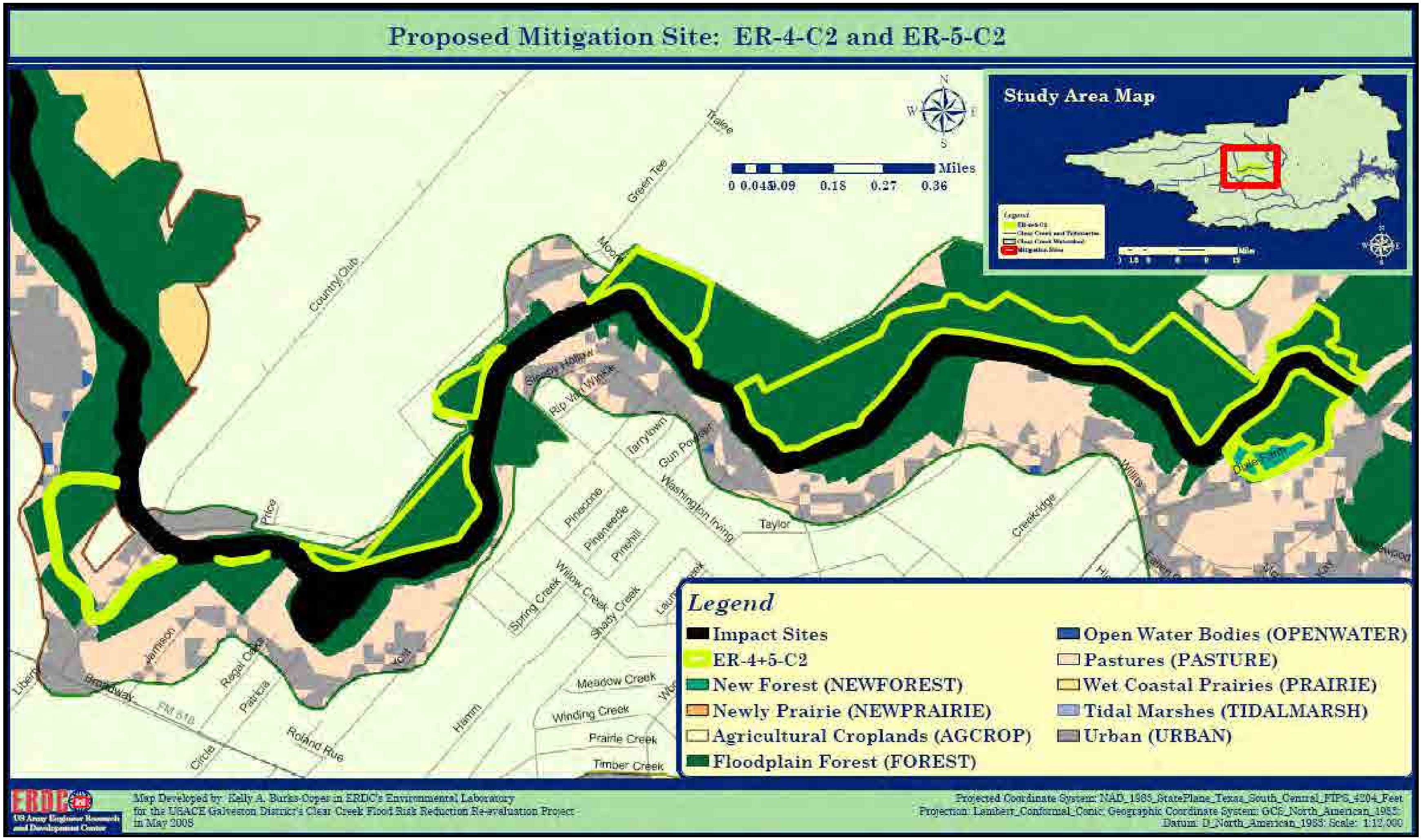

Figure 52. Cover type map of the ER-4-C2 and ER-5-C2 mitigation measure.

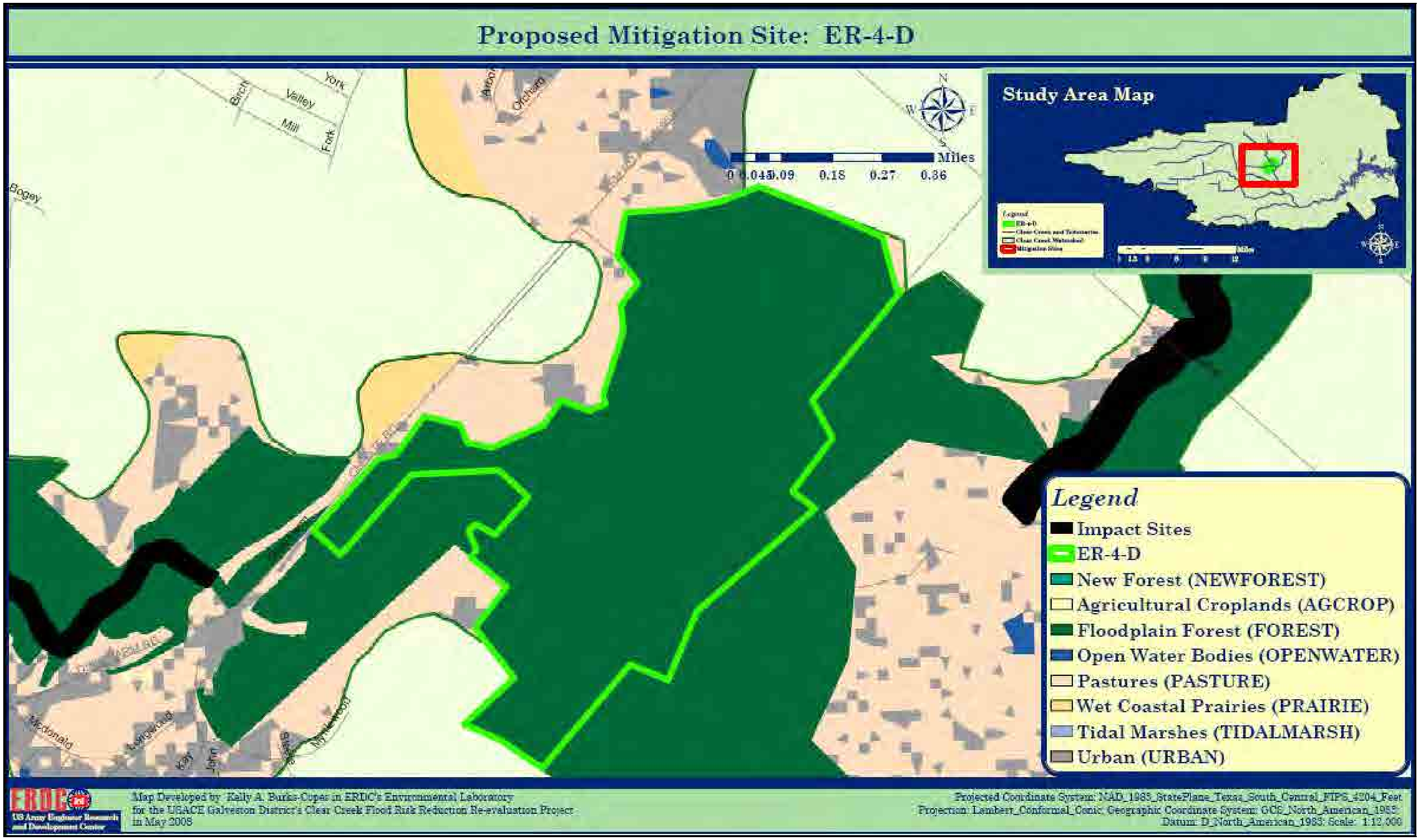

Figure 53. Cover type map of the ER-4-D mitigation measure.

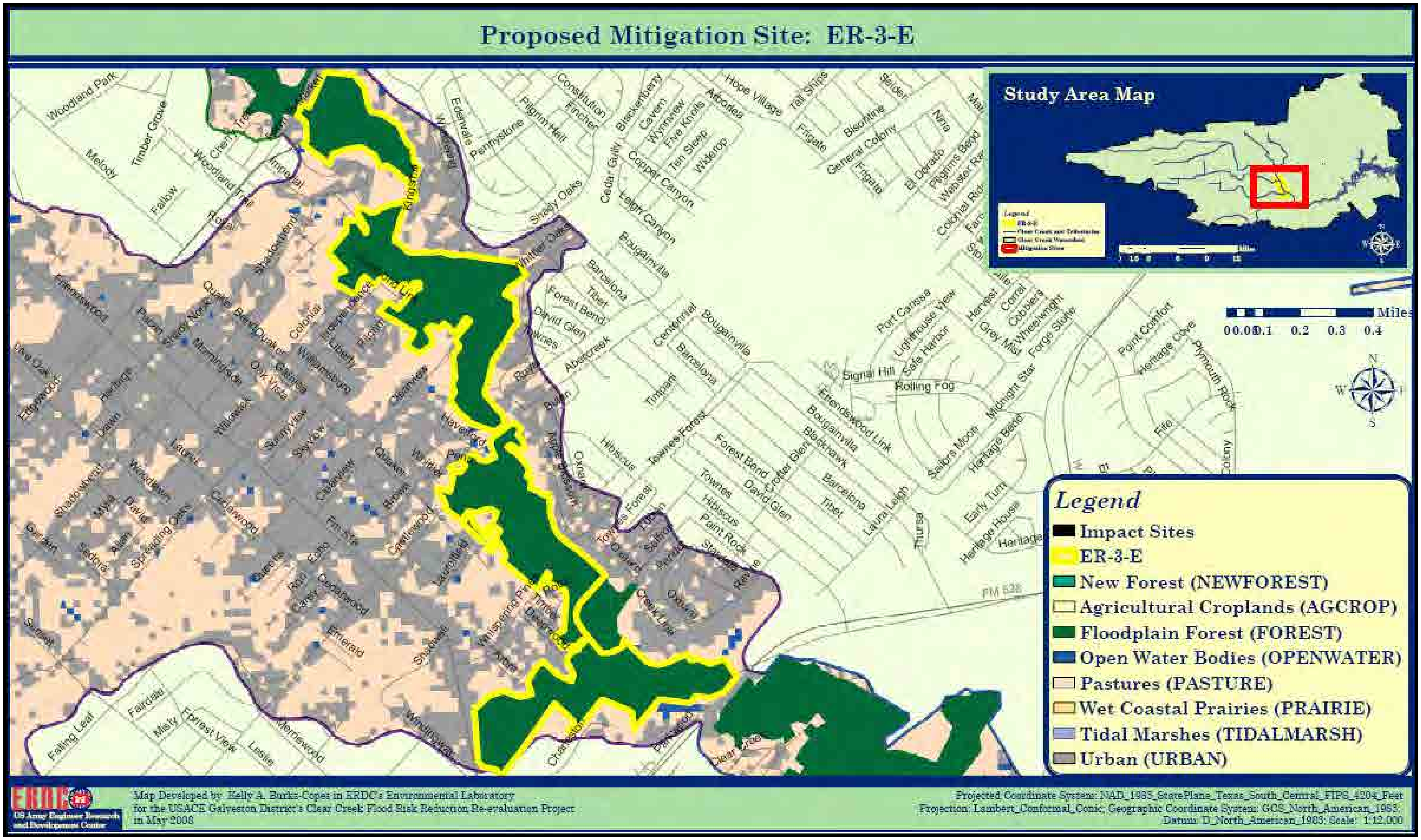

Figure 54. Cover type map of the ER-3-E mitigation measure.

ER-2-F

The *F* measure proposed the preservation and restoration of 388 acres of existing floodplain forest including the riparian corridor along Clear Creek in Eco-Reach 2. This measure required the purchase of vacant land along Clear Creek between FM 528 and FM 518 (Figure 55).

ER-2-G

The *G* measure proposed the preservation and restoration of 144 acres of existing floodplain forest including the riparian corridor along Clear Creek in Eco-Reach 2 as well. This measure required the purchase of vacant land along Clear Creek between FM 518 and Challenger 7 Park (Figure 56).

ER-2-I

The *I* measure proposed the preservation and restoration of 91 acres of existing floodplain forest including the riparian corridor along Chigger Creek near its confluence with Clear Creek in Eco-Reach 2. This measure requires the purchase of vacant land along Chigger Creek from FM 518 to approximately 9,000 feet upstream (Figure 57).

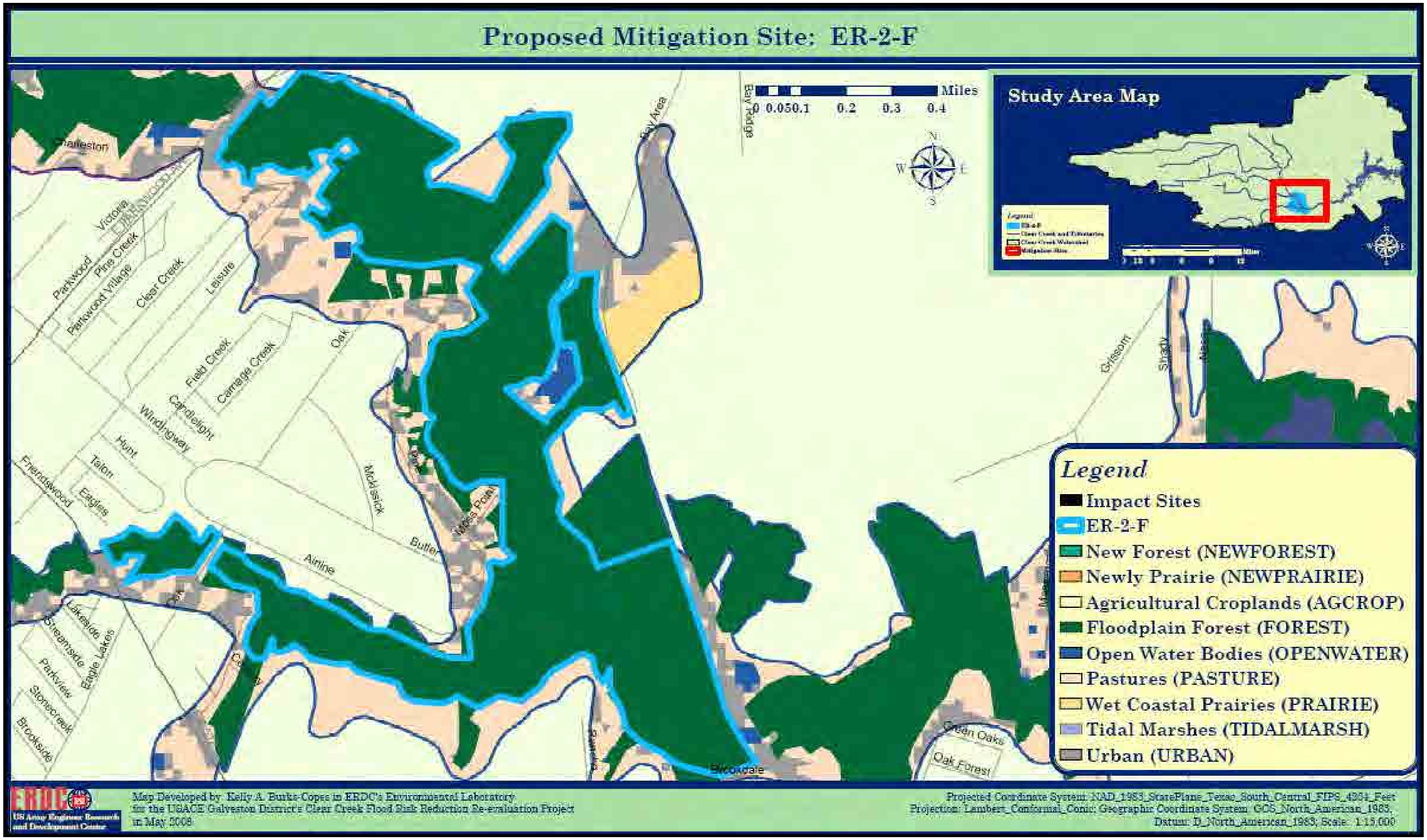

Figure 55. Cover type map of the ER-2-F mitigation measure.

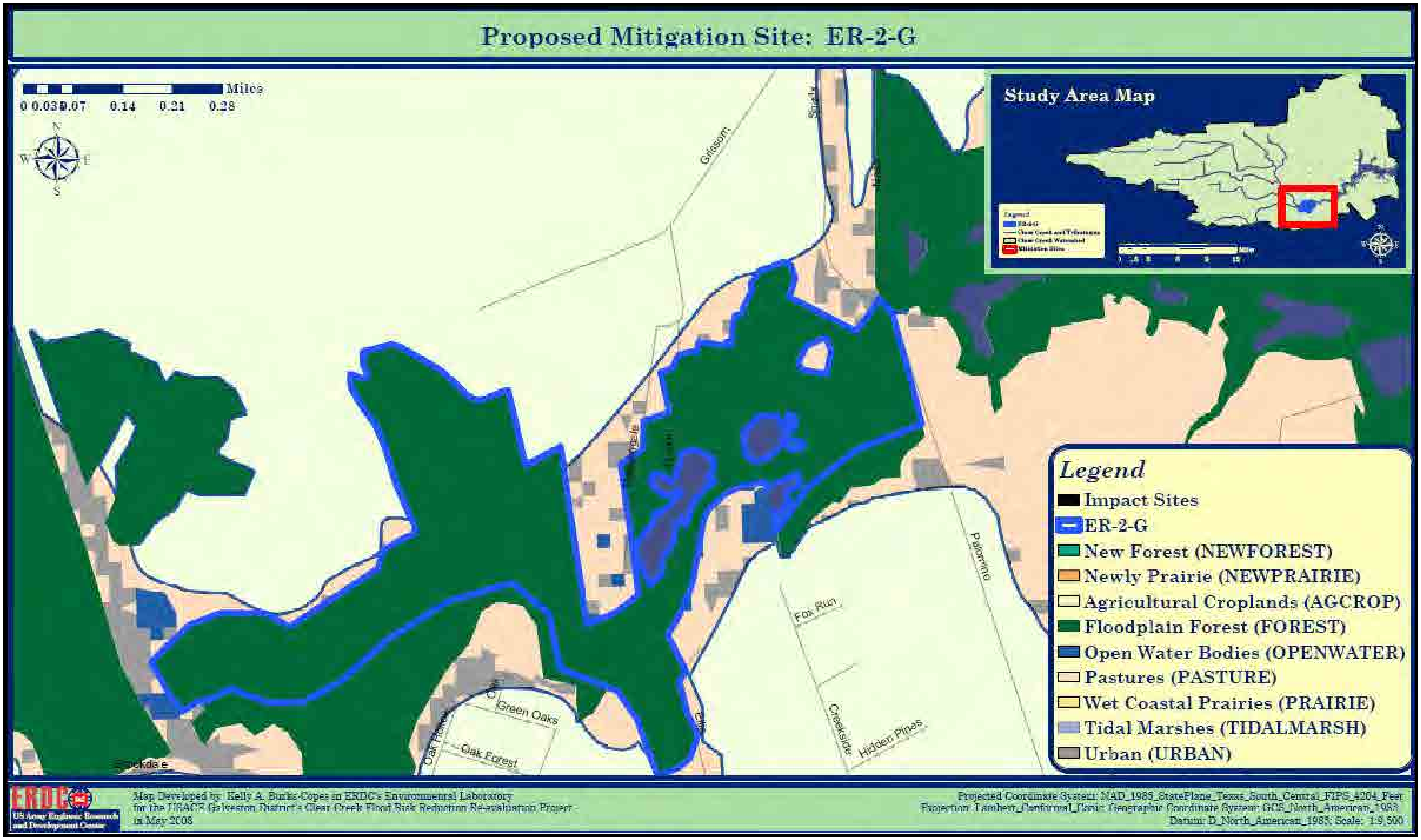

Figure 56. Cover type map of the ER-2-G mitigation measure.

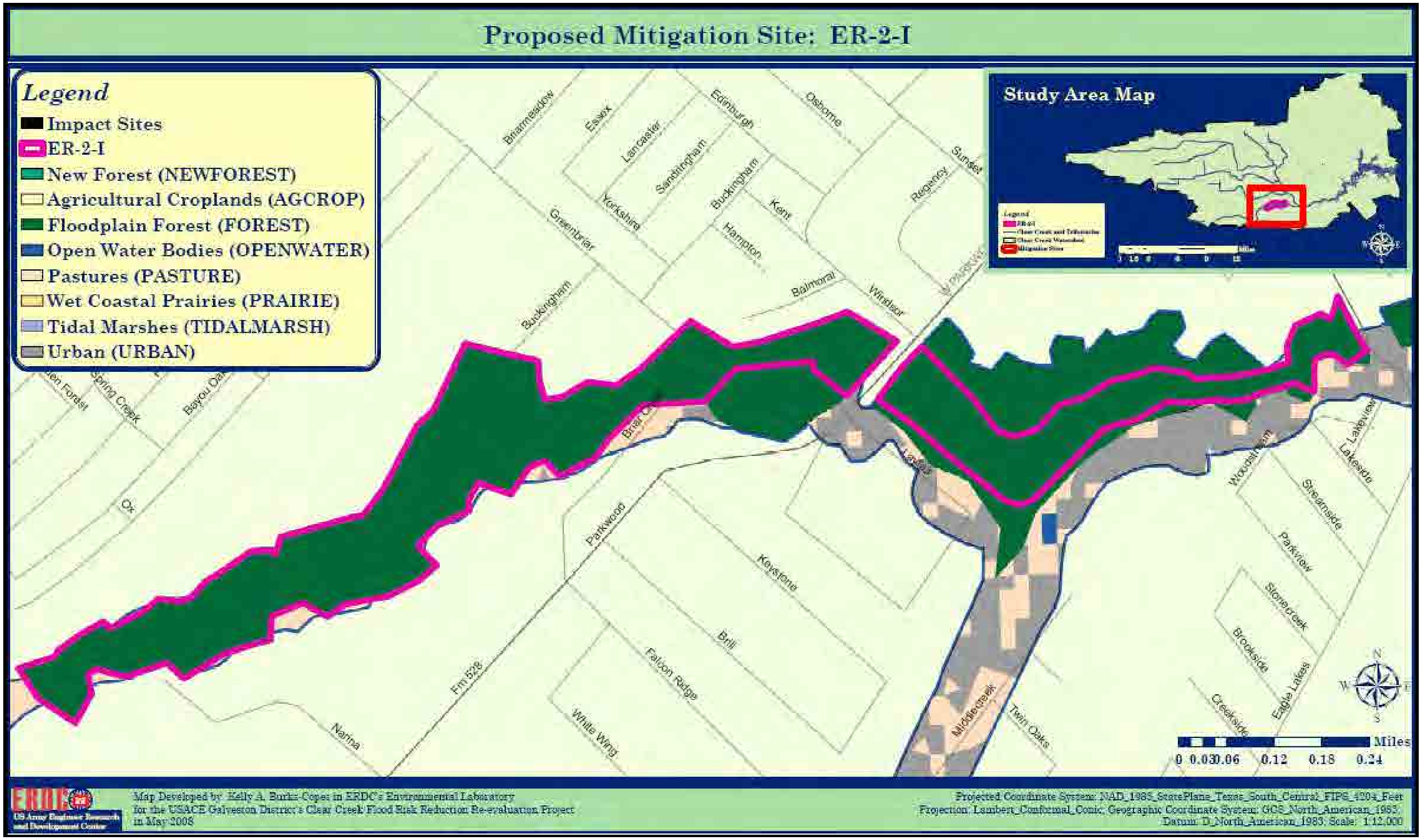

Figure 57. Cover type map of the ER-2-I mitigation measure.

Predicted WOP Trends (Quantity and Quality)

The same trends used to assess the WOP condition under the NED plan analysis were used to quantify the WOP conditions for the mitigation measures. Refer to the WOP sections above to review this information and the predicted WOP forecast for the Clear Creek watershed.[1]

Predicted WP Acreage Trends (Quantity)

In order to complete the HEP assessments, individual measures and increments were assessed independently (per Eco-Reach), and their cumulative effects were combined to generate an estimate of total benefits in terms of AAHUs. The first step was to develop acreage projections over the life of the project for each measure (Table 34 - Table 45). In this manner, the E-Team was able to capture the localized affects of the various measures, yet maintain the landscape-level trends experienced across the affected eco-reaches (including the omnipresent urban encroachment).

Table 34. WP acre projections for the ER-6-A1a mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	1,305	1,219	1,166	1,032	951	1,305	1,219	1,166	1,032	951
FOREST	489	448	426	368	334	489	448	427	372	339
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	180	163	154	132	119	180	163	154	132	119
PASTURES	8,378	7,814	7,527	6,811	6,381	8,378	7,814	7,527	6,811	6,381
PRAIRIE	1,077	982	928	792	711	1,077	982	933	811	738
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	2,871	3,674	4,099	5,165	5,804	2,871	3,674	4,093	5,142	5,772
TOTALS:	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300

[1] Electronic files available upon request - contact the District POC, Andrea Catanzaro (Table 1).

Table 35. WP acre projections for the ER-6-A1b mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	1,305	1,219	1,166	1,032	951	1,305	1,219	1,166	1,032	951
FOREST	489	448	426	368	334	489	448	427	372	339
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	180	163	154	132	119	180	163	154	132	119
PASTURES	8,378	7,814	7,527	6,811	6,381	8,378	7,814	7,527	6,811	6,381
PRAIRIE	1,077	982	928	792	711	1,077	982	933	811	738
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	2,871	3,674	4,099	5,165	5,804	2,871	3,674	4,093	5,142	5,772
TOTALS:	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300

Table 36. WP acre projections for the ER-6-A2a mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	1,305	1,219	1,166	1,032	951	1,305	1,219	1,166	1,032	951
FOREST	489	448	426	368	334	489	448	427	373	341
NEWFOREST	0	0	0	0	0	0	9	9	9	9
OPENWATER	180	163	154	132	119	180	163	154	132	119
PASTURES	8,378	7,814	7,527	6,811	6,381	8,378	7,807	7,520	6,804	6,374
PRAIRIE	1,077	982	928	792	711	1,077	982	928	792	711
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	2,871	3,674	4,099	5,165	5,804	2,871	3,672	4,096	5,158	5,795
TOTALS:	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300	14,300

Table 37. WP acre projections for the ER-4-C1 mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	2	2	2	2	2	2	2	2	2	2
FOREST	1,053	931	852	655	536	1,053	931	854	663	548
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	17	15	14	12	10	17	15	14	12	10
PASTURES	1,521	1,370	1,271	1,019	871	1,521	1,370	1,271	1,019	871
PRAIRIE	26	24	23	20	18	26	24	23	20	18
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,753	2,030	2,210	2,664	2,935	1,753	2,030	2,208	2,656	2,923
TOTALS:	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372

Table 38. WP acre projections for the ER-5-C1 mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	28	25	24	21	20	28	25	24	21	20
FOREST	337	309	295	258	236	337	309	295	258	236
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	11	10	10	8	7	11	10	10	8	7
PASTURES	692	625	592	511	463	692	625	592	511	463
PRAIRIE	1,094	988	941	826	755	1,094	988	941	826	755
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	601	806	901	1,139	1,282	601	806	901	1,139	1,282
TOTALS:	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763

Table 39. WP acre projections for the ER-4-C2 mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	2	2	2	2	2	2	2	2	2	2
FOREST	1,053	931	852	655	536	1,053	931	860	683	576
NEWFOREST	0	0	0	0	0	0	5	5	5	5
OPENWATER	17	15	14	12	10	17	15	14	12	10
PASTURES	1,521	1,370	1,271	1,019	871	1,521	1,366	1,267	1,015	867
PRAIRIE	26	24	23	20	18	26	24	23	20	18
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,753	2,030	2,210	2,664	2,935	1,753	2,029	2,201	2,635	2,894
TOTALS:	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372

Table 40. WP acre projections for the ER-5-C2 mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	28	25	24	21	20	28	25	24	21	20
FOREST	337	309	295	258	236	337	309	295	258	236
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	11	10	10	8	7	11	10	10	8	7
PASTURES	692	625	592	511	463	692	625	592	511	463
PRAIRIE	1,094	988	941	826	755	1,094	988	941	826	755
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	601	806	901	1,139	1,282	601	806	901	1,139	1,282
TOTALS:	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763	2,763

Table 41. WP acre projections for the ER-4-D mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	2	2	2	2	2	2	2	2	2	2
FOREST	1,053	931	852	655	536	1,053	931	875	736	652
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	17	15	14	12	10	17	15	14	12	10
PASTURES	1,521	1,370	1,271	1,019	871	1,521	1,370	1,271	1,019	871
PRAIRIE	26	24	23	20	18	26	24	23	20	18
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,753	2,030	2,210	2,664	2,935	1,753	2,030	2,187	2,583	2,819
TOTALS:	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372

Table 42. WP acre projections for the ER-3-E mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	34	31	29	25	22	34	31	29	25	22
FOREST	253	206	196	171	156	253	206	206	206	206
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	20	17	16	14	12	20	17	16	14	12
PASTURES	2,522	2,196	2,069	1,747	1,555	2,522	2,196	2,069	1,747	1,555
PRAIRIE	0	0	0	0	0	0	0	0	0	0
TIDALMARSH	0	0	0	0	0	0	0	0	0	0
URBAN	1,869	2,248	2,388	2,741	2,953	1,869	2,248	2,378	2,706	2,903
TOTALS:	4,698	4,698	4,698	4,698	4,698	4,698	4,698	4,698	4,698	4,698

Table 43. WP acre projections for the ER-2-F mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	97	94	92	86	83	97	94	92	86	83
FOREST	1,095	941	869	689	581	1,095	941	899	793	730
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	66	62	60	56	53	66	62	60	56	53
PASTURES	1,997	1,814	1,716	1,470	1,323	1,997	1,814	1,716	1,470	1,323
PRAIRIE	33	28	26	20	17	33	28	26	20	17
TIDALMARSH	64	55	51	42	36	64	55	55	55	55
URBAN	763	1,121	1,301	1,752	2,022	763	1,121	1,267	1,635	1,854
TOTALS:	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115

Table 44. WP acre projections for the ER-2-G mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	97	94	92	86	83	97	94	92	86	83
FOREST	1,095	941	869	689	581	1,095	941	880	728	636
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	66	62	60	56	53	66	62	60	56	53
PASTURES	1,997	1,814	1,716	1,470	1,323	1,997	1,814	1,716	1,470	1,323
PRAIRIE	33	28	26	20	17	33	28	26	20	17
TIDALMARSH	64	55	51	42	36	64	55	55	55	55
URBAN	763	1,121	1,301	1,752	2,022	763	1,121	1,286	1,700	1,948
TOTALS:	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115

Table 45. WP acre projections for the ER-2-I mitigation measure.

Code	Without-project Conditions					With-project Conditions				
	Calendar Year and Target Year					Calendar Year and Target Year				
	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2000 TY0	2020 TY1	2030 TY11	2055 TY36	2070 TY51
AGCROP	97	94	92	86	83	97	94	92	86	83
FOREST	1,095	941	869	689	581	1,095	941	876	713	616
NEWFOREST	0	0	0	0	0	0	0	0	0	0
OPENWATER	66	62	60	56	53	66	62	60	56	53
PASTURES	1,997	1,814	1,716	1,470	1,323	1,997	1,814	1,716	1,470	1,323
PRAIRIE	33	28	26	20	17	33	28	26	20	17
TIDALMARSH	64	55	51	42	36	64	55	55	55	55
URBAN	763	1,121	1,301	1,752	2,022	763	1,121	1,290	1,715	1,968
TOTALS:	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115

Just as they did in the WOP conditions, these tables indicate urban encroachment will continue to change the face of the Clear Creek watershed over the next 50 years regardless of the implementation of the NED plan and its various mitigation measures.

Predicted WP Variable Trends (Quality)

Rather than presenting copious amounts of tables documenting variable projections here, the authors chose to provide a brief synopsis of general WP trends under the mitigation scenarios (and the E-Team assumptions supporting these trends).[1] Generally speaking, the E-Team surmised that the hydrologic parameters (hydroregime, roughness, etc.) would be improved with the proposed mitigation scenarios – hydroregime would be returned to a somewhat natural state, sinuosity would be recovered, engineering designs would be tailored to introduce manageable levels of roughness (i.e., with tree plantings along the water's edge) and the overall depth of waters would be controlled to simulate more natural conditions. With respect to the vegetative components of the community model, the E-Team assumed mitigation efforts would contend with the invasive presence of exotics and noxious species in the system. They further assumed the planting scenarios adopted would improve the overhead, hanging vegetation and the instream cover returning the system to a shaded riverine complex. The E-team assumed in most instances that habitat fragmentation was still likely to occur in areas unprotected by the

[1] To review the variable WP projections for the mitigation measures contact the District.

mitigation scenarios, and as such, they presumed that landscape level parameters such as adjacent landuse, patchsize, distance between patches, core and edge trends would likely emulate the WOP scenario (counteracting the fragmentation trends seen under the unmitigated NED measure proposal). Detailed (native) planting schemes and intensive 30+ year maintenance measures were predicted to generate highly functioning systems in 40 years or less (Table 46 - Table 60).

Table 46. FOREST cover type WP variable projections for the ER-6-A1a mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	30	30	30	40	45
	ROUGHNESS	0.11	0.08	0.08	0.08	0.08
	SINUOSITY	1.16	1.16	1.16	1.16	1.16
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	80	85
	INSTRMCOV	5	5	5	5	5
	NATIVE	70	75	75	80	80
	OVRHDCOV	30	20	20	20	20
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	5	4	4	4	4
	CORE	0	0	0	0	0
	EDGE	70	60	60	50	45
	NEIGHBOR	55	65	65	75	80
	PATCHSIZE	70	60	60	50	45

Table 47 FOREST cover type WP variable projections for the ER-6-A1b mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	30	30	30	40	45
	ROUGHNESS	0.11	0.08	0.08	0.08	0.08
	SINUOSITY	1.16	1.16	1.16	1.16	1.16
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	80	85
	INSTRMCOV	5	5	5	5	5
	NATIVE	70	75	75	80	80
	OVRHDCOV	30	20	20	20	20
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	5	4	4	4	4
	CORE	0	0	0	0	0
	EDGE	70	60	60	50	45
	NEIGHBOR	55	65	65	75	80
	PATCHSIZE	70	60	60	50	45

Table 48 FOREST cover type WP variable projections for the ER-6-A2a mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	1	1	1	1
	EROSION	3	4	4	5	5
	IMPERVIOUS	30	30	30	40	45
	ROUGHNESS	0.11	0.08	0.08	0.08	0.08
	SINUOSITY	1.16	1.16	1.16	1.16	1.16
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	80	85
	INSTRMCOV	5	5	5	5	5
	NATIVE	70	75	75	80	80
	OVRHDCOV	30	20	20	20	20
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	5	4	4	5	5
	CORE	0	0	0	0	0
	EDGE	70	65	65	55	50
	NEIGHBOR	55	15	15	15	15
	PATCHSIZE	70	65	65	55	50

Table 49. NEWFOREST cover type WP variable projections for the ER-6-A2a mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	0	1	1	1	1
	EROSION	0	4	4	5	5
	IMPERVIOUS	0	30	30	40	45
	ROUGHNESS	0	0.08	0.08	0.08	0.08
	SINUOSITY	0	1.16	1.16	1.16	1.16
	SUBSTRATE	0	1	1	1	1
	WATERDEPTH	0	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	0	5	30	70	75
	INSTRMCOV	0	5	5	5	5
	NATIVE	0	100	100	100	100
	OVRHDCOV	0	20	20	20	20
	VEGSTRATA	0	2	3	5	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	0	7	7	8	8
	AREAWETDRY	0	4	4	5	5
	CORE	0	0	0	0	0
	EDGE	0	65	65	55	50
	NEIGHBOR	0	15	15	15	15
	PATCHSIZE	0	65	65	55	50

Table 50. FOREST cover type WP variable projections for the ER-4-C1 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	2	2	2	2	2
	IMPERVIOUS	40	45	50	60	70
	ROUGHNESS	0.11	0.12	0.12	0.12	0.12
	SINUOSITY	1.74	1.86	1.86	1.86	1.86
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	70	75
	INSTRMCOV	5	20	25	35	40
	NATIVE	60	65	67	70	70
	OVRHDCOV	60	60	60	70	75
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	4	4	3	3
	CORE	40	34	30	25	20
	EDGE	310	265	245	190	160
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	525	450	415	325	270

Table 51. NEWFOREST cover type WP variable projections for the ER-4-C1 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	0	3	3	3	3
	EROSION	0	2	2	2	2
	IMPERVIOUS	0	45	50	60	70
	ROUGHNESS	0	0.12	0.12	0.12	0.12
	SINUOSITY	0	1.86	1.86	1.86	1.86
	SUBSTRATE	0	1	1	1	1
	WATERDEPTH	0	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	0	5	30	70	75
	INSTRMCOV	0	5	10	25	35
	NATIVE	0	100	100	100	100
	OVRHDCOV	0	60	60	65	70
	VEGSTRATA	0	2	3	5	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	0	8	8	8	8
	AREAWETDRY	0	4	4	3	3
	CORE	0	34	30	25	20
	EDGE	0	265	245	190	160
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	0	450	415	325	270

Table 52. FOREST cover type WP variable projections for the ER-5-C1 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	3	3	3	3	3
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.23	1.26	1.26	1.26	1.26
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	80	85
	INSTRMCOV	5	20	25	35	40
	NATIVE	60	65	65	70	70
	OVRHDCOV	20	20	20	30	35
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	20	18	17	15	13
	CORE	5	5	5	5	5
	EDGE	65	55	55	45	40
	NEIGHBOR	30	30	30	40	45
	PATCHSIZE	65	55	55	45	40

Table 53. FOREST cover type WP variable projections for the ER-4-C2 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	2	2	2	2	2
	IMPERVIOUS	40	40	45	55	65
	ROUGHNESS	0.11	0.12	0.12	0.12	0.12
	SINUOSITY	1.74	1.86	1.86	1.86	1.86
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	70	75
	INSTRMCOV	5	20	25	35	40
	NATIVE	60	65	65	70	70
	OVRHDCOV	60	60	60	70	75
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	5	5	5	6
	CORE	40	41	40	30	25
	EDGE	310	280	260	200	165
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	525	480	440	345	285

Table 54. NEWFOREST cover type WP variable projections for the ER-4-C2 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	0	3	3	3	3
	EROSION	0	2	2	2	2
	IMPERVIOUS	0	40	45	55	65
	ROUGHNESS	0	0.12	0.12	0.12	0.12
	SINUOSITY	0	1.86	1.86	1.86	1.86
	SUBSTRATE	0	1	1	1	1
	WATERDEPTH	0	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	0	5	30	70	75
	INSTRMCOV	0	5	10	25	35
	NATIVE	0	100	100	100	100
	OVRHDCOV	0	60	60	65	70
	VEGSTRATA	0	2	3	5	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	0	8	8	8	8
	AREAWETDRY	0	5	5	5	6
	CORE	0	41	40	30	25
	EDGE	0	280	260	200	165
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	0	480	440	345	285

Table 55. FOREST cover type WP variable projections for the ER-5-C2 mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	3	3	3	3	3
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.11	0.11	0.11	0.11	0.11
	SINUOSITY	1.23	1.26	1.26	1.26	1.26
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	75	75	75	80	85
	INSTRMCOV	5	20	25	35	40
	NATIVE	60	65	65	70	70
	OVRHDCOV	20	20	20	30	35
	VEGSTRATA	6	6	6	6	6
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	7	7	8	8
	AREAWETDRY	20	18	17	15	13
	CORE	5	5	5	5	5
	EDGE	65	55	55	45	40
	NEIGHBOR	30	30	30	40	45
	PATCHSIZE	65	55	55	45	40

Table 56. FOREST cover type WP variable projections for the ER-4-D mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	1	3	3	3	3
	EROSION	2	2	2	2	2
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.11	0.08	0.08	0.08	0.08
	SINUOSITY	1.74	3.1	3.1	3.1	3.1
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	45	45	50	65	80
Structure and Biotic Integrity (BIOINTEG)	CANTREE	65	65	65	70	75
	INSTRMCOV	5	20	25	35	40
	NATIVE	60	65	65	70	70
	OVRHDCOV	60	60	60	70	75
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	5	8	8	9	10
	CORE	40	38	35	30	25
	EDGE	310	280	265	225	200
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	525	475	445	380	340

Table 57. FOREST cover type WP variable projections for the ER-3-E mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	3	2	2	1	1
	EROSION	4	4	4	4	4
	IMPERVIOUS	55	65	65	75	85
	ROUGHNESS	0.11	0.08	0.08	0.08	0.08
	SINUOSITY	1.64	1.64	1.64	1.64	1.64
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	40	65	70	80	85
Structure and Biotic Integrity (BIOINTEG)	CANTREE	45	45	45	45	45
	INSTRMCOV	0	5	5	15	20
	NATIVE	40	45	45	50	55
	OVRHDCOV	40	40	40	40	40
	VEGSTRATA	5	5	5	5	5
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	3	8	8	8	8
	AREAWETDRY	0	20	20	20	20
	CORE	0	0	0	0	0
	EDGE	240	205	205	205	205
	NEIGHBOR	0	0	0	0	0
	PATCHSIZE	255	205	205	205	205

Table 58. FOREST cover type WP variable projections for the ER-2-F mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	5	2	2	1	1
	EROSION	3	3	3	3	3
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.1	0.08	0.08	0.08	0.08
	SINUOSITY	1.57	1.57	1.57	1.57	1.57
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	30	55	60	70	75
Structure and Biotic Integrity (BIOINTEG)	CANTREE	70	70	70	70	70
	INSTRMCOV	25	65	65	65	65
	NATIVE	75	85	85	90	90
	OVRHDCOV	60	60	60	60	60
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	2	7	7	8	8
	AREAWETDRY	10	14	14	13	13
	CORE	10	10	10	8	7
	EDGE	135	125	120	110	100
	NEIGHBOR	35	35	35	45	50
	PATCHSIZE	155	140	135	115	100

Table 59. FOREST cover type WP variable projections for the ER-2-G mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	5	2	2	1	1
	EROSION	3	3	3	3	3
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.1	0.08	0.08	0.08	0.08
	SINUOSITY	1.57	1.57	1.57	1.57	1.57
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	30	55	60	70	75
Structure and Biotic Integrity (BIOINTEG)	CANTREE	70	70	70	70	70
	INSTRMCOV	25	65	65	65	65
	NATIVE	75	85	85	90	90
	OVRHDCOV	60	60	60	60	60
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	2	7	7	8	8
	AREAWETDRY	10	12	11	10	10
	CORE	10	10	10	10	10
	EDGE	135	125	115	100	90
	NEIGHBOR	35	35	35	45	50
	PATCHSIZE	155	140	130	115	105

Table 60. FOREST cover type WP variable projections for the ER-2-I mitigation measure.

Model Components	Variables	Calendar Years and Target Years				
		2000	2020	2030	2055	2070
		TY0	TY1	TY11	TY36	TY51
Soils and Hydrology (HYDRO)	ALTERHYDRO	5	2	2	1	1
	EROSION	3	3	3	3	3
	IMPERVIOUS	40	40	40	50	55
	ROUGHNESS	0.1	0.08	0.08	0.08	0.08
	SINUOSITY	1.57	1.57	1.57	1.57	1.57
	SUBSTRATE	1	1	1	1	1
	WATERDEPTH	30	55	60	70	75
Structure and Biotic Integrity (BIOINTEG)	CANTREE	70	70	70	70	70
	INSTRMCOV	25	65	65	65	65
	NATIVE	75	85	85	90	90
	OVRHDCOV	60	60	60	60	60
	VEGSTRATA	7	7	7	7	7
Spatial Integrity and Disturbance (SPATIAL)	ADJLANDUSE	2	7	7	8	8
	AREAWETDRY	10	6	6	5	4
	CORE	10	10	10	10	10
	EDGE	135	125	115	95	80
	NEIGHBOR	35	45	45	55	65
	PATCHSIZE	155	140	130	105	85

WP Results

The changes predicted above under the proposed mitigation measures resulted in quantifiable benefits for both the floodplain forest and wet coastal prairie communities across the watershed (Table 61).[1]

Table 61. Final results for the mitigation analysis.

Mitigation Measure	Eco-Reach 2	Eco-Reach 3	Eco-Reach 4	Eco-Reach 5	Eco-Reach 6	SUM of Net AAHUs
ER-6-A1a					8	8
ER-6-A1b					8	8
ER-6-A2a					20	20
ER-4-C1			97			97
ER-5-C1				34		34
ER-4-C2			117			117
ER-5-C2				34		34
ER-4-D			179			179
ER-3-E		48				48
ER-2-F	99					99
ER-2-G	65					65
ER-2-I	46					46
SUM of Net AAHUs	210	48	393	68	36	755

The single most productive measure was the *D* measure that produces 179 AAHUs in Eco-Reach 4. The *C2* scenario was the next most productive measure, generating 117 AAHUs in Eco-Reach 4 and an additional 34 AAHUs in Eco-Reach 5 (Total = 151 AAHUs). Following closely behind was the *C1* measure that produces 97 AAHUs in Eco-Reach 4 and an additional 34 AAHUs in Eco-Reach 5 (Total = 131 AAHUs). It was important to note that 106 AAHUs were needed to fully compensate for the proposed NED measure – three of these measures could stand alone as replacement measures for the predicted losses (i.e., *C1*, *C2*, and *D*) (Figure 58).

[1] To review electronic summaries of the without-project results generated by the E Team contact the District.

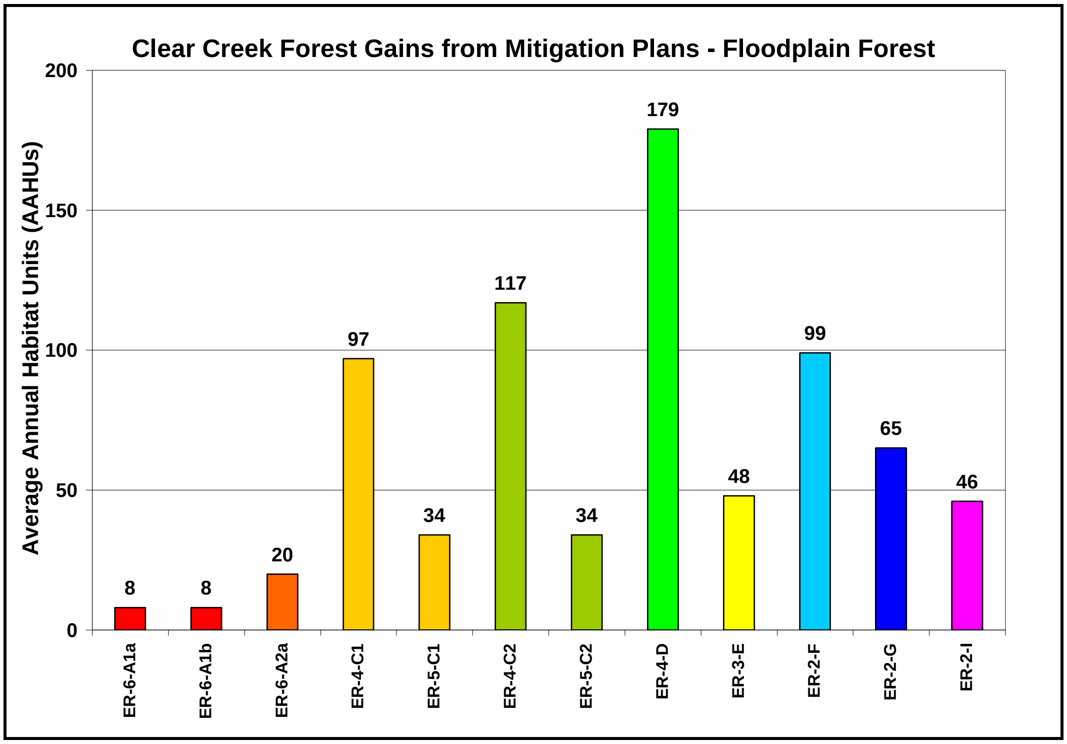

Figure 58. Final results of the HEP analysis providing the results of the mitigation measures for the forested floodplain community.

Ultimately, the identification of suitable mitigation measures hinged upon the cost analyses comparisons of the proposed measures. Below we detail the HEP and CEA/ICA analyses that evaluated the productivity of the proposed mitigation measures for the study.

Cost Analysis

Cost effectiveness (CEA) and incremental cost analyses (ICA) were performed using the IWR Planning Suite software.[1] The sections below summarize the outputs, costs and CEA/ICA results generated as the E-Team evaluated the suite of Clear Creek mitigation alternatives.

Plan Costs

The District developed annualized "first costs" for the proposed mitigation measures using a 4.875% interest rate and a 0.053722282 amoritization rate for construction (amortized over the 50-year project life) (Table 62).[2]

1 http://www.pmcl.com/iwrplan/

2 Refer all questions regarding cost generation to the District.

These costs were then added to the annualized O&M costs for each measure and summed to generate the total annualized costs per measure (Table 63).

Table 62. First cost annualization data for the proposed mitigation measures.

Measures	Description	Contract Cost	Monitoring	Total	Annualized First Cost
ER-6-A1 (Forest)	20 acre restoration Floodplain Forest	$4,738,450	$23,692	$4,762,142	**$255,833**
ER-6-A2a	29 acre restoration/9 acres creation Floodplain Forest	$2,015,770	$10,079	$2,025,849	**$108,833**
ER-4-C1 + ER-5-C1	31 acres restoration Floodplain Forest	$2,739,208	$13,696	$2,752,904	**$147,892**
ER-4-C2 + ER-5-C2	103 acres restoration Floodplain Forest	$5,634,123	$28,171	$5,662,294	**$304,191**
ER-4-D	272 acres restoration Floodplain Forest	$9,446,370	$47,232	$9,493,602	**$510,018**
ER-3-E	241 acres restoration Floodplain Forest	$8,373,210	$41,866	$8,415,076	**$452,077**
ER-2-F	388 acres restoration Floodplain Forest	$13,454,180.00	$67,271	$13,521,451	**$726,403**
ER-2-G	144 acres restoration Floodplain Forest	$5,016,465.00	$25,082	$5,041,547	**$270,843**
ER-2-I	91 acres restoration Floodplain Forest	$3,185,710.00	$15,929	$3,201,639	**$171,999**

Interest rate = 4.875%.
Amoritization factor = 0.053722282.
Project Life =50 years.

Table 63. Annualized costs input into the cost analyses for the Clear Creek mitigation plans.

Measures	Description	Annualized First Cost	Annualized O&M	Total Annualized Costs
ER-6-A1 (Forest)	20 acre restoration Floodplain Forest	$255,833	$192,341	**$448,174**
ER-6-A2a	29 acre restoration/9 acres creation Floodplain Forest	$108,833	$116,381	**$225,214**
ER-4-C1 + ER-5-C1	31 acres restoration Floodplain Forest	$147,892	$94,942	**$242,834**
ER-4-C2 + ER-5-C2	103 acres restoration Floodplain Forest	$304,191	$315,454	**$619,645**
ER-4-D	272 acres restoration Floodplain Forest	$510,018	$833,042	**$1,343,060**
ER-3-E	241 acres restoration Floodplain Forest	$452,077	$738,100	**$1,190,177**
ER-2-F	388 acres restoration Floodplain Forest	$726,403	$1,188,310	**$1,914,713**
ER-2-G	144 acres restoration Floodplain Forest	$270,843	$441,022	**$711,866**
ER-2-I	91 acres restoration Floodplain Forest	$171,999	$278,702	**$450,701**

All possible combinations of these measures were generated in the CE-ICA analysis to form potential mitigation plans with 2 exceptions:

1. the increments of measure *A1* (i.e., *a* and *b*) could not be combined together; and
2. the increments of measure C (i.e., *C1* and *C2*) could not be combined together.

These 384 possible plans, in turn, were compared against the total annualized outputs generated in the HEP analyses (AAHUs) using CE/ICA (Table 64).

Table 64. Costs and outputs submitted to CE/ICA analysis.

Measures	Average Annual Habitat Units (AAHUs)	Total Annualized Costs	Annualized Cost per Output ($/AAHU)
ER-6-A1	8	430405	$53,801
ER-6-A2a	20	225214	$11,261
ER-4-C1 + ER-5-C1	131	242835	$1,854
ER-4-C2 + ER-5-C2	151	619645	$4,104
ER-4-D	179	1343060	$7,503
ER-3-E	48	1190177	$24,795
ER-2-F	99	1914714	$19,341
ER-2-G	65	711866	$10,952
ER-2-I	46	450701	$9,798

Cost Analysis Results

Cost Effective Analysis

Cost effective analyses identified the least-costly plans for each level of output. The three criteria used for identifying non-cost effective plans or combinations include: (1) The same level of output could be produced by another plan at less cost; (2) A larger output level could be produced at the same cost; or (3) A larger output level could be produced at the least cost. Table 65 and Figure 59 below detail the results of the cost effective analyses for the floodplain forest mitigation plans. Twenty-nine plans (combinations of measures) were considered cost-effective. These ranged from $225,214 and $6,885,782 and produced between 20 and 616 AAHUS of floodplain forest.

Table 65. Cost effective analysis results for the floodplain forest mitigation plans.

Count	Potential Mitigation Plans for the Floodplain Forest Community	Reaches Affected	Average Annual Habitat Units (AAHUs)	Costs ($1000)	Average Cost ($1000)
1	No Action Plan	–	0	0	0
2	A2a	6	20	225,214	11,261
3	C1	4 and 5	131	242,835	1,854
4	C1 + A2a	4, 5 and 6	151	468,049	3,100
5	C1 + I	2, 4 and 5	177	693,536	3,918
6	C1 + I + A2a	2, 4, 5 and 6	197	918,750	4,664
7	C1 + G + A2a	2, 4, 5 and 6	216	1,179,915	5,463
8	C2 + I + A2a	2, 4, 5 and 6	217	1,295,560	5,970
9	C1 + G + I	2, 4 and 5	242	1,405,402	5,807
10	C1 + D	4 and 5	310	1,585,895	5,116
11	C1 + D + A2a	4, 5 and 6	330	1,811,109	5,488
12	C1 + D + I	2, 4 and 5	356	2,036,596	5,721
13	C1 + D + I + A2a	2, 4, 5 and 6	376	2,261,810	6,015
14	C1 + D + G + A2a	2, 4, 5 and 6	395	2,522,975	6,387
15	C2 + D + I + A2a	2, 4, 5 and 6	396	2,638,620	6,663
16	C1 + D + G + I	2, 4 and 5	421	2,748,462	6,528
17	C1 + D + G + I + A2a	2, 4, 5 and 6	441	2,973,676	6,743
18	C2 + D + G + I + A2a	2, 4, 5 and 6	461	3,350,486	7,268
19	C2 + D + G + I + A1a + A2a	2, 4, 5 and 6	469	3,780,891	8,062
20	C1 + D + E + G + I + A2a	2, 3, 4, 5, and 6	489	4,163,853	8,515
21	C1 + D + F + G + A2a	2, 4, 5 and 6	494	4,437,689	8,983
22	C2 + D + E + G + I + A2a	2, 3, 4, 5, and 6	509	4,540,663	8,921
23	C1 + D + F + G + I	2, 4, 5 and 6	520	4,663,176	8,968
24	C1 + D + F + G + I + A2a	2, 4, 5 and 6	540	4,888,390	9,053
25	C2 + D + F + G + I + A2a	2, 4, 5 and 6	560	5,265,200	9,402
26	C2 + D + F + G + I + A1a + A2a	2, 4, 5 and 6	568	5,695,605	10,027
27	C1 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	588	6,078,567	10,338
28	C2 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	608	6,455,377	10,617
29	C2 + D + E + F + G + I + A1a + A2a	2, 3, 4, 5, and 6	616	6,885,782	11,178

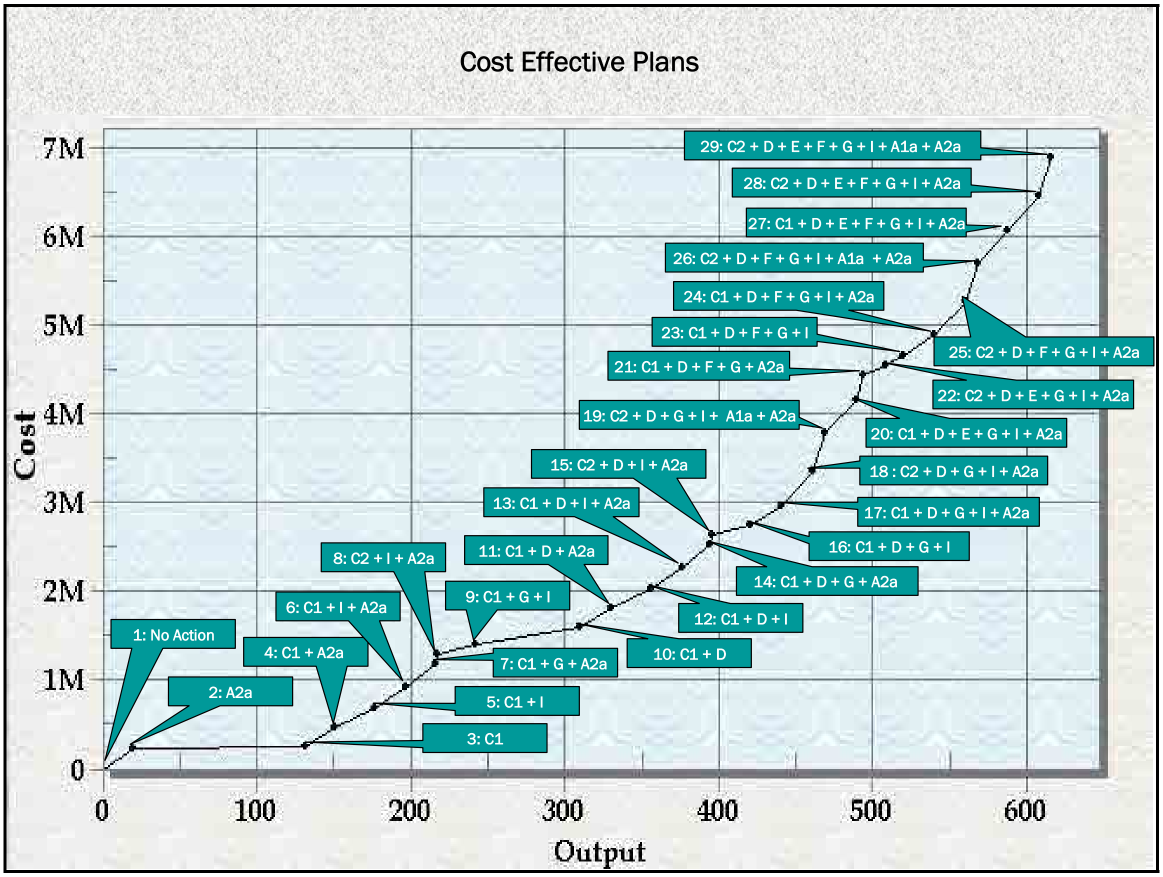

Figure 59. Cost effective analysis results (graphical depiction) for the floodplain forest mitigation plans.

Incremental Cost Analysis

ICA compared the incremental costs for each additional unit of output. The first step in developing "Best Buy" plans was to determine the incremental cost per unit. The plan with the lowest incremental cost per unit over the No Action Alternative was the first incremental Best Buy plan. Plans that had higher incremental costs per unit for a lower level of output were eliminated. The next step was to recalculate the incremental cost per unit for the remaining plans. This process was reiterated until the lowest incremental cost per unit for the next level of output was determined. The intent of the incremental analysis was to identify large increases in cost relative to output. Table 66 and Figure 60 below detail the results of the incremental cost analyses for the floodplain forest mitigation plans.

Table 66. Incremental cost analysis results for the floodplain forest mitigation plans.

Count	Potential Mitigation Plans for the Floodplain Forest Community	Reaches Affected	Average Annual Habitat Units (AAHUs)	Costs ($1000)	Average Cost ($1000)	Incremental Cost ($1000)	Incremental Outputs (AAHUs)	Incremental Cost Per Output ($1000)
1	No Action	--	0	$0	$0	$0	0	$0
2	C1	4 and 5	131	$242,835	$1,854	$242,835	131	$1,854
3	C1 + D	4 and 5	310	$1,585,895	$5,116	$1,343,060	179	$7,503
4	C1 + D + I	2, 4 and 5	356	$2,036,596	$5,721	$450,701	46	$9,798
5	C1 + D + G + I	2, 4 and 5	421	$2,748,462	$6,528	$711,866	65	$10,952
6	C1 + D + G + I + A2a	2, 4, 5, and 6	441	$2,973,676	$6,743	$225,214	20	$11,261
7	C2 + D + G + I + A2a	2, 4, 5, and 6	461	$3,350,486	$7,268	$376,810	20	$18,841
8	C2 + D + F + G + I + A2a	2, 4, 5, and 6	560	$5,265,200	$9,402	$1,914,714	99	$19,341
9	C2 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	608	$6,455,377	$10,617	$1,190,177	48	$24,795
10	C2 + D + E + F + G + I + A1a + A2a	2, 3, 4, 5, and 6	616	$6,885,782	$11,178	$430,405	8	$53,801

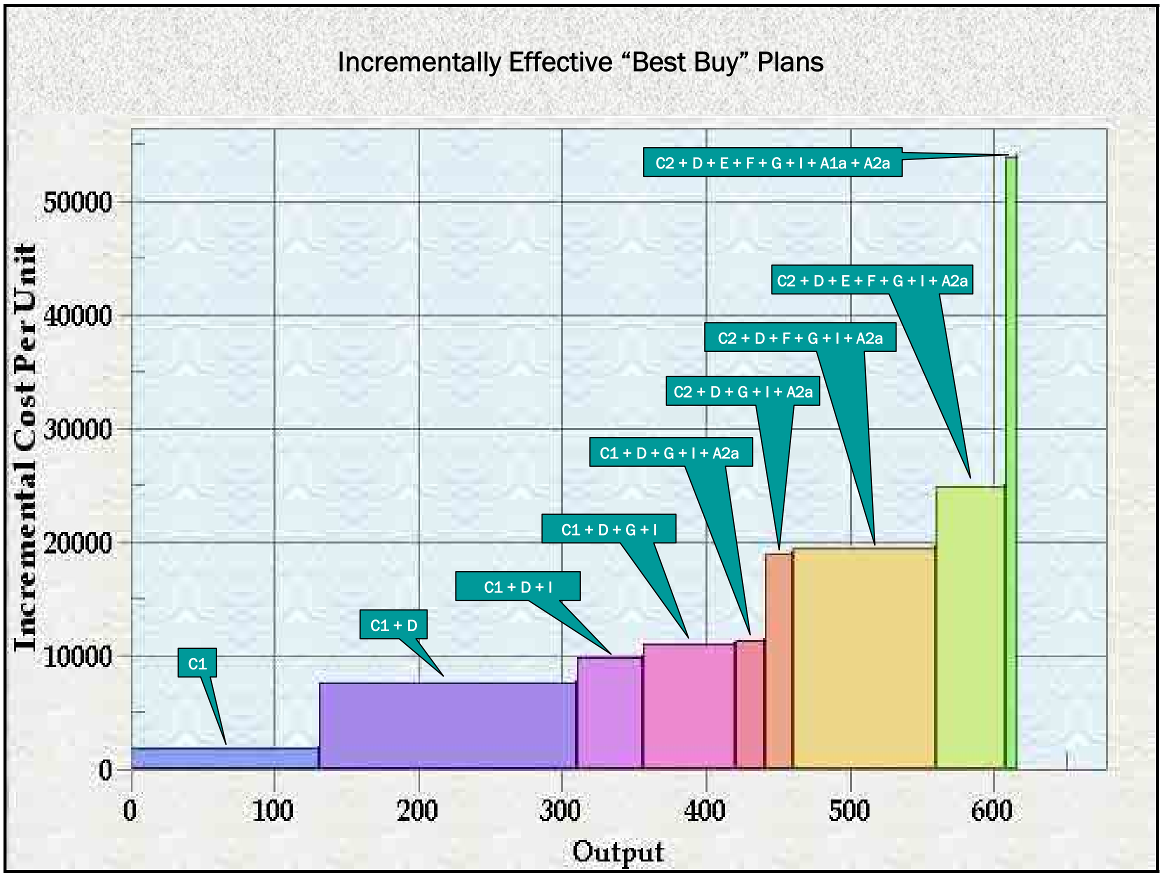

Figure 60. Incremental cost analysis results (graphical depiction) for the floodplain forest mitigation plans.

Nine combinations of designs were considered incrementally effective. These ranged from $242,835 and $6,885,782 and produced between 131 and 616 AAHUS of floodplain forest. The first plan, *ER-4-C1/ER-5-C1* generated enough outputs (131 AAHUs) to satisfy the mitigation requirements (-106 AAHUs), and was the most cost-effective, incrementally effective solution proposed.

7 Summary and Conclusions

Although the District went to great lengths to avoid and minimize impacts under the proposed NED plan, impacts were still anticipated (106 AAHUs for the floodplain forest community). These impacts must be fully compensated for (in-kind), and as such, a suite of mitigation plans afforded full compensation in a cost effective and incrementally effective manner. By focusing on each cost analysis result in turn, the results indicate *ER-4/5-C1* compensates for the impacts in a cost effective, incrementally effective manner (Table 67). The total cost for the NED plan, with mitigation, would be $339,126,000 (i.e. the fully-funded cost), and would result in net overall benefits in excess of the impacts (+25 AAHUs of floodplain forest). The overall footprint of the project would encompass 729 acres. Although 278 acres of floodplain forest would be impacted, 155 acres would be preserved, restored and/or reestablished with the implementation of on-site avoidance, and minimization activities as well as the construction of the indicated offsite mitigation plan.

Given these results, the District can reasonably assume that the goals and objectives of the Clear Creek study have been met – the impacts of the proposed plan can be offset and the community structure and functions will remain intact for the Clear Creek ecosystems. This community-based approach allowed the E-Team to assess impacts and benefits in terms of key components (i.e., hydrology and soils, biotic integrity, and spatial complexity) with the intent of mimicking the dynamic processes seen in the natural ecosystems of the region, yielding more comprehensive and holistic results. The approach served to inject valuable on-the-ground knowledge of experts and stakeholders into the strategic planning of the study's alternative designs and served as a forum for the transparent assessment of impacts to the system's critical ecosystem functions and structure throughout the process.

Table 67. Summary of the measures incorporated into the final NED plan and the conversion of the forested community other landscape features to construct the plan (units = acres for all columns except the last column on the right).

Measures	Footprints (Acres)	FOREST (Floodplain Forest)			PRAIRIE	AGCROP	OPENWATER	PASTURES	URBAN	Net Annualized Outputs (AAHUs)
		Impacted	Preserved, Restored and Rehabilitated	reestablished Floodplain Forest (NEWFOREST)	Coastal Prairies	Farms and Croplands	Open Bodies of Water Deeper than 1-3m	Old Fields, Haylands and Pastures	Existing Residential, Industrial and Transportation	Floodplain Forest
Mainstem-Upstream Conveyance (*Super C*)	432	-186	88	33	-3	0	-1	-71	-15	-64
Mainstem-Downstream Conveyance [*C5(d)*]	109	-72	34	0	0	0	0	-2	-1	5
Turkey Creek Conveyance (*TKC1d*)	68	-20	0	0	0	0	-1	-43	-4	-47
Mary's Creek Conveyance (Ma*C2a*)	63	0	0	0	-5	0	0	-45	-13	0
Mud Gully Conveyance (*MudG1b*)	26	0	0	0	0	0	0	-5	-21	0
NED Plan Totals	1,010	-278	122	33	-8	0	-2	-166	-54	-106
ER-4-C1 and ER-5-C1	31	0	31	0	0	0	0	0	0	131
Mitigation Plan	31	0	31	0	0	0	0	0	0	131

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Appendix A: Notation

AAHU	Average Annual Habitat Unit
BCDD	Brazoria County Drainage District No. 4
BCR	Benefit-Cost Ratio
CEA	Cost Effectiveness Analysis
CT	Cover Type
EC	Engineering Circular
EIS	Environmental Impact Statement
ER	Eco-Reach
ERDC-EL	Engineer Research and Development Center, Environmental Laboratory
E-Team	Ecosystem Assessment Team
ETR	Expert Technical Review
ETRT	Expert Technical Review Team
EXHEP	EXpert Habitat Evaluation Procedures Module
EXHGM	EXpert Hydrogeomorphic Approach to Wetland Assessments Module
GBNEP	Galveston Bay National Estuary Program
GIS	Geographic Information System
GRP	General Reevaluation Plan
HCFCD	Harris County Flood Control District
HEAT	Habitat Evaluation and Assessment Tools
HEP	Habitat Evaluation Procedures
HSI	Habitat Suitability Index
HU	Habitat Unit
ICA	Incremental Cost Analysis
ITRT	Independent Technical Review Team
LRSI	Life Requisite Suitability Index
LPDT	Laboratory-based Project Delivery Team
LPP	Locally Preferred Plan
LTR	Laboratory-based Technical Review
LTRT	Laboratory-based Technical Review Team
LULC	Land Use/Land Cover
NED	National Economic Development Plan

NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
PDT	Project Delivery Team
PMIP	USACE Planning Models Improvement Program
RA	Relative Area
ROW	Right-of-Way
SI	Suitability Index
TCEQ	Texas Commission on Environmental Quality
TGLO	Texas General Land Office
TPWD	Texas Parks and Wildlife Department
TY	Target Year
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WOP	Without-project Condition
WP	With-project Condition

Appendix B: Glossary of Terms

Activity	The smallest component of a management measure that is typically a nonstructural, ongoing (continuing or periodic) action in USACE planning studies (Robinson, Hansen, and Orth 1995).
Alternative (aka Alternative Plan, Plan, or Solution)	An alternative can be composed of numerous management measures that in turn are comprised of multiple features or activities. Alternatives are mutually exclusive, but management measures may or may not be combinable with other management measures or alternatives (Robinson, Hansen, and Orth 1995). In HEP analyses, this is the "With-project" condition commonly used in restoration studies. Some examples of Alternatives include: *Alternative 1: Plant food plots, increase wetland acreage by 10 percent, install 10 goose nest boxes, and build a fence around the entire site.* *Alternative 2: Build a dam, inundate 10 acres of riparian corridor, build 50 miles of supporting levee, and remove all wetlands in the levee zone.*

Alternative (cont)

Alternative 3: Reduce the grazing activities on the site by 50 percent, replant grasslands (10 acres), install a passive irrigation system, build 10 escape cover stands, use 5 miles of willow fascines along the stream bank for stabilization purposes.

Assessment Model

A simple mathematical tool that defines the relationship between ecosystem/landscape scale variables and either functional capacity of a wetland or suitability of habitat for species and communities. Habitat Suitability Indices are examples of assessment models that the HEAT software can be used to assess impacts/benefits of alternatives.

Average Annual Habitat Units (AAHUs)

A quantitative result of annualizing Habitat Unit (HU) gains or losses across all years in the period of analysis.

AAHUs = Cumulative HUs ÷ Number of years in the life of the project, where:

Cumulative HUs =

$$\sum (T2 - T1)[\{((A1\ H1 + A2\ H2)\ /\ 3)\} + \{((A2\ H1 + A1\ H2)\ /\ 6)\}]$$

and where:

T1 = First Target Year time interval
T2 = Second Target Year time interval
A1 = Area of available wetland assessment area at beginning of T1
2 = Area of available wetland assessment area at end of T2
H1 = HSI at beginning of T1
H2 = HSI at end of T2.

Baseline Condition (aka Existing Conditions) The point in time before proposed changes are implemented in habitat assessment and planning analyses. Baseline is synonymous with Target Year (TY = 0).

Blue Book In the past, the USFWS was responsible for publishing documents identifying and describing HSI models for numerous species across the nation. Referred to as "Blue Books" in the field, due primarily to the light blue tint of their covers, these references fully illustrate and define habitat relationships and limiting factor criteria for individual species nationwide. Blue Books provide: HSI Models, life history characteristics, SI curves, methods of variable collection, and referential material that can be used in the application of the HSI model in the field. For copies of Blue Books, or a list of available Blue Books, contact your local USFWS office.

Calibration The use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.

Combined NED/NER Plan (Combined Plan) Plans that produce both types of benefits such that no alternative plan or scale has a higher excess of NED plus NER benefits over total project costs (USACE 2003).

Cover Type (CT)	Homogenous zones of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, cover types are defined on the basis of species recognition and dependence.
Ecosystem	A biotic community, together with its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole, unified through life processes. Ecosystems are hierarchical, and can be viewed as nested sets of open systems in which physical, chemical and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multi-states, more localized watersheds or a smaller complex of aquatic habitat.
Ecosystem Assessment Team (E-Team)	An interdisciplinary group of regional and local scientists responsible for determining significant resources, identification of reference sites, construction of assessment models, definition of reference standards, and calibration of assessment models. In some instances the E-Team is also referred to as the Environmental Assessment Team or simply the Assessment Team.

Ecosystem Integrity

The state or condition of an ecosystem that displays the biodiversity characteristic of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning (SERI 2004). These characteristics are often defined in terms such as health, biodiversity, stability, sustainability, naturalness, wildness, and beauty.

Equivalent Optimal Area (EOA)

The concept of equivalent optimal area (EOA) is used in HEP applications where the composition of the landscape, in relation to providing life requisite habitat, is an important consideration. An EOA is used to weight the value of the LRSI score to compensate for this inter-relationship. For example, for optimal wood duck habitat conditions, at least 20 percent of an area should be composed of cover types providing brood-cover habitat (a life requisite). If an area has less than 20 percent in this habitat, the suitability is adjusted downward.

Existing Condition

Also referred to as the baseline condition, the existing condition is the point in time before proposed changes, and is designated as Target Year (TY = 0) in the analysis.

Feature

A feature is the smallest component of a management measure that is typically a structural element requiring construction in USACE planning studies (Robinson, Hansen, and Orth 1995).

Field Data This information is collected on various parameters (i.e., variables) in the field, and from aerial photos, following defined, well-documented methodology in typical HEP applications. An example is the measurement of percent herbaceous cover, over ten quadrats, within a cover type. The values recorded are each considered “field data.” Means of variables are applied to derive suitability indices and/or functional capacity indices.

Goal A goal is defined as the end or final purpose. Goals provide the reason for a study rather than a reason to formulate alternative plans in USACE planning studies (Yoe and Orth 1996).

Guild A group of functionally similar species with comparable habitat requirements whose members interact strongly with one another, but weakly with the remainder of the community. Often a species HSI model is selected to represent changes (impacts) to a guild.

Habitat Assessment The process by which the suitability of a site to provide habitat for a community or species is measured. This approach measures habitat suitability using an assessment model to determine an HSI.

Habitat Suitability Index Model (HSI)	A quantitative estimate of suitability habitat for a site. The ideal goal of an HSI model is to quantify and produce an index that reflects functional capacity at the site. The results of an HSI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland. An HSI model can be defined in words, or mathematical equations, that clearly describe the rules and assumptions necessary to combine functional capacity indices in a meaningful manner for the wetland.
Habitat Suitability Index Model (HSI) (cont)	For example: HSI = (SI V_1 * SI V_2) / 4, where: SI V_1 is the Variable Subindex for variable 1; SI V_2 is the SI for variable 2

Habitat Unit (HU) A quantitative environmental assessment value, considered the biological currency in HEP. Habitat Units (HUs) are calculated by multiplying the area of available habitat (quantity) by the quality of the habitat for each species or community. Quality is determined by measuring limiting factors for the species (or community), and is represented by values derived from Habitat Suitability Indices (HSIs).

HU = AREA (acres) X HSI.

Changes in HUs represent potential impacts or improvements of proposed actions.

Life Requisite Suitability Index (LRSI) A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting life requisite component within the habitat type in HEP applications. LRSIs are depicted using scatter plots and bar charts (i.e., life requisite suitability curves). The LRSI value (Y axis) ranges on a scale from 0.0 to 1.0, where an LRSI = 0.0 means the factor is extremely limiting and an LRSI = 1.0 means the factor is in abundance (not limiting) in most instances.

Limiting Factor A variable whose presence/absence directly restrains the existence of a species or community in a habitat in HEP applications. A deficiency of the limiting factor can reduce the quality of the habitat for the species or community, while an abundance of the limiting factor can indicate an optimum quality of habitat for the same species or community.

Locally Preferred Plan (LPP)	The name frequently given to a plan that is preferred by the non-Federal sponsor over the National Economic Development (NED) plan (USACE 2000).
Management Measure	The components of a plan that may or may not be separable actions that can be taken to affect environmental variables and produce environmental outputs. A management measure is typically made up of one or more features or activities at a particular site in USACE Planning studies (Robinson, Hansen, and Orth 1995).
Measure	The act of physically sampling variables such as height, distance, percent, etc., and the methodology followed to gather variable information in HEP applications (i.e., see “Sampling Method” below).

Multiple Formula Model (MM) (aka Life Requisite Model)

In HEP applications, there are two types of HSI models, the Single Formula Model (SM) (refer to the definition below) and the Multiple Formula Model (MM). In this case a multiple formula model is, as one would expect, a model that uses more than one formula to assess the suitability of the habitat for a species or a community. If a species/community is limited by the existence of more than one life requisite (food, cover, water, etc.), and the quality of the site is dependent on a minimal level of each life requisite, then the model is considered an MM model. In order to calculate the HSI for any MM, one must derive the value of a Life Requisite Suitability Index (LRSI) (see definition below) for each life requisite in the model – a process requiring the user to calculate multiple LRSI formulas. This Multiple Formula processing has led to the name "Multiple Formula Model" in HEP.

Multi-Criteria Decision Analysis (MCDA)

The study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process", as defined by the International Society on Multiple Criteria Decision Making (http://www.terry.uga.edu/mcdm/ MAY 2008).

MCDA is also referred as Multi-Criteria Decision Making (MCDM), Multi-Dimensions Decision-Making (MDDM), and Multi-Attributes Decision Making (MADM)

National Economic Development (NED) Plan	For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economics benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASACW) may grant an exception when there are overriding reasons for selecting another plan based upon other Federal, State, local and international concerns (USACE 2000).
National Ecosystem Restoration (NER) Plan	For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan. (USACE 2000).
No Action Plan (aka No Action Alternative or Without-project Condition)	Also referred to as the Without-project condition, the No Action Plan describes the project area's future if there is no Federal action taken to solve the problem(s) at hand. Every alternative is compared to the same Without-project condition (Yoe and Orth 1996).

Objective	A statement of the intended purposes of the planning process; it is a statement of what an alternative plan should try to achieve. More specific than goals, a set of objectives will effectively constitute the mission statement of the Federal/non-Federal planning partnership. A planning objective is developed to capture the desired changes between the without- and With-project conditions that when developed correctly identify effect, subject, location, timing, and duration (Yoe and Orth 1996).
Plan (aka Alternative, Alternative Plan, or Solution)	A set of one or more management measures functioning together to address one or more planning objectives (Yoe and Orth 1996). Plans are evaluated at the site level with HEP or other assessment techniques and cost analyses in restoration studies (Robinson, Hansen, and Orth 1995).
Program	Combinations of recommended plans from different sites make up a program. Where the recommended plan at each such site within a program is measured in the same units, a cost analyses can be applied in a programmatic evaluation (Robinson, Hansen, and Orth 1995).
Project Area	The area that encompasses all activities related to an ongoing or proposed project.
Project Manager	Any biologist, economist, hydrologist, engineer, decision- maker, resource project manager, planner, environmental resource specialist, limnologist, etc., who is responsible for managing a study, program, or facility.

Reference Domain	The geographic area from which reference communities or wetland are selected in HEP applications. A reference domain may, or may not, include the entire geographic area in which a community or wetland occurs.
Reference Ecosystems	All the sites that encompass the variability of all conditions within the region in HEP applications. Reference ecosystems are used to establish the range of conditions for construction and calibration of HSIs and establish reference standards.
Reference Standard Ecosystems	The ecosystems that represent the highest level of habitat suitability or function found within the region for a given species or community in HEP applications.
Relative Area (RA)	The relative area is a mathematical process used to "weight" the various applicable cover types on the basis of quantity in HEP applications. To derive the relative area of a model's CTs, the following equation can be utilized: $\text{Relative Area} = \frac{\text{Acres of Cover Type}}{\text{Total Applicable Area}}$ where: Acres of Cover Type = only those acres assigned to the cover type of interest within the site Total Applicable Area = the sum of the acres associated with the model at the site.

Risk

The volatility of potential outcomes. In the case of ecosystem values, the important risk factors are those that affect the possibility of service flow disruptions and the reversibility of service flow disruptions. These are associated with controllable and uncontrollable on-site risk factors (e.g., invasive plants, overuse, or restoration failure) and landscape risk factors (e.g., changes in adjacent land uses, water diversions) (King et al. 2000).

Sampling Method

The protocol followed to collect and gather field data in HEP and HGM applications. It is important to document the relevant criteria limiting the collection methodology. For example, the time of data collection, the type of techniques used, and the details of gathering this data should be documented as much as possible. An example of a sampling method would be:

Between March and April, run five random 50-m transects through the relevant cover types. Every 10-m along the transect, place a 10-m^2 quadrat on the right side of the transect tape and record the percent herbaceous cover within the quadrat. Average the results per transect.

Scale In some geographical methodologies, the scale is the defined size of the image in terms of miles per inch, feet per inch, or pixels per acres. Scale can also refer to different "sizes" of plans (Yoe and Orth 1996) or variations of a management measure in cost analyses. Scales are mutually exclusive, and therefore a plan or alternative may only contain one scale of a given management measure (Robinson, Hansen, and Orth 1995).

Sensitivity Analysis The study of how the variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model (Saltelli et al. 2008). In other words, it is a technique for systematically changing parameters in a model to determine the effects of such changes. In more general terms uncertainty and sensitivity analyses investigate the robustness of a study when the study includes some form of mathematical modeling.

Single Formula Model (SM) In habitat assessments, there are two potential types of models selected to assess change at a site – the Single Formula Model and the Multiple Formula Model (refer to the definition above). In this instance, an HSI model is based on the existence of a single life requisite requirement, and a single formula is used to depict the relationship between quality and carrying capacity for the site.

Site	The location upon which the project manager will take action, evaluate alternatives and focus cost analysis (Robinson, Hansen, and Orth 1995).
Solutions (aka Alternative, Alternative Plan, or Plan)	A solution is a way to achieve all or part of one or more planning objectives (Yoe and Orth 1996). In cost analysis, this is the alternative (see definition above).
Spreadsheet	A type of computer file or page that allows the organization of data (alpha-numeric information) in a tabular format. Spreadsheets are often used to complete accounting/economic exercises.
Suitability Index (SI)	A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type in HEP applications. These indices are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges on a scale from 0.0 to 1.0, where an SI = 0.0 means the factor is extremely limiting, and an SI = 1.0 means the factor is in abundance (not limiting) for the species/community (in most instances).

Target Year (TY) A unit of time measurement used in HEP that allows the project manager to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1, and a TY = X_2. TY_1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TY_{X2} designates the ending target year. A new target year must be assigned for each year the project manager intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses.

Trade-Offs (TOs) Used to adjust the model outputs by considering human values. There are no right or proper answers, only acceptable ones. If trade-offs are used, outputs are no longer directly related to optimum habitat or wetland function (Robinson, Hansen, and Orth 1995).

Validation Establishing by objective yet independent evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place. Validation can encompass all of the information that can be verified, as well as all of the things that cannot -- i.e., all of the information that the model designers might never have anticipated the user might want or expect the product to do.

For purposes of this effort, *validation* refers to independent data collections (bird surveys, water quality surveys, etc.) that can be compared to the model outcomes to determine whether the model is capturing the essence of the ecosystem's functionality.

Variable A measurable parameter that can be quantitatively described, with some degree of repeatability, using standard field sampling and mapping techniques. Often, the variable is a limiting factor for a wetland's functional capacity used in the development of SI curves and measured in the field (or from aerial photos) by personnel, to fulfill the requirements of field data collection in an HEP application. Some examples of variables include: height of grass, percent canopy cover, distance to water, number of snags, and average annual water temperature.

Verification	Model verification refers to a process by which the development team confirms by examination and/or provision of objective evidence that specified requirements of the model have been fulfilled with the intention of assuring that the model performs (or behaves) as it was intended. Sites deemed to be highly functional wetlands according to experts, should produce high index scores. Sites deemed dysfunctional (by the experts) should produce low index scores.
Without-project Condition(WOP) (aka No Action Plan or No Action Alternative)	Often confused with the terms "Baseline Condition" and "Existing Condition," the Without-Project Condition is the expected condition of the site without implementation of an alternative over the life of the project, and is also referred to as the "No Action Plan" in traditional planning studies (Yoe and Orth 1996; USACE 2000).
With-project Condition (WP)	In planning studies, this term is used to characterize the condition of the site after an alternative is implemented (Yoe and Orth 1996; USACE 2000).

Appendix C: Index Model Components and Variables

Below, the component algorithms and variables associated with the floodplain forest community index model developed for the Clear Creek study are provided in tabular format (Table C- 1). For further details refer to Burks-Copes and Webb 2010.

Table C- 1. Variables used in the Clear Creek community index models.

Variable Code	Variable Description
ADJLANDUSE	Identification of the Predominant Adjacent Lands Use Class
ALTERHYDRO	Alterations of Hydrology That Effect Hydroperiod
AREAWETDRY	Ratio of Wet to Total Prairie or Forest Acreage
CANTREE	Percent Tree Canopy Cover
CORE	Size of the Core Area (acres)
EDGE	Size of the Edge Area (acres)
EROSION	Erosion Potential
IMPERVIOUS	Percent of the Area That Is Developed
INSTRMCOV	The Amount of the Stream Characterized By In-Stream Cover (%)
NATIVE	Percent Tree Canopy That Is Native Species
NEIGHBOR	Distance to the Nearest Neighbor of Like Patches (m)
OVRHDCOV	Percent of the Water Surface Shaded By Overhanging Vegetation
PATCHSIZE	Patch Size (acres)
ROUGHNESS	Manning's Roughness
SINUOSITY	Ratio of the Stream Distance Between Two Points On Channel and Straight-Line Distance Between Points
SUBSTRATE	Substrate Composition
VEGSTRATA	Vegetation Strata
WATERDEPTH	Average Water Depth (cm)

Appendix D: Model Review Comments and Actions Taken to Address Issues

ERDC-EL used technical experts both within the laboratory itself, and outside the facility (but still within the USACE planning community) to perform a review of both the model development process and the model itself. To assure fair and impartial review of the products, members of the Laboratory-based Technical Review Team (LTRT) were chosen on the basis of expertise, seniority in the laboratory chain of command, and USACE planning experience.

The following were members of the LTRT:

1. Dr. Andrew Casper (ERDC-EL) – technical (peer) reviewer,
2. Ms. Elizabeth Brandreth (Philadelphia District) – technical (peer) reviewer,
3. Janean Shirley – editorial review (Technical Editor),
4. Ms. Antisa Webb - management review (Branch Chief),
5. Dr. Edmond J. Russo – management review (Division Chief),
6. Dr. Steve Ashby – program review (System-wide Water Resources Research Program, Program Manager),
7. Dr. Al Cofrancesco – program review (Technical Director), and
8. Dr. Mike Passmore – executive office review (Environmental Laboratory Deputy Director).

No peer review members of the LTRT were directly associated with the development or application of the model(s) for this study, thus assuring independent technical peer review.[1] Referred to as the in-house Laboratory-based Technical Review (LTR), these experts were asked to consider the following issues when reviewing this document:

1. Whether the concepts, assumptions, features, methods, analyses, and details were appropriate and fully coordinated;

[1] Resumes for Dr. Casper and Ms. Brandreth (i.e., the technical peer reviewers) can be found immediately following the comment/response tables at the end of this appendix.

2. Whether the analytic methods used were environmentally sound, appropriate, reasonable, fall within policy guidelines, and yielded reliable results;
3. Whether any deviations from USACE policy and guidance were identified, documented, and approved;
4. Whether the products met the Environmental Laboratory's standards based on format and presentation; and
5. Whether the products met the customer's needs and expectations.

LTRT Review Comments and Responses

Review comments were submitted to the Laboratory-based Project Delivery Team (LPDT) in written format and the LPDT responded in kind. In the EL Electronic Manuscript Review System (ELEMRS) 2.0, both reviewers indicated that the document was "Acceptable" with grammatical/formatting modifications needed, and when asked to offer their opinion as to the production of the report they stated that it was a, "quality study, well designed and presented [with] important new information."

LTRT Technical Reviewer Curriculum Vitae

US Army Corps of Engineers

Professional Experience

Dr. Andrew F. Casper

Research Biologist - ERDC, Environmental Laboratory
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Research Biologist, Aquatic Ecology and Invasive Species Branch, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS., 2006 to present.

- Specializing in large river science, engineering and ecology spanning the continent from Gulf Coast rivers and estuaries to the Ohio and Mississippi River Valley's to the arctic Mackenzie River Delta and Beaufort Sea in Canada
- Development of conceptual, physical habitat, and watershed models
- Modeling climate change and land use impacts/responses
- Assessment of dam removal and ecological restoration
- Food web and community ecology techniques for fish and invertebrates in large navigable rivers and flood plains
- GIS-based, 2-D water quality mapping in tidal creeks/coastal rivers

Education

- **Ph.D.** Océanography, 2005, Université Laval, Québec City, QC.
- **M.S.** Biological Sciences, 1993 Southern Illinois University Carbondale.
- **B.S.** Natural Sciences, 1990 Southern Illinois University Carbondale

Research & Teaching

- A.F. Casper and C. Fischenich. Framework and Integration of Conceptual Models in the CoE Planning Process (System Wide Water Resource Program Environmental Benefits Analysis Program, USACE HQ).
- Brasfield, S., A.F. Casper and B. S. Payne. Potential Contribution of Climate Change to the Bioassessment of Contaminants on Military Installations: Additive, Synergistic or Antagonistic? (USACE ERDC Basic Research Program).
- K. J. Killgore, J. J. Hoover, D. R. Johnson, and A. F. Casper. Envirofish: A HEC compatible floodplain habitat model for evaluating mitigation scenarios (reimbursable project for D. R. Johnson, Mississippi Valley District).

Other Professional Activities

- Ecosystem restoration/mitigation
- Sensitivity analysis and incorporation of risk/uncertainty
- Forecasting effects of scenarios and plan formulations
- Project/Watershed cumulative impacts assessments
- Coordinate field collections, management, analysis and reporting for river ecology
- SOW proposal and budget writing for multi-year research projects (NSF, EPA, USACE)

Selected Publications & Conference Presentations

- Casper, R. A. Efoymson, S. M. Davis, G. Steyer, and B. Zettle. 2009. Improving Conceptual Model Development: Avoiding Underperformance Due to Project. U.S. Army Engineer Reseawrch and Development Center, Vicksburg, MS.
- Casper A. F., and J. H. Thorp. 2007. Diel and lateral patterns of zooplankton distribution in the St. Lawrence River. Rivers Research and Application 23(1):73-85.
- Casper, A. F., J. H. Thorp, S. P. Davies, and D. L. Courtemanch. 2006. Ecological responses of large river benthos to the removal of the Edwards Dam on Kennebec River, Maine (USA). Archiv fur Hydrobiologie 16(4):541-555 (Large River Supplement 115).
- June 2008 - A surrogate model for future regional climate change: The current affects of the Atlantic Multidecadal Oscillation and its influence on the ecohydrology of Great Lakes and New England rivers. 56th Annual North American Benthological Society International Conference, Salt Lake City, Utah.
- July 2007 - Linking ecological responses to hydrologic characteristics of rivers: Examples from studies of dam removals and PHABSIM modeling for minimum flow standards. US Army Corps of Engineers Waterways Experiment Station. Vicksburg MS.
- A. F. Casper, B. Dixon, E. Steimle, J. Gore, P. Coble, and R. Conmy. Water quality sampling strategies for monitoring coastal rivers & estuaries: Applying technological innovations to Tampa Bay tributaries. Awarded by USEPA (Oct 2006 - Dec 2007).
- Carrabetta, M., A. F. Casper, B. Chernoff, and M. Daniels. The ecological and physical effects of removal of two low-head dams on Eight Mile Creek, a tributary of the Connecticut River. Awarded by TNC/NOAA Community Restoration Program (2005-07).

September 2009

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Photo

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Professional Experience

Ecosystem Biologist, Regional Technical Specialist, Environmental Resource Branch, Planning Division, US Army Corps of Engineers, Philadelphia, PA., 1991 to present.

- Perform a variety of environmental evaluations including Environmental Assessments (EA), Environmental Impact Statements (EIS), and technical reports on District activities
- Conduct surveys and investigations to determine potential impacts (of proposed activities) on water quality, wetlands, and fish and wildlife resources
- Make recommendations to minimize and/or mitigate adverse impacts, as well as to enhance subject resources
- Coordinate environmental aspects of District activities with State, interstate, and Federal agencies
- Conduct Habitat Evaluation Procedure (HEP) analyses and incremental cost analyses for Federal environmental restoration projects
- Identify the need for and acquire permits and Water Quality Certificates for Federal projects
- Act as primary Point of Contact for endangered species coordination in the District
- Prepare Biological Assessments for endangered species as necessary
- Act as mentor to other District employees with regard to cost effectiveness and incremental cost analyses (CE/ICA)
- Aid in teaching modules for the CORE Environmental Considerations in Planning course

Education

- B.S. Marine Biology, 1990, Fairleigh Dickinson University
- A.S. Biology, 1988, Luzerne County Community College

Presentations/Teaching

- Planning Associates Coastal Course, 2003, 2005, 2006, 2008 and 2009.
- Environmental Chiefs' Meeting, 2000, 2003, 2006 and 2009.
- Economic and Environmental Analysis Conference, 2002, 2004, 2006 and 2008.
- Baltimore District CE/ICA Workshop, 2001.
- Environmental Considerations in Planning Training Course, 2001 – Present

Recent Publications

IWR Report 02-R-5 "Lessons Learned from Cost Effectiveness and Incremental Cost Analyses (CE/ICA)", 2002.

USACE Feasibility Report/EIS, 2002. "Manasquan Inlet to Barnegat Inlet Feasibility Study".

USACE Section 7 Biological Assessment for Potential Impacts to the Piping Plover and Seabeach Amaranth Resulting from Beach Nourishment Projects Along the New Jersey Coast, 2001.

Other Professional Activities

- Dredging and dredged material disposal
- Beach restoration
- Environmental restoration
- Planning and construction of water resources projects such as flood control, and shoreline and stream erosion control
- Regulatory functions

March 2010

Administrative Review Status and Technical Transfer Forms

The documentation is now in senior staff and program management review. Two technology transfer forms will be completed when the document has been reviewed approved by both the senior staff and the program managers (Table D - 1 and Table D - 2).

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____

Kelly A. Burks-Copes Date
Principal Investigator
Environmental Laboratory
U.S. Army Engineer Research and Development Center
Vicksburg, MS

APPENDIX E
Initial Alternative Screening Scoresheet

Preliminary Screening of Measures

The team first identified five categories that would be important when considering the success of proposed measures according to the objectives identified for the study. These areas included flood damage reduction effect, eco-friendly, aesthetics/recreation opportunities, engineeringly implementatble, and acceptability/chance of succes. Each measure was then given an Opportunity Value of high (6), medium (4) or low (2). These opportunity values were assigned based on the teams assesment of how successful each measure would be in performing successfully for each of the categories considered. The categories were further weighted based on the teams assessment of how important each would be when considering the goals and objectives of the study. Weights ranged from 1 to 5 and were multiplied by the Opportunity Value to generate a score for each measure in each category. In order to bring each total to 100 for ease of comparison each measure was given a base value of 4 to start off with.

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

	Multiplier:	5	4	2	1	1	3	
Reach	**Components**	**Flood Damage Reduction Effect**	**Eco-Friendly**	**Aesthetics/ Recreational Opportunities**	**Cost Effectivenes s**	**Engineeringly Implementable**	**Acceptability/ Chance of Success**	
18 & 19								
SH 288	Off-line Detention in Reach 19 for Reach 18	30	24	12	6	6	18	100
to	Levee in Reach 18 by Cullen	10	8	4	2	4	6	38
Cullen	In-Line Storage	20	24	12	4	6	18	88
	Conveyance Improvememts	30	24	12	6	6	18	100
	Wetlands Creation	10	24	12	4	6	18	78
	Buyouts	20	24	12	2	6	6	74
16 & 17								
Cullen	Channel Improvements	30	24	12	6	6	18	100
to	Off-Line Detention	30	24	12	6	6	18	100
Bennie Kate	Buyouts	30	24	12	4	6	12	92
	Levees on South Side	30	8	4	2	4	6	58
	Raising Structures on Creek	30	8	4	4	4	18	72
	Bridge Modification @ Mykawa & RR	20	8	4	4	6	18	64

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

	Multiplier:	5	4	2	1	1	3	
Reach	**Components**	**Flood Damage Reduction Effect**	**Eco-Friendly**	**Aesthetics/ Recreational Opportunities**	**Cost Effectiveness**	**Engineeringly Implementable**	**Acceptability/ Chance of Success**	
14 & 15								
Bennie	Off-Line Detention in Reach 14 to help Reach 13	30	24	12	6	6	18	100
to	Expand Existing Detention (David L. Smith Site)	30	24	12	6	6	18	100
Country Club	Hickory Slough Detention	20	24	12	4	6	18	88
	Expanded Buyouts	30	24	12	6	6	18	100
	Levee System (Twin Creek Woods)	30	8	4	2	2	6	56
	Restore Wetlands E. of Creek in City of Pearland	10	24	12	2	6	6	64
	Channel Improvements/Detention	30	24	12	6	6	18	100

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

Reach	Components	Flood Damage Reduction Effect	Eco-Friendly	Aesthetics/ Recreational Opportunities	Cost Effectiveness	Engineeringly Implementable	Acceptability/ Chance of Success	
	Multiplier:	5	4	2	1	1	3	
13								
Country Club	Expanded Buyouts	30	24	12	6	6	18	100
to	Remove Dredged Material (barrier)	30	24	12	6	6	18	100
Dixie Farm	Restore Oxbows	20	24	12	6	6	18	90
	In-Line Storage	20	24	12	4	6	18	88
	Hi-Flow Bypass	20	16	12	6	6	18	82
	Reconnect Oxbows to Lower Flow	10	24	12	6	6	18	80
	Expand Existing Detention (A521-01)	30	24	12	6	6	18	100

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

Reach	Components	Flood Damage Reduction Effect	Eco-Friendly	Aesthetics/ Recreational Opportunities	Cost Effectiveness	Engineeringly Implementable	Acceptability/ Chance of Success	
	Multiplier:	5	4	2	1	1	3	
11 & 12								
Dixie Farm	Maintain Existing Channel	10	24	12	6	6	18	80
to	Bypass Channel	30	16	8	2	2	12	74
FM 2351	Mandatory Buyouts	10	16	8	6	6	18	68
	In-line Detention	10	8	4	2	2	6	36
	Hi-Water Bypasses	20	24	12	6	6	18	90
	Detention on Tribs.	30	24	12	6	6	18	100
	Floodplain Preservation	10	24	12	6	6	18	80
10								
	Expand Buyout (3 homes left in Imperial Estates) Recreation Area	30	24	12	6	6	18	100
FM 2351	South Bypass around Friendswood	30	16	8	2	2	6	68
to	Detention in Imperial Estates	20	8	8	6	6	6	58
Mary's Creek	Selective Clearing	10	8	8	6	6	18	60
	Detention on Mary's Creek	30	24	12	6	6	18	100

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

Reach	Components	Flood Damage Reduction Effect	Eco-Friendly	Aesthetics/ Recreational Opportunities	Cost Effectiveness	Engineeringly Implementable	Acceptability/ Chance of Success	
	Multiplier:	5	4	2	1	1	3	
Reach 9								
Mary's Creek	Expand Buyout	20	24	12	6	6	18	90
to	Increase Conveyance - "channel Improvement	30	8	4	6	6	6	64
Whispering Pines	Modification to High Water Bypasses	30	24	12	6	6	18	100
Reach 8								
Whispering Pines	Expand Buyout - 10 structures in 25-year Floodplain	20	24	12	6	6	18	90
to	Conveyance Expansion	30	8	4	6	6	6	64
FM 528	Expand Existing Detention - Detention on Tributaries	30	24	12	6	6	6	88
	Additional High Flow Bypass	20	16	12	6	6	18	82

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

	Multiplier:	5	4	2	1	1	3	
Reach	**Components**	**Flood Damage Reduction Effect**	**Eco-Friendly**	**Aesthetics/ Recreational Opportunities**	**Cost Effectiveness**	**Engineeringly Implementable**	**Acceptability/ Chance of Success**	
Reach 7								
FM 528	Channelization a Small Segment w/Bypass Channel	30	16	12	2	6	18	88
to	Levee West Side	30	8	4	2	4	6	58
Bay Area Blvd	Hi-Flow Bypass Channel	10	8	4	2	2	6	36
	Increased Conveyance	30	16	8	6	6	6	76
	Detention on Chigger Creeks	30	24	12	6	6	18	100
	Buyout	30	24	16	4	6	8	92
1 - 6								
Bay Area Blvd	Marsh Restoration Recommended by Agencies	10	24	12	6	6	18	80
to	Look at I-45 hydraulics (bridge) - Enlarge Bridge	20	8	4	4	6	18	64
Galveston Bay	Dredging Out Silt from Lake	10	16	8	2	6	12	58
	Look at I-45 hydraulics (bridge) - Enlarge Bridge	10	8	4	2	6	6	40
	Improve Conveyance - Reaches 1-5	10	16	4	4	6	18	62
	Buyout - Reach 6	20	24	12	4	6	18	88

Ranking Base Value = 4; Opportunity Values: High = 6, Medium = 4, Low = 2

Reach	Components	Flood Damage Reduction Effect	Eco-Friendly	Aesthetics/ Recreational Opportunities	Cost Effectiveness	Engineeringly Implementable	Acceptability/ Chance of Success	
	Multiplier:	5	4	2	1	1	3	
Global	Buyout							
	Establish a Greenway Along Creek - Buffer	10	24	12	6	6	18	80
	"Conveyance Improvement Corridor", Wet Benches, Enhanced Understory, Selective Clearing							
	Preserve and/or Reclaim Floodplain							
	Use Existing Low Flow Areas for New Oxbows							
	"Chain of Lakes" Throughout Watershed							
	High-Flow Pipe Under Existing Flowline	10	8	4	2	2	6	36
	Construct Step Pools for Fishery Habitat	10	24	12	4	6	18	78
	Adopt Watershed Mngt Regulations/Strictly Restrict Additional Inflows/Make Elevation Requirements	30	24	8	6	6	6	84
	Detention - Global Scheme - "Pure	20	24	12	2	6	6	74
	Raising Structures	30	16	4	4	6	6	70
	Build Flood Walls	10	8	4	2	2	6	36
	Channelize Entire Creek	30	8	4	6	6	6	64
	Riparian Habitat Preservation	10	24	12	4	6	18	78
	Wetland Function at Detention Facilities	10	24	12	4	6	18	78

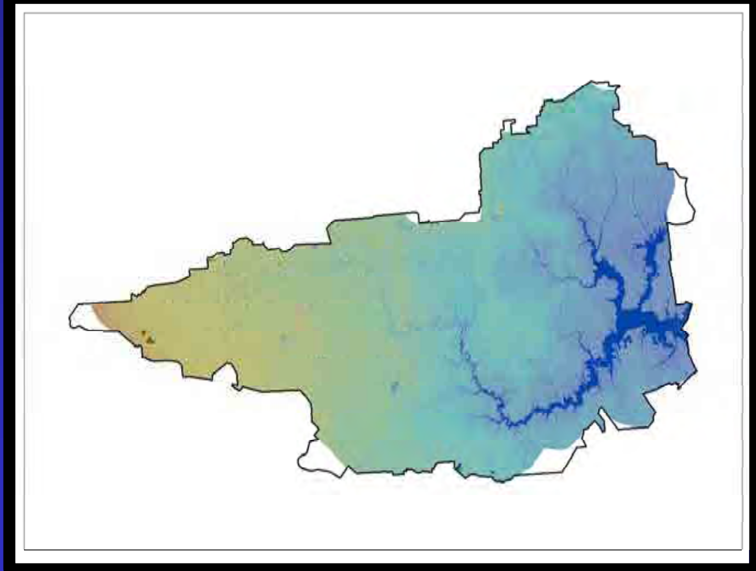
APPENDIX F
Clear Creek General Reevaluation Report
Flood Damage Reduction
1st Added Measures Results

CLEAR CREEK GENERAL REEVALUATION REPORT
FLOOD DAMAGE REDUCTION
1ST ADDED MEASURES RESULTS

Prepared for:

US ARMY CORPS OF ENGINEERS

GALVESTON DISTRICT



Prepared by:

DANNENBAUM

DANNENBAUM ENGINEERING CORPORATION

July 2004

CLEAR CREEK GENERAL REEVALUATION REPORT

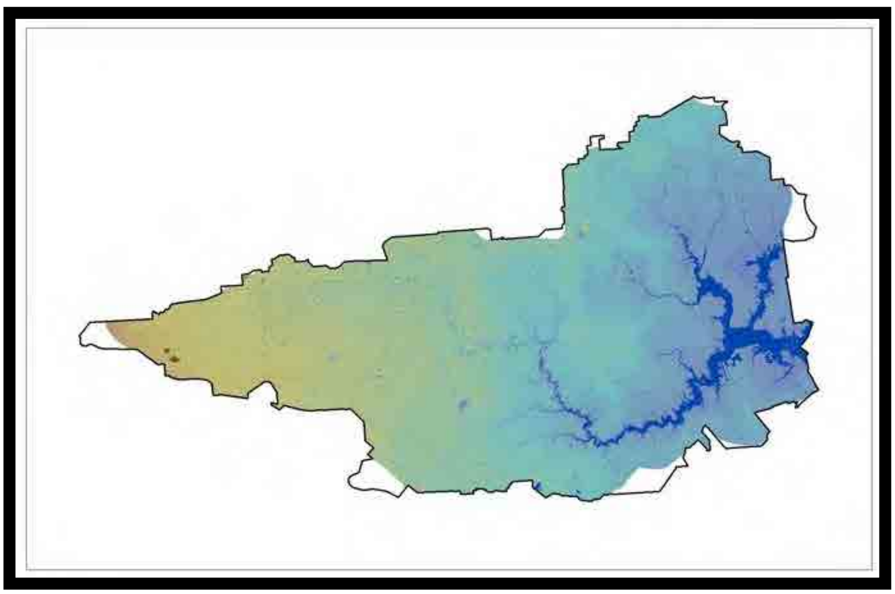
FLOOD DAMAGE REDUCTION

1ST ADDED MEASURES RESULTS

Prepared for:

US ARMY CORPS OF ENGINEERS

GALVESTON DISTRICT



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July 2004

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CLEAR CREEK GENERAL REEVALUATION REPORT
FLOOD DAMAGE REDUCTION
1ST ADDED MEASURES RESULTS

Prepared for:

US ARMY CORPS OF ENGINEERS

Galveston District

3406-02

CLEAR CREEK GENERAL REEVALUATION REPORT
FLOOD DAMAGE REDUCTION
1ST Added Measures Results
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CLEAR CREEK ANALYSIS

TABLES

EXHIBITS

APPENDICES

Clear Creek GRR Analysis
Results of the First-Added Flood Damage Reduction Measures Screening Analysis

General - This report documents the results of the initial screening of flood damage reduction measures for the Clear Creek GRR study. Twenty-four different structural and nonstructural measures were analyzed to determine their costs and benefits. The analysis considered the measures on a "first-added" basis, meaning each measure was tested as a stand-alone element. The screening results show which measures are the most efficient in reducing flood damages and should, therefore, be considered for inclusion in the Federal plan. The next phase of the plan formulation process will attempt to identify "second-added" measures that function efficiently in reducing residual flood damages not remedied by the first-added measures. This systematic screening method allows for identification of the overall most efficient alternative for reducing flooding and establishes the Federal interest in Clear Creek flood damage reduction.

Significance - The Clear Creek study area has experienced repeated flood damage in the past. Stakeholders would generally welcome Federal investment in a plan to reduce damages, but there is controversy over exactly what actions should be taken. The first-added screening analysis was designed to reveal the relative merit of many different structural and nonstructural measures so that continued discussion and planning would be factually grounded. The conclusions drawn from these screening results will set the path and scope for the remaining formulation process. Thus, this report marks a pivotal point in the analysis where decisions must be made that will influence the direction and remaining duration of the Clear Creek GRR study.

Screening list - The list of measures included in the screening analysis was developed by gathering ideas from stakeholders and by conducting brain storming sessions with experts familiar with flood damage reduction projects. These concepts were formed to specifically address damages to existing property while considering environmental resources and flooding characteristics. After reviewing a vast number of potential solutions, a final list of 24 measures was modeled with each measure tested in three size variations. Appendix A is a notebook describing and illustrating all of the first-added measures. The measures can be grouped into the following broad categories:

Nonstructural measures

- Buyouts- (One measure in three sizes) buyout of structures flooded by specific flood frequency events along Clear Creek.

Structural measures

- Conveyance measures- (Ten measures in three sizes) including channelization, clearing and snagging, cutoffs and bypasses, bridge modifications, removal of dredge material mounds, and increasing the outlet capacity from Clear Lake.
- Detention measures- (Twelve measures in three sizes) including off-line detention and linear detention at sites on along the mainstream and major tributaries.
- More stringent development controls- (One measure) creation of a 100%-effective, basin-wide development control policy.

Brief description of screening process - The flood damage reduction measures were ranked based on their efficiency in reducing flood damage. The specific ranking factor for Federal planning studies is the net excess benefit, i.e. the benefit of the measure less the total cost of the measure. The benefit of the measure is the value of the flood damage reduction that it accomplishes. The total project cost of the measure includes construction costs and environmental mitigation costs. Some relevant notes pertaining to the screening process are listed below. These must be considered when drawing conclusions from the results of the process:

- Environmental mitigation costs were based on a simplifying assumption that seven acres of habitat would be preserved for every acre of footprint area occupied by the measure. This was an expedient way to include mitigation costs early in the formulation process but this mitigation cost methodology could not discriminate among habitat quality. For instance, some features were situated in undisturbed, high value habitat while other features were located in poor habitat. Other features would destroy habitat during construction, but would allow for some eventual re-growth over time. Such distinctions would be captured in a detailed HEP analysis, but were not possible for a screening level analysis.
- Some of the first-added features would have a high potential for other uses and benefits besides flood damage reduction, but these other benefits were not captured in the screening. For instance, large scale, linear detention measures like LD2 or LD3 would create huge, park-like tracts through urbanized portions of the basin that could offer opportunities for recreation benefits, ecosystem restoration benefits, and architectural landscaping vistas. The raw results of the screening analysis only reflect the benefits to flood damage reduction.
- The right-of-way costs for conveyance measures assumed that the alignment of the measure would follow the existing creek centerline. In a more detailed analysis, these costs could be reduced by adjusting the alignment to avoid structures (and high quality habitat) as much as possible.
- Estimating the economic costs for the buyout plans follows Corps guidance that requires that the land costs be valued as though they lie outside the 1 percent chance exceedance floodplain. These costs were developed based on October, 2001 prices, four months after Tropical Storm Allison struck the Houston metropolitan area. The value of flood-free land may reflect the market's sensitivity at that time to flooding.
- The measure GWMP would create a 100% effective development control policy throughout the basin that would prevent any future flow increases from development. The costs for this measure were the largest of any of the first-added measures that were considered. These high costs eliminate GWMP from contention. Details on how costs and benefits for this measure were developed are attached in Appendix A.

Results - Table 1 (the foldout sheet included as the last page of this report) presents all the measures evaluated in the first round of screening and also includes the two Legacy Plans, the Authorized Federal Project (AFP) and the Sponsor Proposed Alternative (SPA), which are carried forward for comparison purposes. Table 1 presents damages reduced in expected annual values (2010 condition) and in present worth equivalents at the current interest rate over a fifty-year project life. The total project cost includes first cost and environmental mitigation costs. Table 1 presents costs as first costs and as average annual equivalent costs, based on the current interest rate and a fifty-year project life. Project costs minus environmental mitigation costs were also presented in order to gauge the influence of mitigation on each measure's economic efficiency. The result of subtracting the total project cost from the damages reduced benefits produced the net excess benefits calculation that formed the basis for determining economic efficiency. The measures were then ranked by their net excess benefits.

Costs for the two Legacy Plans, being fully formulated alternative plans, also contain maintenance costs. These costs are high due to increased need for land by the bypass in the Sponsor Proposed Alternative, and addition of costs for activities already completed such as pipeline relocations and bridge modifications on the Authorized Federal Project.

It should be noted that the structures removed from the floodplain as a result of Tropical Storm Allison are included in the calculations detailed in Table 1. These are included to insure that steps taken to reduce flooding during the study by the sponsors do not reduce the likelihood of identifying an implementable Federal project.

Table 1 lists all the first-added measures in each of the three sizes with resultant benefits shown in column (a), costs in column (b), and net benefits in column (a) – (b). Table 2 summarizes the results for the ten best ranking measures. Only the first five measures have positive net benefits, a requirement for Federal participation. The hydraulic performances of all the measures are shown as flood profiles in Appendix C. Flood and damage profiles for the Without-Project Condition are included in Exhibit 2.

Observations and Recommendations

<u>Competing Measures.</u> Clearing and Snagging (CS), Conveyance Improvement (C4), Enlarging High-Flow Bypasses (EHFB), and Removing Dredge Material (RDM1) all compete for the same flood damage reduction benefits in the mid-reach section of the main stem. The conveyance measure, C1, is not influenced by these measures, having its primary positive impact in the upper reaches of the main stem. The Buyout of the 50% Annual Exceedance Probability Floodplain, GBOa, is a minimal buyout of three structures that are damaged by a "2-year" flood event. These buyouts are scattered in Reaches 13, 16, and 18 and will have little impact on the performance of the other measures.

<u>Anchor for Alternatives Analysis (Second Added Analysis)</u> - A strict interpretation of the economic performance of the first-added measures might lead to the conclusion that the anchor component should be the Clearing and Snagging measure. However, the results of the initial screening also showed that buyout of the 50% annual exceedance floodplain produced sufficient net excess benefits to be implementable as a first-added measure and would not significantly impact the performance of the other measures because of its small

scale and its lack of impact to the existing water surface profile. Also, because the C1 conveyance measure lies upstream of the clearing and snagging measure, functions independently of downstream measures, and a large majority of flood damages are located in the upstream reaches, it is reasonable to conclude that C1 should be optimized for economic efficiency in the second phase before clearing and snagging or other mid-reach measures are modeled and tested.

By implementing the buyout as the initial anchor component, the upper reach conveyance measure should be added to the plan and optimized in the residual floodplain of the buyout component. Detention immediately downstream of the conveyance measure should then be tested along with other flood damage reduction measures in the mid-reach portion of the stream such as clearing and snagging, conveyance improvement, or enlarging high-flow bypasses. Possible sites for detention are the existing David L Smith basin, B2 basin, and A521-01 basin. An iterative analysis is anticipated in order to balance measures.

Performance of Detention Basins - Detention measures did not perform well in the first-added analysis. However, experience with other flood damage reduction projects has shown that detention will perform more efficiently when paired with an upstream conveyance measure. Conveyance measures induce high, flashy peak flows immediately downstream of their terminus, and detention is most effective in that setting. Thus, detention should be carefully considered in the next phase of the analysis as a second-added feature to complement first-added conveyance measures.

Tributary Analysis - Flood damages along tributaries were generally not considered in the first-added measures evaluation because, initially, the study focused on the main stem of Clear Creek for flood damage reduction. It was not until the study was underway that the team realized that a watershed approach was necessary to fully understand the flooding problem and opportunities for flood remediation.

Six tributaries have been selected for the continuing analysis including Mary's Creek, Cowart's Creek, and Chigger Creek in Brazoria and Galveston Counties; Mud Gully and Turkey Creek in Harris County; and Hickory Slough in Brazoria County. These six were selected based on their significant flow contributions to the main stem of Clear Creek and also the potential for flood damages along each tributary. Some smaller tributaries are known to have substantial, reoccurring flood damage but could not be included in the analysis. ER 1165-2-21 (30 Oct 80) sets the size limits for Federal interest for tributaries to those streams exceeding 800 cubic feet per second for a ten percent annual exceedance event. This flow requirement excludes small tributaries. Armand Bayou was excluded from analysis because it is generally independent from Clear Creek. Armand Bayou empties into Clear Lake, so its impacts to Clear Creek are limited. Also, the lower reaches of Armand Bayou are within the Armand Bayou Nature Preserve, so there are limited opportunities for flood reduction measures.

Nonstructural Measures - The study team decided to include evacuation/buyout as its only nonstructural measure for the initial screening of measures. While buyout of the

50% annual exceedance floodplain proved to be economically feasible and implementable, it is notable that the analysis failed to justify the buyout of 10 residential structures purchased by FEMA following Tropical Storm Allison's flooding. This situation reveals the differences in justification methodology between the COE and FEMA. It is recommended that the study team be vigilant in recognizing opportunities for additional buyouts and other nonstructural flood damage reduction measures throughout the plan formulation process.

Alternate Land Use Benefits - It was observed that because of the nature of the screening-level buyouts, no alternate use of the evacuated floodplain could be anticipated. Subsequent plan formulation efforts should attempt to identify localized pockets of damage that may lend themselves to complete evacuation/buyout, thereby allowing for an alternate land use such as recreation or ecosystem restoration.

The Environmental Mitigation Methodology - The limitations expressed with regard to mitigation methodology used in the initial screening process lend support for a refined method to be applied in subsequent planning iterations. Thus, HEP evaluation techniques should be applied during the second and subsequent phases of plan formulation.

Clear Lake Second Outlet - The Second Outlet is a component of the Authorized Federal Project that was actually constructed and operated prior to the project's reevaluation. The existence of the outlet presents an analytical challenge in that it was initially constructed as a mitigation measure to the Authorized Federal Project but, as it is in place and functional, was included as a flood damage reduction measure for first-added measure evaluation. The Clear Lake second outlet was found not to be economically justified in the without project condition as shown in Table 1. However, the outlet should be carried forward for possible hydrologic mitigation as it was originally intended. It should be included in the plan formulation as the "last-added" measure for evaluation of its performance in the residual floodplain of other flood damage reduction measures.

Ecosystem Restoration Alternative with Flood Damage Reduction Benefits - One of the strongest public sentiments expressed about Clear Creek is the desire to preserve a natural, pristine stream in a large metropolitan area where most natural habitat has fallen victim to urban encroachment and development. Urban streams have been channelized and reshaped to reduce damages to nearby structures susceptible to flooding. Providing flood damage reduction within urban streams has diminished their original ecological value.

In order to answer the public's desire to preserve and restore habitat, the study team proposes to develop an alternative that would produce ecosystem restoration benefits but would also provide flood damage reduction benefits as a dual purpose. Alternatives under consideration include habitat creation/restoration in conjunction with proposed conveyance, detention, and buy-out measures. Ecosystem restoration could be performed in the footprint of these flood damage reduction measures or in areas adjacent that have the potential for generating high restoration benefits. Recreation would be an added purpose for consideration on both ecosystem restoration and flood damage reduction but would be secondary to the primary purpose identified.

Summary and Conclusions

The second-added analysis of the main stem measures will begin with refinement of the upstream conveyance and detention measures. From there additional measures will be added and evaluated as we move towards the selection of a recommended plan. Mitigation amounts will also be refined with the use of a formal Habitat Evaluation Procedure that will allow us to develop more precise mitigation requirements and associated costs. Concurrent with this, flood damage reduction measures have been identified for the tributaries and these will be evaluated on a first added basis. The team will also be evaluating ecosystem restoration opportunities during refinement and development of all flood damage reduction measures. Results from all of these analyses will be utilized in the development of a complete, effective, efficient, and acceptable project.

The conclusion of the first-added measures analysis has produced results that are enlightening and challenging. The study team now has a far better understanding of the dynamics of flooding along the main stem and a new interest in the potential for damage reduction from measures along the tributaries. The recommendations made for further analysis will require a revision in the study schedule to allow for a full exploration of the opportunities that lie ahead. The team is committed to reducing the chronic flooding problem on Clear Creek in a way that meets the varied interests of the many stakeholders in the community. The recommendations outlined in this document present a direction for successful completion of the study team's goal for Clear Creek.

TABLES

TABLE 1 - SUMMARY TABLE

	Plan_Desc	2010 Expected Annual Damages in thousands	2010 Expected Annual Damages Reduced in thousands	PWE Damages Reduced @ .05625% in thousands (a)	Total Project Cost	Total Project Cost in thousands (b)	Mitigation Cost	AAE Total Project Cost @ .05625% in thousands	Mitigation Cost in thousands	Cost minus Mitigation	Cost minus Mitigation in thousands (d)	Net Excess PWE Exp Damages Reduced minus Total Project Cost (a)-(b)	Net Excess PWE Exp Damages Reduced minus Project Cost Less Mitigation (a)-(d)	BCR (a)/(b)	Rank by net excess benefits
	Without project condition	$5,483.06													
1	Interstate 45 Bridge Widening -size a	$5,477.13	$5.93	$98.59	$1,763,678.00	$1,763.68	$0.00	$106.08	$0.00	$1,763,678.00	$1,763.68	($1,665.09)	($1,665.09)	0.06	13
2	Interstate 45 Bridge Widening -size b	$5,475.97	$7.09	$117.88	$3,012,813.00	$3,012.81	$0.00	$181.21	$0.00	$3,012,813.00	$3,012.81	($2,894.94)	($2,894.94)	0.04	15
3	Interstate 45 Bridge Widening -size c	$5,471.12	$11.94	$198.51	$4,004,053.00	$4,004.05	$0.00	$240.84	$0.00	$4,004,053.00	$4,004.05	($3,805.54)	($3,805.54)	0.05	17
4	A521 Detention - size a	$5,481.27	$1.79	$29.76	$4,726,667.00	$4,726.67	$85,000.00	$284.30	$85.00	$4,641,667.00	$4,641.67	($4,696.91)	($4,611.91)	0.01	19
5	A521 Detention - size b	$5,479.73	$3.33	$55.36	$9,937,472.00	$9,937.47	$161,875.00	$597.72	$161.88	$9,775,597.00	$9,775.60	($9,882.11)	($9,720.23)	0.01	32
6	A521 Detention - size c	$5,479.03	$4.03	$67.00	$15,548,568.00	$15,548.57	$246,875.00	$935.22	$246.88	$15,301,693.00	$15,301.69	($15,481.57)	($15,234.69)	0.00	49
7	Additional Clear Lake Outlet Capacity -Size a	$5,362.19	$120.87	$2,009.54	$11,538,117.00	$11,538.12	$0.00	$693.99	$0.00	$11,538,117.00	$11,538.12	($9,528.57)	($9,528.57)	0.17	30
8	Additional Clear Lake Outlet Capacity -Size b	$5,351.33	$131.73	$2,190.10	$17,307,175.50	$17,307.18	$0.00	$1,040.99	$0.00	$17,307,175.50	$17,307.18	($15,117.08)	($15,117.08)	0.13	47
9	Additional Clear Lake Outlet Capacity -Size c	$5,331.58	$151.48	$2,518.45	$23,076,234.00	$23,076.23	$0.00	$1,387.99	$0.00	$23,076,234.00	$23,076.23	($20,557.78)	($20,557.78)	0.11	56
10	B1 Detention- Size a	$5,441.73	$41.33	$687.14	$19,661,681.00	$19,661.68	$4,663,250.00	$1,182.61	$4,663.25	$14,998,431.00	$14,998.43	($18,974.54)	($14,311.29)	0.03	55
11	B1 Detention- Size b	$5,396.13	$86.93	$1,445.27	$39,684,147.00	$39,684.15	$9,317,750.00	$2,386.92	$9,317.75	$30,366,397.00	$30,366.40	($38,238.88)	($28,921.13)	0.04	62
12	B1 Detention- Size c	$5,371.72	$111.34	$1,851.10	$60,427,236.00	$60,427.24	$14,150,750.00	$3,634.58	$14,150.75	$46,276,486.00	$46,276.49	($58,576.14)	($44,425.39)	0.03	67
13	B2 detention- Size a	$5,457.58	$25.48	$423.62	$15,393,481.00	$15,393.48	$4,340,750.00	$925.89	$4,340.75	$11,052,731.00	$11,052.73	($14,969.86)	($10,629.11)	0.03	46
14	B2 detention- Size b	$5,439.02	$44.04	$732.19	$31,247,010.00	$31,247.01	$8,669,375.00	$1,879.45	$8,669.38	$22,577,635.00	$22,577.64	($30,514.82)	($21,845.44)	0.02	60
15	B2 detention- Size c	$5,427.95	$55.11	$916.24	$47,625,798.00	$47,625.80	$13,143,500.00	$2,864.60	$13,143.50	$34,482,298.00	$34,482.30	($46,709.56)	($33,566.06)	0.02	66
16	**C1- Size a**	$4,236.43	$1,246.63	$20,726.04	$19,996,341.00	$19,996.34	$7,707,125.00	$1,202.74	$7,707.13	$12,289,216.00	$12,289.22	**$729.70**	$8,436.83	**1.04**	**7**
17	C1- Size b	$4,054.18	$1,428.88	$23,756.07	$31,836,609.00	$31,836.61	$11,862,250.00	$1,914.91	$11,862.25	$19,974,359.00	$19,974.36	($8,080.54)	$3,781.71	*0.75*	27
18	C1- Size c	$3,969.12	$1,513.94	$25,170.25	$43,238,808.00	$43,238.81	$15,968,375.00	$2,600.73	$15,968.38	$27,270,433.00	$27,270.43	($18,068.56)	($2,100.19)	0.58	53
19	DLS1 -Size a	$5,464.80	$18.26	$303.58	$3,927,542.00	$3,927.54	$954,625.00	$236.23	$954.63	$2,972,917.00	$2,972.92	($3,623.96)	($2,669.33)	0.08	16
20	DLS1 -Size b	$5,444.23	$38.83	$645.57	$7,741,145.00	$7,741.15	$1,909,250.00	$465.61	$1,909.25	$5,831,895.00	$5,831.90	($7,095.57)	($5,186.32)	0.08	24
21	DLS1 -Size c	$5,410.53	$72.53	$1,205.86	$11,583,902.00	$11,583.90	$2,896,250.00	$696.75	$2,896.25	$8,687,652.00	$8,687.65	($10,378.04)	($7,481.79)	0.10	33
22	HFB1 -Size a	$5,527.08	($44.02)	($731.86)	$7,186,369.00	$7,186.37	$5,273,750.00	$432.25	$5,273.75	$1,912,619.00	$1,912.62	($7,918.23)	($2,644.48)	(0.10)	26
23	HFB1 -Size b	$5,545.61	($62.55)	($1,039.93)	$9,876,288.00	$9,876.29	$6,668,750.00	$594.04	$6,668.75	$3,207,538.00	$3,207.54	($10,916.22)	($4,247.47)	(0.11)	35
24	HFB1 -Size c	$5,536.78	($53.72)	($893.13)	$13,436,029.00	$13,436.03	$8,963,750.00	$808.15	$8,963.75	$4,472,279.00	$4,472.28	($14,329.16)	($5,365.41)	(0.07)	44
25	Marys Creek Detention -Size a	$5,469.49	$13.57	$225.61	$5,448,245.00	$5,448.25	$897,250.00	$327.70	$897.25	$4,550,995.00	$4,551.00	($5,222.63)	($4,325.38)	0.04	20
26	Marys Creek Detention -Size b	$5,459.53	$23.53	$391.20	$11,289,407.00	$11,289.41	$1,782,375.00	$679.04	$1,782.38	$9,507,032.00	$9,507.03	($10,898.21)	($9,115.83)	0.03	34
27	Marys Creek Detention -Size c	$5,392.58	$90.48	$1,504.29	$16,944,500.00	$16,944.50	$2,724,125.00	$1,019.18	$2,724.13	$14,220,375.00	$14,220.38	($15,440.21)	($12,716.09)	0.09	48
28	Mud Gully Detention - Size a	$5,243.93	$239.13	$3,975.69	$9,213,375.00	$9,213.38	$0.00	$554.17	$0.00	$9,213,375.00	$9,213.38	($5,237.68)	($5,237.68)	0.43	21
29	Mud Gully Detention - Size b	$4,859.26	$623.80	$10,371.08	$18,889,912.00	$18,889.91	$0.00	$1,136.19	$0.00	$18,889,912.00	$18,889.91	($8,518.83)	($8,518.83)	*0.55*	28
30	Mud Gully Detention - Size c	$4,705.55	$777.51	$12,926.61	$27,436,054.00	$27,436.05	$0.00	$1,650.22	$0.00	$27,436,054.00	$27,436.05	($14,509.44)	($14,509.44)	0.47	45
31	**Remove Dredge Material / Deepen -Size a**	$5,429.07	$53.99	$897.62	$1,324,147.00	$1,324.15	$586,688.00	$79.64	$586.69	$737,459.00	$737.46	**($426.53)**	$160.16	0.68	11
32	Remove Dredge Material / Deepen -Size b	$5,308.57	$174.49	$2,901.01	$9,369,114.00	$9,369.11	$2,895,750.00	$563.53	$2,895.75	$6,473,364.00	$6,473.36	($6,468.10)	($3,572.35)	0.31	23
33	Remove Dredge Material / Deepen -Size c	$5,283.65	$199.41	$3,315.32	$14,369,484.00	$14,369.48	$6,435,375.00	$864.30	$6,435.38	$7,934,109.00	$7,934.11	($11,054.16)	($4,618.79)	0.23	37
34	Detention on Turkey Creek -Size a	$5,236.23	$246.83	$4,103.71	$8,307,274.00	$8,307.27	$1,680,750.00	$499.67	$1,680.75	$6,626,524.00	$6,626.52	($4,203.56)	($2,522.81)	*0.49*	18
35	Detention on Turkey Creek -Size b	$5,130.92	$352.14	$5,854.56	$14,655,588.00	$14,655.59	$3,361,500.00	$881.50	$3,361.50	$11,294,088.00	$11,294.09	($8,801.03)	($5,439.53)	0.40	29
36	Detention on Turkey Creek -Size c	$5,009.39	$473.67	$7,875.07	$21,477,769.00	$21,477.77	$5,082,750.00	$1,291.84	$5,082.75	$16,395,019.00	$16,395.02	($13,602.69)	($8,519.94)	0.37	42
37	Cowart Creek Detention -Size a	$5,468.46	$14.60	$242.73	$12,125,717.00	$12,125.72	$5,932,125.00	$729.34	$5,932.13	$6,193,592.00	$6,193.59	($11,882.98)	($5,950.86)	0.02	39
38	Cowart Creek Detention -Size b	$5,448.46	$34.60	$575.25	$21,225,406.00	$21,225.41	$11,338,875.00	$1,276.67	$11,338.88	$9,886,531.00	$9,886.53	($20,650.16)	($9,311.28)	0.03	57
39	Cowart Creek Detention -Size c	$5,414.53	$68.53	$1,139.36	$33,203,066.00	$33,203.07	$16,725,375.00	$1,997.10	$16,725.38	$16,477,691.00	$16,477.69	($32,063.71)	($15,338.33)	0.03	61
40	C2 Size a	$5,455.97	$27.09	$450.39	$17,419,747.00	$17,419.75	$12,632,125.00	$1,047.76	$12,632.13	$4,787,622.00	$4,787.62	($16,969.36)	($4,337.23)	0.03	50
41	C2 Size b	$5,456.47	$26.59	$442.08	$18,433,732.00	$18,433.73	$11,475,000.00	$1,108.75	$11,475.00	$6,958,732.00	$6,958.73	($17,991.66)	($6,516.66)	0.02	52
42	C2 -Size c	$5,465.91	$17.15	$285.13	$22,234,648.00	$22,234.65	$13,518,750.00	$1,337.37	$13,518.75	$8,715,898.00	$8,715.90	($21,949.52)	($8,430.77)	0.01	58
43	LD1-Size a	$5,386.96	$96.10	$1,597.73	$11,151,670.00	$11,151.67	$6,871,250.00	$670.75	$6,871.25	$4,280,420.00	$4,280.42	($9,553.94)	($2,682.69)	0.14	31
44	LD1-Size b	$5,290.78	$192.28	$3,196.78	$16,133,504.00	$16,133.50	$9,471,500.00	$970.40	$9,471.50	$6,662,004.00	$6,662.00	($12,936.72)	($3,465.22)	0.20	41
45	LD1-Size c	$5,199.13	$283.93	$4,720.52	$21,716,741.00	$21,716.74	$11,978,000.00	$1,306.22	$11,978.00	$9,738,741.00	$9,738.74	($16,996.22)	($5,018.22)	0.22	51
46	**EHFB- Size a**	$5,385.54	$97.52	$1,621.33	$944,074.00	$944.07	$141,750.00	$56.78	$141.75	$802,324.00	$802.32	**$677.26**	$819.01	**1.72**	**9**
47	**EHFB- Size b**	$5,363.51	$119.55	$1,987.60	$1,215,788.00	$1,215.79	$141,750.00	$73.13	$141.75	$1,074,038.00	$1,074.04	**$771.81**	$913.56	**1.63**	**6**
48	**EHFB- Size c**	$5,339.48	$143.58	$2,387.11	$1,695,210.00	$1,695.21	$141,750.00	$101.96	$141.75	$1,553,460.00	$1,553.46	**$691.90**	$833.65	**1.41**	**8**
49	LD2- Size a	$4,970.10	$512.96	$8,528.30	$47,320,176.00	$47,320.18	$5,568,750.00	$2,846.21	$5,568.75	$41,751,426.00	$41,751.43	($38,791.88)	($33,223.13)	0.18	63
50	LD2- Size b	$4,804.17	$678.89	$11,286.99	$93,511,098.00	$93,511.10	$11,134,375.00	$5,624.51	$11,134.38	$82,376,723.00	$82,376.72	($82,224.11)	($71,089.73)	0.12	68
51	LD2- Size c	$4,777.21	$705.85	$11,735.22	$155,377,928.00	$155,377.93	$16,871,875.00	$9,345.67	$16,871.88	$138,506,053.00	$138,506.05	($143,642.71)	($126,770.83)	0.08	71
52	**CS- Size a**	$5,368.88	$114.18	$1,898.32	$312,754.00	$312.75	$0.00	$18.81	$0.00	$312,754.00	$312.75	**$1,585.56**	$1,585.56	**6.07**	**5**
53	**CS- Size b**	$4,734.73	$748.33	$12,441.48	$3,682,382.00	$3,682.38	$2,515,500.00	$221.49	$2,515.50	$1,166,882.00	$1,166.88	**$8,759.10**	$11,274.60	**3.38**	**1**
54	**CS- Size c**	$4,682.87	$800.19	$13,303.68	$8,641,450.00	$8,641.45	$6,288,750.00	$519.77	$6,288.75	$2,352,700.00	$2,352.70	**$4,662.23**	$10,950.98	**1.54**	**2**
55	LD3- Size a	$5,410.61	$72.45	$1,204.53	$45,308,847.00	$45,308.85	$11,148,000.00	$2,725.24	$11,148.00	$34,160,847.00	$34,160.85	($44,104.32)	($32,956.32)	0.03	65
56	LD3- Size b	$5,292.73	$190.33	$3,164.36	$89,606,859.00	$89,606.86	$22,296,000.00	$5,389.67	$22,296.00	$67,310,859.00	$67,310.86	($86,442.50)	($64,146.50)	0.04	69
57	LD3- Size c	$5,153.18	$329.88	$5,484.47	$146,692,578.00	$146,692.58	$33,787,500.00	$8,823.27	$33,787.50	$112,905,078.00	$112,905.08	($141,208.11)	($107,420.61)	0.04	70
58	CHG1 detention-size a	$5,482.09	$0.97	$16.13	$5,812,649.00	$5,812.65	$2,430,000.00	$349.62	$2,430.00	$3,382,649.00	$3,382.65	($5,796.52)	($3,366.52)	0.00	22
59	CHG1 detention-size b	$5,481.78	$1.28	$21.28	$12,500,687.00	$12,500.69	$3,789,625.00	$751.89	$3,789.63	$8,711,062.00	$8,711.06	($12,479.41)	($8,689.78)	0.00	40
60	CHG1 detention-size c	$5,481.46	$1.60	$26.60	$22,347,415.00	$22,347.42	$5,149,250.00	$1,344.15	$5,149.25	$17,198,165.00	$17,198.17	($22,320.81)	($17,171.56)	0.00	59
61	Global Watershed Management Practices	$5526.56 aaev	$879.00	$14,613.95	$321,992,645.00	$321,992.65	$90,373,338.00	$19,367.21	$90,373.34	$231,619,307.00	$231,619.31	($307,378.69)	($217,005.35)	0.05	72
62	C3-Size a	$4,550.26	$932.80	$15,508.41	$26,478,293.00	$26,478.29	$10,512,250.00	$1,592.62	$10,512.25	$15,966,043.00	$15,966.04	($10,969.88)	($457.63)	0.59	36
63	C3-Size b	$4,521.52	$961.54	$15,986.23	$30,186,644.00	$30,186.64	$10,512,500.00	$1,815.67	$10,512.50	$19,674,144.00	$19,674.14	($14,200.41)	($3,687.91)	0.53	43
64	C3-Size c	$4,518.17	$964.89	$16,041.93	$34,191,927.00	$34,191.93	$10,512,250.00	$2,056.58	$10,512.25	$23,679,677.00	$23,679.68	($18,150.00)	($7,637.75)	0.47	54
65	**C4-Size a**	$4,534.00	$949.06	$15,778.75	$13,331,000.00	$13,331.00	$1,762,000.00	$801.83	$1,762.00	$11,569,000.00	$11,569.00	**$2,447.75**	$4,209.75	1.18	**3**
66	C4-Size b	$4,418.17	$1,064.89	$17,704.50	$17,161,000.00	$17,161.00	$2,138,000.00	$1,032.20	$2,138.00	$15,023,000.00	$15,023.00	**$543.50**	$2,681.50	1.03	**10**
67	C4-Size c	$4,378.74	$1,104.32	$18,360.05	$21,055,000.00	$21,055.00	$2,495,000.00	$1,266.42	$2,495.00	$18,560,000.00	$18,560.00	($2,694.95)	($199.95)	0.87	14
68	**Buyout of 3 structures in 2yr floodplain**	$5,318.74	$164.32	$2,731.93	$1,089,841.00	$1,089.84	$0.00	$65.55	$0.00	$1,089,841.00	$1,089.84	**$1,642.09**	$1,642.09	**2.51**	**4**
69	Buyout of 96 structures in 5yr floodplain + 2yr	$4,891.97	$591.09	$9,827.26	$21,348,199.00	$21,348.20	$0.00	$1,284.05	$0.00	$21,348,199.00	$21,348.20	($11,520.94)	($11,520.94)	0.46	38
70	Buyout of 10 structures in 5yr floodplain (FEMA)	$5,400.49	$82.57	$1,372.78	$2,003,430.00	$2,003.43		$120.50	$0.00	$2,003,430.00	$2,003.43	($630.65)	($630.65)	0.69	12
71	Buyout of 182 structures in 10yr floodplain + 5yr +2yr	$4,276.04	$1,207.02	$20,067.50	$59,640,027.00	$59,640.03	$0.00	$3,587.23	$0.00	$59,640,027.00	$59,640.03	($39,572.53)	($39,572.53)	0.34	64
72	Buyout of 46 structures in 10yr floodplain (FEMA)	$5,255.83	$227.23	$3,777.85	$11,437,675.00	$11,437.68		$687.95	$0.00	$11,437,675.00	$11,437.68	($7,659.83)	($7,659.83)	0.33	25
73	Sponsor Proposed Alt to Dixie Farm Rd	$4,024.93	$1,458.13	$24,242.37	$304,492,000.00	$304,492.00	$16,595,000.00	$18,314.58	$16,595.00	$287,897,000.00	$287,897.00	($280,249.63)	($263,654.63)	0.08	
74	Authorized Fed Project to Mykawa Rd	$1,811.98	$3,671.08	$61,034.12	$279,738,000.00	$279,738.00	$22,226,000.00	$16,825.68	$22,226.00	$257,512,000.00	$257,512.00	($218,703.88)	($196,477.88)	0.22	

amortization factor, 5.625%, 50yrs.= .060148

Table 2
Net Benefits for the Ten Best Measures

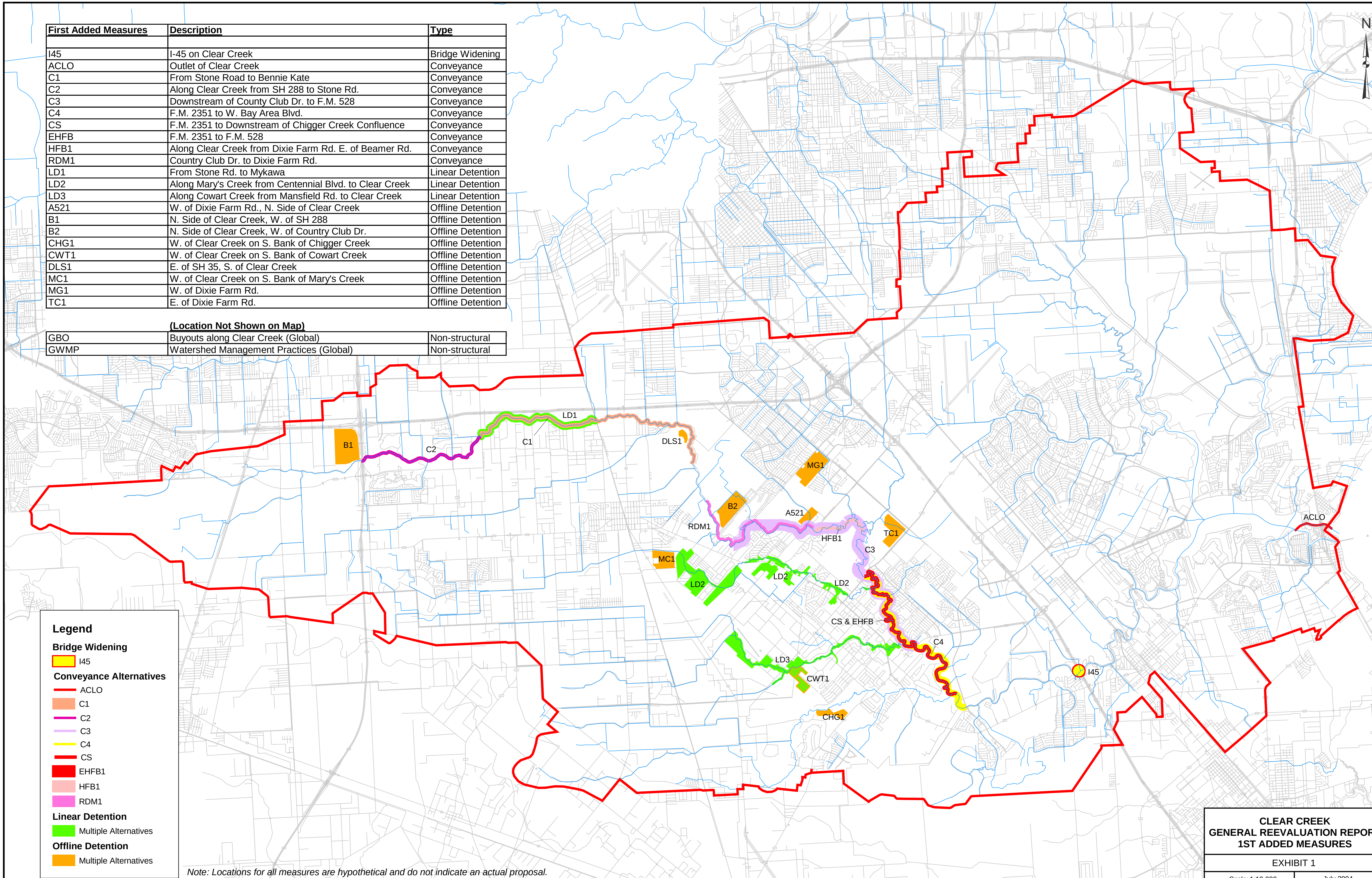
Measure	Size	Description	Net Benefit Present Worth Equivalent (Thousands)
CS	**b**	**Clear and snag channel and 20 feet outside both banks through the Friendswood reach.**	**$8,759**
C4	**a**	**Conveyance improvement from D/S FM 2351 to West Bay Area Blvd.**	**$2,448**
GBO	**a**	**Buyout of the only three structures flooded by the 2-year flood.**	**$1,642**
EHFB	**b**	**Enlarge existing high flow bypasses in reach 9 to 150-feet and deepen by 2 feet.**	**$772**
C1	**a**	**High flow channel from Stone Road to Bennie Kate Road, (shallow, 200-foot wide cut)**	**$730**
RDM1	a	Remove dredged material from Country Club Drive to Dixie Farm Road.	($427)
GBO	FEMA-5yr	FEMA buyout of 10 residential structures in the 5 year floodplain	($631)
I45	a	Widen bridge opening for Interstate 45 from 450 feet to 600 feet.	($1,665)
DLS1	a	Half of the capacity of the existing David L. Smith detention site.	($3,624)
TC1	a	Offline detention on Turkey Creek, east of Dixie Farm Road.	($4,204)

EXHIBITS

First Added Measures	Description	Type
I45	I-45 on Clear Creek	Bridge Widening
ACLO	Outlet of Clear Creek	Conveyance
C1	From Stone Road to Bennie Kate	Conveyance
C2	Along Clear Creek from SH 288 to Stone Rd.	Conveyance
C3	Downstream of County Club Dr. to F.M. 528	Conveyance
C4	F.M. 2351 to W. Bay Area Blvd.	Conveyance
CS	F.M. 2351 to Downstream of Chigger Creek Confluence	Conveyance
EHFB	F.M. 2351 to F.M. 528	Conveyance
HFB1	Along Clear Creek from Dixie Farm Rd. E. of Beamer Rd.	Conveyance
RDM1	Country Club Dr. to Dixie Farm Rd.	Conveyance
LD1	From Stone Rd. to Mykawa	Linear Detention
LD2	Along Mary's Creek from Centennial Blvd. to Clear Creek	Linear Detention
LD3	Along Cowart Creek from Mansfield Rd. to Clear Creek	Linear Detention
A521	W. of Dixie Farm Rd., N. Side of Clear Creek	Offline Detention
B1	N. Side of Clear Creek, W. of SH 288	Offline Detention
B2	N. Side of Clear Creek, W. of Country Club Dr.	Offline Detention
CHG1	W. of Clear Creek on S. Bank of Chigger Creek	Offline Detention
CWT1	W. of Clear Creek on S. Bank of Cowart Creek	Offline Detention
DLS1	E. of SH 35, S. of Clear Creek	Offline Detention
MC1	W. of Clear Creek on S. Bank of Mary's Creek	Offline Detention
MG1	W. of Dixie Farm Rd.	Offline Detention
TC1	E. of Dixie Farm Rd.	Offline Detention

(Location Not Shown on Map)

GBO	Buyouts along Clear Creek (Global)	Non-structural
GWMP	Watershed Management Practices (Global)	Non-structural



Note: Locations for all measures are hypothetical and do not indicate an actual proposal.

CLEAR CREEK
GENERAL REEVALUATION REPORT
1ST ADDED MEASURES

EXHIBIT 1

Scale: 1:10,000 | July 2004

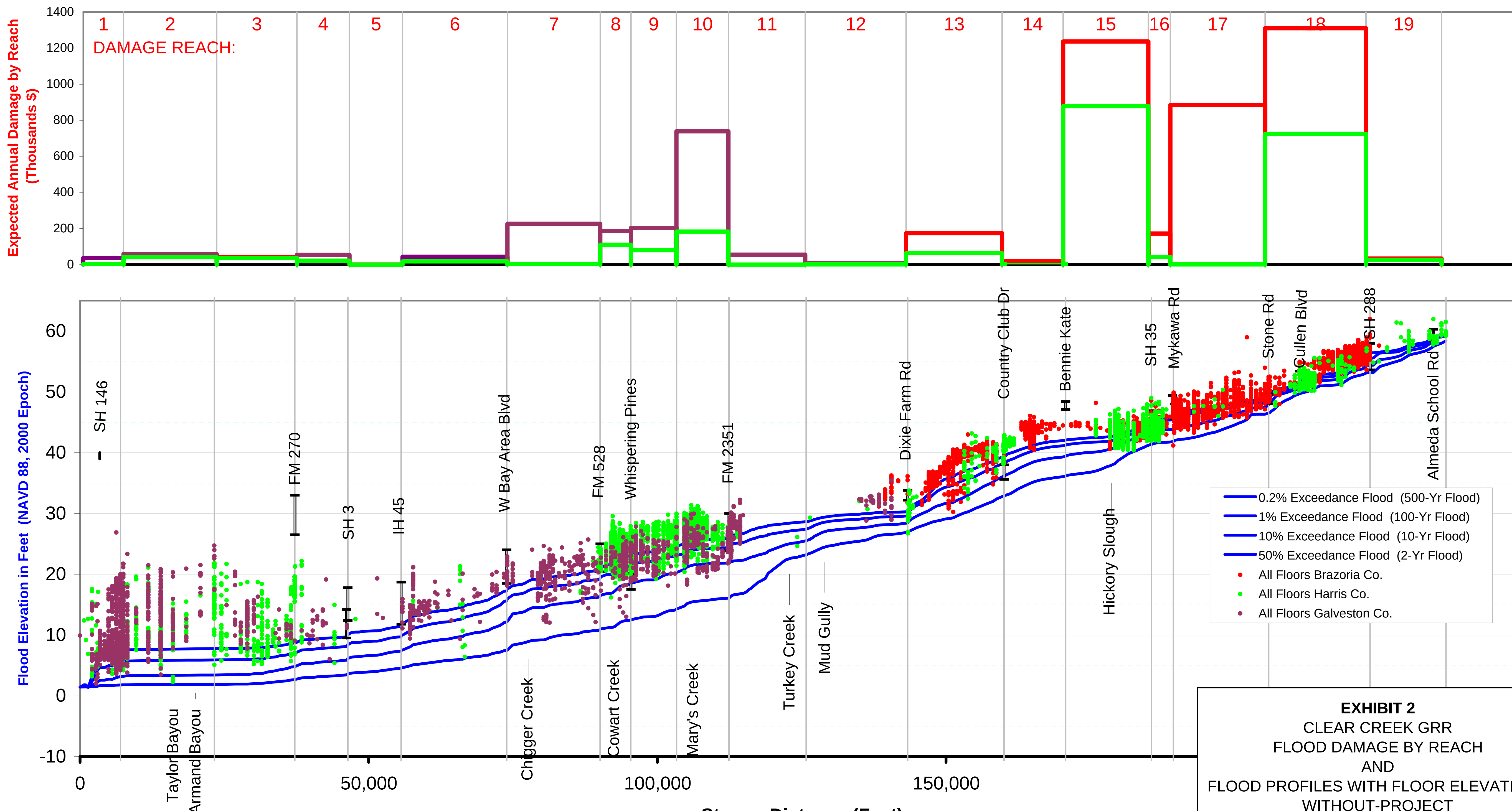


EXHIBIT 2
CLEAR CREEK GRR
FLOOD DAMAGE BY REACH
AND
FLOOD PROFILES WITH FLOOR ELEVATIONS
WITHOUT-PROJECT
2010 CONDITIONS

Note: Structure floor elevations from "REF_FLRELE" in fda-woprojstructuresFINAL.xls 8-26-04

APPENDIX A

DERIVATION OF COSTS AND BENEFITS FOR GLOBAL WATERSHED MANAGEMENT PRACTICES

Derivation of Costs and Benefits for Global Watershed Management Practices

Global Watershed Management Practices (GWMP) was the most costly measure considered in the first-added analysis. Its costs far outweigh computed benefits. Watershed management is somewhat unconventional as a flood damage reduction measure, so an explanation of how benefits and costs were determined is in order. GWMP would reduce flood damage by eliminating development related flow increases along Clear Creek for the entire economic analysis period (2010 to 2060). It would accomplish this by unifying and enhancing detention requirements throughout the Clear Creek watershed for all new development projects, other new land use changes, and all new drainage improvements.

Many areas within the Clear Creek watershed are *already* covered by detention policies. This existing level of control is reflected in the GRR without-project condition, so costs for meeting these existing requirements were not included for GWMP. Costs were only counted for extending coverage for those areas not currently controlled, plus some additional requirements throughout the basin to strengthen current policies. The following factors were used to estimate the total required detention volume.

Detention Volume Factors for Estimating Total Required Detention Volume for GWMP

Detention Volume Factor	Size of Area to Apply	Description
0.55 acre feet per acre (Source: commonly accepted value)	20% of area developing during 2010-2060	Volume needed to meet nominal requirements for new, developing areas that do not currently have a mitigation requirement (estimated to be 20% of the area developing during 2010 – 2060).
0.13 acre feet per acre (Source: DEC studies with HEC-1 modeling)	100% of area developing during 2010-2060	Volume needed (beyond nominal requirements) to mitigate for all frequencies instead of just the 1% annual exceedance event.
0.10 acre feet per acre (Source: engineering judgment)	100% of area developing during 2010-2060	Volume needed (beyond nominal requirements) to makeup for loopholes, variances, exclusions, errors, etc.

Development projections for the GRR show that 27 percent of the basin, or 44,928 acres, will develop over the period 2010 to 2060 (source: Table III.3, *Hydrologic Analysis for Without Project Conditions*, July 2003). Multiplied by the above factors this equates to a total detention volume of 15,276 acre-feet for GWMP. The required footprint area for detention was estimated to be 2,100 acres by assuming an average depth of 8 feet and adding additional area for R.O.W. buffer. Total costs were estimated by applying unit costs (for excavation, real estate, and other cost items) that were derived from the other detention basin measures in the first-added analysis.

HEC-1 modeling tests were conducted to confirm the detention volume requirement for GWMP. It was determined that reducing each HEC-1 hypothetical rainfall event by one inch results in computed 2060 peak flows (at the mouth of Clear Creek) that are equal to 2010 peak flows resulting from un-adjusted hypothetical rainfall. This is true for all eight HEC-1 frequency-events used in the GRR analysis. The volume requirement determined with the factors in the above table (15,276 acre-feet) is equivalent to 1.1 inches of rainfall distributed over the 260 square mile Clear Creek watershed. Thus, the HEC-1 results are consistent with the earlier estimate.

Flood damage reduction benefits for GWMP were determined with the Flood Damage Analysis (FDA) economics model. The development-control effects of the measure were modeled in FDA by entering 2010 condition flood flows and flood profiles (computed for without-project conditions) to represent the GWMP measure for both 2010 *and 2060*. Thus, the computed flood damage with GWMP in place would be the same as for without-project conditions for year 2010, but damage potential would not increase through 2060. The flood damage values were only computed for the mainstream of Clear Creek. GWMP would also reduce flood damage along tributaries. However, the costs for the measure were over 20 times larger than mainstream benefits, so the additional tributary benefits would not be sufficient to create positive net benefits.

APPENDIX B

1ST ADDED MEASURES NOTEBOOK

CLEAR CREEK GRR
FLOOD DAMAGE REDUCTION

FIRST ADDED MEASURES NOTEBOOK
7-29-04

TABLE OF CONTENTS

Measure: C1

Description: Conveyance Improvement Reach from Stone Road to Bennie Kate Road

Orthophotos: 31313775, 31413775, and 31513775 **Stream cross section limits**: 205,888 – 170,703

Template: A shallow, wide, trapezoidal cut that preserves the existing channel. The shallow cut will straddle the natural channel forming benches on each side. (1v:4h side slopes). A schematic of the channel improvement is attached. This channel improvement is typical of all First Added channel improvements, unless otherwise noted.

Invert / gradient: The invert of the cut will be three feet below the level of the 50% exceedance flood (2010c, without-project). Designer's comment: The invert was lowered to five feet below the level of the 50% exceedance flood for better performance. The hydraulic modeling results and excavation quantities reflect this change.

Sizes:

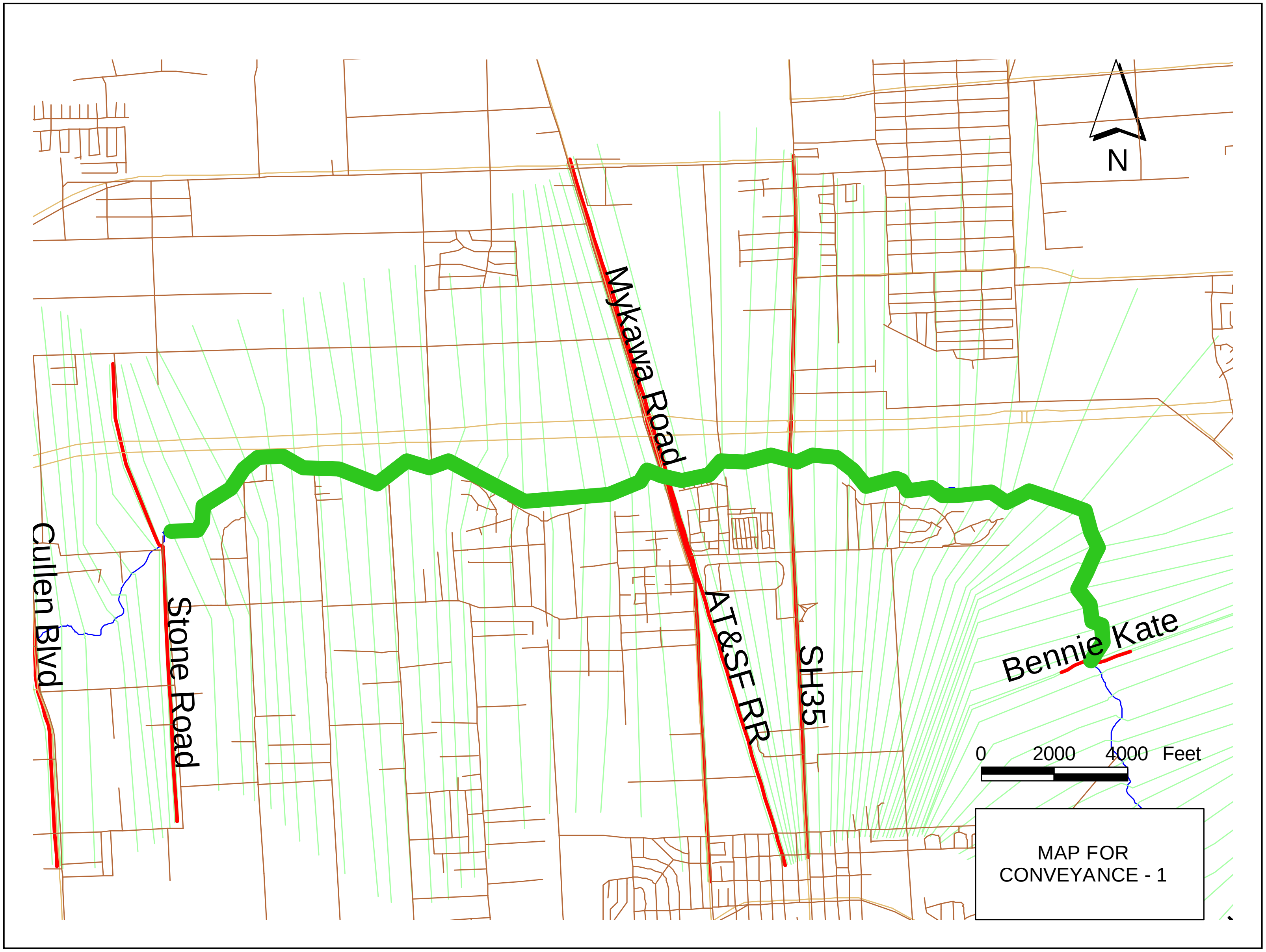
Reach:	**Bottom Width (Feet)**		
	C1a	**C1b**	**C1c**
Stone Road – Bennie Kate Road	200	300	400

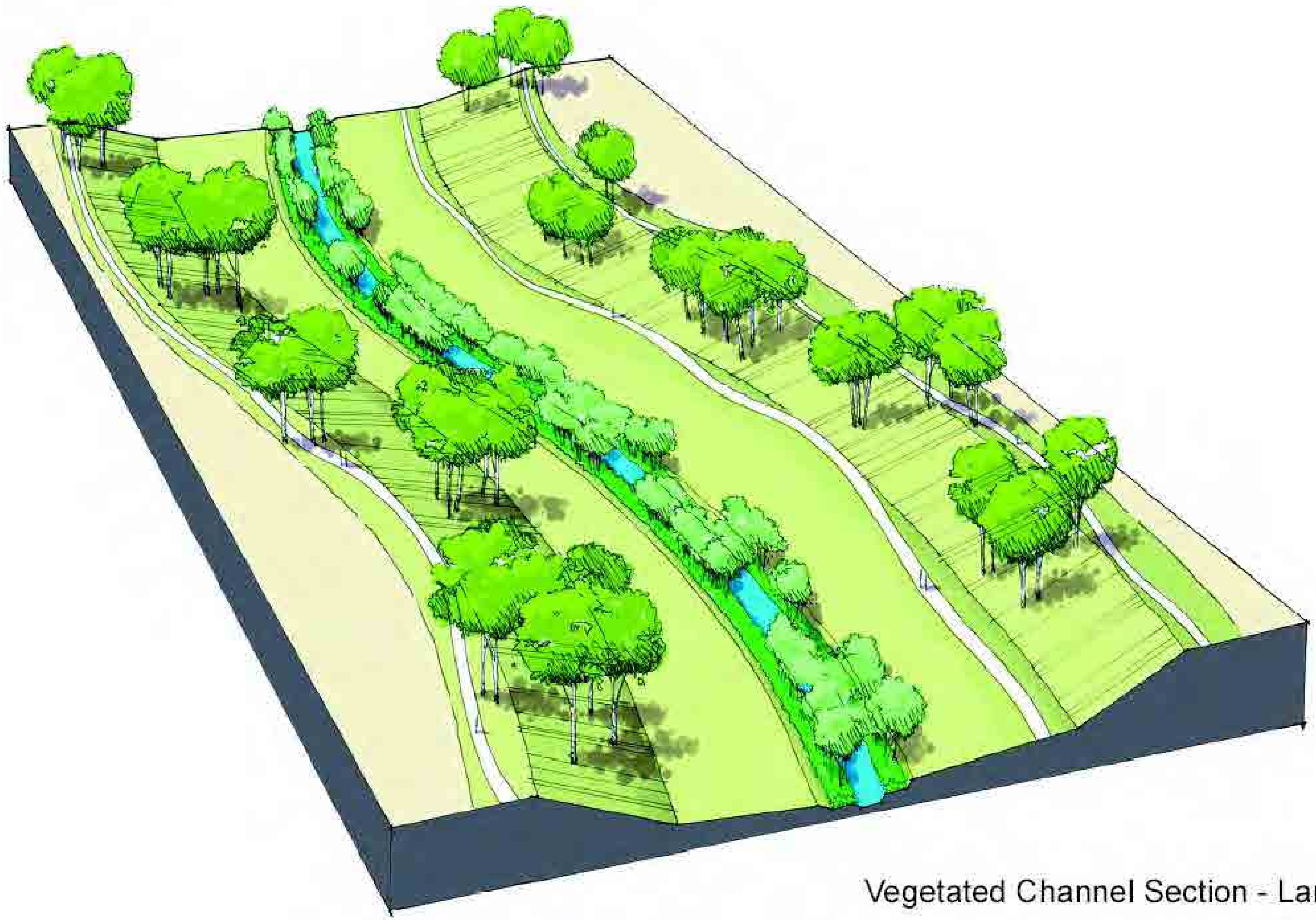
Alignment: Follow existing creek centerline from Stone Road to Mykawa, and then follow the Authorized Federal Project alignment from Mykawa to Bennie Kate.

Green /Recreation Opportunities: Existing channel will be preserved and un-maintained (shaded with riparian vegetation). Cut areas will be park like, i.e. mowed routinely with tree plantings (14 per acre). Hiking trails.

Quantities/Costing comments: Consider maintenance access R.O.W. costs. Bridges at Mykawa, AT&SF RR, and SH35 will be raised and widened. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Assume bridges at Mykawa, AT&SF RR, and SH35 are modified such that there is minimal head loss.
Model the conveyance feature to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show tailing effects. Upstream performance without tailing effects will be same as no-project profile, so no special modeling is needed for that case.


N
Mykawa Road
Cullen Blvd
Stone Road
AT&SF RR
SH35
Bennie Kate
0 2000 4000 Feet
MAP FOR CONVEYANCE - 1



Vegetated Channel Section - Large

Measure: B1

Description: Offline Detention just West of SH288

Orthophotos: 31113775 **Location**: North side of Clear Creek just west of SH288 or similar sized area in same vicinity.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert of basin is +43 feet based on Clear Creek invert of 42.
Designer's comment: An invert of +43.6 feet was used.

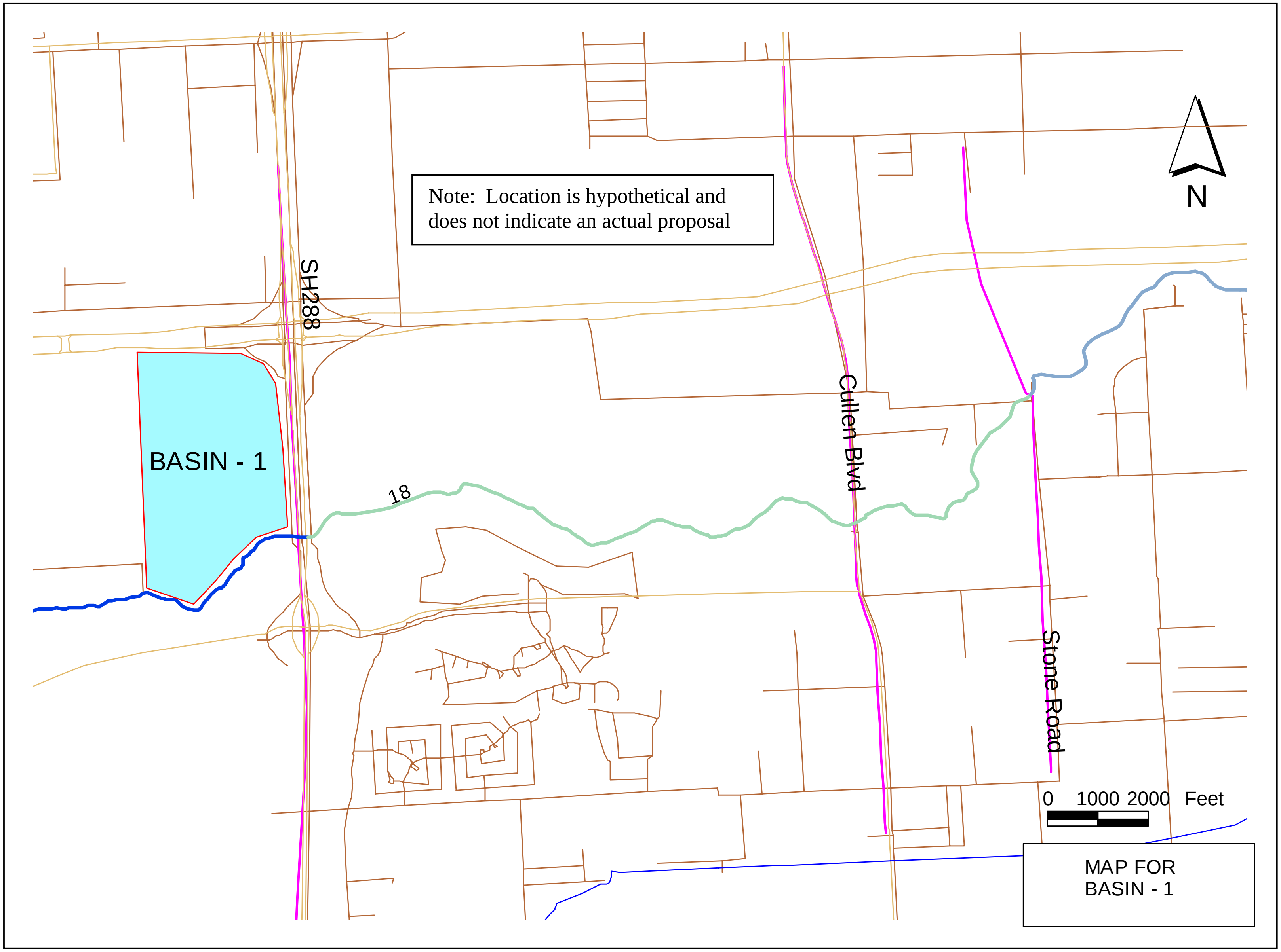
Sizes: Mapped area is approximately 284 acres. Assume full depth for all sizes. B1a= 33% area; B1b= 66% area; B1c= 100% area

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity


Note: Location is hypothetical and
does not indicate an actual proposal
N
SH288
BASIN - 1
18
Cullen Blvd
Stone Road
0 1000 2000 Feet
MAP FOR
BASIN - 1

Measure: B2

Description: Offline Detention just West of Country Club Drive.

Orthophotos: 31513765, 31613765 **Location**: North of Clear Creek just west of Country Club Drive or similar sized area in same vicinity.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert of basin is +19 feet based on invert of Clear Creek +18.
Designer's comment: An invert of +18.75 feet was used.

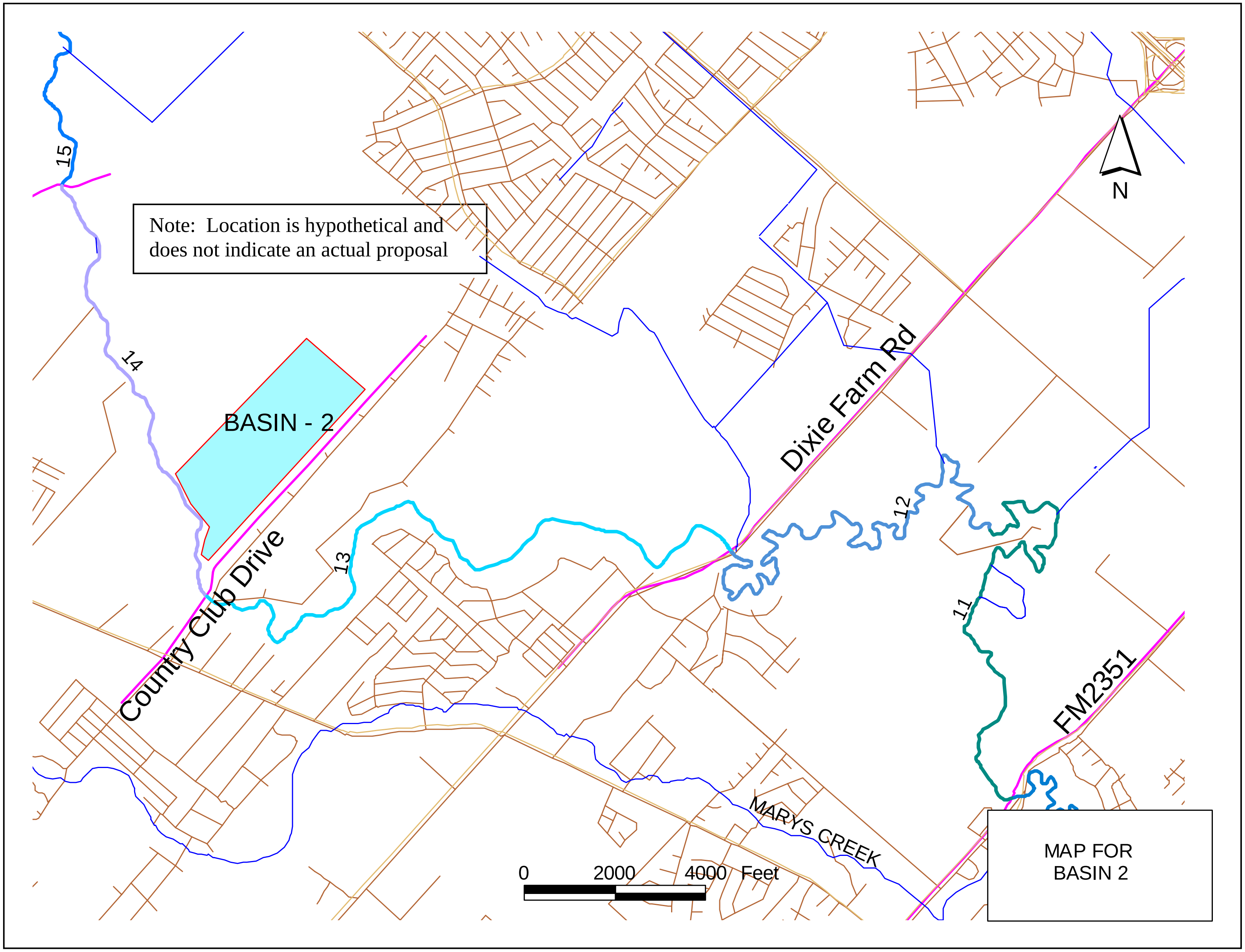
Sizes: Mapped area is approximately 186 acres. Assume full depth for all sizes. B2a= 33% area; B2b= 66% area; B2c= 100% area

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity


Note: Location is hypothetical and
does not indicate an actual proposal
BASIN - 2
Country Club Drive
Dixie Farm Rd
FM2351
MARYS CREEK
15
14
13
12
11
N
0
2000
4000
Feet
MAP FOR
BASIN 2

Measure: LD1

Description: Linear Detention from Stone Road to Mykawa (See map for C1 but shorter reach)

Orthophotos: 31313775 and 31413775 **Stream cross section limits**: 205,888 – 189,432

Template: A shallow, wide, trapezoidal cut that preserves the existing channel. The shallow cut will straddle the natural channel forming benches on each side. The excavated area will be densely planted and un-maintained to negate any conveyance so that the template only provides storage.

Invert / gradient: The invert of the cut will be 3 feet below the 50% flood (2010c, without-project).
Designer's note: Five feet below the 50% exceedance flood was used.

Sizes: LD1a= 200-foot bottom width; LD1b= 300-foot bottom width; LD1c= 400-foot bottom width (1v4h side slopes)

Alignment: Follow existing creek centerline from Stone Road to Mykawa, and then follow the Authorized Federal Project alignment from Mykawa to Bennie Kate.

Green /Recreation Opportunities: Existing channel will remain in current state. Excavated benches will be densely planted and not mowed. Hiking trails.

Quantities/Costing comments: No maintenance required for excavated areas. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments:

Measure: DLS1

Description: Expand existing detention at David L Smith Site

Orthophotos: 31513775 **Location**: 2 miles east of State Highway 35 on south side of creek.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert of basin is +23 feet based on invert of Clear Creek +22.
Designer's note: An invert of +21.6 feet was used. The pond's stage-volume relationship was taken from City of Pearland plans.

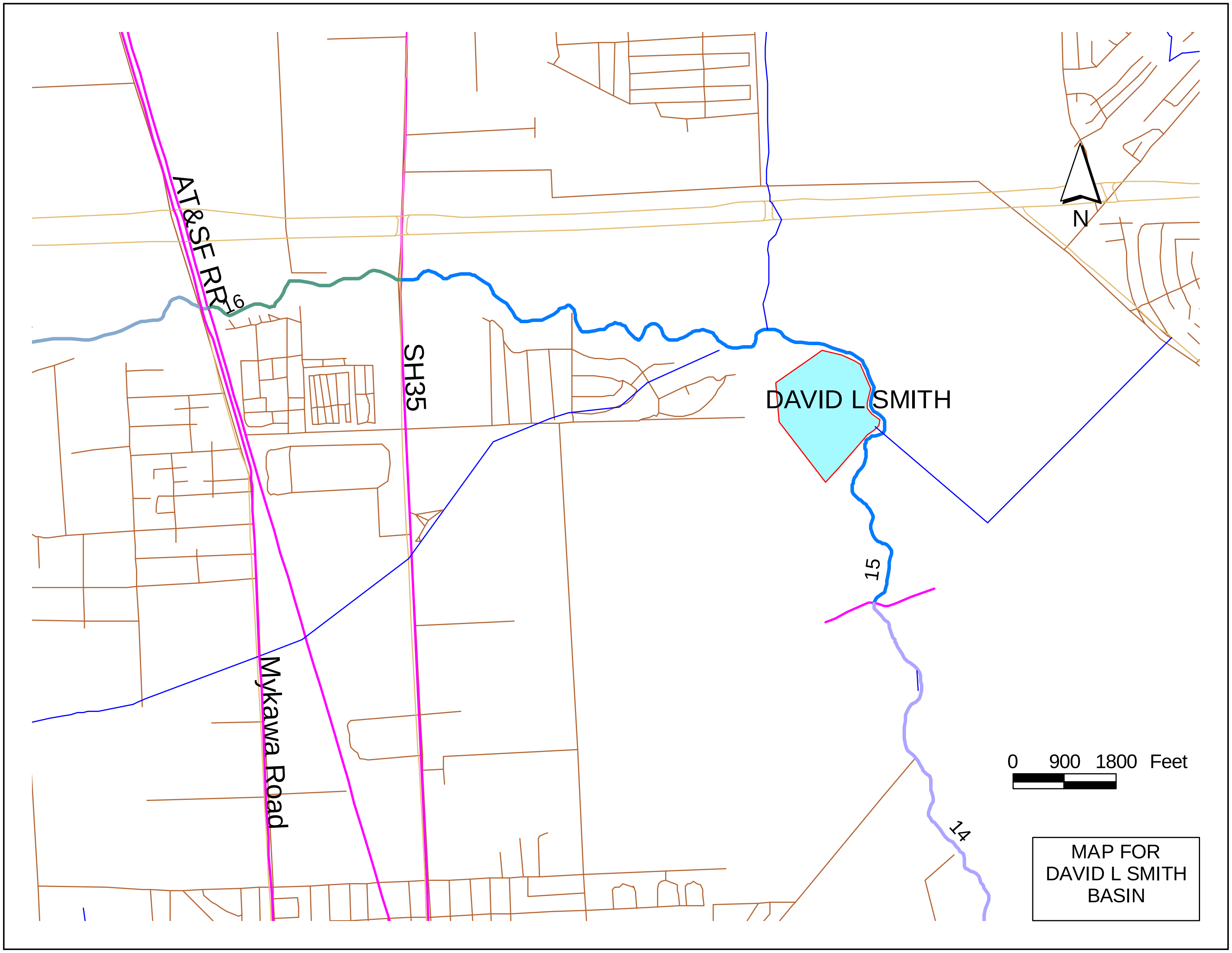
Sizes: Mapped area is approximately 59 acres and represents existing site. Assume full depth for all sizes. DLS1a= 50% of existing site potential; DLS1b= 50% of existing site potential plus an additional developed 50%; DLS1c= 50% of existing site potential plus an additional developed 100%

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Do not include in costs half of existing basin (allocated for development mitigation). Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity. Do not include the volume of half of the existing basin (allocated for development mitigation).


AT&SF RR
16
SH35
DAVID L SMITH
15
Mykawa Road
14
N
0 900 1800 Feet
MAP FOR
DAVID L SMITH
BASIN

Measure: A521-01

Description: Expand existing detention at A521-01

Orthophotos: 31613765, 31713765 **Location**: West of Dixie Farm Road on north side of creek.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert of existing basin is +20 feet.
Designer's note: An invert of +13.5 feet was used.

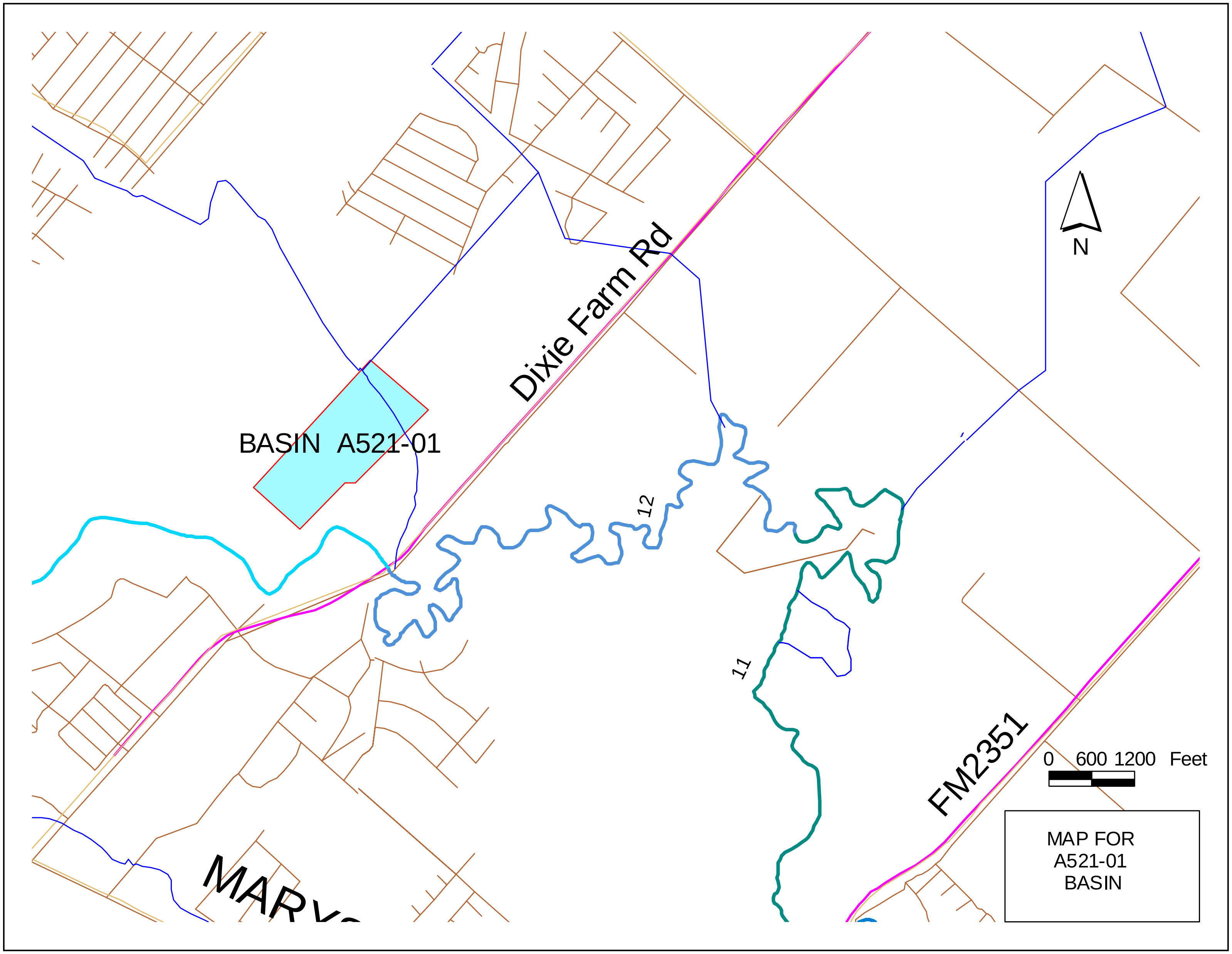
Sizes: Mapped area is approximately 54 acres and represents existing site. Assume full depth for all sizes. A521a= 50% of existing site potential; A521b= 50% of existing site potential plus an additional developed 50%; A521c= 50% of existing site potential plus an additional developed 100%

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Do not include in costs half of existing basin (allocated for development mitigation). Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity. Do not include the volume of half of the existing basin (allocated for development mitigation).



Dixie Farm Rd
BASIN A521-01
N
12
11
FM2351
0 600 1200 Feet
MAP FOR
A521-01
BASIN

Measure: RDM1

Description: Remove dredge material from upstream of Country Club Drive to Dixie Farm Road.

Orthophotos: 31513765, 31613765, 31713765 **Stream cross section limits**: 165,236 – 143,670

Template: RDM1a- Remove dredge material mounds on the north bank of the creek. Footprint of mounds totals about 29 acres.
RDM1b- Make a trapezoidal cut with a 200-foot bottom width and a centerline 100 feet north of the existing centerline.
RDM1c- Make a trapezoidal cut with a 300-foot bottom width and a centerline 150 feet north of the existing centerline.

Invert / gradient: The cut invert will be 2-feet below the 50% flood (2010c, without-project).

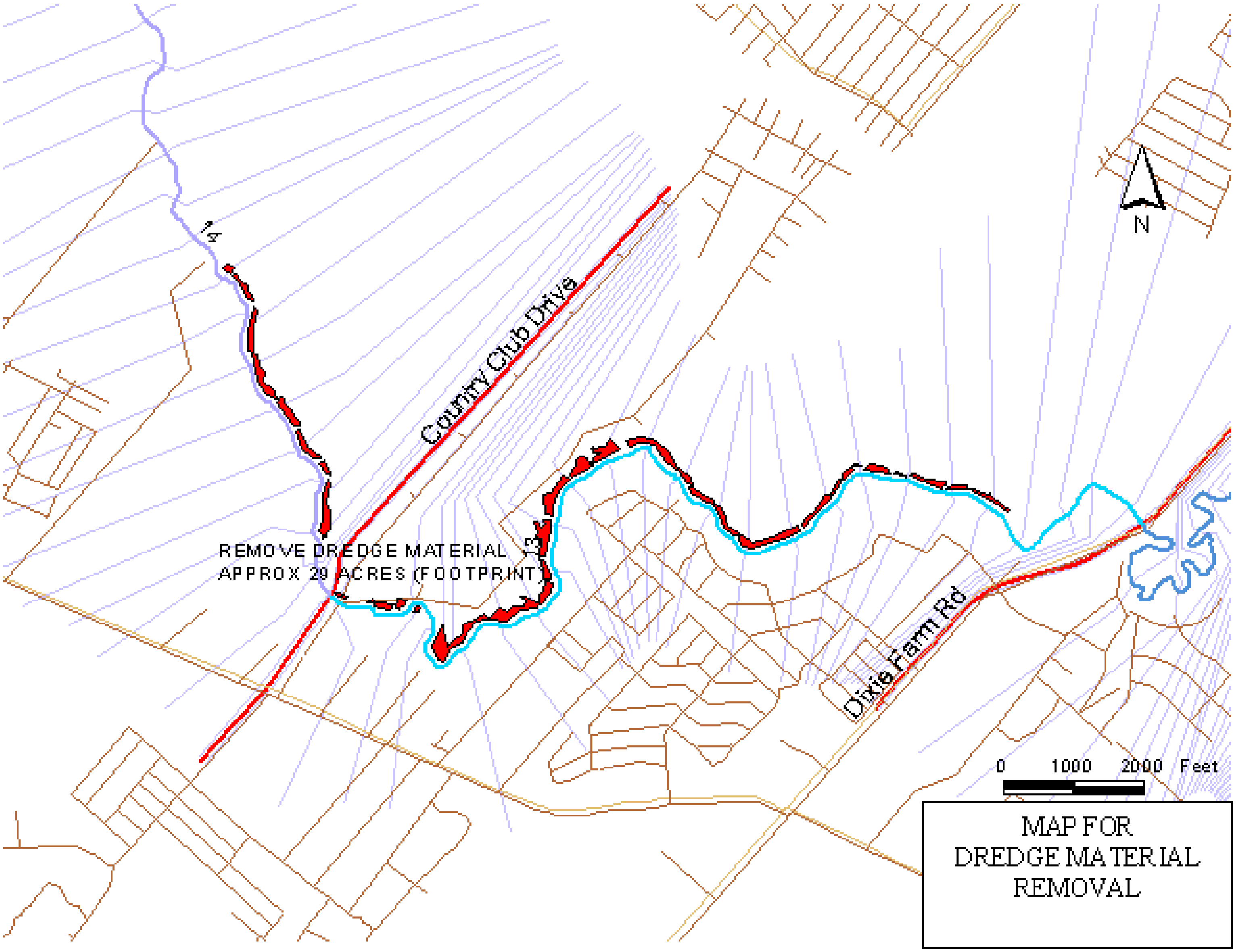
Sizes: See template

Alignment:

Green /Recreation Opportunities: Cut areas will be park like, i.e. mowed routinely with tree plantings (14 per acre). Hiking trails. Riparian tree plantings along low flow channel for improved water quality.

Quantities/Costing comments: Include costs for tree plantings. Maintenance costs for mowing. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Roughness of existing channel will be increased to show riparian tree plantings.


Country Club Drive
Dixie Farm Rd
REMOVE DREDGE MATERIAL
APPROX 29 ACRES (FOOTPRINT)
N
0 1000 2000 Feet
MAP FOR
DREDGE MATERIAL
REMOVAL

Measure: MG1

Description: Offline detention on Mud Gully.

Orthophotos: 31613775, 31713765, 31713775 **Location**: West of Dixie Farm Road or similar sized area in same vicinity

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert for full development is +15 feet (based on invert of Mud Gully from TIN = +13 to +14 feet)
Designer's note: An invert of +14.5 feet was used.

Sizes: Mapped area is approximately 178 acres. Assume full depth for all sizes. MG1a= 33% area; MG1b= 66% area; MG1c= 100% area

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity

Measure: TC1

Description: Offline detention on Turkey Creek.

Orthophotos: 31713765, 31813765 **Location**: East of Dixie Farm Road or similar sized area in same vicinity.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert for full development is +6 feet (based on invert of Turkey Creek from TIN = +4 to +5 feet)

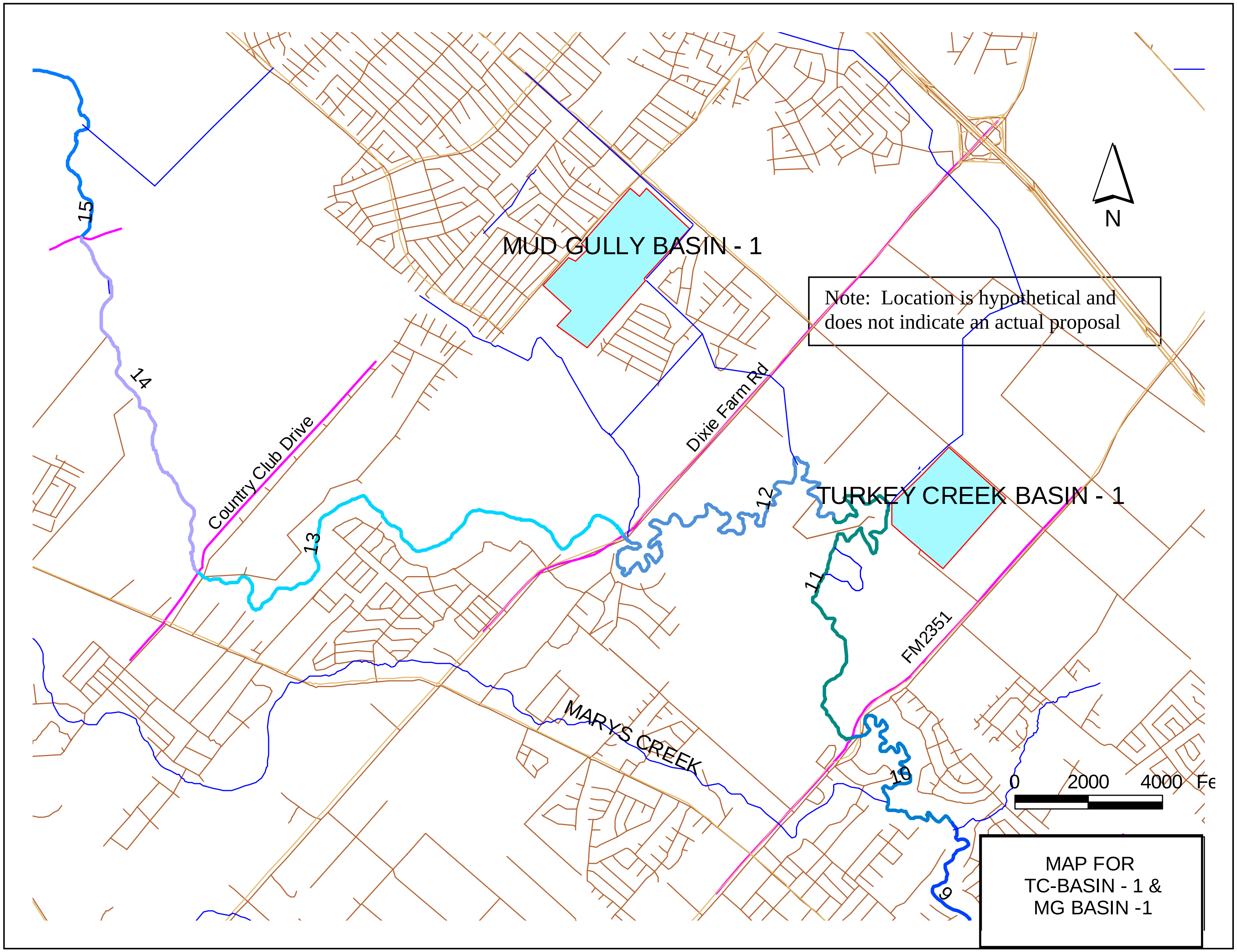
Sizes: Mapped area is approximately 125 acres. Assume full depth for all sizes. TC1a= 33% area; TC1b= 66% area; TC1c= 100% area

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity


MUD GULLY BASIN - 1
TURKEY CREEK BASIN - 1
Note: Location is hypothetical and
does not indicate an actual proposal
N
Country Club Drive
Dixie Farm Rd
FM2351
MARYS CREEK
15
14
13
12
11
10
9
0
2000
4000
MAP FOR
TC-BASIN - 1 &
MG BASIN -1

Measure: MC1

Description: Offline detention on Mary's Creek.

Orthophotos: 31513765 **Location**: On south bank of Mary's Creek, 5 miles west of Clear Creek or similar sized area in same vicinity.

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: Invert for full development is +30 feet (based on invert of Mary's Creek from TIN = +27 to +28 feet)
Designer's note: An invert of 33.2 feet was used.

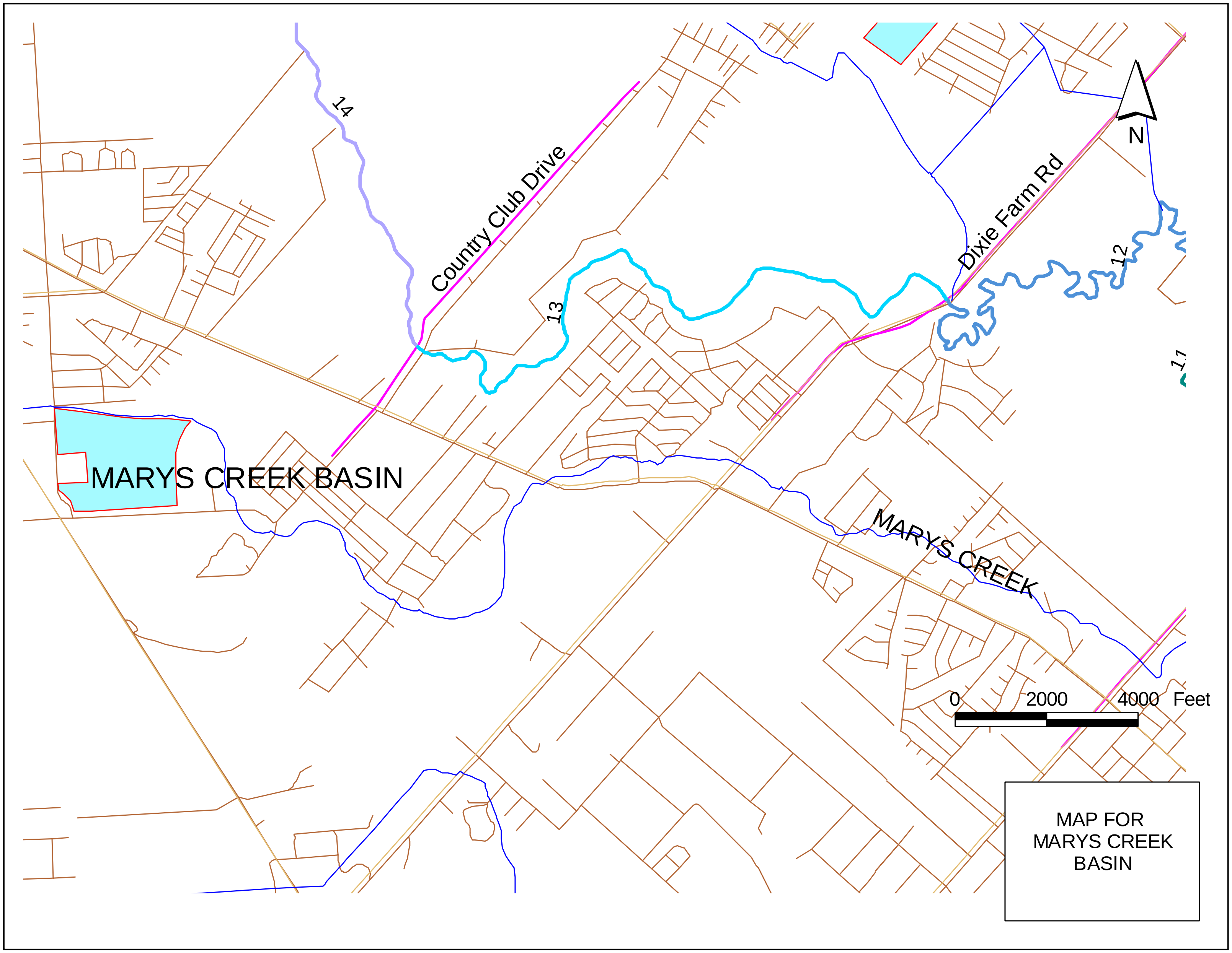
Sizes: Mapped area is approximately 110 acres. Assume full depth for all sizes. MC1a= 33% area; MC1b= 66% area; MC1c= 100% area

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity



14
Country Club Drive
13
Dixie Farm Rd
12
N
MARYS CREEK BASIN
MARYS CREEK
0
2000
4000
Feet
MAP FOR
MARYS CREEK
BASIN

Measure: HFB1

Description: High-Flow By-Pass Downstream of Dixie Farm Road

Orthophotos: 31313765 **Stream cross section limits**: 143,346 to 119,200

Template: A shallow, wide, trapezoidal cut that preserves the existing channel. The shallow cut will follow the alignment shown on the map.

Invert / gradient: The invert of the cut will be at the 50% exceedance flood level (2010c, without-project).

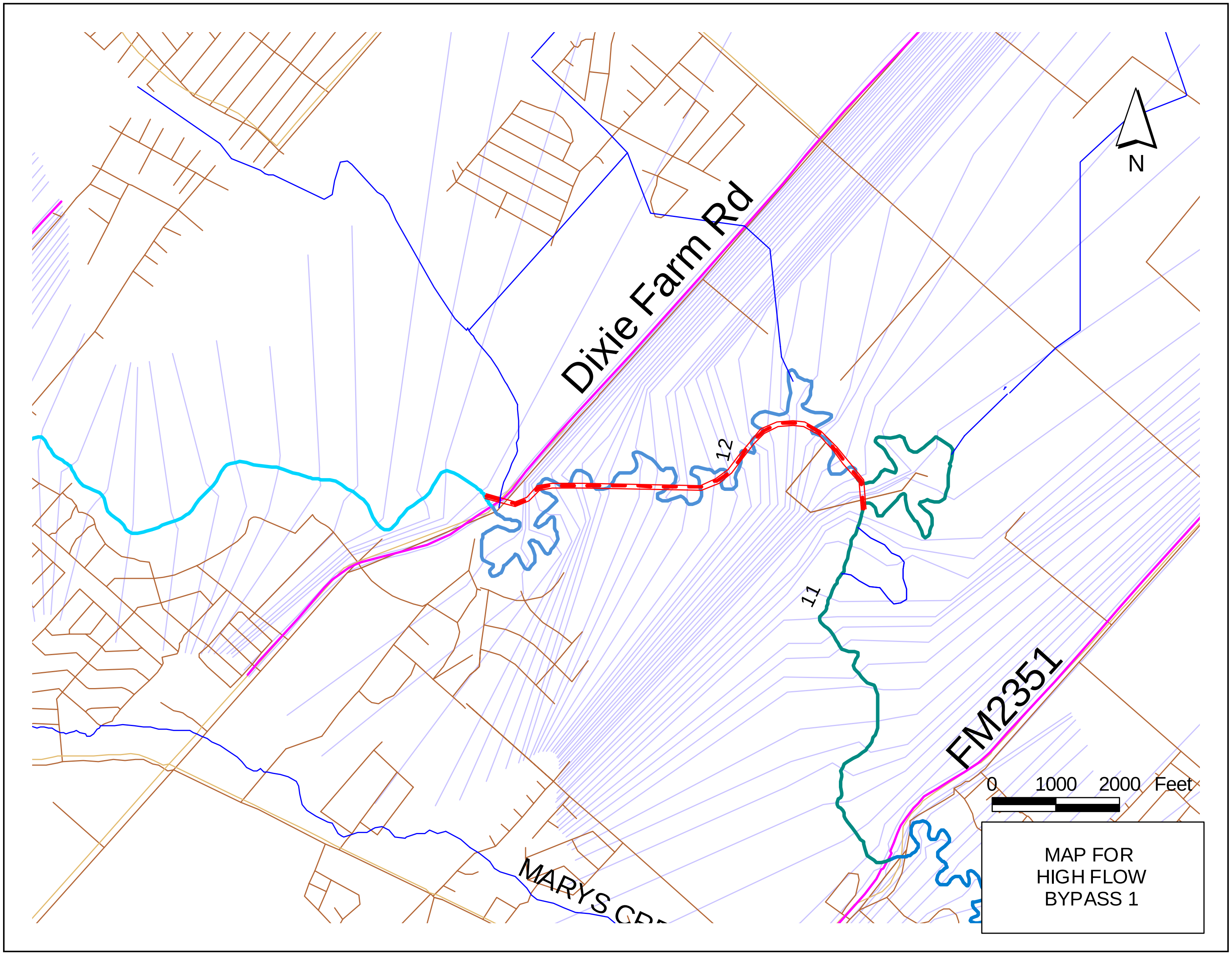
Sizes: HFB1a= 150-foot cut bottom width; HFB1b= 200-foot cut bottom width; HFB1c= 250-foot cut bottom width (1v:4h side slopes)

Alignment: See map.

Green /Recreation Opportunities: Existing channel will be preserved and un-maintained (shaded with riparian vegetation). Cut areas will be park like, i.e. mowed routinely with tree plantings (14 per acre). Hiking trails.

Quantities/Costing comments: The excavated high-flow channel will be routinely mowed. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Model to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show tailing effects. Upstream performance without tailing effects will be same as no-project profile so no special run is needed for that case.



Dixie Farm Rd
FM2351
MARYS CR
12
11
N
0 1000 2000 Feet
MAP FOR
HIGH FLOW
BYPASS 1

Measure: CHG1

Description: Expand existing detention on Chigger Creek

Orthophotos: 31713745 **Location**: On south bank of Chigger Creek, 3 miles west of Clear Creek

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: +17 feet (based on TIN invet elevation of Chigger Creek = +15 to +16 feet)
Designer's note: An invert of +15.9 feet was used.

Sizes: Mapped area is approximately 26 acres and represents existing site. Assume full depth for all sizes. CHG1a= 100% of existing site potential; CHG1b= 100% of existing site potential plus an additional developed 50%; CHG1c= 100% of existing site potential plus an additional developed 100%. The area of the hypothetical addition shown on the map is 27 acres.

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Do not include in costs half of existing basin (allocated for development mitigation). Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity. Do not include the volume of half of the existing basin (allocated for development mitigation).

Measure: CWT1

Description: Expand existing detention on Cowart Creek

Orthophotos: 31613745, 31713745 **Location**: On south bank of Cowart Creek, 2.5 miles west of Clear Creek

Template: 1v:4h side slopes with flat bottom, 30-foot buffer around perimeter

Invert / gradient: +17 feet (based on TIN invert elevation of Cowart Creek = +15 to +16 feet)
Designer's note: An invert of +13.9 feet was used.

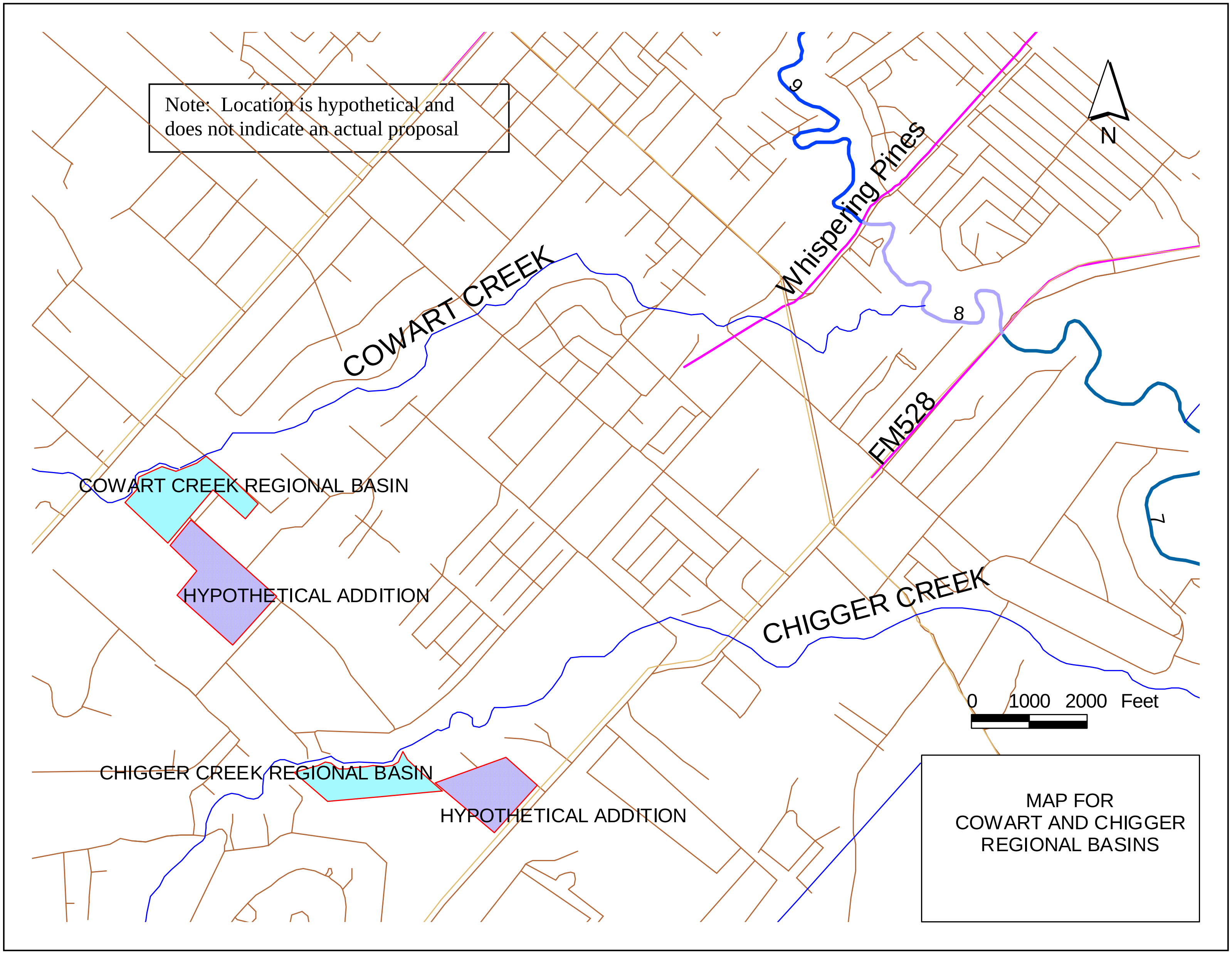
Sizes: Mapped area is approximately 37 acres and represents existing site. Assume full depth for all sizes. CWT1a= 100% of existing site potential; CWT1b= 100% of existing site potential plus an additional developed 50%; CWT1c= 100% of existing site potential plus an additional developed 100%. The area of the hypothetical addition shown on the map is 43 acres.

Alignment:

Green /Recreation Opportunities: Wetland creation, hiking trails, tree plantings

Quantities/Costing comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing excavation. Do not include in costs half of existing basin (allocated for development mitigation). Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Account for 30-foot buffer around perimeter and 1:4 side slopes when computing hydraulic capacity. Do not include the volume of half of the existing basin (allocated for development mitigation).


Note: Location is hypothetical and
does not indicate an actual proposal
N
Whispering Pines
COWART CREEK
9
8
FM528
7
COWART CREEK REGIONAL BASIN
HYPOTHETICAL ADDITION
CHIGGER CREEK
0 1000 2000 Feet
CHIGGER CREEK REGIONAL BASIN
HYPOTHETICAL ADDITION
MAP FOR
COWART AND CHIGGER
REGIONAL BASINS

Measure: EHFB

Description: Enlarge high flow bypasses in Reach 9 (8,9,&10)

Orthophotos: 31313765 **Location**: FM 2351 to FM 528

Template: A shallow, wide, trapezoidal cut that preserves the existing channel.

Invert / gradient:

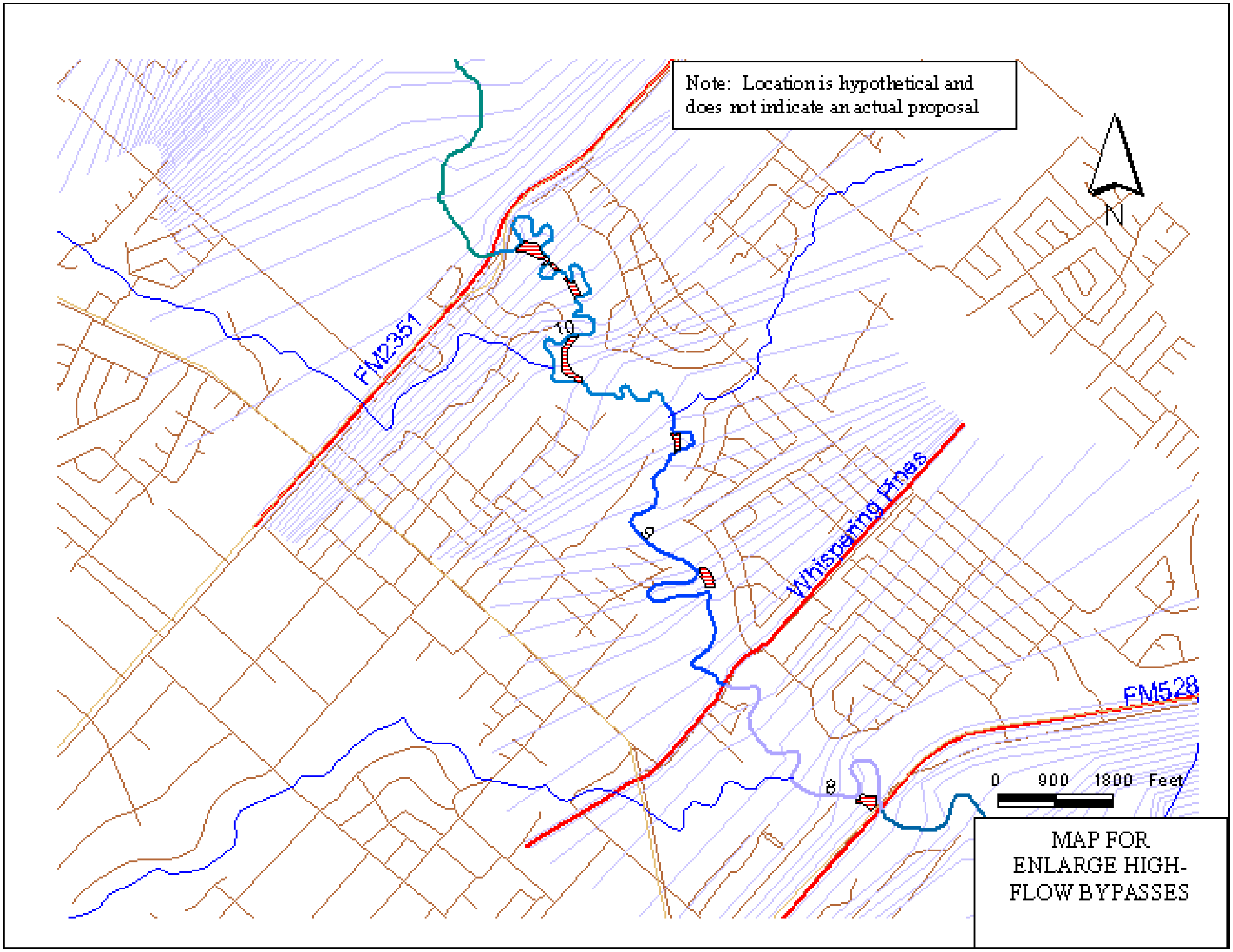
Sizes: EHFBa= widen to 150-foot bottom width; EHFBb= widen to 150-foot bottom width and deepen by 2 feet; EHFBc= widen to 150-foot cut bottom width and deepen by 5 feet

Alignment: See map.

Green /Recreation Opportunities: Limited tree plantings within the bypass. (Say 14 per acre)

Quantities/Costing comments: The excavated high-flow channel will be routinely mowed. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments:


Note: Location is hypothetical and does not indicate an actual proposal
N
FM2351
10
9
Whispering Pines
FM528
8
0 900 1800 Feet
MAP FOR ENLARGE HIGH-FLOW BYPASSES

Measure: I-45

Description: Widen bridge opening for Interstate 45

Orthophotos: 32013745 **Stream cross section limits**: 55,625

Template:

Invert / gradient:

Sizes: I-45a = Increase from 450-foot width to 500-foot; I-45b = 600-foot; I-45c = 700-foot

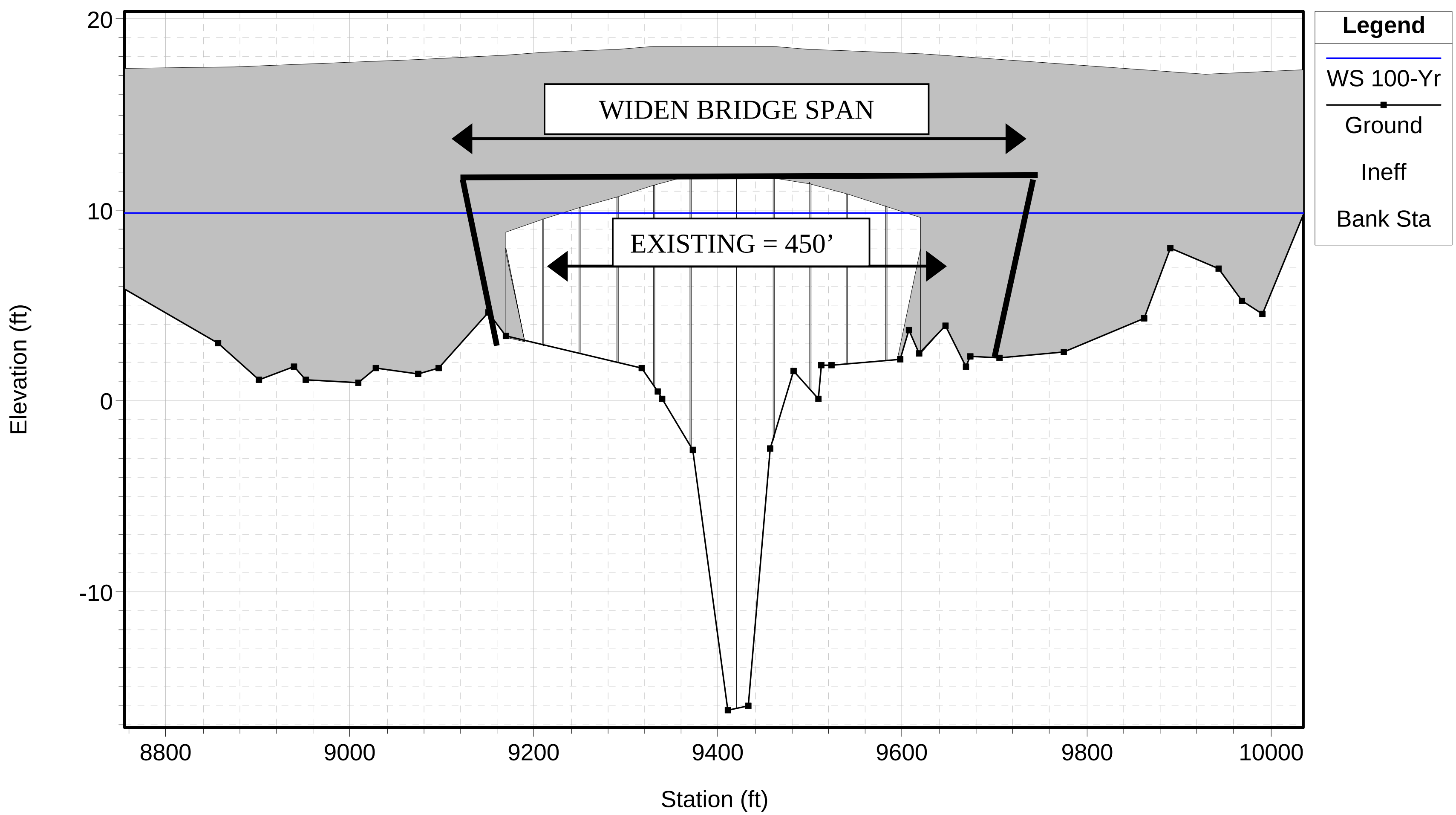
Alignment:

Green /Recreation Opportunities:

Quantities/Costing comments: Widen all three bridges

Modeling comments: Bridges are included as one bridge in the HEC-RAS model.

Interstate 45 Bridge Sketch



Measure: GBO

Description: Global buyout along mainstream of Clear Creek

Orthophotos: **Stream cross section limits**: Full length of Clear Creek in Brazoria, Harris, & Galveston County

Template:

Invert / gradient:

Sizes: GBOa=Homes flooded by the 50% flood; GBOb=Homes flooded by the 20% flood; GBOc=Homes flooded by the 10% flood. See tables with structure counts and values by municipality on the following pages.

Alignment:

Green /Recreation Opportunities: Flood plain restoration, hiking trails

Quantities/Costing comments: In this phase of the analysis the total costs for the buyouts will be compared to the flood damage reduction benefits. Later phases will consider proportioning some costs to ecosystem restoration and or recreation.

Modeling comments: No modeling required.

Clear Creek GRR
Without Project - 2010 Conditions
Count of Structures Inundated by the 50- 20- and 10-Percent Chance Annual Exceedance Floods

Percent Chance Annual Exceedance	Brookside Village	El Lago	Friendswood	Houston	Kemah	League City	Pearland	Taylor Lake Village	Webster	Unincorporated (Brazoria County)	Unincorporated (Harris County)	Unincorporated (Galveston County)	Total Count
50-percent (2-Year)	-	-	-	2	-	-	1	-	-	-	3	-	6
20-percent (5-Year)	9	3	11	48	-	3	11	-	-	-	27	-	112
10-percent (10-Year)	45	4	75	126	1	4	28	1	1	1	54	-	340

Note:
Considers only stream flooding from the main stem of Clear Creek.
Data are preliminary and subject to change.
Data may include some outbuildings and or structures bought out following Tropical Storm Allison.
Data include residential and commercial structure types.

Clear Creek GRR
Without Project - 2010 Conditions
Value of Structures Inundated by the 50- 20- and 10-Percent Chance Annual Exceedance Floods

(Values in Thousands of Dollars)

Percent Chance Annual Exceedance	Brookside Village	El Lago	Friendswood	Houston	Kemah	League City	Pearland	Taylor Lake Village	Webster	Unincorporated (Brazoria County)	Unincorporated (Harris County)	Unincorporated (Galveston County)	Total value
50-percent (2-Year)	-	-	-	318.8	-	-	199.9	-	-	-	82.1	-	600.8
20-percent (5-Year)	493.1	96.3	1,343.3	3,201.9	-	193.4	859.5	-	-	-	1,595.3	-	7,782.8
10-percent (10-Year)	2,201.4	424.7	7,302.8	8,649.6	13.9	310.3	2,657.0	46.5	0	103.0	3,041.3	-	24,750.5

Note:
Values shown are for structures only and do not include land values or structure contents.
Values shown do not include some structure values that were unavailable.
Also, see notes for the previous table, which apply here as well.

Measure: GWMP

Description: Test the cost efficiency of more stringent watershed management practices.

Orthophotos: All **Stream cross section limits**: N.A.

Sizes: One size; defined as the additional detention required over current practices such that there will be no peak flow increases from 2010 to 2060. Currently, some areas have mitigation requirements for development and some do not.

Green /Recreation Opportunities:

Quantities/Costing comments: Many areas already have a detention requirement, and this is reflected in the GRR "base condition." Costs for this measure would only be for the remaining uncontrolled areas plus any additional requirements throughout the basin needed to meet the desired goal. Thus,

Assume 0.55 acre-feet per acre for areas developed 2010-2060 that do not currently have a mitigation requirement (say 20% of new development.

Assume 0.13 acre-feet per acre for <u>total</u> area developed 2010-2060 to represent stiffer requirement to mitigate for all frequencies.

Assume 0.10 acre-feet per acre for <u>total</u> area developed 2010-2060 to makeup for loopholes, variances, waivers, exclusions, errors etc.

This adds up to 15, 276 acre-feet, which is equivalent to 1.1 inches of basin rainfall runoff. As a confirmation it is noted that reducing HEC-1 hypothetical rainfall totals by about one inch results in 2060 peak flows (at the mouth of Clear Creek) that are equal to 2010 peak flows resulting from the full hypothetical rainfall totals.

Required footprint area is estimated to be 2,100 acres assuming an average depth of 8 feet and adding additional area for R.O.W. buffer.

Modeling comments: No hydrologic modeling required. The flood damages with this measure in place will be determined by assuming that the without-project profiles for 2010 condition will not increase over time through 2060 (i.e., 2010 condition profiles will be entered into the economics model for both 2010 and 2060).

Measure: C2

Description: Conveyance Improvement from SH 288 to Stone Road

Orthophotos: 31113775, 31213775, and 31313775 **Stream cross section limits**: 223,668 – 205,888

Template: A shallow, wide, trapezoidal cut that preserves the existing channel. The shallow cut will straddle the natural channel forming benches on each side. (1v4h side slopes)

Invert / gradient: The invert of the cut will be 3-feet below the level of the 50% exceedance flood (2010c, without-project).

Sizes:

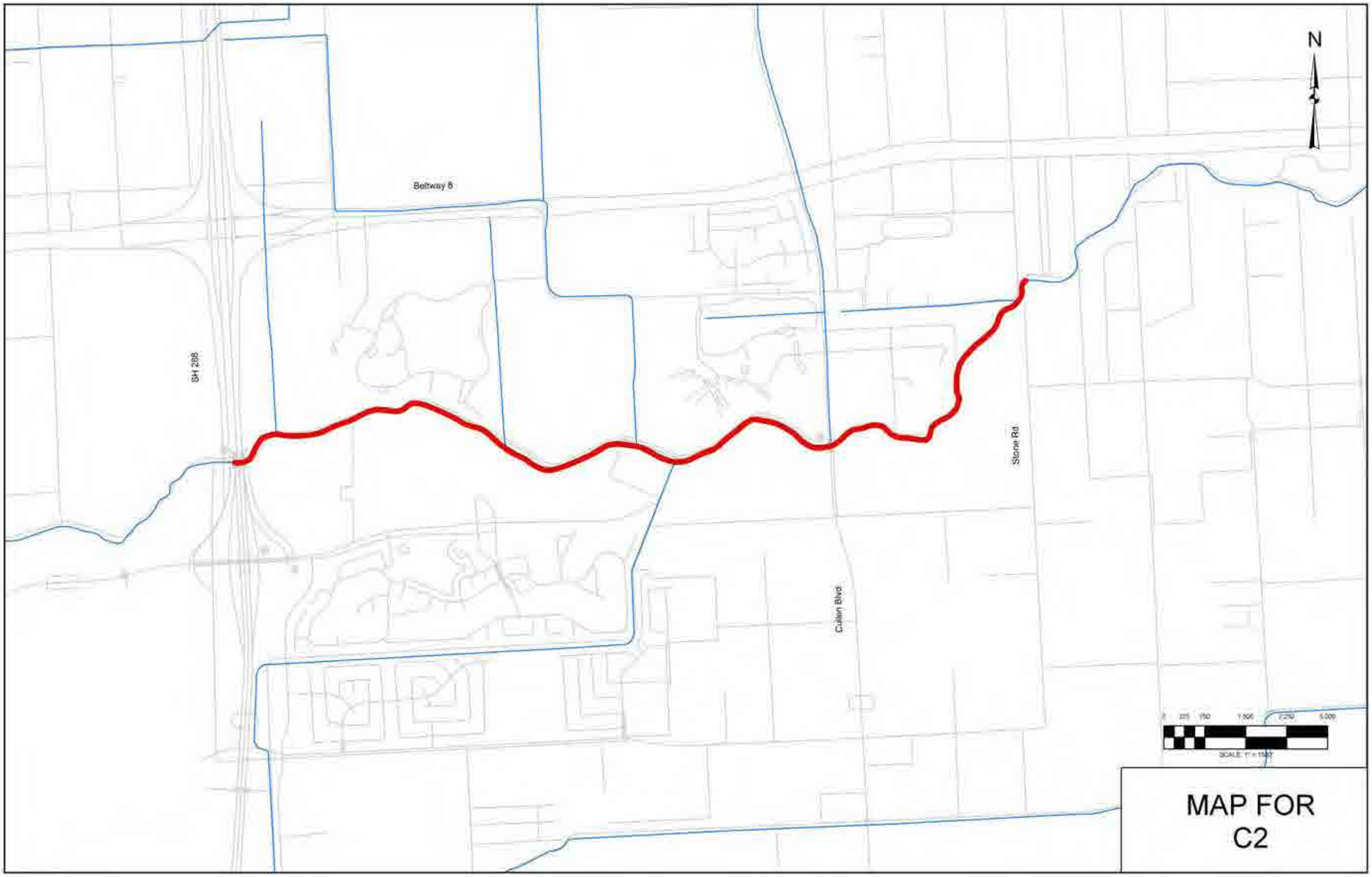
Reach:	**Bottom Width (Feet)**		
	C2a	**C2b**	**C2c**
SH 288 – Stone Road	200	300	400

Alignment: Follow existing creek centerline from SH 288 to Stone Rd.

Green /Recreation Opportunities: Existing channel will be preserved and un-maintained (shaded with riparian vegetation). Cut areas will be park like, i.e. mowed routinely with tree plantings (14 per acre). Hiking trails.

Quantities/Costing comments: Consider maintenance access R.O.W. costs. Bridges at SH 288, Cullen Blvd. and Stone Rd. will be raised and widened. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Assume bridges at Stone Rd. and SH 288 are modified such that there is minimal head loss.
Model the conveyance feature to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show draw down effects. Upstream performance without draw down effects will be same as no-project profile, so no special run is needed for that case.


N
Beltway 8
SH 288
Cullen Blvd
Stone Rd
MAP FOR
C2

Measure: LD2

Description: Linear detention along Mary's Creek from Centennial Blvd. to Clear Creek.

Orthophotos: 31513755, 31513765, 31613755, 31613765, 31713755 and 31713765 **Stream cross section limits**: 32,356 – 650

Template: A deep, wide, trapezoidal cut that follows the existing channel alignment. The excavated area will be densely planted and partially maintained to negate any conveyance increases so that the template provides storage volume. Areas off of the main channel will be excavated to provide additional storage volume.

Invert / gradient: The invert of the LD2c cut will match the flow line of the existing channel.

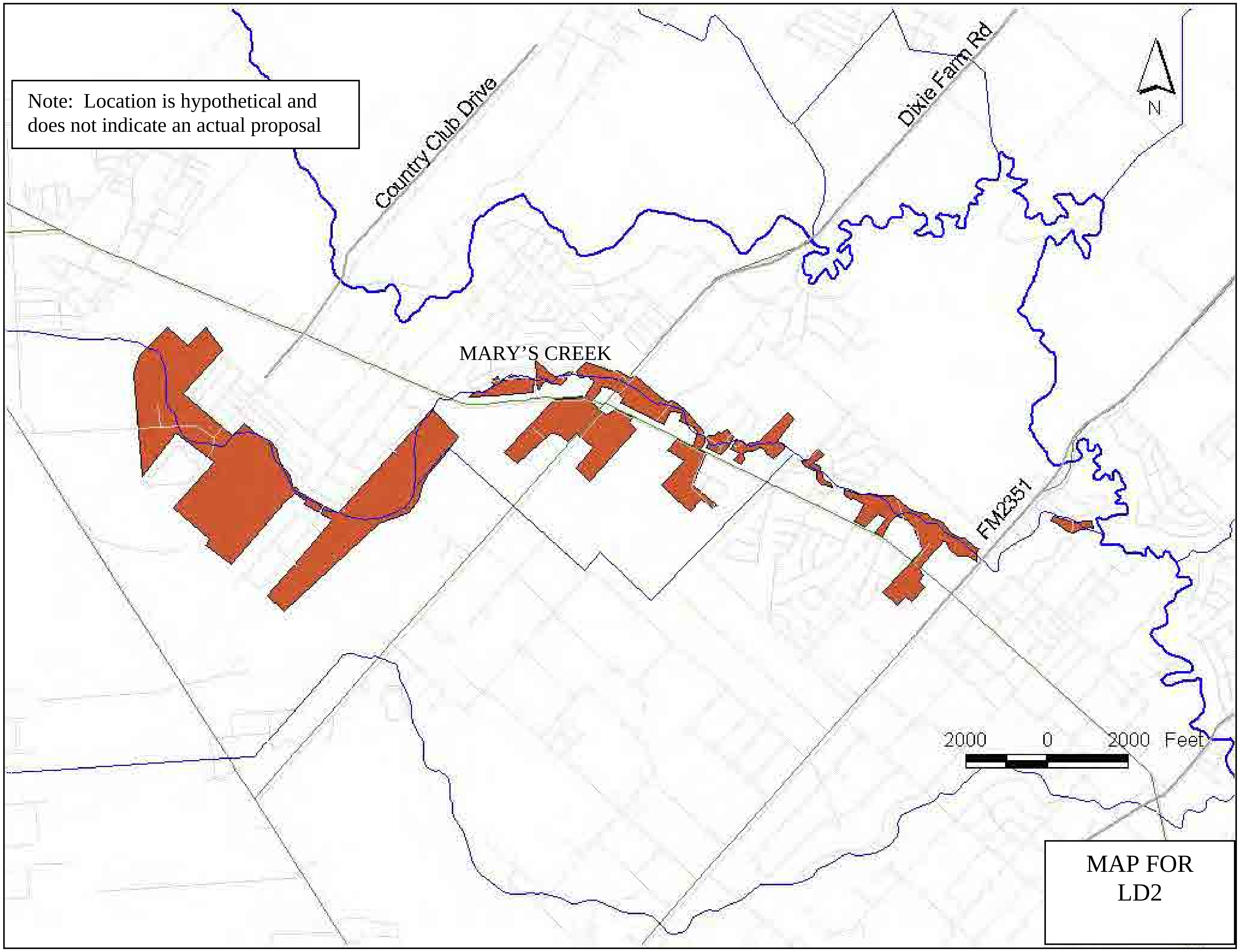
Sizes: LD2c= Maximize the channel bottom width within the park area. (1v:4h side slopes); LD2b= 66% of LD2c additional storage capacity; LD2a= 33% of LD2c additional storage capacity

Alignment: Follow existing Mary's Creek centerline from Centennial Blvd. to Clear Creek.

Green /Recreation Opportunities: Channel will remain in a partially maintained state (densely planted w/ hiking and jogging trails).

Quantities/Costing comments: Maintenance required for hiking and jogging trails. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments:


Note: Location is hypothetical and
does not indicate an actual proposal
Country Club Drive
Dixie Farm Rd
N
MARY'S CREEK
FM2351
2000
0
2000
Feet
MAP FOR
LD2

Measure: LD3

Description: Linear detention along Cowart Creek from Mansfield Rd. (CR 127) to Clear Creek.

Orthophotos: 31613745, 31613755, 31713745, 31713755, 31813745 and 31813755 **Stream cross section limits**: 26,581 – 0

Template: A deep, wide, trapezoidal cut that follows the existing channel alignment. The excavated area will be densely planted and partially maintained to negate any conveyance increases so that the template provides storage volume. Areas off of the main channel will be excavated to provide additional storage.

Invert / gradient: The invert of the LD3c cut will match the flow-line of the existing channel.

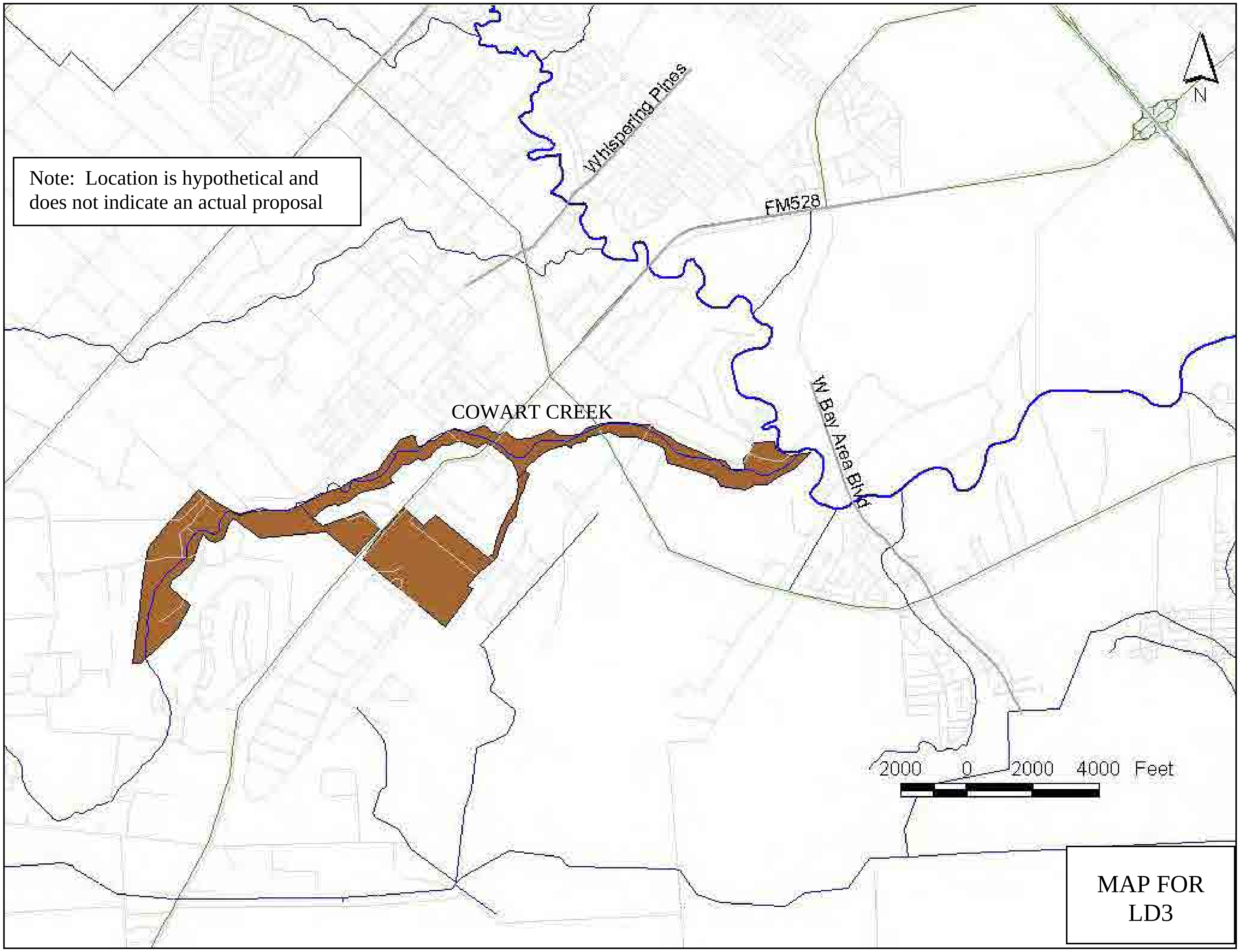
Sizes: LD3c= Maximize the channel bottom width within the park area. (1v:4h side slopes); LD3b= 66% of LD3c additional storage capacity; LD3a= 33% of LD3c additional storage capacity

Alignment: Follow existing Mary's Creek centerline from Mansfield Rd. (CR 127) to Clear Creek.

Green /Recreation Opportunities: Channel will remain in a partially maintained state (densely planted w/ hiking and jogging trails).

Quantities/Costing comments: Maintenance required for hiking and jogging trails. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments:


Note: Location is hypothetical and
does not indicate an actual proposal
Whispering Pines
FM528
W Bay Area Blvd
COWART CREEK
N
2000 0 2000 4000 Feet
MAP FOR
LD3

Measure: ACLO

Description: Additional Clear Lake Outlet Capacity

Orthophotos: 32313755 **Stream cross section limits**:

Template: ACLOa = Existing Second Outlet; ACLOb = 50% larger; ACLOc = 100% larger

Invert / gradient:

Sizes:

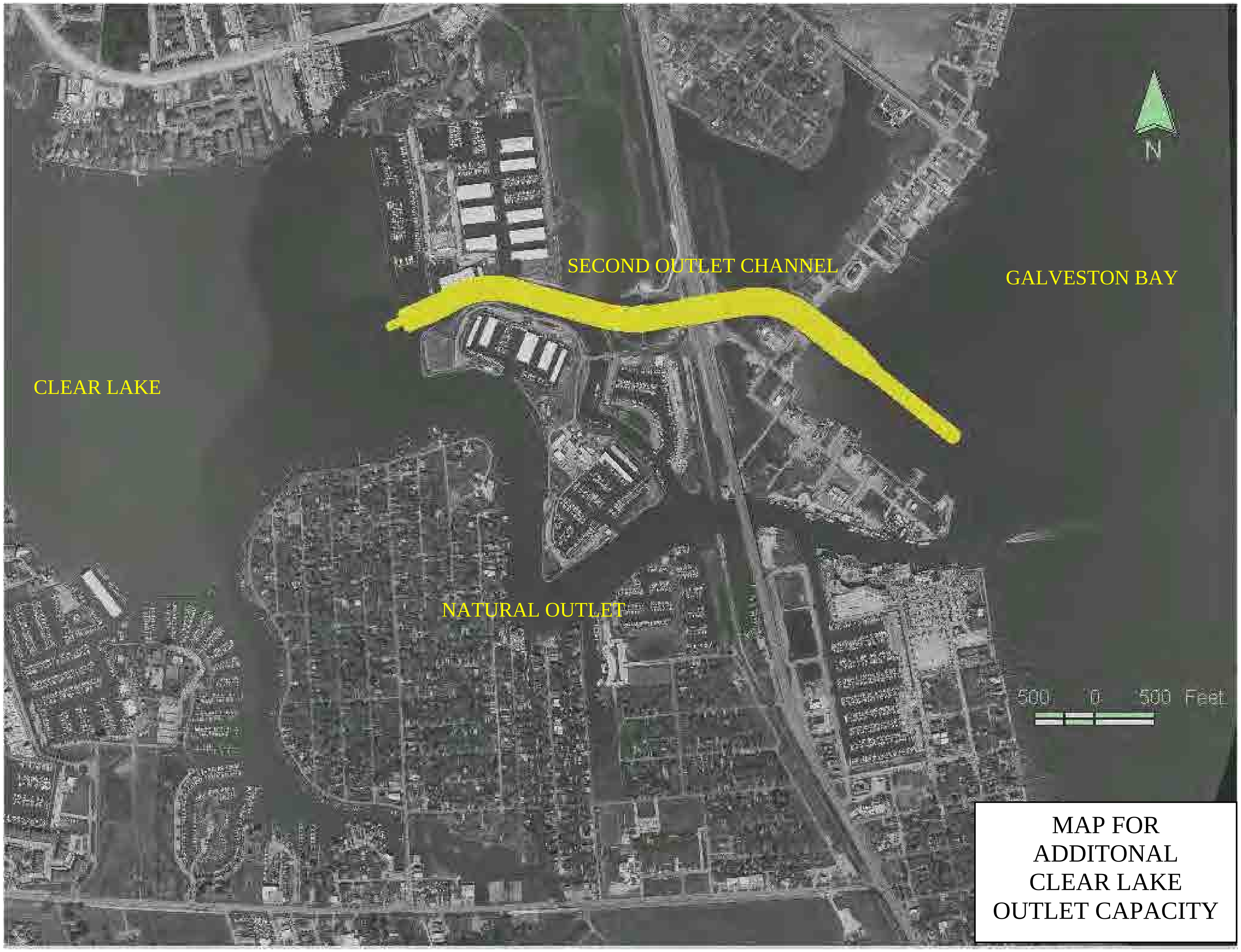
Alignment:

Green /Recreation Opportunities:

Quantities/Costing comments: Costs for ACLOa will be based on actual construction costs.

Modeling comments: Hydraulic modeling for this alternative was included in the DEC contract for without-project modeling.

The Clear Lake Second Outlet is a dredged outlet channel connecting Clear Lake to Galveston Bay. It is technically a project feature (a portion of the Authorized Federal Project). Thus, the Second Outlet is deliberately excluded from the GRR without-project models and will instead be considered as a conveyance feature. Its effectiveness will be measured first as a stand-alone feature dedicated to flood damage reduction for property around Clear Lake and later as a flow mitigation feature as was originally intended. A goal of the GRR will be to determine which function is the most efficient for reducing flood damage.


SECOND OUTLET CHANNEL
GALVESTON BAY
N
CLEAR LAKE
NATURAL OUTLET
500 0 500 Feet
MAP FOR ADDITONAL CLEAR LAKE OUTLET CAPACITY

Measure: CS

Description: Conveyance Improvement Reach from FM 2351 to just downstream of the Chigger Creek confluence with and without upstream draw down

Orthophotos: 31713755, 31813745, and 31813755 **Stream cross section limits**: 112,517 – 77,113

Template: Clear Creek will undergo a selective clearing and snag removal.
CSa: Channel will be cleared (n-value in channel will be reduced by 25%)
CSb: Channel will be cleared (same as CSa); in addition 20' outside the channel banks (both sides) will be selectively cleared (n-value reduced to 0.07).
CSc: Channel will be cleared (same as CSa); in addition 50' outside the channel banks (both sides) will be selectively cleared (n-value reduced to 0.07).

Invert / gradient: The invert will match the flow line of the existing channel.

Sizes:

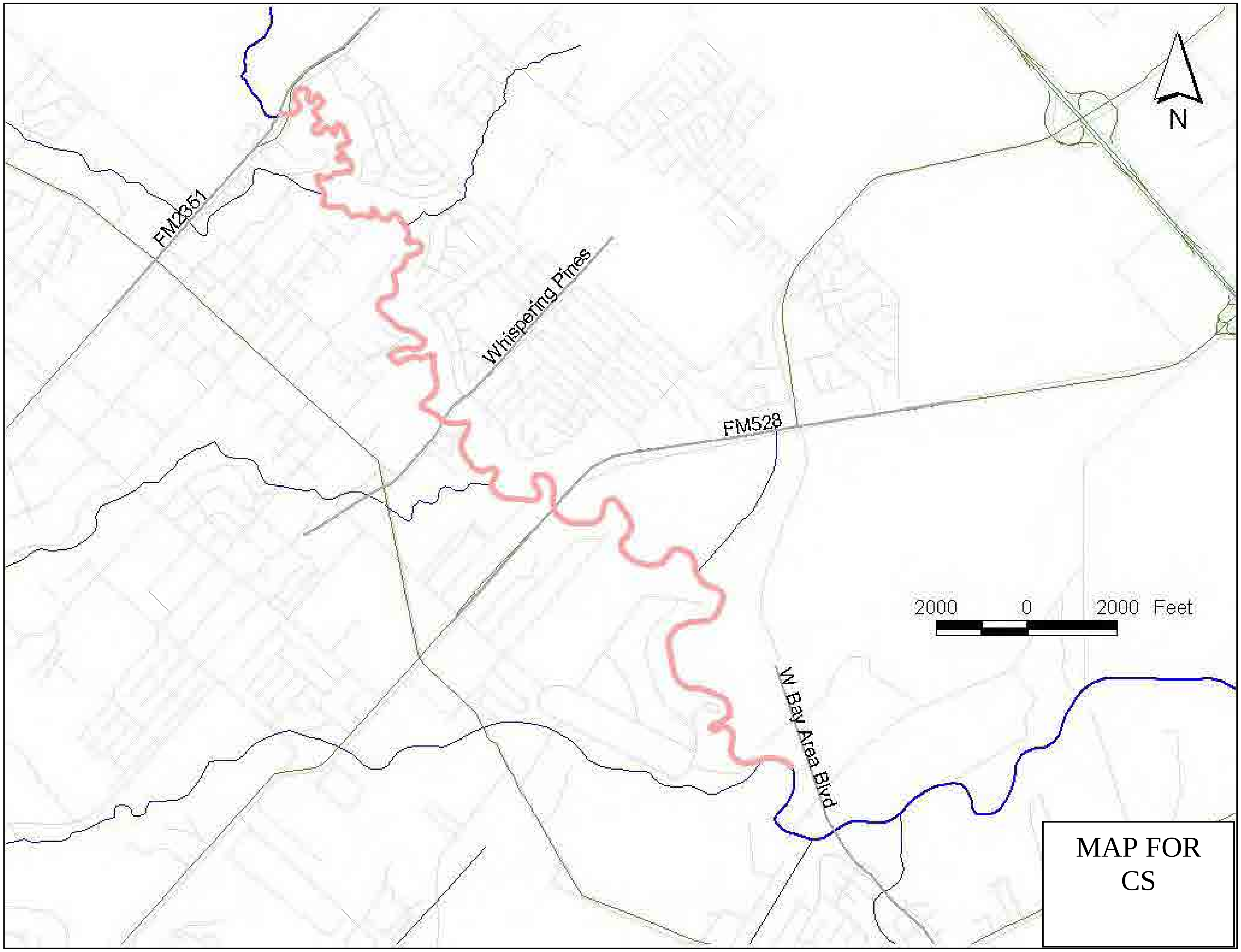
Reach:	**Clearing Limits (Feet)**		
	CSa	**CSb**	**CSc**
FM 2351 – Chigger Confluence	Channel banks	20' outside banks	50' outside banks

Alignment: Follow existing creek centerline from FM 2351 to just downstream of Chigger Creek confluence.

Green /Recreation Opportunities: Existing channel will be preserved and un-maintained (shaded with riparian vegetation). Cleared areas will be mowed several times a year.

Quantities/Costing comments: Consider maintenance access R.O.W. costs.

Modeling comments: Model the conveyance feature to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show draw down effects. Upstream performance without draw down effects will be same as no-project profile, so no special run is needed for that case.



FM2351
Whispering Pines
FM528
W. Bay Area Blvd
N
2000
0
2000 Feet
MAP FOR
CS

Measure: C3

Description: Conveyance Improvement from Downstream of Country Club to FM 528

Orthophotos: 31613765, 31713755, 31713765 and 31813755 **Stream cross section limits**: 157,136 – 90,072

Template: A trapezoidal channel that follows the alignment of the existing Authorized Federal Project (1v:4h side slopes).

Invert / gradient: The invert of the template will match the Authorized Federal Project.

Sizes:

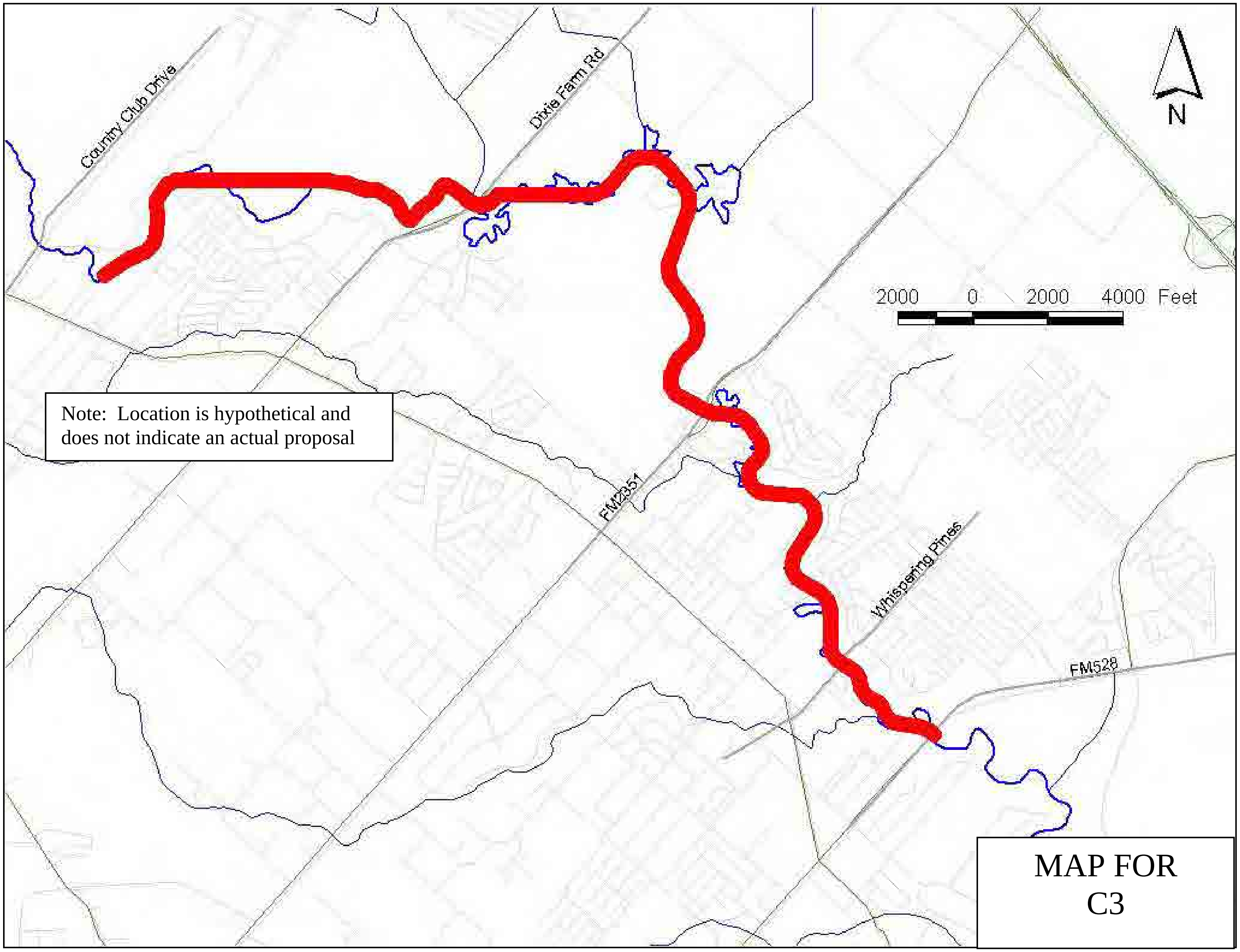
Reach:	**Bottom Width (Feet)**		
	C3a	**C3b**	**C3c**
2,500 ft D/S of Country Club – 12,500 ft D/S of Dixie Farm Road.	17.5’	35’	52.5’
12,500 ft D/S of Dixie Farm Rd – 6,700 ft U/S of FM 2351	18.8’	37.5’	56.3’
6,700 ft U/S of FM 2351 – 2,400 ft U/S of FM 2351	25’	50’	75’
2,400 ft U/S of FM 2351 – 2,050 ft U/S of Whispering Pines	30’	60’	90’
2,500 ft U/S of Whispering Pines – FM 528	32.5’	65’	97.5’

Alignment: Follow the Authorized Federal Project alignment from 2,500 ft downstream of Country Club Drive to FM 528.

Green /Recreation Opportunities:

Quantities/Costing comments: Consider maintenance access R.O.W. costs. Bridges at Dixie Farm Road, Edgewood (FM 2351), Whispering Pines and FM 528 will be raised and widened. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Assume bridges at Dixie Farm Road, Edgewood (FM 2351), Whispering Pines and FM 528 are modified such that there is minimal head loss. Model the conveyance feature to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show tailing effects. Upstream performance without tailing effects will be same as no-project profile, so no special run is needed for that case.


Country Club Drive
Dixie Farm Rd
N
2000 0 2000 4000 Feet
Note: Location is hypothetical and does not indicate an actual proposal
FM2351
Whispering Pines
FM528
MAP FOR C3

Measure: C4

Description: Conveyance Improvement from D/S of FM 2351 to U/S of West Bay Area Blvd.

Orthophotos: 31713755, 31713765, 31813745, 31813755, and 31913745 **Stream cross section limits**: 112,393 – 73,997

Template: A trapezoidal channel that follows the alignment of the existing Authorized Federal Project (1v:4h side slopes).

Invert / gradient: The invert of the cut will match the Authorized Federal Project.

Sizes:

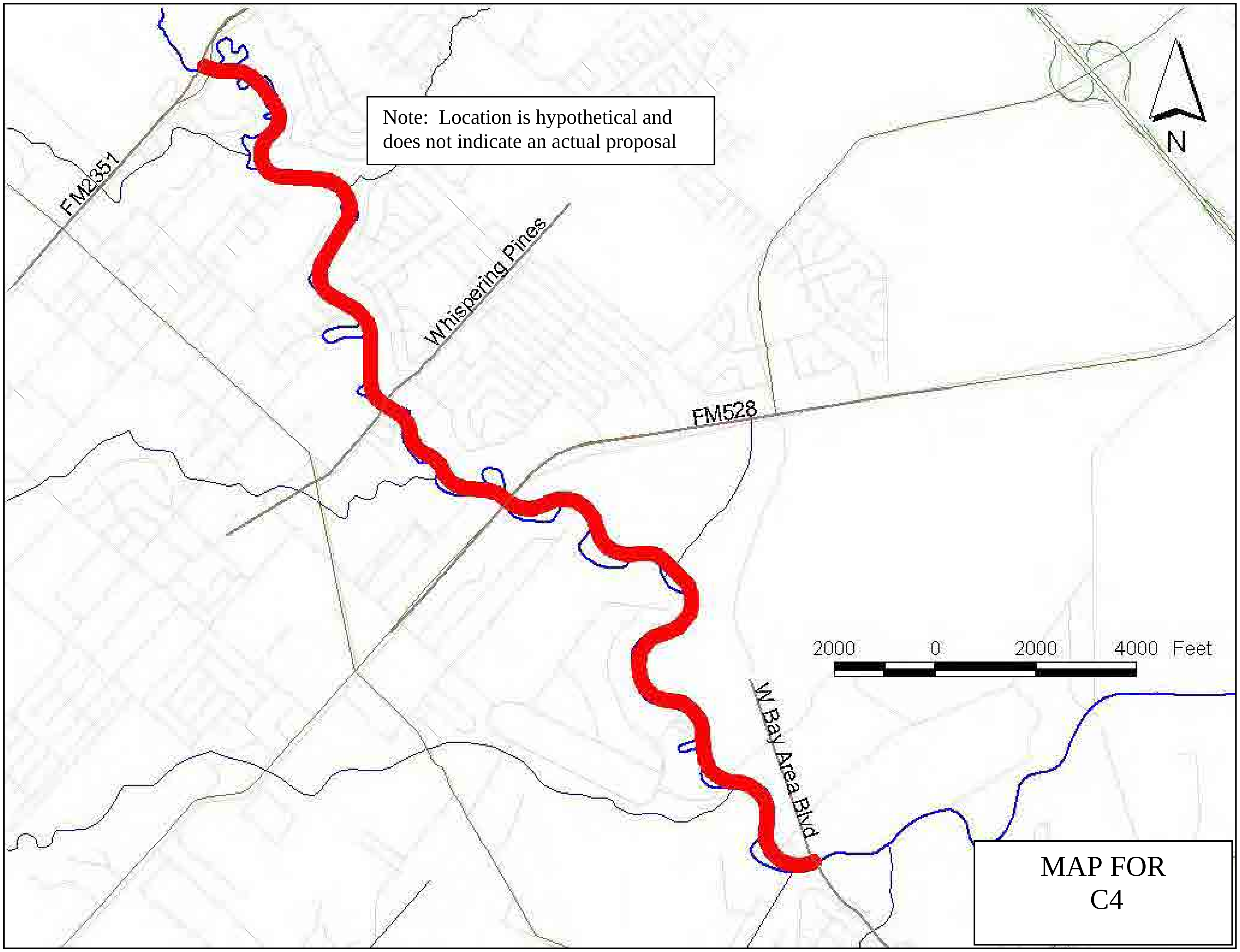
Reach:	**Bottom Width (Feet)**		
	C4a	**C4b**	**C4c**
FM 2351 – 2,050 ft U/S of Whispering Pines	30’	60’	90’
2,500 ft U/S of Whispering Pines – West Bay Area Blvd.	32.5’	65’	97.5’

Alignment: Follow the Authorized Federal Project alignment from FM 2351 to West Bay Area Blvd.

Green /Recreation Opportunities:

Quantities/Costing comments: Consider maintenance access R.O.W. costs. Whispering Pines will be raised and widened. Excavation quantities will be provided from the hydraulic modeling.

Modeling comments: Assume bridge at Whispering Pines is modified such that there is minimal head loss. Model the conveyance feature to show full effects upstream of reach, within reach, and downstream of reach. Downstream will show induced flooding and upstream will show tailing effects. Upstream performance without tailing effects will be same as no-project profile, so no special run is needed for that case.


Note: Location is hypothetical and
does not indicate an actual proposal
FM2351
Whispering Pines
FM528
W Bay Area Blvd
N
2000
0
2000
4000 Feet
MAP FOR
C4

Measure: Authorized Federal Project (AFP)

Description: Conveyance improvement from Mykawa Road to Clear Lake plus the Second Outlet Channel and Gate Structure. The project was sized to contain a 10-percent annual exceedance flood for future watershed development conditions. A detailed description is provided in the Preconstruction Authorization Planning Report dated May 1982. A formal agreement was signed in 1986 by the local sponsors (Harris County Flood Control District and Galveston County) and the US Army Corps of Engineers to construct the fourteen-mile reach of the project downstream of Dixie Farm Road. Only the Second Outlet Channel and Gate Structure were ever constructed. A Sponsor Proposed Plan was developed in 1997 as an alternative to the authorized project. However, the Corps of Engineers decided that the sponsor plan was not sufficiently similar to the federal plan to allow construction under the original project authorization.

Orthophotos: 31413775, 31513775, 31513765, 31613765, 31713765, 31713755, etc. **Stream cross section limits**: 189,432 – 0.0

Template: A trapezoidal earth channel (1v:3h side slopes). Bottom width varies from 50 feet to 130 feet.

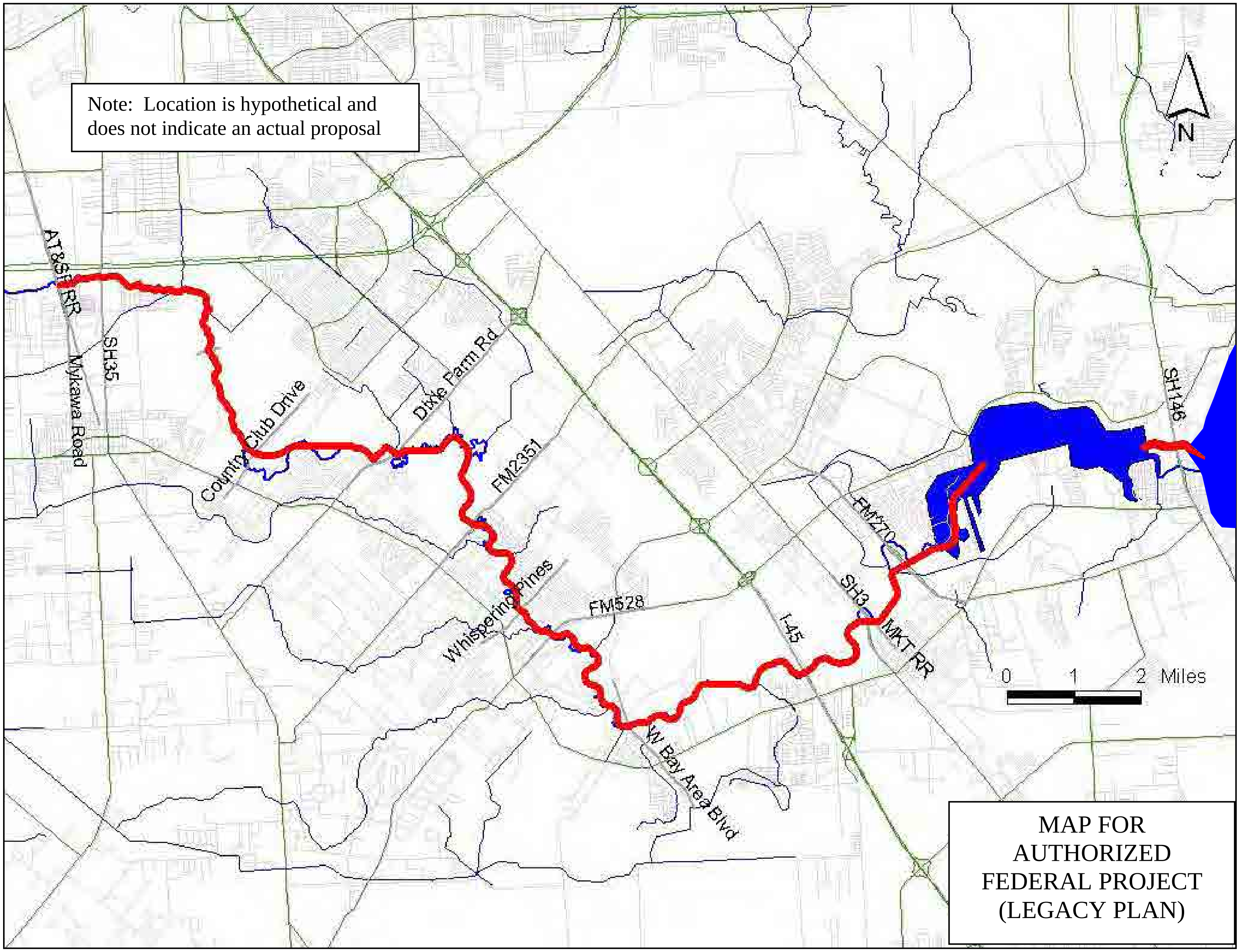
Invert / gradient: Deeper than the existing natural channel

Alignment: Follows a straightened alignment along the Clear Creek mainstream

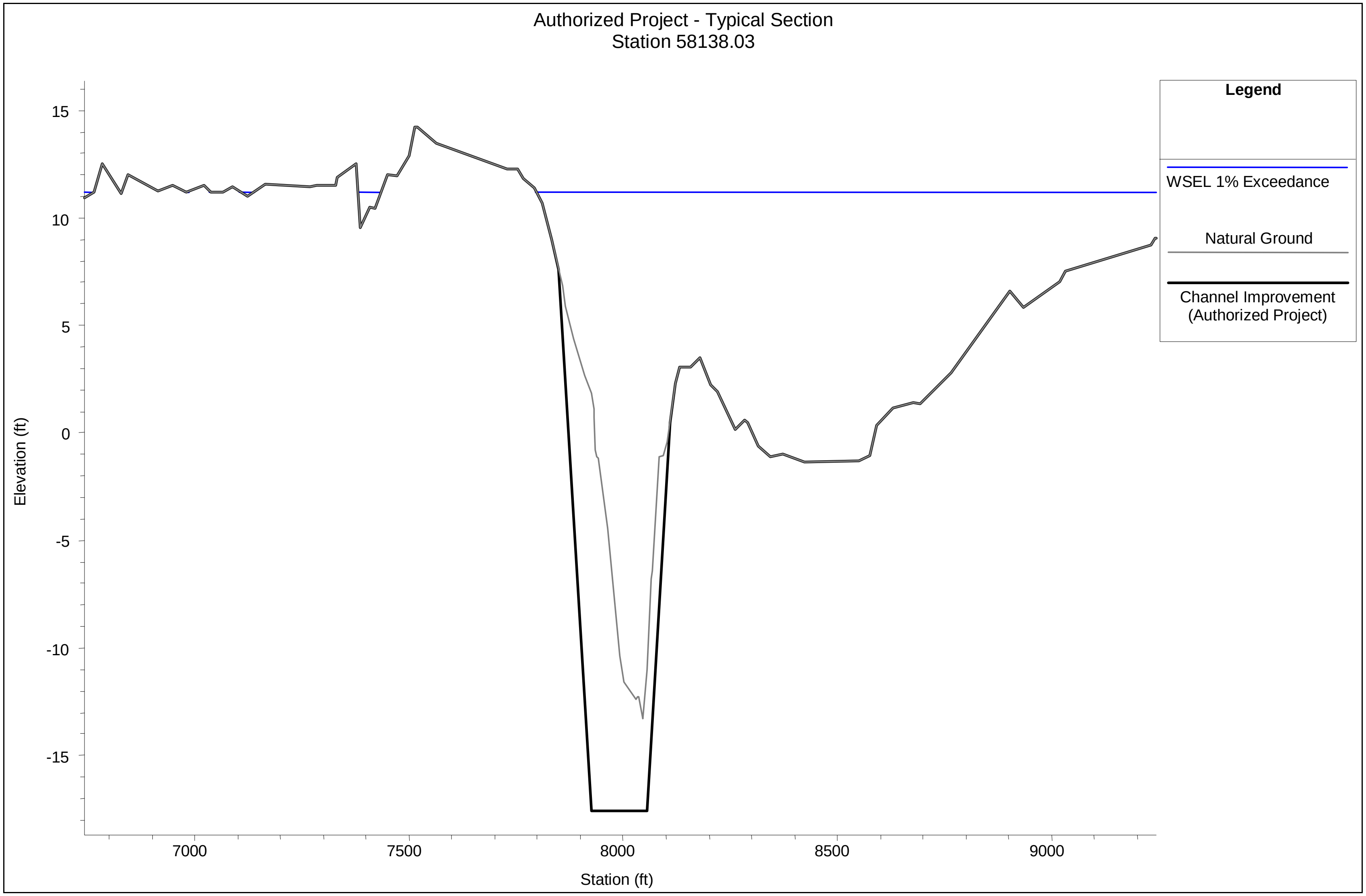
Green /Recreation Opportunities: Beneficial use of dredge material for marsh creation

Quantities/Costing comments: The Second Outlet costs will be included since this completed feature will be part of any federal plan.

Modeling comments:



Note: Location is hypothetical and does not indicate an actual proposal
N
AT&SF RR
SH35
Mykawa Road
Country Club Drive
Dixie Farm Rd
FM2351
Whispering Pines
FM528
W Bay Area Blvd
I-45
SH3
MKT RR
FM270
SH146
0 1 2 Miles
MAP FOR AUTHORIZED FEDERAL PROJECT (LEGACY PLAN)



Authorized Project - Typical Section
Station 58138.03
Legend
WSEL 1% Exceedance
Natural Ground
Channel Improvement
(Authorized Project)
15
10
5
0
-5
-10
-15
Elevation (ft)
7000
7500
8000
8500
9000
Station (ft)

Measure: Sponsor Proposed Alternative (SPA)

Description:. The plan was developed in 1997 as an alternative to the Authorized Federal Project. A detailed description of the plan is provided in the December 1997 report titled, "Clear Creek, Federal Flood Control Project Review." The main features of the plan were "reduced channel rectification" and a bypass channel. The channel rectification was reduced in size (smaller bottom widths) from the Authorized Federal Project. A reach of the natural Clear Creek channel near the Friendswood area would be avoided by providing the needed flood capacity with a bypass channel.

Orthophotos: 31713765, 31713755, 31813755, 31813745, 31913745, etc. **Stream cross section limits**: 143,346 – 0

Template: A trapezoidal channel that follows the alignment of the existing Authorized Federal Project except for the bypass channel near the Friendswood area. Bottom widths for the plan vary from 30 feet to 80 feet.

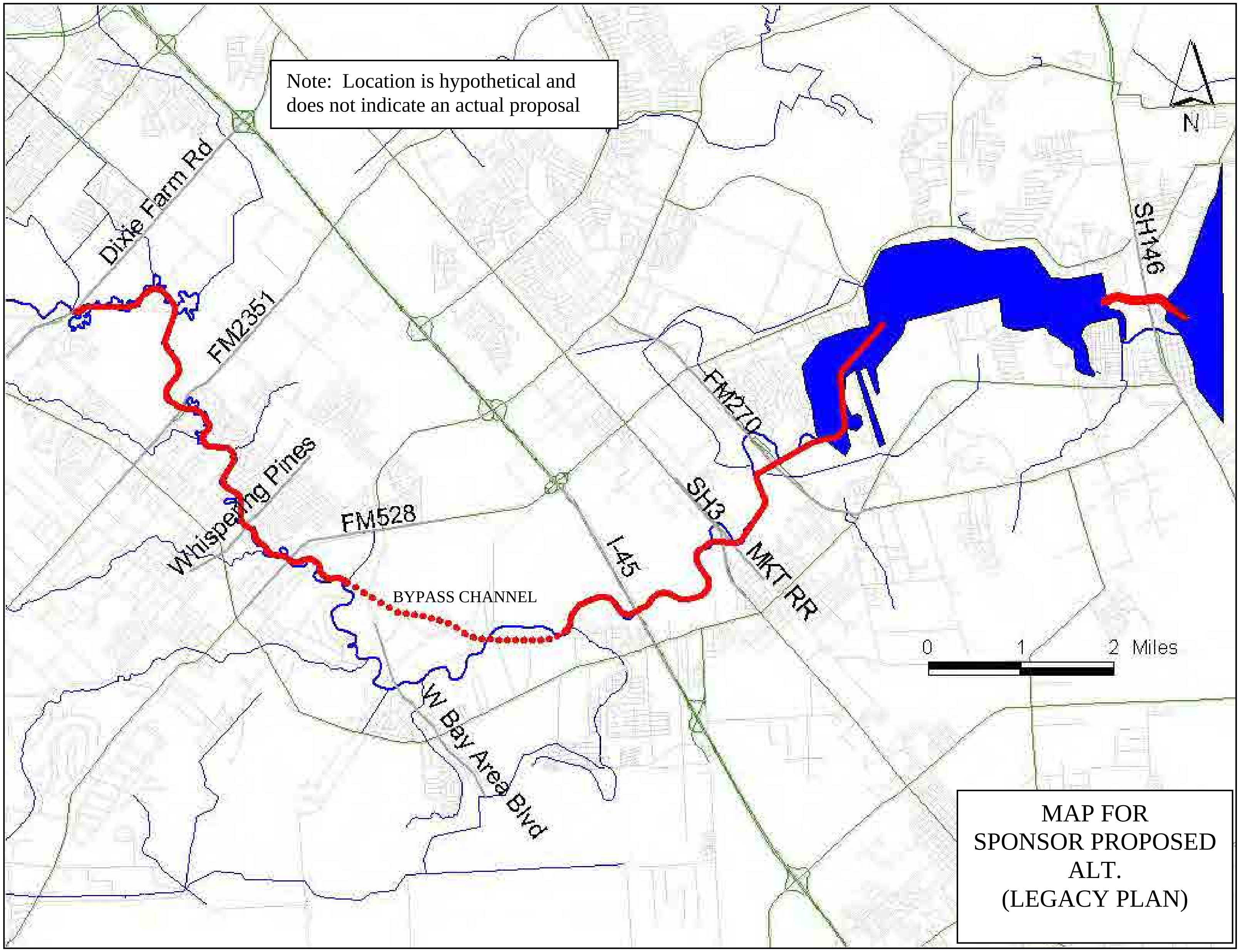
Invert / gradient: The invert of the cut will match the Authorized Federal Project.

Alignment: Follow the Authorized Federal Project alignment from Dixie Farm Road to Clear Lake. A bypass channel roughly between FM528 and Challenger Seven Park would eliminate the need for channelization through that reach.

Green /Recreation Opportunities: Beneficial use of dredge material. The plan proposed various other environmental features.

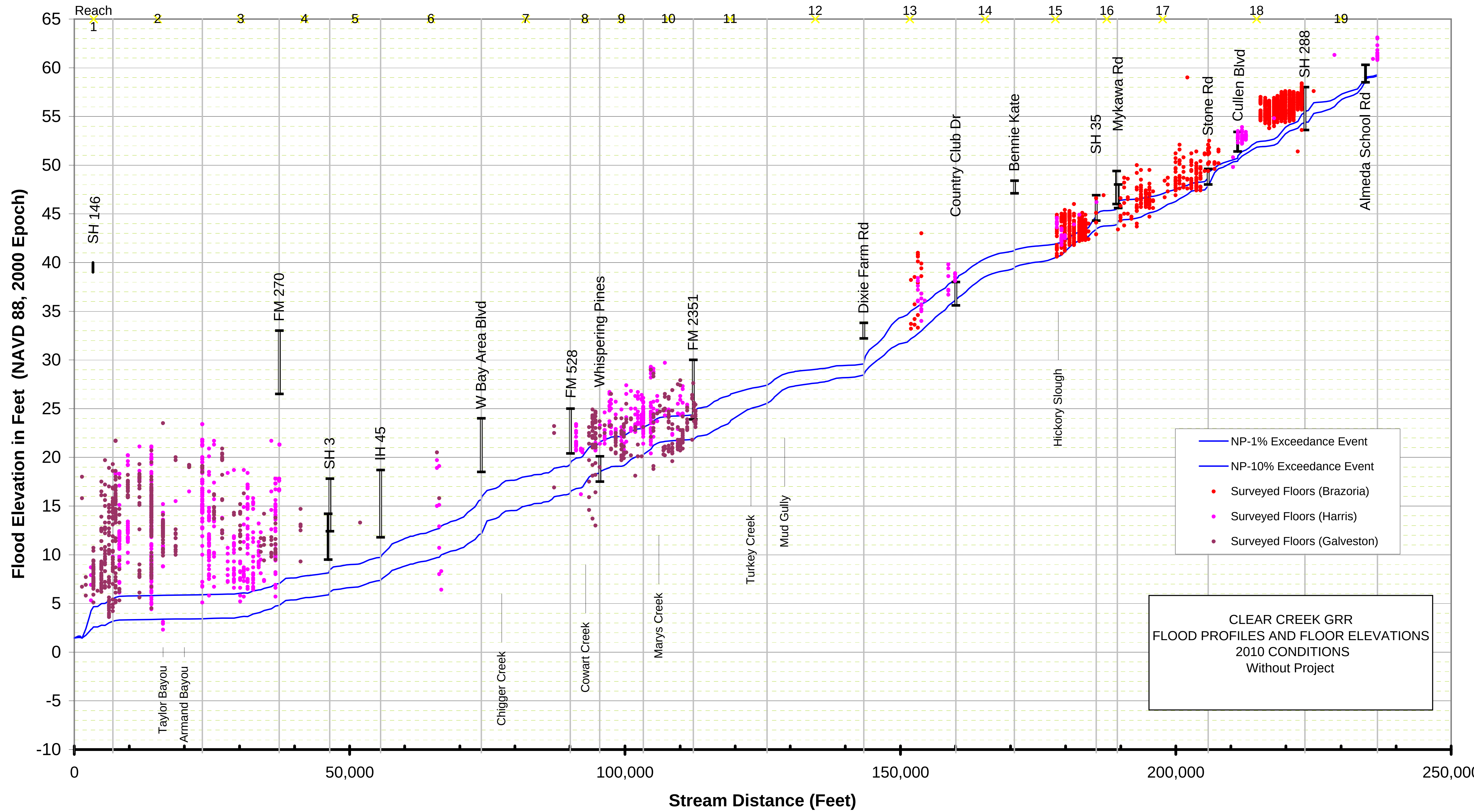
Quantities/Costing comments: The GRR cost studies will only consider the channel and bypass features. Other features (detention and buyouts) are described in the 1997 report, but will not be included in the GRR cost estimate or the GRR hydraulic and economic modeling. The Second Outlet costs will be included since this completed feature will be part of any federal plan.

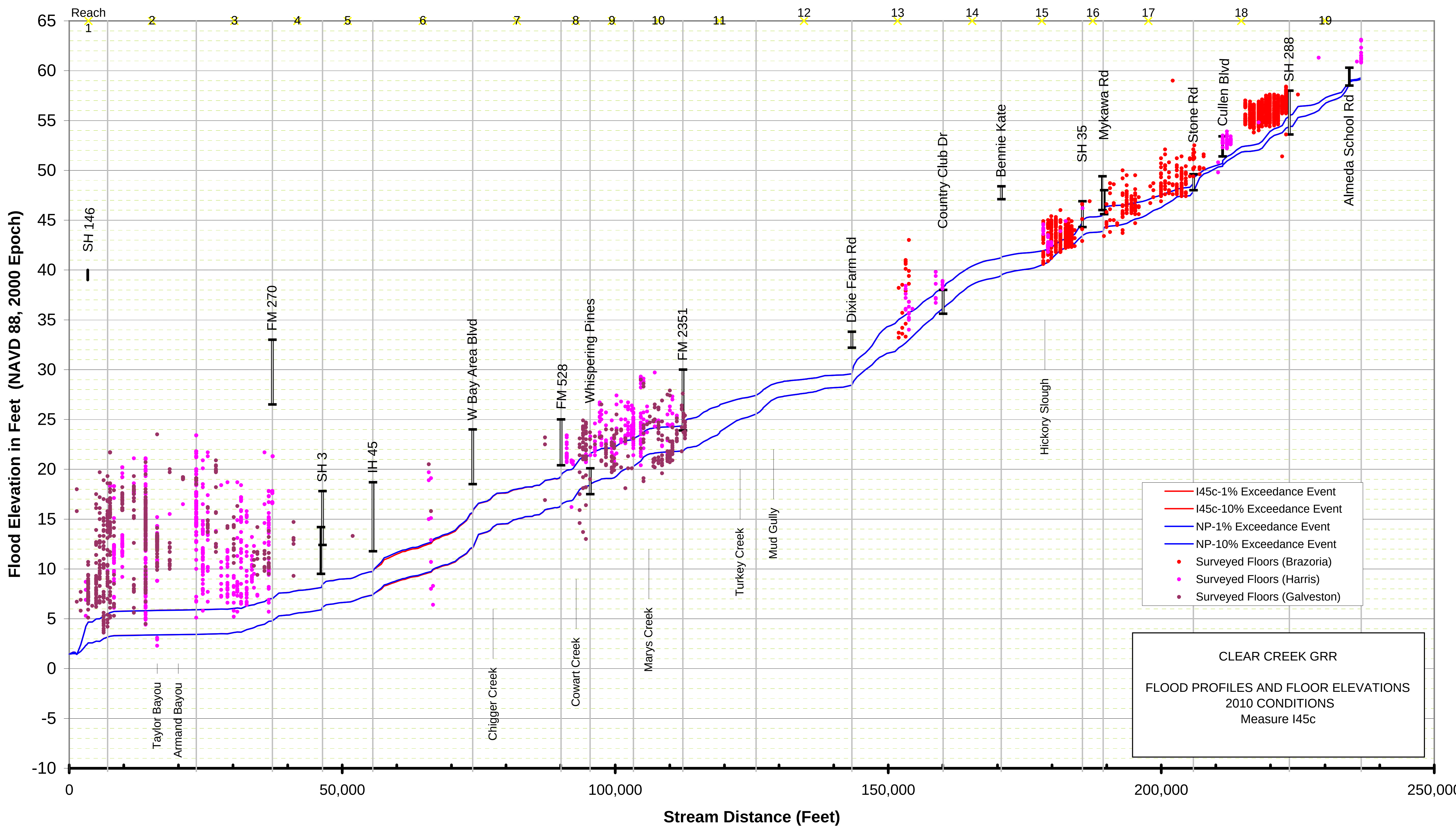
Modeling comments: The GRR hydrologic modeling will only consider the channel and bypass features.


Note: Location is hypothetical and
does not indicate an actual proposal
Dixie Farm Rd
FM2351
Whispering Pines
FM528
BYPASS CHANNEL
W Bay Area Blvd
I-45
SH3
MKT RR
FM270
SH146
N
0
1
2 Miles
MAP FOR
SPONSOR PROPOSED
ALT.
(LEGACY PLAN)

APPENDIX C

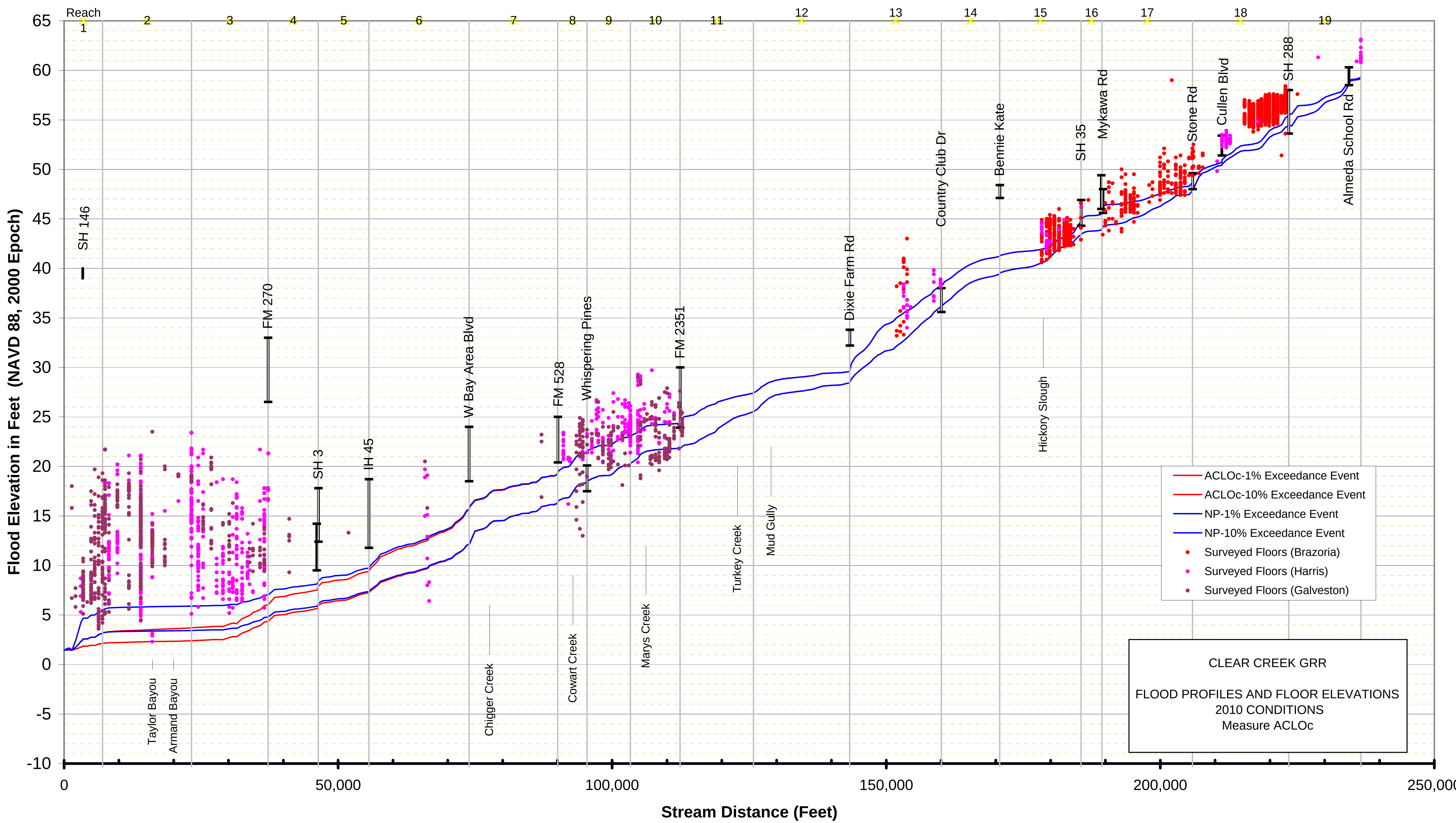
1ST ADDED MEASURES FLOOD PROFILES


CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Without Project
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
Reach
SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough



CLEAR CREEK GRR

FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure I45c



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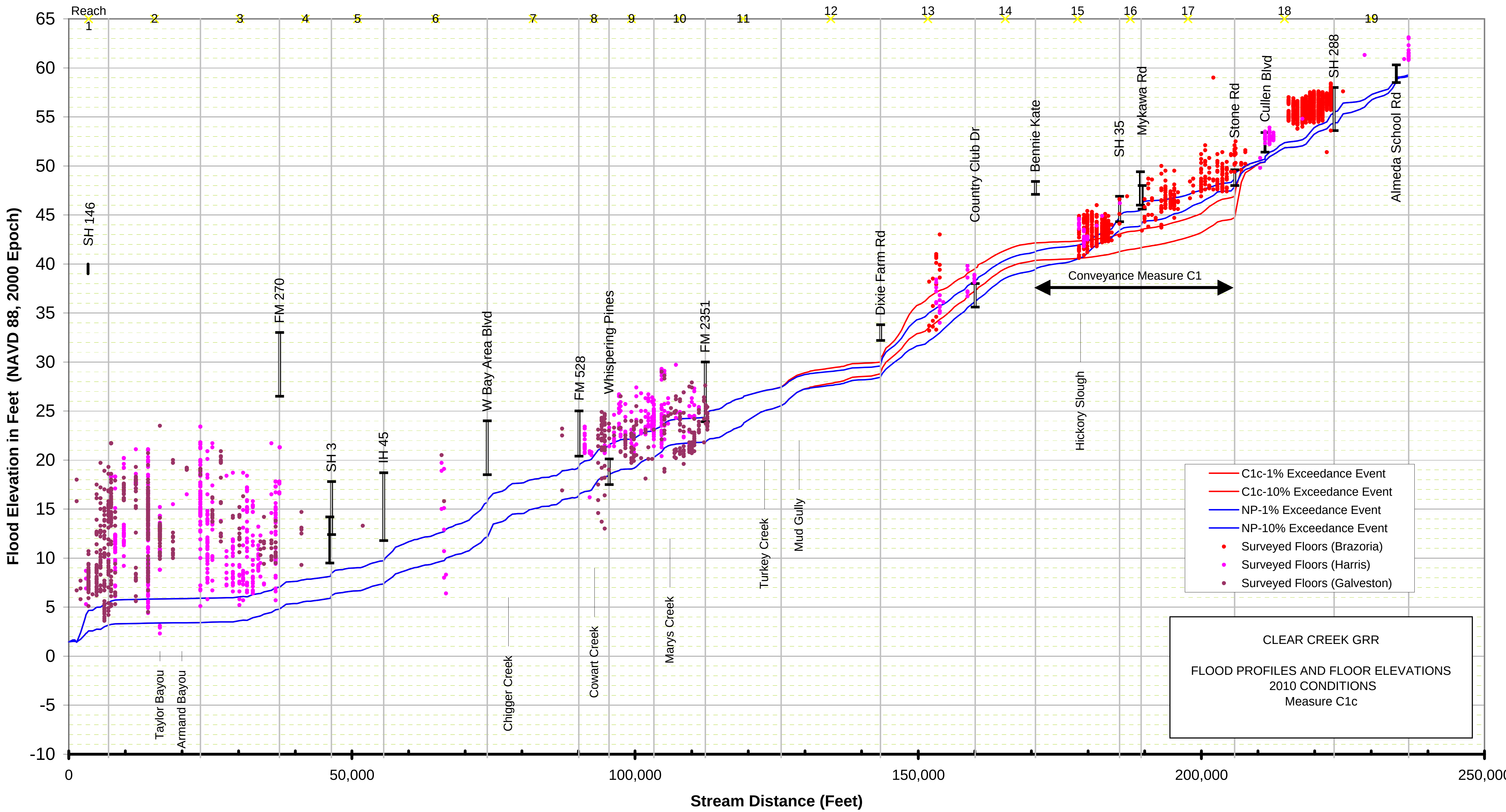
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
ACLOc-1% Exceedance Event
ACLOc-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure ACLOc



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IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Conveyance Measure C1
Hickory Slough
Turkey Creek
Mud Gully
Marys Creek
Cowart Creek
Chigger Creek
Taylor Bayou
Armand Bayou
C1c-1% Exceedance Event
C1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure C1c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
65
60
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35
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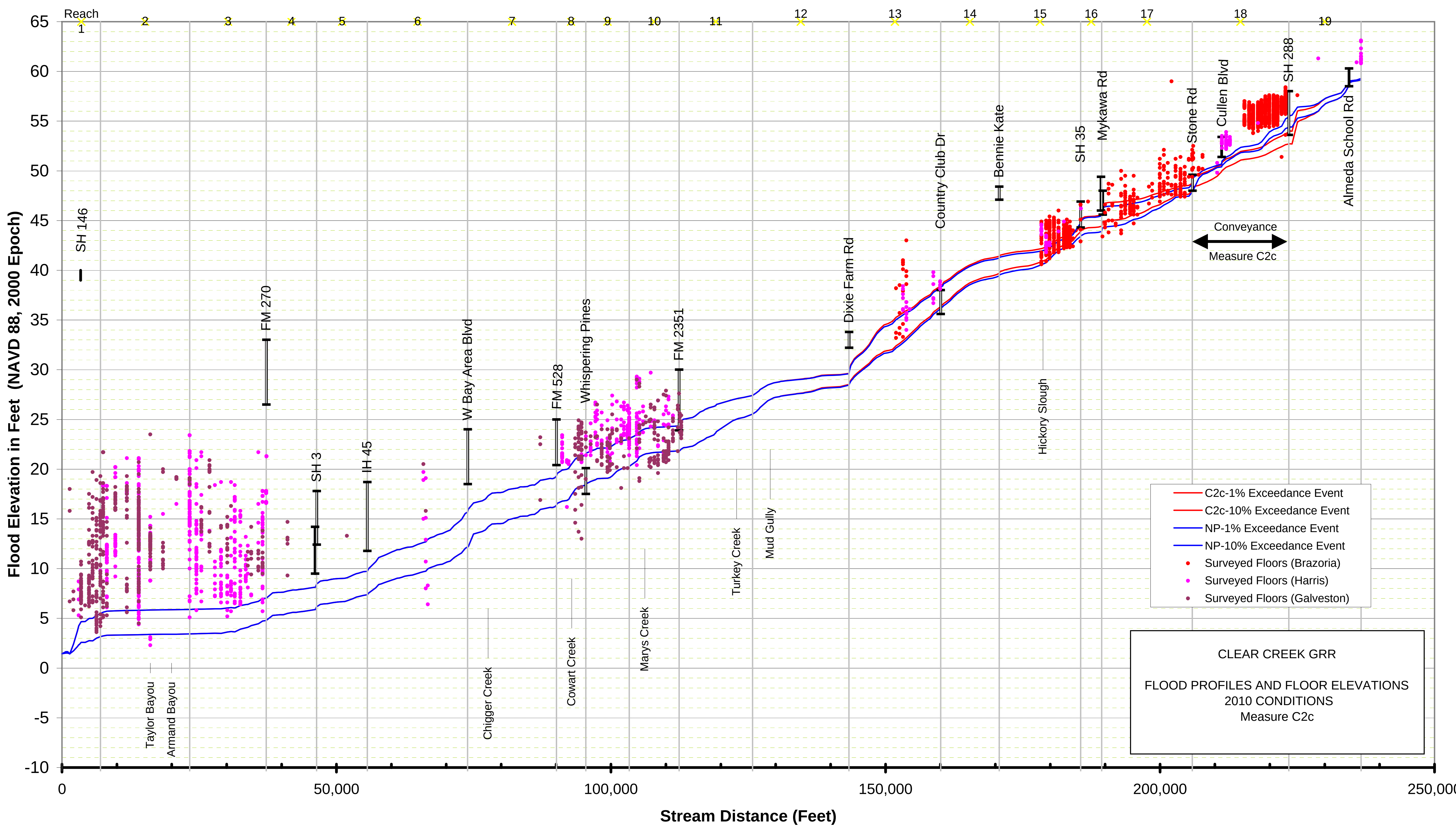
250,000



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SH 146
FM 270
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IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Conveyance
Measure C2c
C2c-1% Exceedance Event
C2c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure C2c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
65
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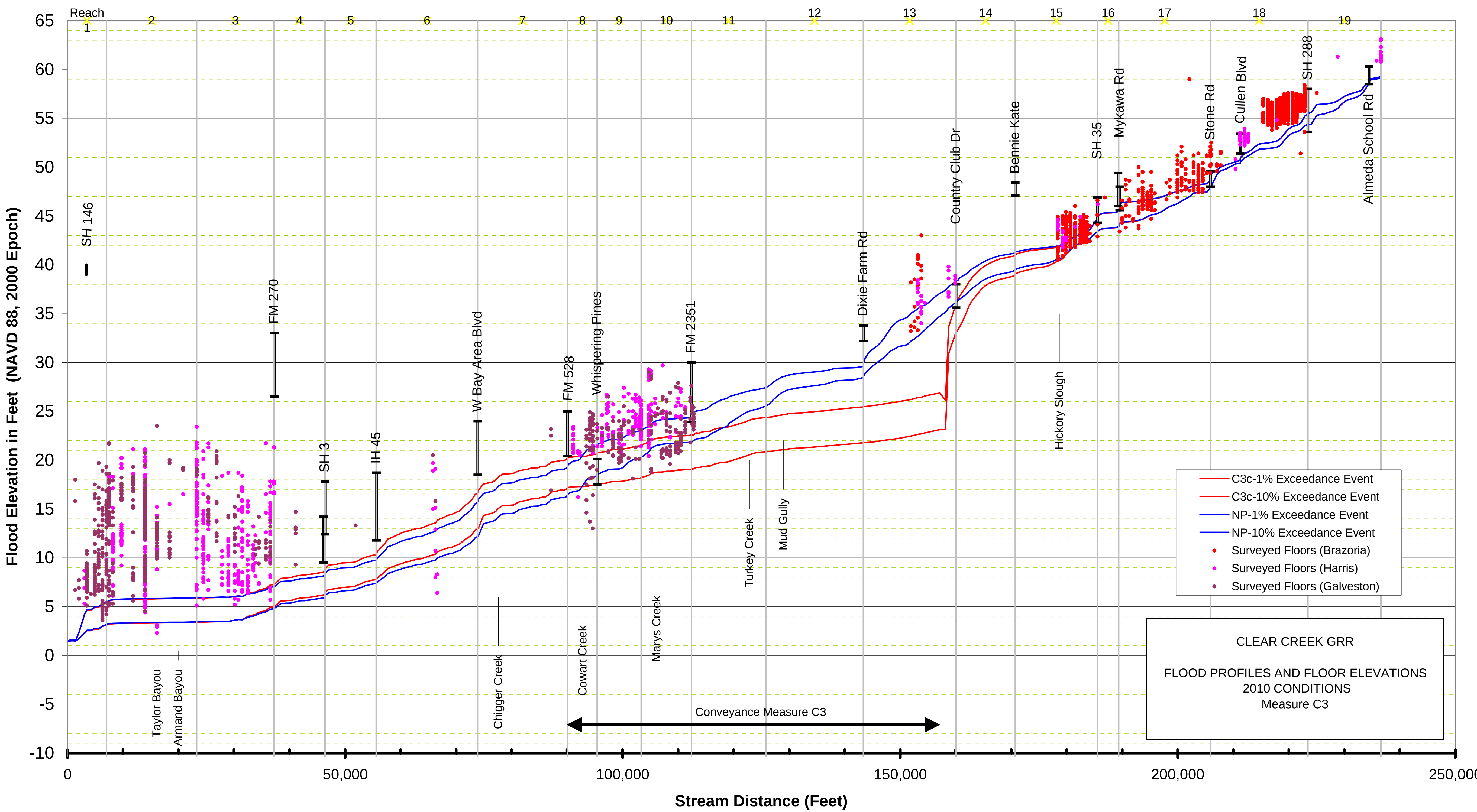

CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure C3
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
C3c-1% Exceedance Event
C3c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
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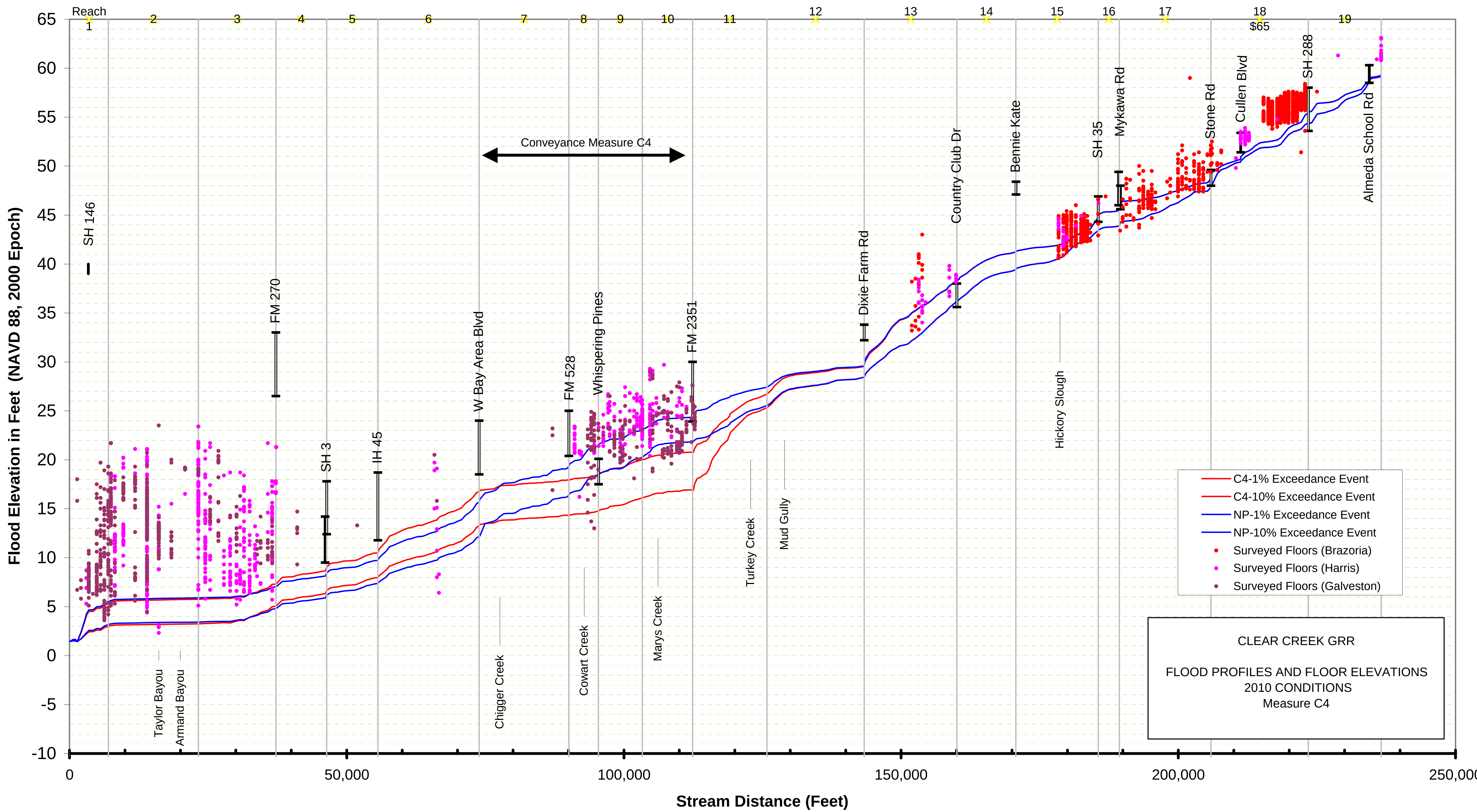
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Conveyance Measure C3



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Conveyance Measure C4
SH 146
FM 270
SH 3
IH 45
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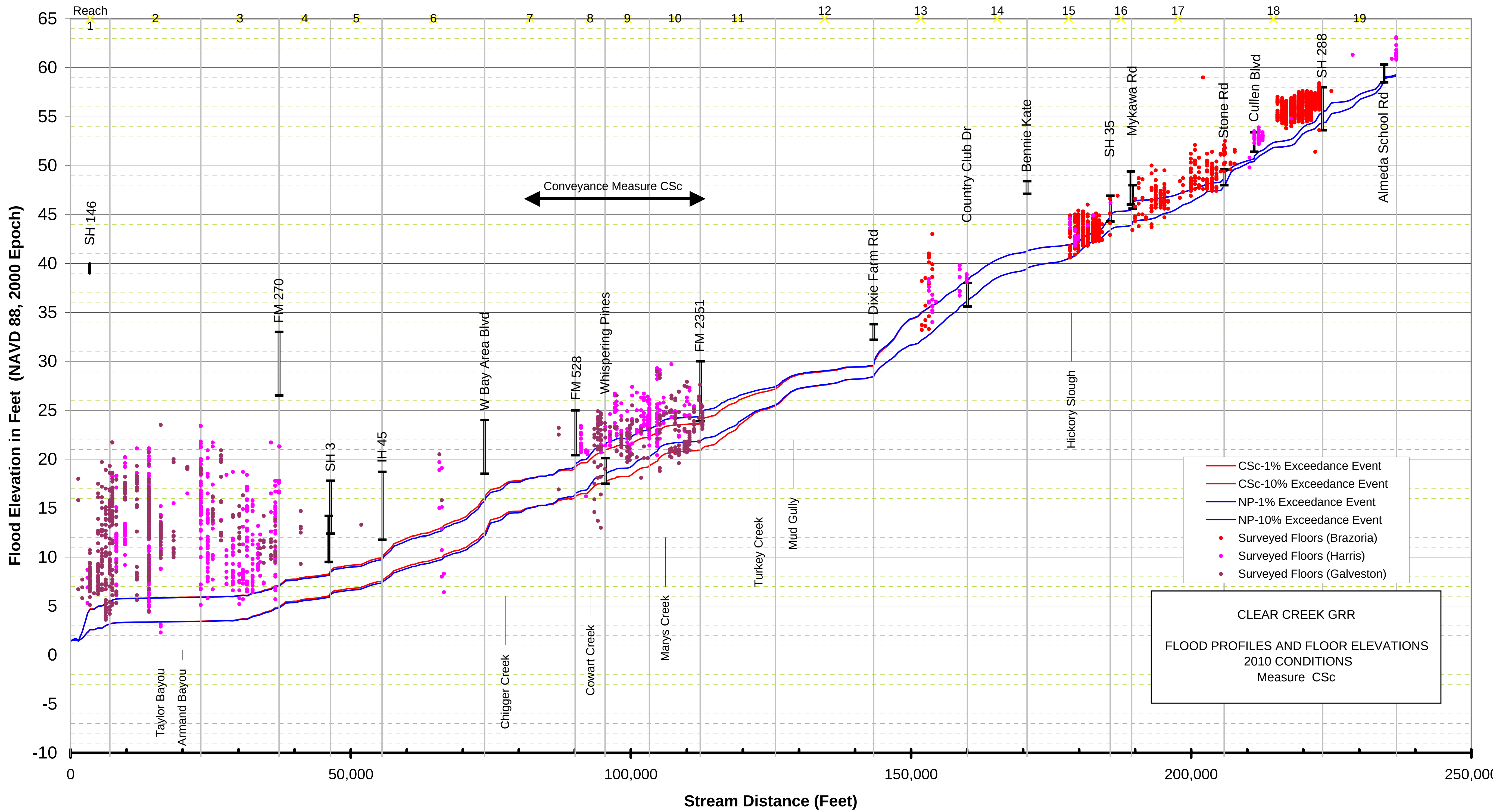
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
C4-1% Exceedance Event
C4-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure C4
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure CSc
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
Conveyance Measure CSc
CSc-1% Exceedance Event
CSc-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
SH 146
FM 270
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IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
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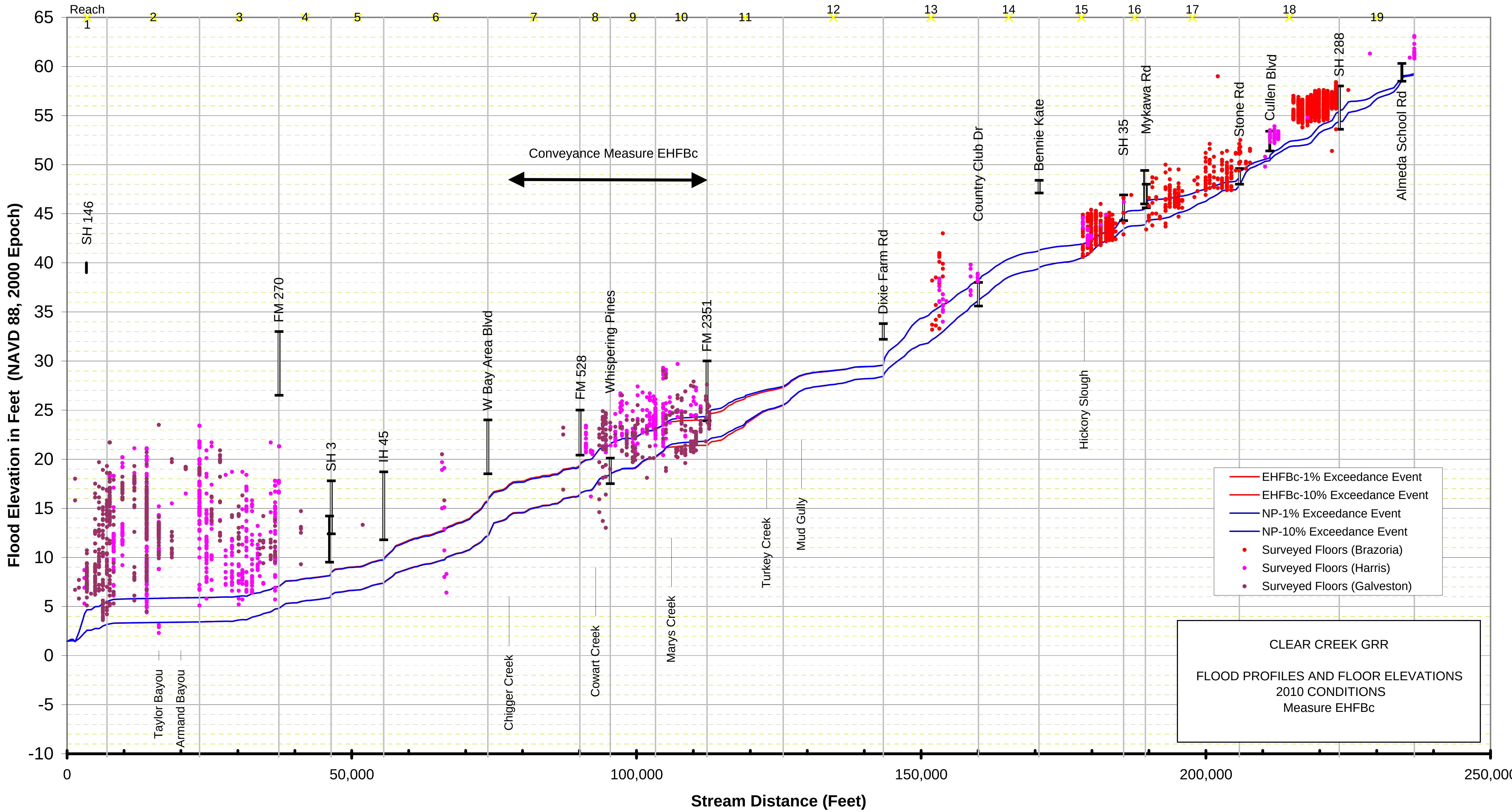
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough



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W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Conveyance Measure EHFBc
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
EHFBc-1% Exceedance Event
EHFBc-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure EHFBc
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
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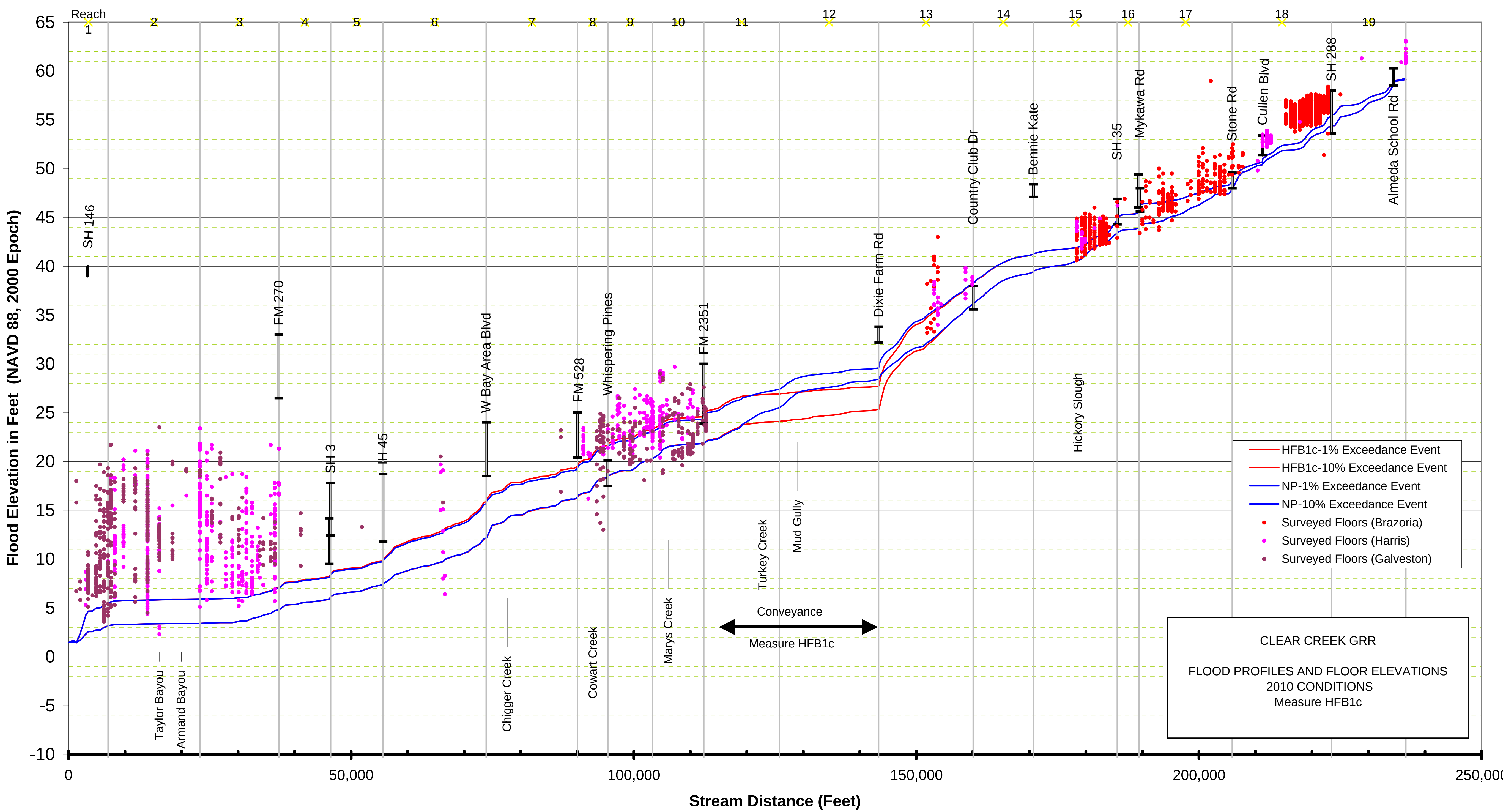

CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure HFB1c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
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FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Conveyance
Measure HFB1c
HFB1c-1% Exceedance Event
HFB1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
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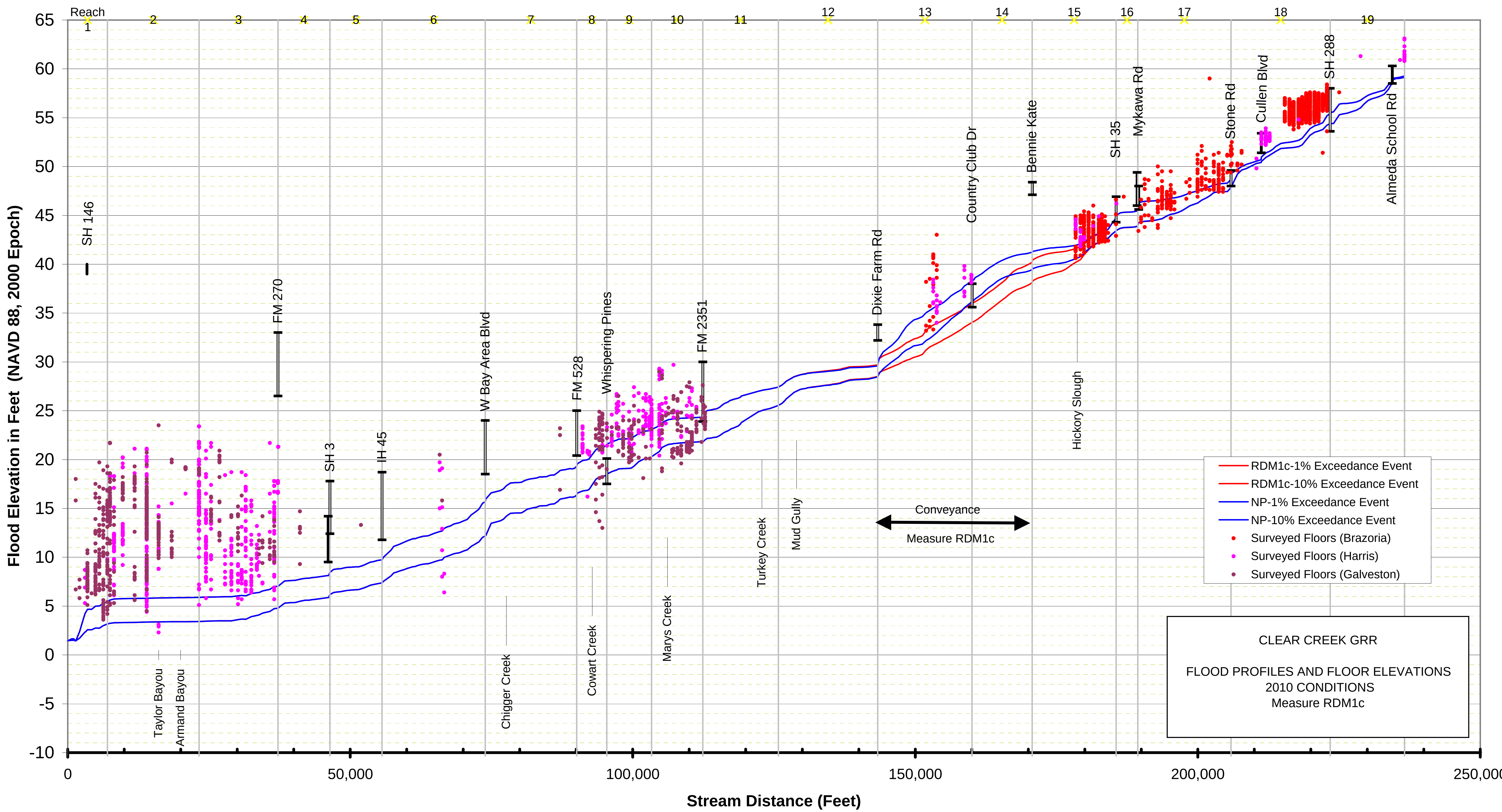
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure RDM1c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
RDM1c-1% Exceedance Event
RDM1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
Conveyance
Measure RDM1c
SH 146
FM 270
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IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
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Mykawa Rd
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Marys Creek
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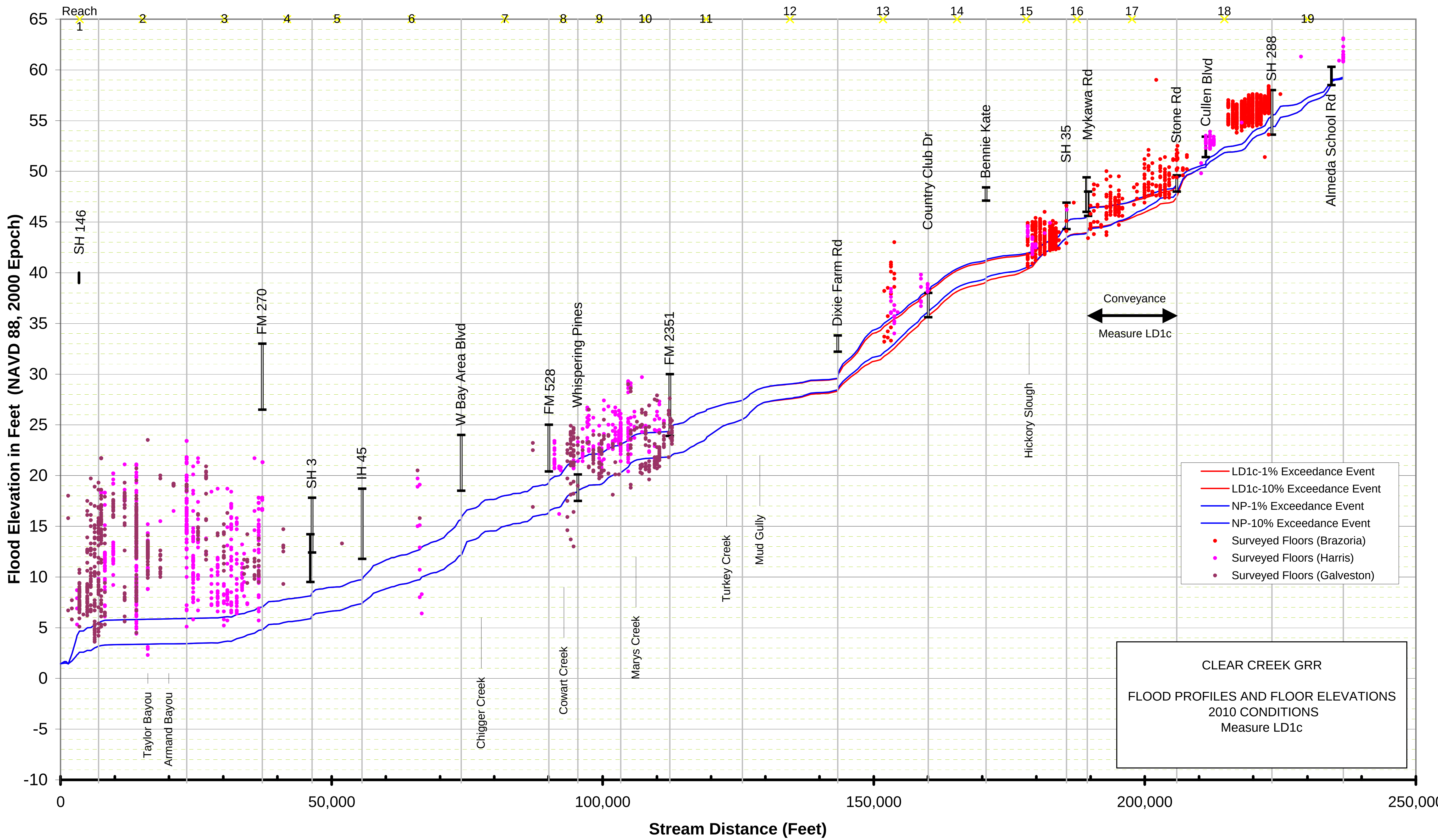
Mud Gully
Hickory Slough



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure LD1c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
LD1c-1% Exceedance Event
LD1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
Conveyance
Measure LD1c
SH 146
FM 270
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W Bay Area Blvd
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Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
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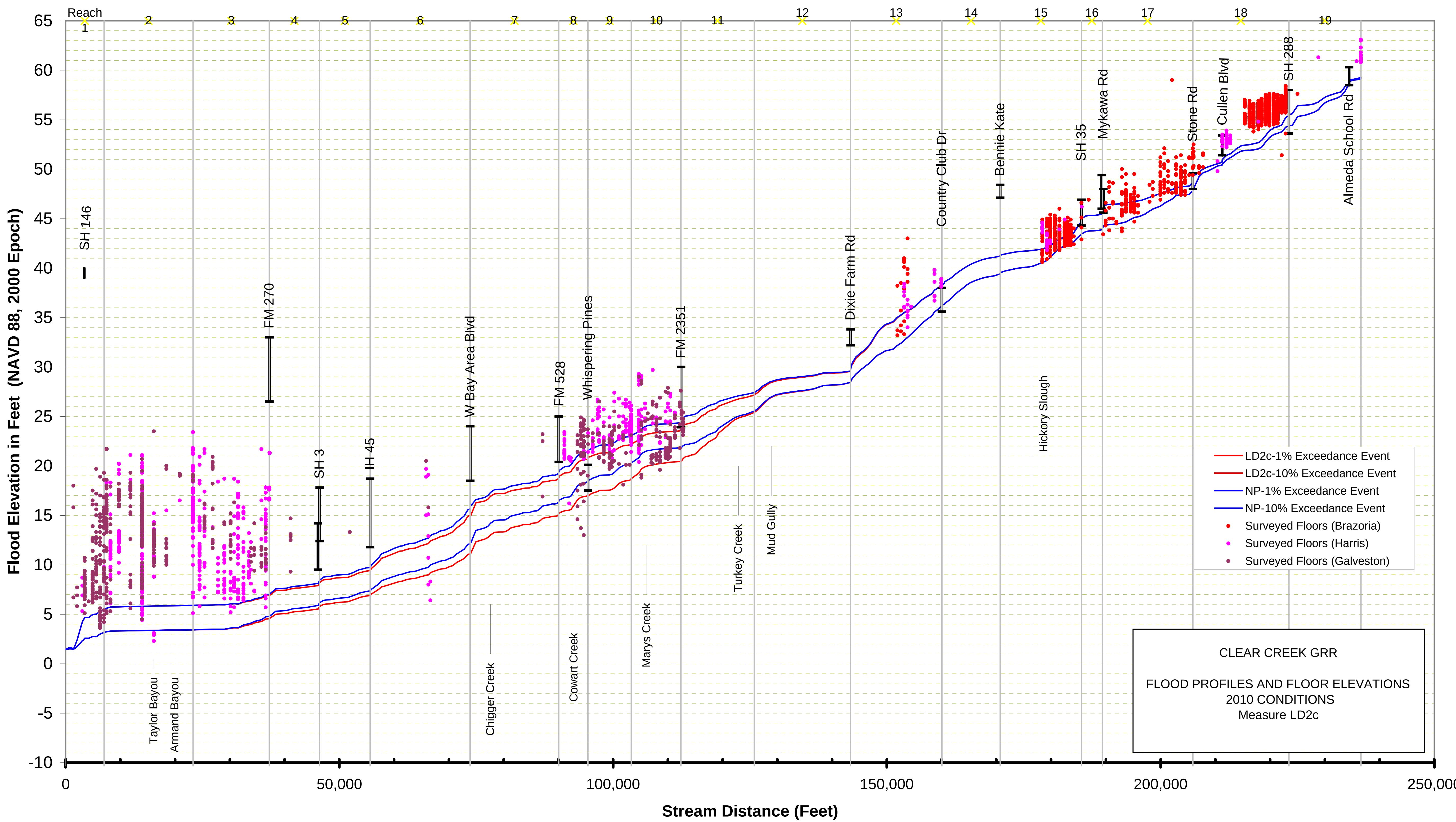
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough



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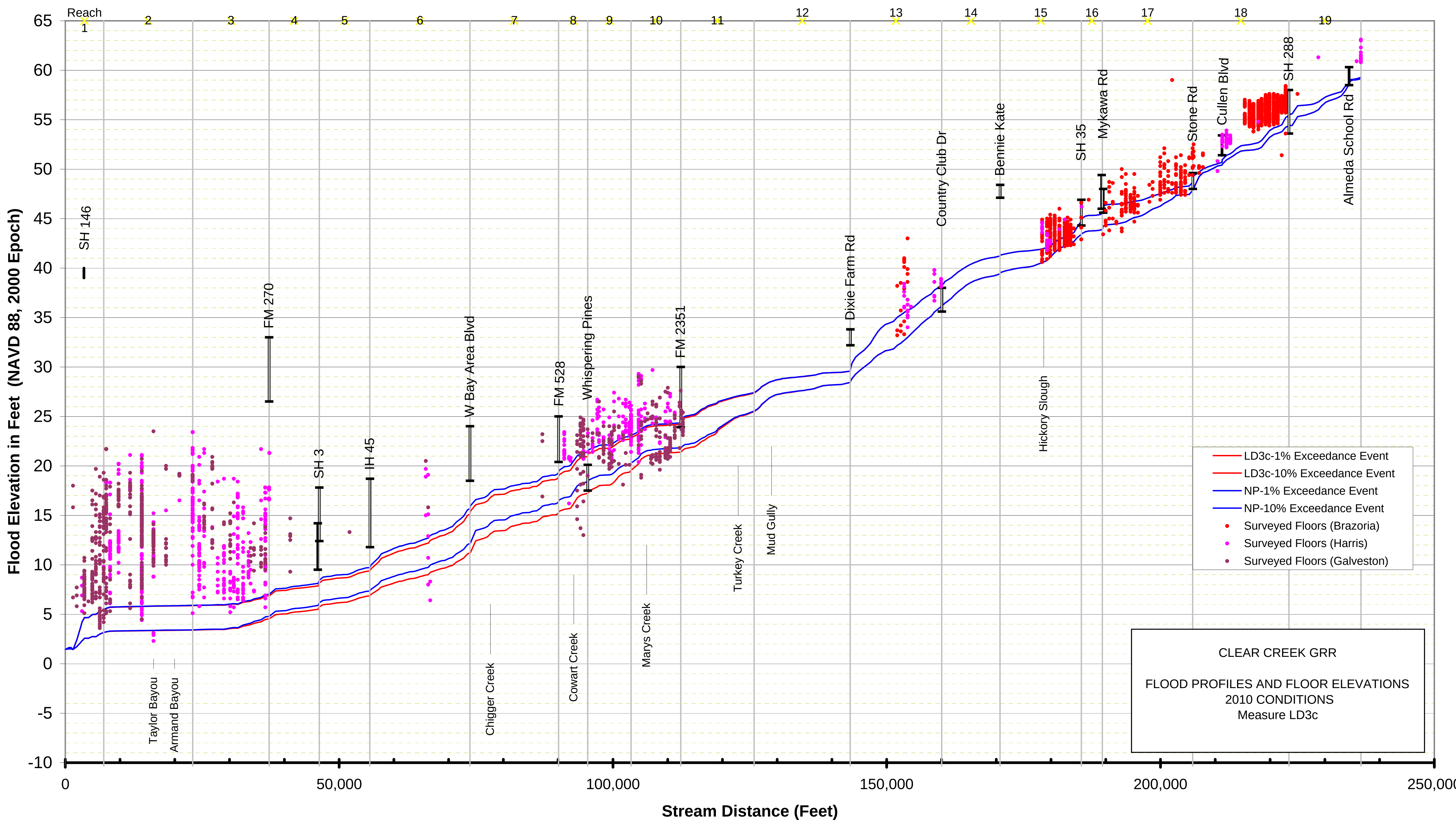
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
LD2c-1% Exceedance Event
LD2c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure LD2c



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Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
LD3c-1% Exceedance Event
LD3c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure LD3c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
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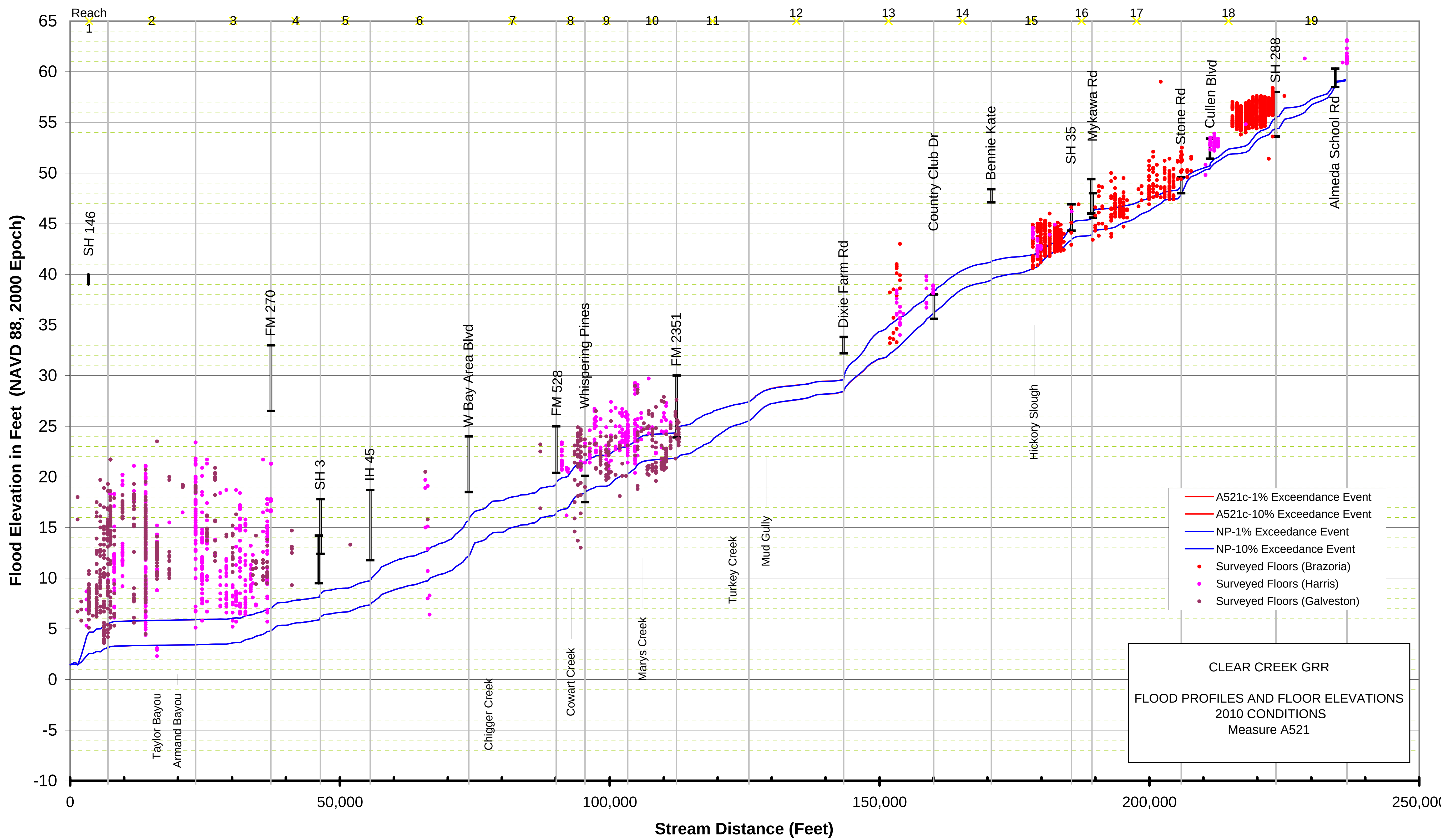
0 50,000 100,000 150,000 200,000 250,000



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure A521
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
A521c-1% Exceedance Event
A521c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
SH 146
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Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
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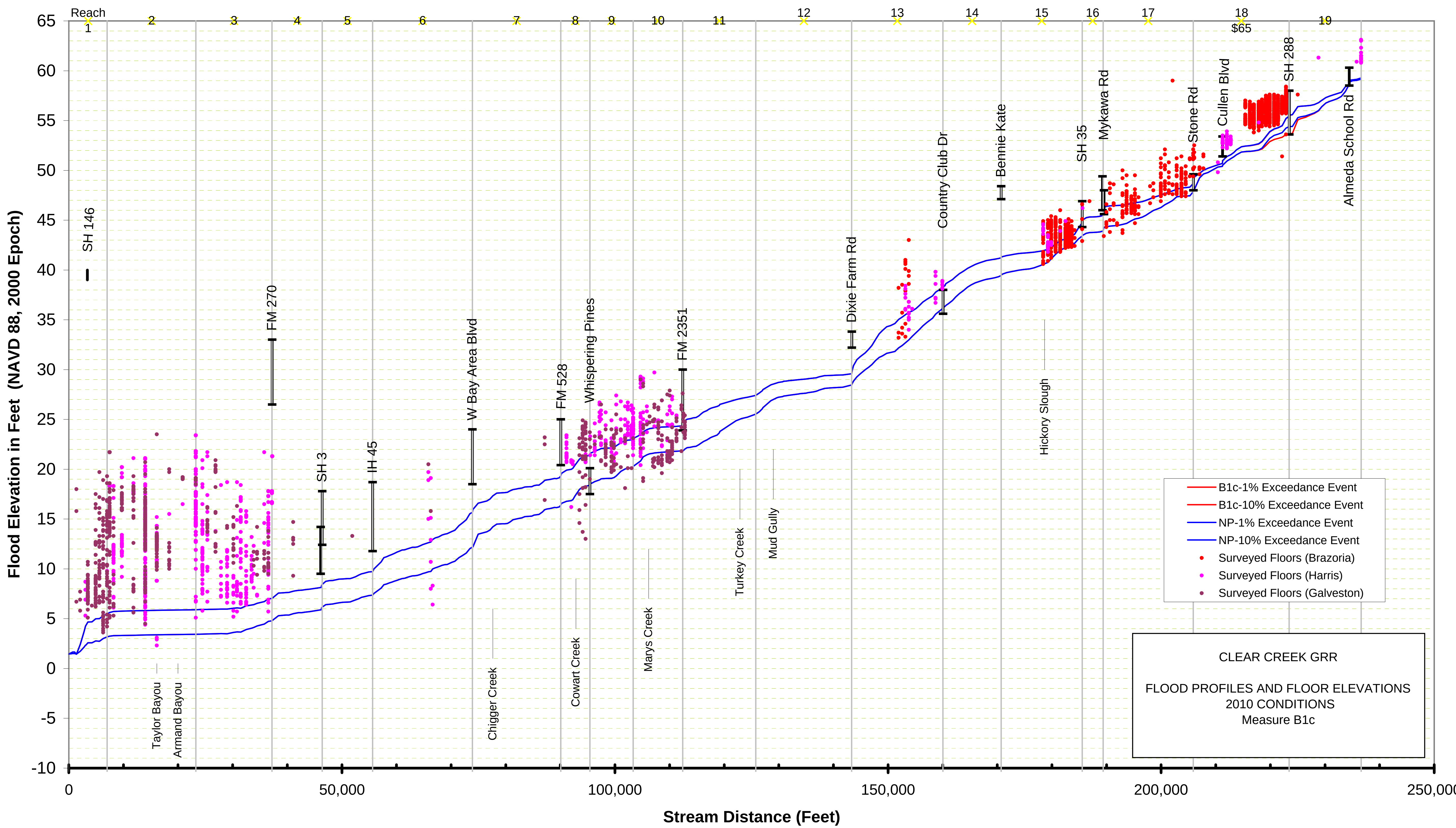
Mud Gully
Hickory Slough



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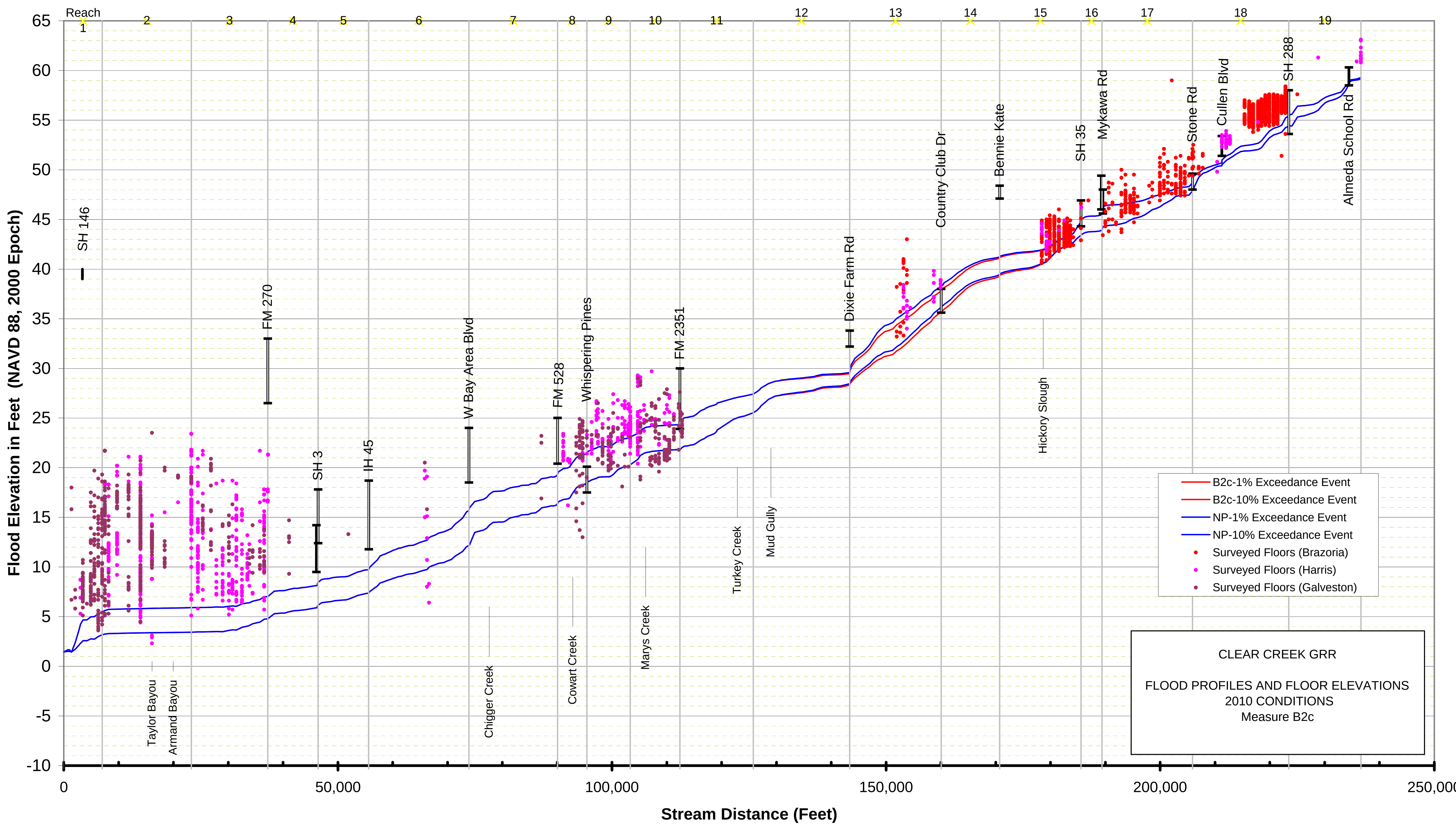
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
B1c-1% Exceedance Event
B1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure B1c



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure B2c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
B2c-1% Exceedance Event
B2c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
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FM 2351
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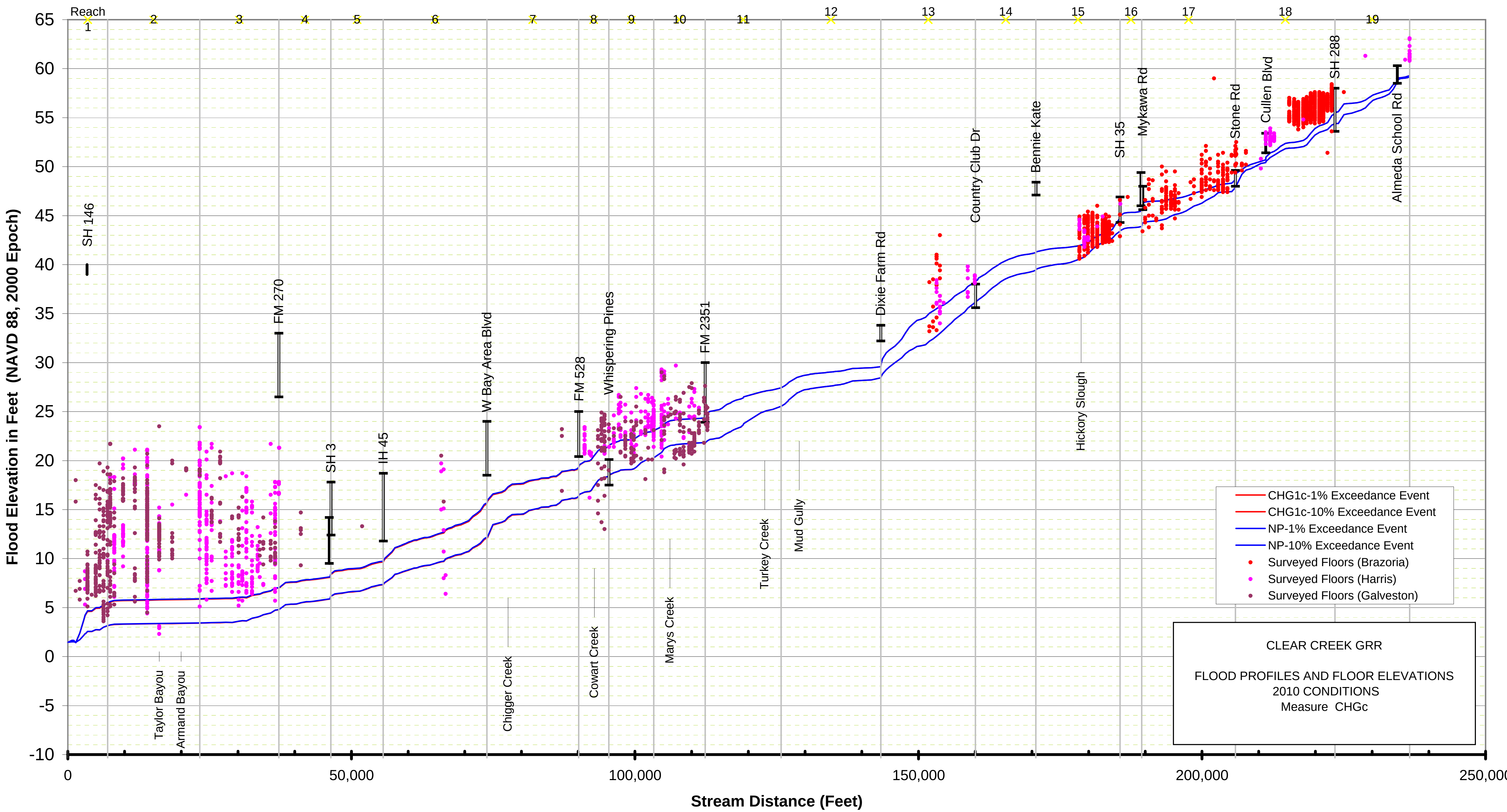

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Armand Bayou
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Chigger Creek
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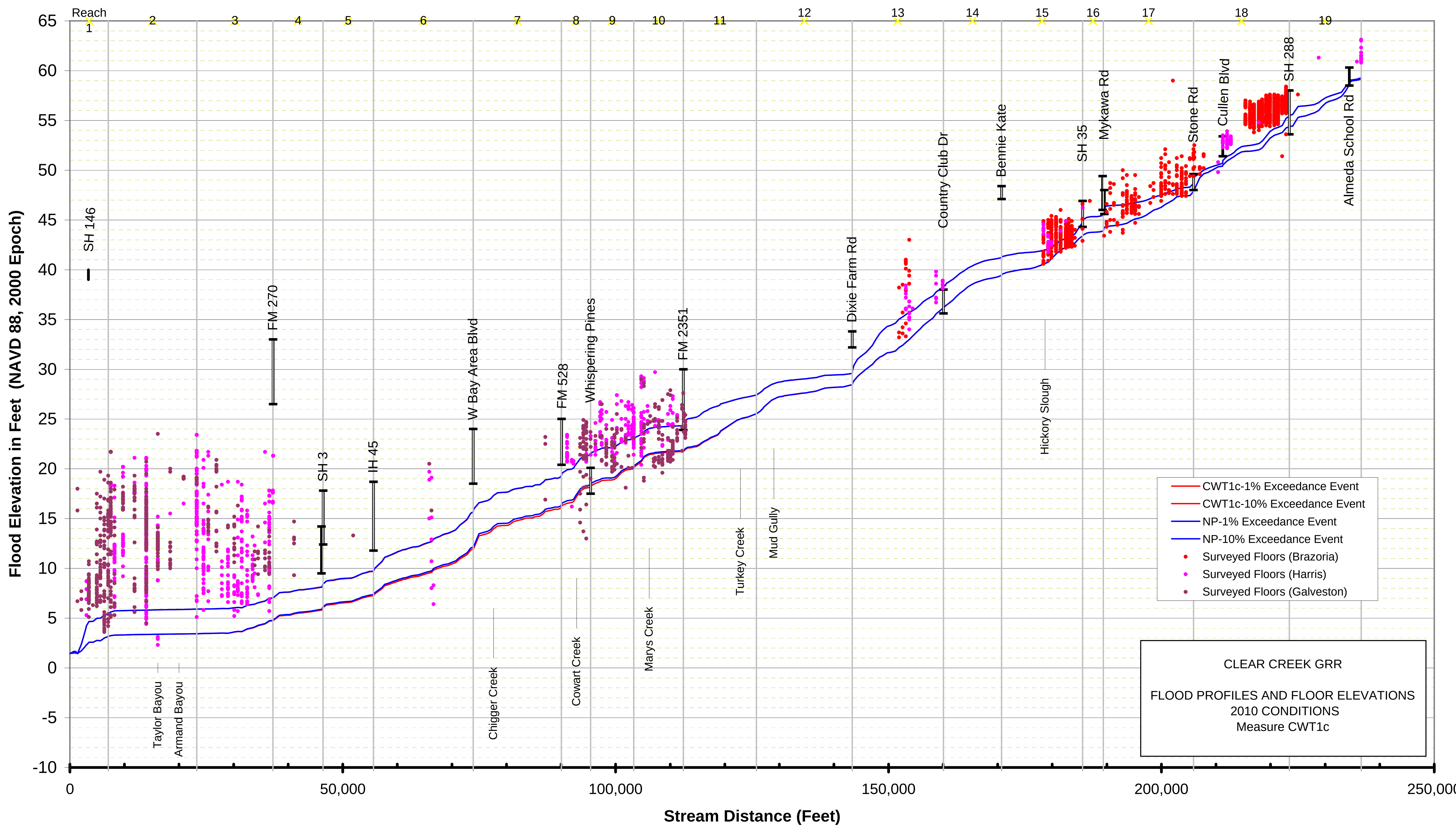
Whispering Pines
Cowart Creek
Marys Creek
FM 2351
Turkey Creek
Mud Gully
Dixie Farm Rd
Country Club Dr
Bennie Kate
Hickory Slough
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
CHG1c-1% Exceedance Event
CHG1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure CHGc



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Cullen Blvd
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Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
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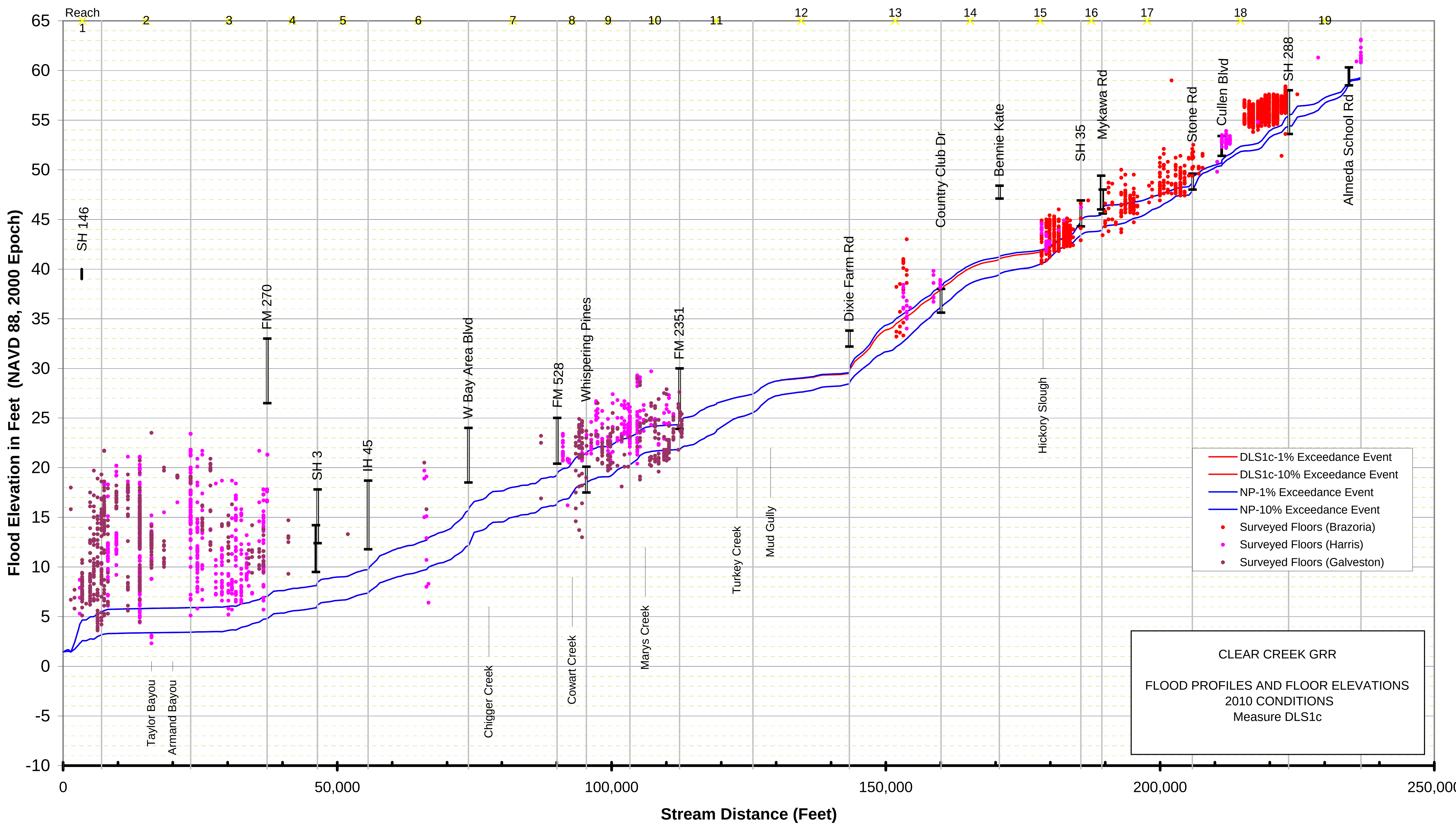
200,000
250,000
CWT1c-1% Exceedance Event
CWT1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure CWT1c



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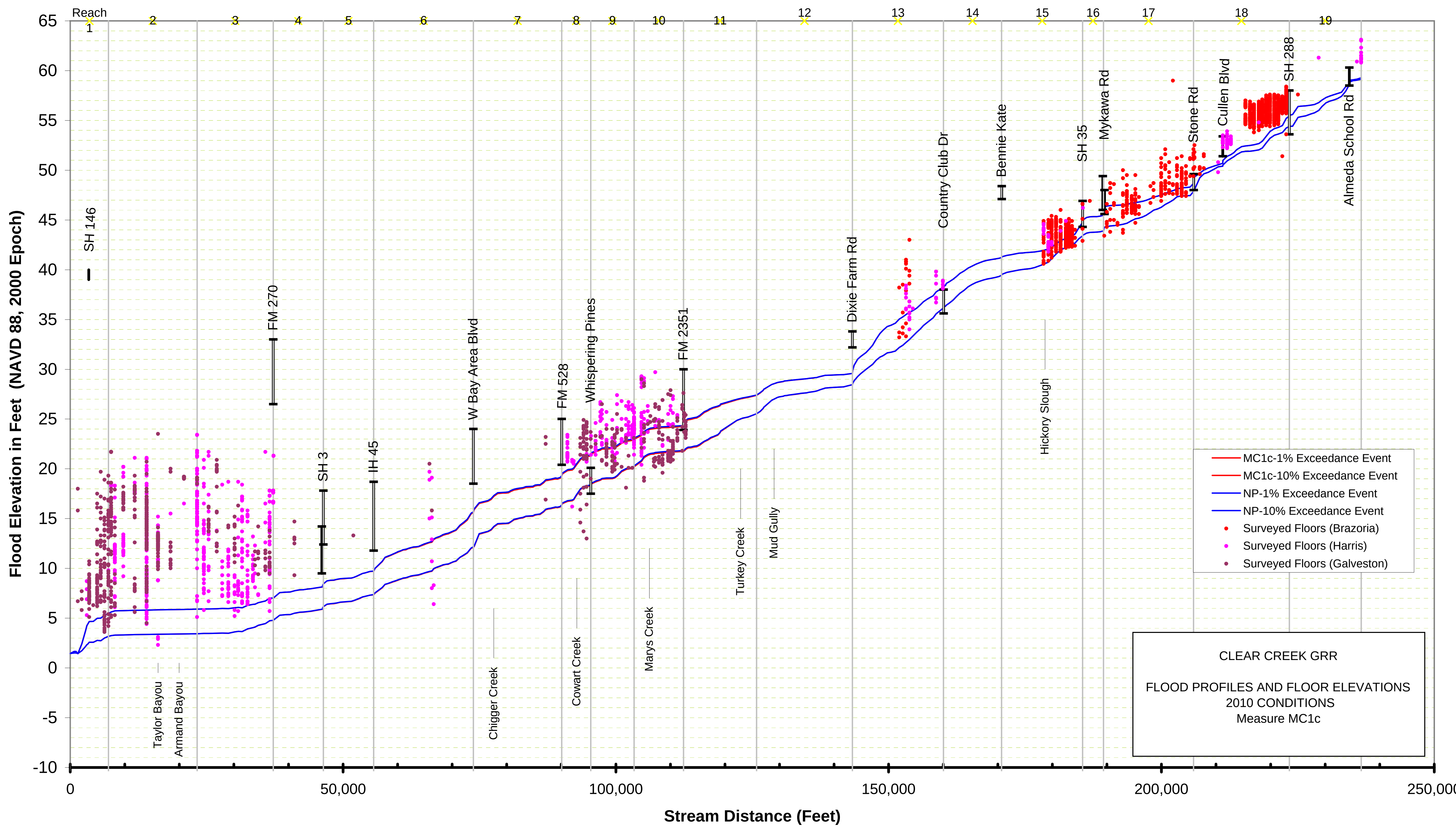
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
DLS1c-1% Exceedance Event
DLS1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure DLS1c



Reach
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
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FM 2351
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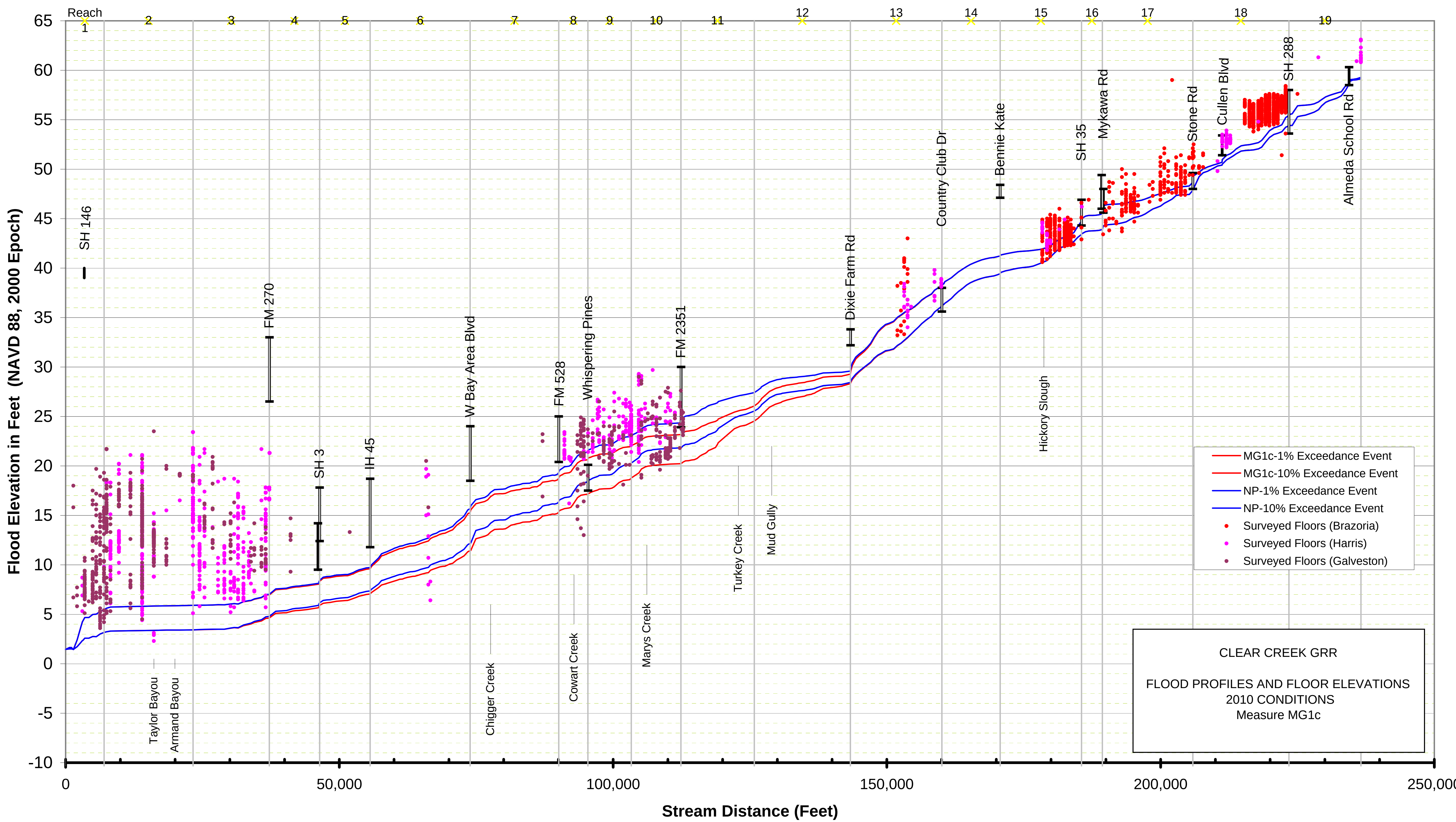
MC1c-1% Exceedance Event
MC1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure MC1c



Reach
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
FM 528
Whispering Pines
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Flood Elevation in Feet (NAVD 88, 2000 Epoch)
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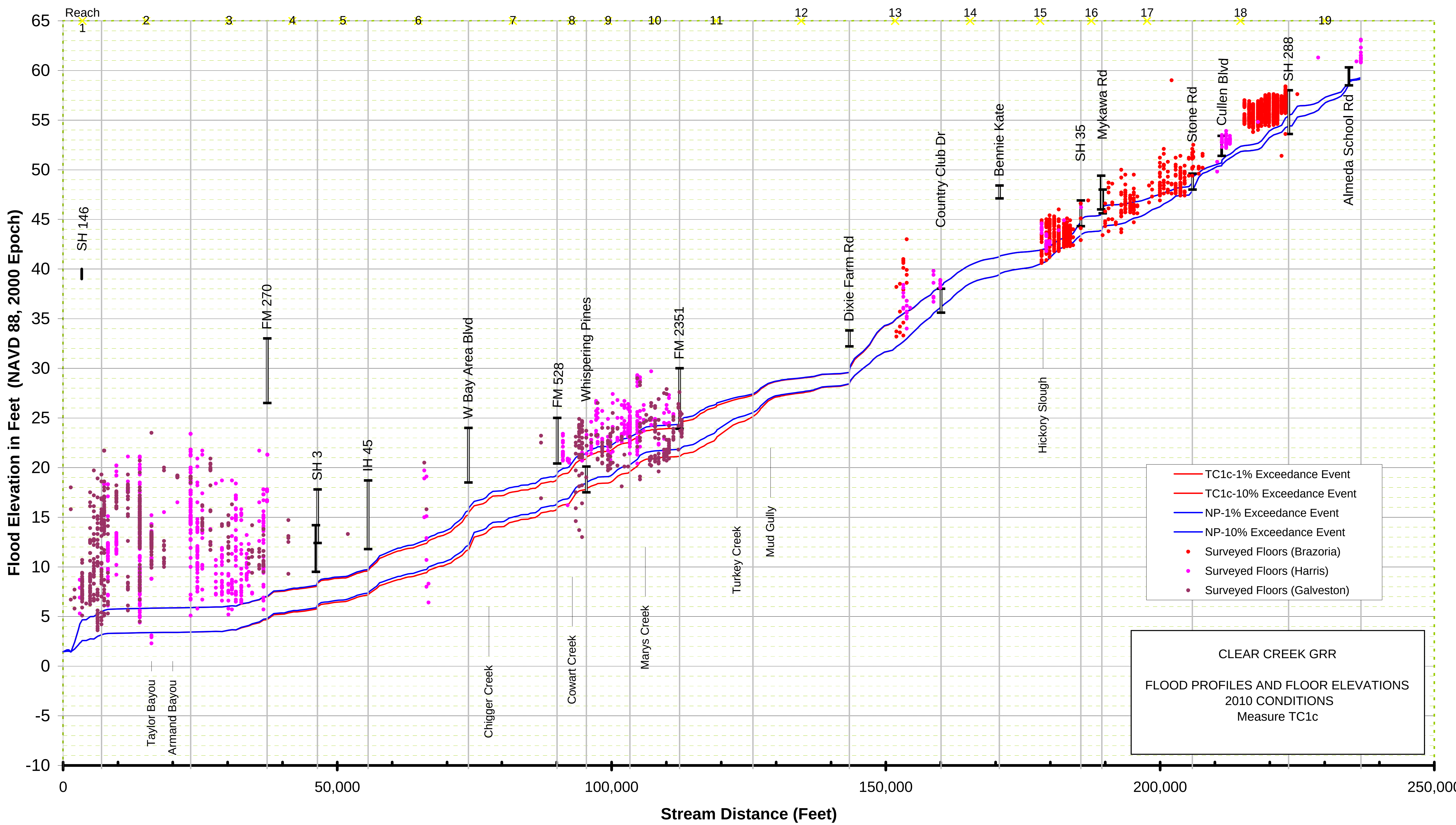
MG1c-1% Exceedance Event
MG1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure MG1c



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Measure TC1c
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
TC1c-1% Exceedance Event
TC1c-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
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FM 2351
Dixie Farm Rd
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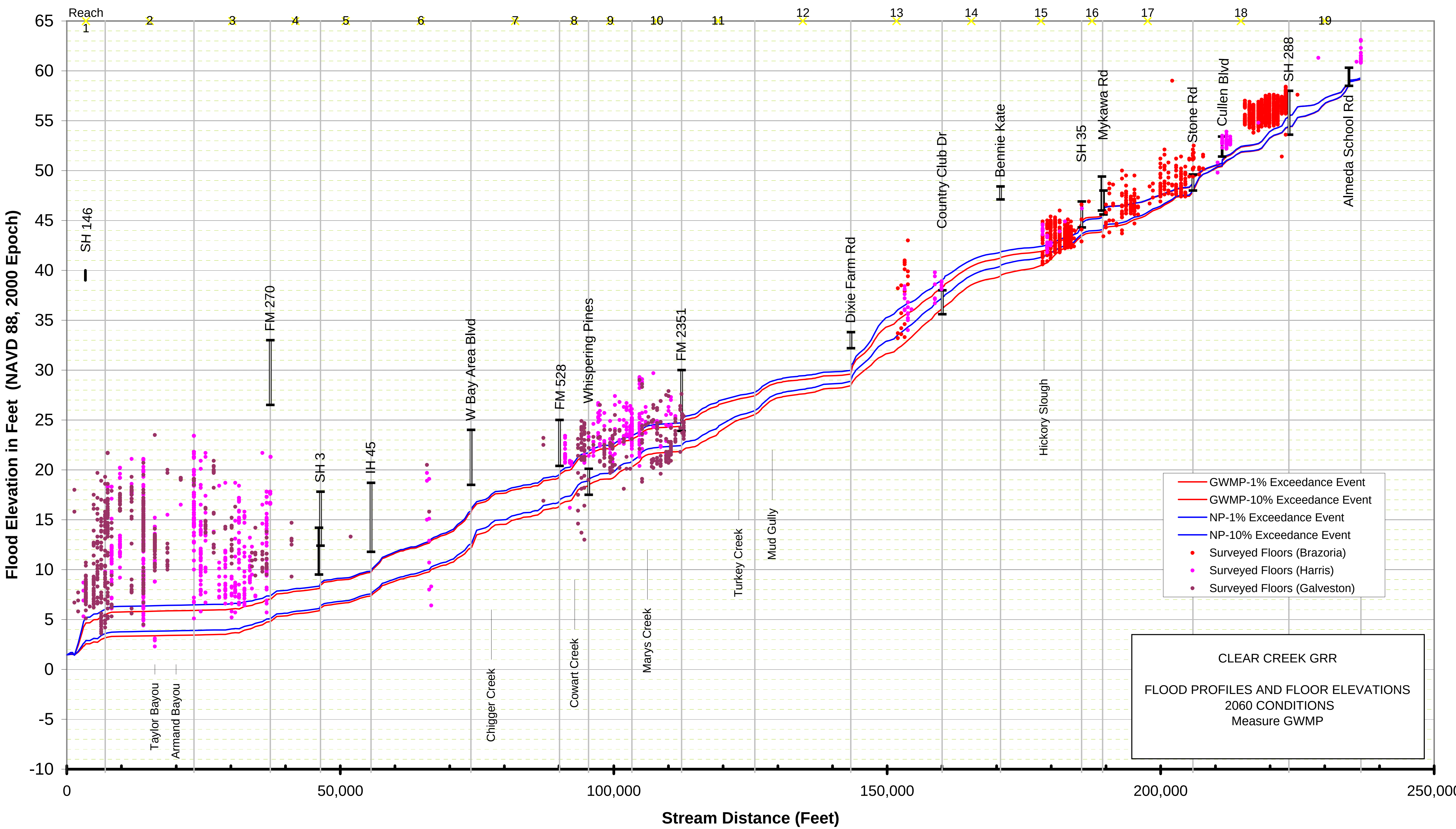
Cullen Blvd
SH 288
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2060 CONDITIONS
Measure GWMP
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
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SH 146
FM 270
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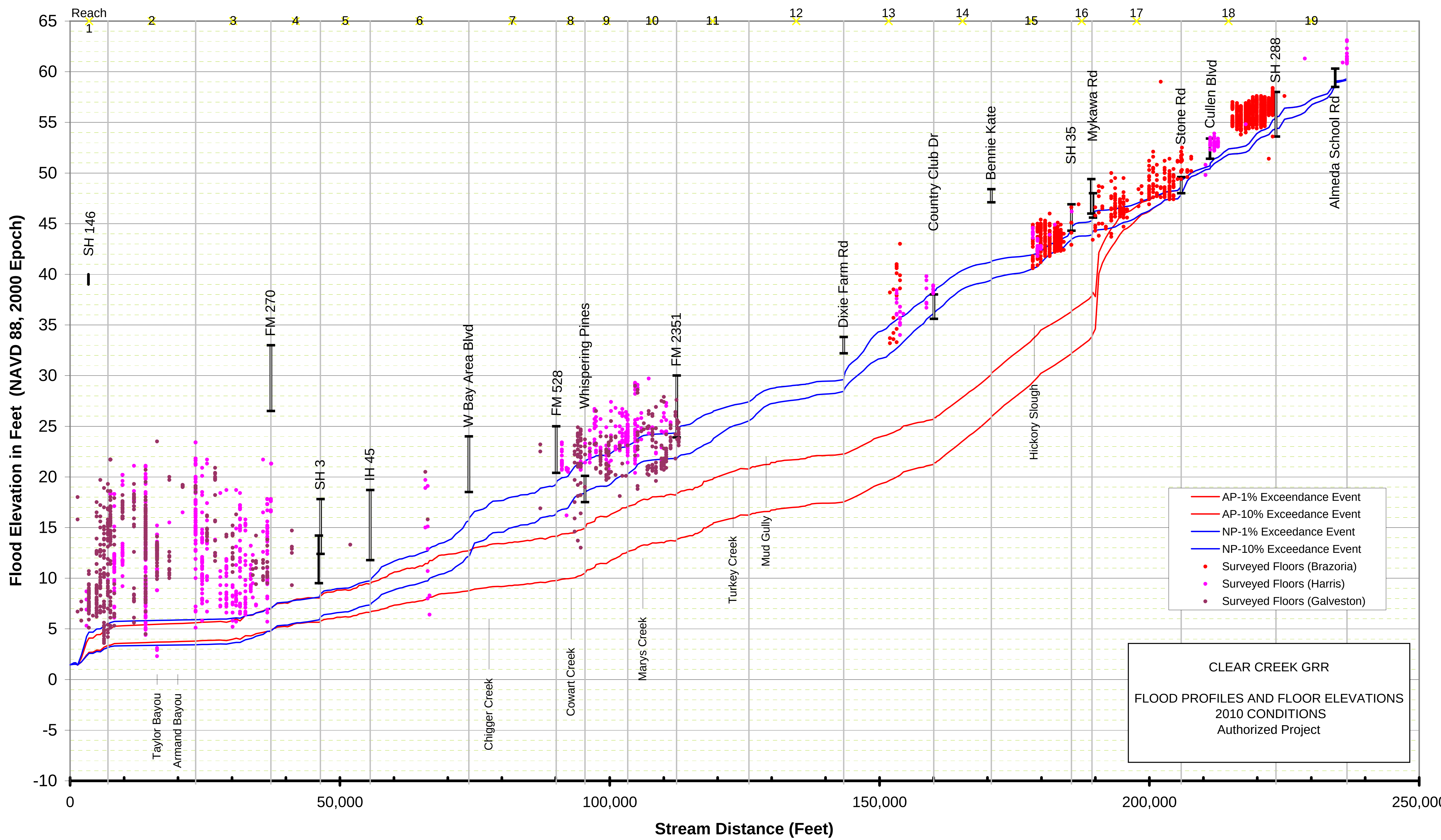
GWMP-1% Exceedance Event
GWMP-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)

APPENDIX D

LEGACY PLAN FLOOD PROFILES


CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Authorized Project
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
1
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SH 146
FM 270
SH 3
IH 45
W Bay Area Blvd
FM 528
Whispering Pines
FM 2351
Dixie Farm Rd
Country Club Dr
Bennie Kate
SH 35
Mykawa Rd
Stone Rd
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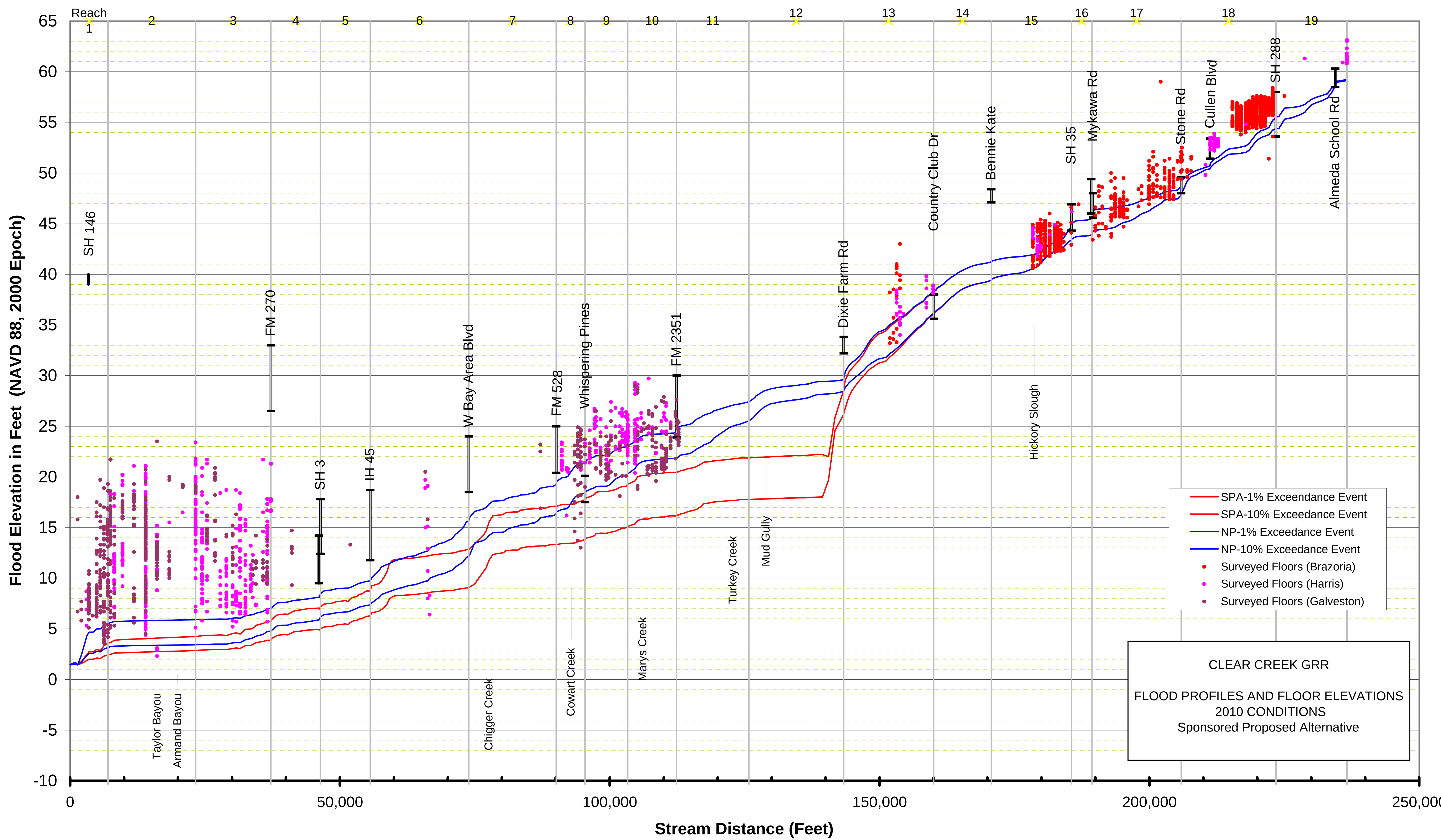
Almeda School Rd
Taylor Bayou
Armand Bayou
Chigger Creek
Cowart Creek
Marys Creek
Turkey Creek
Mud Gully
Hickory Slough
AP-1% Exceedance Event
AP-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
Surveyed Floors (Brazoria)
Surveyed Floors (Harris)
Surveyed Floors (Galveston)
0
50,000
100,000
150,000
200,000
250,000
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10



CLEAR CREEK GRR
FLOOD PROFILES AND FLOOR ELEVATIONS
2010 CONDITIONS
Sponsored Proposed Alternative
Flood Elevation in Feet (NAVD 88, 2000 Epoch)
Stream Distance (Feet)
Reach
SPA-1% Exceedance Event
SPA-10% Exceedance Event
NP-1% Exceedance Event
NP-10% Exceedance Event
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Surveyed Floors (Harris)
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Marys Creek
Turkey Creek
Mud Gully
Hickory Slough

APPENDIX G
Real Estate Plan

GALVESTON DISTRICT REAL ESTATE PLAN

CLEAR CREEK

FLOOD CONTROL PROJECT

HARRIS & BRAZORIA COUNTY, TEXAS

23 JUNE 2008

REVISED

22 August 2012

CESWG-RE 22 August 2012

Project Manager: CESWG-PE-PL Sheri Willey
Prepared by: CESWG-RE Jerry Benavides, Carlos Hidalgo, Brian Murphy
Submitted by: CESWG-RE Orlando Rosas

REAL ESTATE PLAN - TABLE OF CONTENTS

LIST OF EXHIBITS

CLEAR CREEK FLOOD CONTROL PROJECT
HARRIS & BRAZORIA COUTY, TEXAS
REAL ESTATE PLAN

1. **General Background**. This Real Estate Plan (REP) is the real estate work product of the U.S. Army Corps of Engineers, Galveston District, Real Estate Division (the "District") that supports project plan formulation for the Clear Creek Flood Control Project (the "Project"). It identifies and describes the lands, easements, and rights-of-way (LER) required for the construction, operation and maintenance of the proposed project, including those required for relocations, borrow material, mitigation and dredged or excavated material disposal. The REP also identifies and describes the facility/utility relocations that are necessary to implement the Project. Further, the REP describes the estimated LER value, together with the estimated administrative and incidental costs attributable to providing project LER, and the acquisition process.

2. **Project Type & Applicability**. The purpose of this study is to develop and evaluate alternatives for flood risk management in the Clear Creek watershed. Authority for the Clear Creek Flood Control Project is contained in Section 203 of the Flood Control Act approved August 13, 1968 (Public Law 90-483).

The pertinent part of the Act is as follows:

> "The project for flood protection on Clear Creek, Texas, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Number 351, nineteenth Congress."

3. **Project Location**. The Clear Creek watershed is located south of the city of Houston and includes parts of Galveston, Harris, Brazoria and Fort Bend Counties. The watershed is approximately 250 square miles and is partly inclusive within the City of Houston. Clear Creek flows from West to East and drains into Clear Lake and then into western Galveston Bay. (See Exhibit "A" Map Sheet Index)

4. **Scope and Content**. The General Re-Evaluation Report describes a range of potential alternatives such as increased conveyance, detention, and bridge widening. Alternatives addressing increased conveyance include excavation of material from adjacent to the creek bed, removal of dredged material from adjacent areas, new and expanded high-flow bypasses, selective clearing, excavation of areas adjacent to the channel, and additional outlet capacity in Clear Lake. The report describes the NED plan. The project consists of (7) seven contracts reaches. The total length of the proposed watershed is approximately 45 miles long. (See Exhibit "A" Map Sheet Index)

5. **Purpose**. The purpose of the REP is to identify the real estate requirements for the Project and to estimate the costs of acquisition. The plan will also identify the estate to be acquired for the various tracts. The Non-Federal Sponsors for the Clear Creek Flood

Control Project are, Harris County Flood Control District (HCFCD) and Brazoria Drainage District #4. HCFCD and Galveston County are the sponsors for the portion of the project known as the "Second Outlet Gate", which was completed in the late 1990s. HCFCD and Brazoria Drainage District #4 are the sponsors for the remainder of the proposed project. The Sponsors will receive credit for the fair market value of any lands required, at the time they are made available to the Government for construction. The Sponsors will also receive credit for the administrative costs of acquisition for all lands acquired within 5 years preceding the signing of the Project Partnership Agreement.

6. **Real Estate Requirements**. The Project Sponsor is required to furnish the lands, easements, and rights-of-way (LER) for the proposed cost-shared project, including those required for relocations, borrow material, mitigation, and dredged or excavated material disposal. The real estate requirements must support construction as well as operation and maintenance of the project after completion. Standard Estates, as defined in ER 405-1-12, Chapter 5, will be acquired for this project. The seven contract reaches involved in this project are as follow:

Contract 1: Mud Gully Conveyance and Placement Areas 4A, 4B, 4C, 4D, and 4E.

Contract 2: Turkey Creek Conveyance and Placement Area 2.

Contract 3: Mary's Creek Conveyance and Placement Area 5.

Contract 4: Lower Clear Creek Conveyance (sta. 0+00 to 220+87) and Placement Areas 4A, 4B, 4C, 4D, and 4E.

Contract 5: RR Bridge Replacement at Mykawa for Super C (sta. 434+36).

Contract 6: Bennie Kate to Mykawa (sta. 220+87 to 435+00) Inline Detention and Upper Clear Creek Conveyance and Placement Areas 3A, 3B, 3C, and 3D.

Contract 7: Mykawa to HWY 288 (sta. 435+00 to 764+77) Inline Detention and Upper Clear Creek Conveyance and Placement Areas SP1, SP2, and SP3.

Consistent with the current policy of the USACE the non-federal sponsors will provide Fee Title to 64.93 acres, consisting as follows: 31.21 acres of Habitat Mitigation areas and 32.9 acres of Environmental Conveyance areas. In addition, there will be a 0.82 acres required for a Railroad Easement, which will be assigned as Estate **Fee Excluding Minerals** (with Restriction on Use of the Surface and Subordination to the Right to Flood). The non-federal sponsors will also provide Perpetual Channel Improvement Easements on 544.23 acres, and **Temporary Work Area Easements** which will be required on 626.29 acres for both temporary Placement and Sand Pit areas. The Government will require the non-federal sponsor to provide proof of recordable instruments applicable to such sites, as deems necessary, in order to place the general public on notice of the project requirements and protect Government operations from interference by third parties.

<u>ESTATES</u>

Fee Estate - Estate No. 1, Fee for Detentions, Habitat Mitigation and Environmental Conveyance.

Channel Improvement Easement- Estate No. 8 for Channel Improvement

Temporary Work Area Easement - Estate No. 15, for both temporary Placement and Sand Pit Areas.

7. **Borrow Material**. The proposed project does not require any borrow material. All material needed for the construction of any placement area levees will be borrowed from within the footprint of the proposed required placement areas. The Sponsor will get credit for the entire tract acquired for the required placement areas or sand pits.

8. **Access/Staging Area**. The proposed project has both temporary Placement and Sand Pit Areas. All of the proposed work will be performed within the tracts required for right-of-way, placement areas and sand pits and existing roads and highways within the project area. No credit will be allowed for access/staging areas since these areas fall within the boundary lines of the land acquired. The sponsor will get credit for the entire tracts acquired for the required placement areas, sand pits and work areas needed for the project.

9. **Recreation Features**. The proposed project does not have any recreation features.

10. **Induced Flooding**. There will be no induced flooding by virtue of the construction of the project.

11. **Mitigation**. To compensate for unavoidable impacts, approximately 31 acres of floodplain forest would be restored through reestablishing the historic low-flow circulation of Clear Creek through 13 remnant channel meanders located between Country Club Drive and Dixie Farm Road. Flow within these former channel meanders was cut off during the original channel straightening activities during the mid 1900s, resulting in a series of man-made oxbows. Restoration would be accomplished by excavating a small pilot channel into the oxbows to reestablish low-flow conditions while maintaining high-flow conditions with the current channel acting as a high-flow bypass to guarantee flood protection for the area. Excavated material stockpiled along the north bank of the creek from the past channel construction and maintenance activities would be removed as necessary to construct project features, and the existing cleared overbank areas along the channel would be rehabilitated where possible by densely planting native trees to restore the existing floodplain forest to a desired state.

12. **Federally Owned Land & Existing Federal Project**. There is no federally owned land in the project area.

13. **Navigation Servitude**. Navigation Servitude will not be exercised on any portion of the proposed project.

14. **Public Law 91-646 Relocations**. Acquisition of the right-of-way will require the relocation of 16 residential homes and 6 commercial type structures. There are no farms within the project area. Relocation Assistance provided by the local sponsors must comply with the provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646 as amended by PL 100-17.

15. **Assessment of Project Sponsor Land Acquisition Capabilities**. The Non-Federal Sponsors for the Clear Creek Flood Control Project have the authority and capability to furnish lands, easements, and rights-of-way in accordance with the Feasibility Cost-Sharing Agreement. The Non-Federal Sponsors for the proposed project are highly capable of performing the real estate acquisition required by this project. A copy of the non-federal capability assessment for each other the Non-Federal Sponsors is attached as Exhibit "*C*" (Brazoria Drainage District #4) and Exhibit "*D*" (Harris County Flood Control District "HCFCD").

16. **Baseline Cost Estimate for Real Estate**. The cost estimate below reflects estimated Federal and Non-Federal real estate costs for the proposed 7 Contracts for the proposed flood control project. These costs include land payments, acquisition administrative costs, surveying, mapping and administrative costs. The real estate costs for the proposed project are estimated below:

Clear Creek Flood Control Project Cost Estimate

COSTRUCTION CONTRACT #1--NON-FEDERAL COSTS

Mud Gully Conveyance & Placement Areas 4A, 4B, 4C, 4D & 4E
(Total Parcels = 61 ; Total Acreage = 372.69)

		AMOUNT	CONTINGENCY
(a) Land Payments			
Value of 3.06 acres CIE (outside existing channel) (10% contingency)		145,000	14,500
Value of 11.43 acres CIE (within existing channel) (10% contingency)		57,200	5,720
Value of 358.2 acres TWAE (for 6 years) (10% contingency)		9,388,700	938,870
Damages (10% contingency)		15,000	1,500
(b) Project Related Administration		610,000	160,430
($10,000 x # of parcels) (26.3% contingency)			
(c) Appraisals		152,500	40,108
($2,500 per appraisal) (26.3% contingency)			
(d) Condemnations		68,625	18,048
(15% of total parcels x $7,500 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocation Execution Costs		13,600	3,577
(For Construction Costs See Cost Engineering Appendix)			
(1 bridge relo for this contract) ($13,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS		244,078	64,193
Calculation for Crediting/Audit Compliance			
Total all Contract #1 Creditable Costs Except LERRD Crediting (items a-f)	10,450,625		
Total all Contract #1 Contingency Costs Except LERRD Crediting	1,182,753		
Total all Contract #1 Construction Costs Taken from Engineering Appendix, Part 6	648,580		
Total all Contract #1 Construction Contingency Costs Taken from Engineering Appendix, Part 6	171,000		
Total Creditable Costs	12,452,958		
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**244,078**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**64,193**		
		10,694,703	1,246,945
TOTAL CONTRACT #1 - NON-FEDERAL COSTS		11,941,648	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #1--FEDERAL COSTS

Mud Gully Conveyance & Placement Areas 4A, 4B, 4C, 4D & 4E
(Total Parcels = 61 ; Total Acreage = 372.69)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		30,500	8,022
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		30,500	8,022
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		36,600	9,626
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		45,750	12,032
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocations		1,600	421
(1 bridge relo for this contract) ($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		171,851	45,197
Calculation for Crediting/Audit Compliance			
Total Creditable Costs Taken from Contract 1 Non-Fed Costs	12,452,958		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**171,851**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**45,197**		
		316,801	83,319
TOTAL CONTRACT #1 - FEDERAL COSTS		400,119	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #2--NON-FEDERAL COSTS

Turkey Creek Conveyance & Placement Area 2
(Total Parcels = 44 ; Total Acreage = 97.24)

	AMOUNT	CONTINGENCY
(a) Land Payments		
Value of 16.33 acres CIE (outside existing channel) (15% contingency)	310,000	46,500
Value of 42.91 acres CIE (within existing channel) (15% contingency)	85,800	12,870
Value of 38 acres TWAE (for 2 years) (15% contingency)	71,700	10,755
Improvements (metal barn) (15% contingency)	5,000	750
Damages (15% contingency)	40,100	6,015
(b) Project Related Administration	440,000	115,720
($10,000 x # of parcels) (26.3% contingency)		
(c) Appraisals	110,000	28,930
($2,500 per appraisal) (26.3% contingency)		
(d) Condemnations	49,500	13,019
(15% of total parcels x $7,500 per parcel) (26.3% contingency)		
(e) PL 91-646	10,000	2,630
(metal barn; demo; $10,000 per demo) (26.3% contingency)		
(f) Facility/Utility Relocations	516,800	135,918
(34 pipeline and 4 bridge relos for this contract)		
($13,600 per unit) (26.3% contingency)		
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS	221,795	58,332
	1,860,695	431,439

Calculation for Crediting/Audit Compliance

Total all Contract #2 Creditable Costs Except LERRD Crediting (items a-f)	1,638,900
Total all Contract #2 Contingency Costs Except LERRD Crediting	373,107
Total all Contract #2 Construction Costs Taken from Engineering Appendix, Part 6	7,366,655
Total all Contract #2 Construction Contingency Costs Taken from Engineering Appendix, Part 6	1,937,430
Total Creditable Costs	11,316,092
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**221,795**
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**58,332**

TOTAL CONTRACT #2 - NON-FEDERAL COSTS	2,292,134

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #2--FEDERAL COSTS

Turkey Creek Conveyance & Placement Area 2
(Total Parcels = 44 ; Total Acreage = 97.24)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		22,000	5,786
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		22,000	5,786
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		26,400	6,943
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		33,000	8,679
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646		2,090	550
(review of metal barn demo) (19 hrs needed for review of one unit)			
(19 hrs = $2,090 per unit) (26.3% contingency)			
(f) Facility/Utility Relocations		60,800	15,990
(review of 34 pipeline and 4 bridge relos) ($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		156,162	41,071
Calculation for Crediting/Audit Compliance			
Total Creditable Costs Taken From Contract 2 Non-Fed Costs	11,316,092		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**156,162**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**41,071**		
		322,452	84,805
TOTAL CONTRACT #2 - FEDERAL COSTS		407,257	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #3--NON-FEDERAL COSTS

Mary's Creek Conveyance & Placement Area 5
(Total Parcels = 310 ; Total Acreage = 118.89)

		AMOUNT	CONTINGENCY
(a) Land Payments			
Value of 15.13 acres CIE (outside existing channel) (20% contingency)		144,000	28,800
Value of 42.86 acres CIE (within existing channel) (20% contingency)		42,900	8,580
Value of 60.9 acres TWAE (for 2 years) (20% contingency)		402,000	80,400
Improvements (5 structures) (20% contingency)		251,000	50,200
Damages (20% contingency)		87,600	17,520
(b) Project Related Administration		3,100,000	815,300
($10,000 x # of parcels) (26.3% contingency)			
(c) Appraisals		775,000	203,825
($2,500 per appraisal) (26.3% contingency)			
(d) Condemnations		348,750	91,721
(15% of total parcels x $7,500 per parcel) (26.3% contingency)			
(e) PL 91-646		75,000	19,725
(5 structures; relo; $15,000 per relo) (26.3% contingency)			
(f) Facility/Utility Relocations		54,400	14,307
(2 pipeline and 2 bridge relos for this contract)			
($13,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS		183,623	48,293
Calculation for Crediting/Audit Compliance			
Total all Contract #3 Creditable Costs Except LERRD Crediting (items a-f)	5,280,650		
Total all Contract #3 Contingency Costs Except LERRD Crediting	1,330,378		
Total all Contract #3 Construction Costs Taken from Engineering Appendix, Part 6	2,183,291		
Total all Contract #3 Construction Contingency Costs Taken from Engineering Appendix, Part 6	574,206		
Total Creditable Costs	9,368,525		
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**183,623**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**48,293**		
		5,464,273	1,378,671
TOTAL CONTRACT #3 - NON-FEDERAL COSTS		6,842,944	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCT CONTRACT #3--- FEDERAL COSTS

Mary's Creek Conveyance & Placement Area 5
(Total Parcels = 310 ; Total Acreage = 118.89)

	AMOUNT	CONTINGENCY
(a) Acquisition Reviews	155,000	40,765
($500 per parcel) (26.3% contingency)		
(b) Project Related Administration	155,000	40,765
($500 per parcel) (26.3% contingency)		
(c) Appraisal Reviews	186,000	48,918
($600 per appraisal) (26.3% contingency)		
(d) Condemnation Reviews	232,500	61,148
(15% of total parcels x $5,000 per parcel) (26.3% contingency)		
(e) PL 91-646	10,450	2,748
(review of relo for 5 structures) (19 hrs needed for review of one unit)		
(19 hrs = $2,090 per unit) (26.3% contingency)		
(f) Facility/Utility Relocations	6,400	1,683
(review of 2 pipeline and 2 bridge relos) ($1,600 per unit) (26.3% contingency)		
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS	129,286	34,002
	874,636	230,029

Calculation for Crediting/Audit Compliance

Total Creditable Costs Taken from Contract 3 Non-Fed Costs	9,368,525
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**129,286**
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**34,002**

TOTAL CONTRACT #3 - FEDERAL COSTS 1,104,665

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #4-- NON-FEDERAL COSTS

Lower Clear Creek Conveyance (sta. 0+00 to 220+87) & Placement Areas 4A, 4B, 4C, 4D, & 4E
(Total Parcels = 218 ; Total Acreage = 132.08)

	Calculation	AMOUNT	CONTINGENCY
(a) Land Payments			
Value of 20.83 acres CIE (outside existing channel) (10% contingency)		198,000	19,800
Value of 75.36 acres CIE (within existing channel) (10% contingency)		75,400	7,540
Value of 35.89 acres Fee (10% contingency)		717,800	71,780
Damages (10% contingency)		27,300	2,730
(b) Project Related Administration		2,180,000	573,340
($10,000 x # of parcels) (26.3% contingency)			
(c) Appraisals		545,000	143,335
($2,500 per appraisal) (26.3% contingency)			
(d) Condemnations		245,250	64,501
(15% of total parcels x $7,500 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocations		13,600	3,577
(1 bridge relo for this contract) ($13,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS		123,753	32,547
Calculation for Crediting/Audit Compliance			
Total all Contract #4 Creditable Costs Except LERRD Crediting (items a-f)	4,002,350		
Total all Contract #4 Contingency Costs Except LERRD Crediting	886,603		
Total all Contract #4 Construction Costs Taken from Engineering Appendix, Part 6	1,128,238		
Total all Contract #4 Construction Contingency Costs Taken from Engineering Appendix, Part 6	296,727		
Total Creditable Costs	6,313,917		
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**123,753**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**32,547**		
		4,126,103	919,150
TOTAL CONTRACT #4 - NON-FEDERAL COSTS		5,045,252	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #4--FEDERAL COSTS

Lower Clear Creek Conveyance (sta. 0+00 to 220+87) & Placement Areas 4A, 4B, 4C, 4D, & 4E
(Total Parcels = 218 ; Total Acreage = 132.08)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		109,000	28,667
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		109,000	28,667
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		130,800	34,400
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		163,500	43,001
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocations		1,600	421
(review of 1 bridge relo) ($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		87,132	22,916
Calculation for Crediting/Audit Compliance			
Total Creditable Costs Taken From Contract 4 Non-Fed Costs	6,313,917		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**87,132**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**22,916**	601,032	158,071
TOTAL CONTRACT #4 - FEDERAL COSTS		759,103	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #5--NON-FEDERAL COSTS

RR Bridge Replacement at Mykawa for Super C (sta.434+36)
(Total Parcels = 1 ; Total Acreage = 0.82)

		AMOUNT	CONTINGENCY
(a) Land Payments			
Value of 0.82 Railroad *Easement** (15% contingency)		7,800	1,170
(b) Project Related Administration		10,000	2,630
($10,000 x # of parcels) (26.3% contingency)			
(c) Appraisals		2,500	658
($2,500 per appraisal) (26.3% contingency)			
(d) Condemnations		1,125	296
(15% of total parcels x $7,500 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocations		13,600	3,577
(1 RR bridge relo for this contract) ($13,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS		39,230	10,317
Calculation for Crediting/Audit Compliance			
Total all Contract #5 Creditable Costs Except LERRD Crediting (items a-f)	35,025		
Total all Contract #5 Contingency Costs Except LERRD Crediting	8,330		
Total all Contract #5 Construction Costs Taken from Engineering Appendix, Part 6	1,550,409		
Total all Contract #5 Construction Contingency Costs Taken from Engineering Appendix, Part 6	407,758		
Total Creditable Costs	2,001,522		
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**39,230**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**10,317**		
		74,255	18,648
TOTAL CONTRACT #5 - NON-FEDERAL COSTS		92,902	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #5--FEDERAL COSTS

RR Bridge Replacement at Mykawa for Super C, (sta.434+36)
(Total Parcels = 1 ; Total Acreage = 0.82)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		500	132
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		500	132
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		600	158
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		750	197
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646		0	0
(f) Facility/Utility Relocations		1,600	421
(review of 1 bridge relo) ($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		27,621	7,264
Calculation for Crediting/Audit Compliance			
Total Creditable Costs Taken From Contract 5 Non-Fed Costs	2,001,522		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**27,621**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**7,264**		
		31,571	8,303
TOTAL CONTRACT #5 - FEDERAL COSTS		39,874	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #6--NON-FEDERAL COSTS

Bennie Kate to Mykawa (sta. 220+87 to 435+00) Inline Detention & Upper Clear Creek Conveyance & PA's 3A, 3B, 3C & 3D
(Total Parcels = 71 ; Total Acreage = 214.44)

	AMOUNT	CONTINGENCY
(a) Land Payments		
Value of 20.51 acres CIE (outside existing channel) (25% contingency)	292,000	73,000
Value of 108.13 acres CIE (within existing channel) (25% contingency)	162,200	40,550
Value of 77.34 acres TWAE (for 3 years) (25% contingency)	1,073,100	268,275
Value of 8.16 acres Fee (25% contingency)	163,200	40,800
Value of 30 lots (25% contingency)	300,000	75,000
Improvements (16 dwellings)	3,200,000	800,000
Damages (25% contingency)	45,400	11,350
(b) Project Related Administration	710,000	186,730
($10,000 x # of parcels) (26.3% contingency)		
(c) Appraisals	177,500	46,683
($2,500 per appraisal) (26.3% contingency)		
(d) Condemnations	79,875	21,007
(15% of total parcels x $7,500 per parcel) (26.3% contingency)		
(e) PL 91-646	240,000	63,120
(16 dwellings; relos; $15,000 per relo) (26.3% contingency)		
(f) Facility/Utility Relocations	122,400	32,191
(6 pipeline and 3 bridge relos for this contract)		
($13,600 per unit) (26.3% contingency)		
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS	302,670	79,602
	6,868,345	1,738,308

Calculation for Crediting/Audit Compliance

Total all Contract #6 Creditable Costs Except LERRD Crediting (items a-f)	6,565,675
Total all Contract #6 Contingency Costs Except LERRD Crediting	1,658,706
Total all Contract #6 Construction Costs Taken from Engineering Appendix, Part 6	5,714,947
Total all Contract #6 Construction Contingency Costs Taken from Engineering Appendix, Part 6	1,503,031
Total Creditable Costs	15,442,359
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**302,670**
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**79,602**

TOTAL CONTRACT #6 - NON-FEDERAL COSTS 8,606,653

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #6--FEDERAL COSTS

Bennie Kate to Mykawa (sta. 220+87 to 435+00) Inline Detention & Upper Clear Creek Conveyance & PA's 3A, 3B, 3C & 3D
(Total Parcels = 71 ; Total Acreage = 214.14)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		35,500	9,337
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		35,500	9,337
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		42,600	11,204
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		53,250	14,005
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646		33,440	8,795
(review of relo for 16 structures) (19 hrs needed for review of one unit)			
(19 hrs = $2,090 per unit) (26.3% contingency)			
(f) Facility/Utility Relocations		14,400	3,787
(review of 6 pipeline and 3 bridge relos)			
($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		213,105	56,046
Calculation for Crediting/Audit Compliance			
Total Creditable Costs Taken From Contract 6 Non-Fed Costs	15,442,359		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**213,105**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**56,046**		
		427,795	112,510
TOTAL CONTRACT #6 - FEDERAL COSTS		540,305	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #7--NON-FEDERAL COSTS

Mykawa to HWY 288 (sta. 435+00 to 764+77) Inline Detention & Upper Clear Creek Conveyance & Placement Areas SP1, SP2, & SP3.
(Total Parcels = 71 ; Total Acreage = 299.59)

		AMOUNT	CONTINGENCY
(a) Land Payments			
Value of 37.77 acres CIE (outside existing channel) (25% contingency)		718,000	179,500
Value of 149.91 acres CIE (within existing channel) (25% contingency)		299,800	74,950
Value of 91.85 acres TWAE (for 3 years) (25% contingency)		382,300	95,575
Value of 20.06 acres Fee (25% contingency)		401,200	100,300
Improvements (6 structures) (25% contingency)		616,000	154,000
Golf Course Damage		3,250,000	812,500
Damages (25% contingency)		163,400	40,850
(b) Project Related Administration		710,000	186,730
($10,000 x # of parcels) (26.3% contingency)			
(c) Appraisals		177,500	46,683
($2,500 per appraisal) (26.3% contingency)			
(d) Condemnations		79,875	21,007
(15% of total parcels x $7,500 per parcel) (26.3% contingency)			
(e) PL 91-646		90,000	23,670
(6 structures; relo; $15,000 per relo) (26.3% contingency)			
(f) Facility/Utility Relocations		40,800	10,730
(1 pipeline and 2 bridge relos for this contract)			
($13,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.96% OF ALL CREDITABLE COSTS		189,133	49,742
Calculation for Crediting/Audit Compliance			
Total all Contract #7 Creditable Costs Except LERRD Crediting (items a-f)	6,928,875		
Total all Contract #7 Contingency Costs Except LERRD Crediting	1,746,495		
Total all Contract #7 Construction Costs Taken from Engineering Appendix, Part 6	771,402		
Total all Contract #7 Construction Contingency Costs Taken from Engineering Appendix, Part 6	202,879		
Total Creditable Costs	9,649,651		
Calculate LERRD Crediting/Audit Costs 1.96% times Total Creditable Costs	**189,133**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**49,742**		
		7,118,008	1,796,237
TOTAL CONTRACT #7 - NON-FEDERAL COSTS		8,914,245	

Clear Creek Flood Control Project Cost Estimate

CONSTRUCTION CONTRACT #7--FEDERAL COSTS

HWY 288 to Mykawa Upper Clear Creek Conveyance (sta 435+00 to 764+77), Inline Detention & Placement Area 3A, 3B, 3C and 3D

(Total Parcels = 71 ; Total Acreage = 299.59)

		AMOUNT	CONTINGENCY
(a) Acquisition Reviews		35,500	9,337
($500 per parcel) (26.3% contingency)			
(b) Project Related Administration		35,500	9,337
($500 per parcel) (26.3% contingency)			
(c) Appraisal Reviews		42,600	11,204
($600 per appraisal) (26.3% contingency)			
(d) Condemnation Reviews		53,250	14,005
(15% of total parcels x $5,000 per parcel) (26.3% contingency)			
(e) PL 91-646			
Review of work for Improvements (6 structures)		14,630	3,848
Review of Golf Course Damage			
(review of relo for 16 structures) (19 hrs needed for review of one unit)			
(19 hrs = $2,090 per unit) (26.3% contingency)			
(f) Facility/Utility Relocations		4,800	1,262
(review of 1 pipeline and 2 bridge relos) ($1,600 per unit) (26.3% contingency)			
(g) LERRD Crediting/Audit Compliance 1.38% OF ALL CREDITABLE COSTS		133,165	35,022
Calculation for Crediting/Audit Compliance			
Total Creditable Costs From Contract 7 Non-Fed Costs	9,649,651		
Calculate LERRD Crediting/Audit Costs 1.38% times Total Creditable Costs	**133,165**		
Calculate LERRD Crediting/Audit Costs Contingency 26.3% times LERRD Crediting Costs	**35,022**	319,445	84,014
TOTAL CONTRACT #7 - FEDERAL COSTS		403,459	

TOTAL ESTIMATED COSTS FOR THE NON-FEDERAL SPONSOR	$ 43,735,778
TOTAL ESTIMATED COSTS FOR THE FEDERAL GOVERNMENT	$ 3,654,782
TOTAL ESTIMATED RE PROJECT COSTS	$47,390,560

17. **Acquisition Schedule**. The Acquisition of the LER necessary for the Project is the responsibility of the Non-Federal Sponsors; an Acquisition Schedule is attached as Exhibit “B”.

18. **Mineral Activity**. There are no known mineral interests within the proposed project area. Review of databases maintained by Federal, State and Local Regulatory Agencies were conducted to determine the locations and status of oil and gas wells located within the study area. A total of 34 permitted oil and gas well sites are located within the project features. These well sites include 16 active wells, 9 wells plugged, 7 wells were dry holes and 2 permitted sites that have not been drilled. None of these are expected to impact construction.

19. **Zoning Ordinances.** The cities of Clear Lake, League City and Friendswood, which are along Clear Creek, have zoning ordinances; however, there are no known proposed zoning ordinances that will affect the tentatively proposed project.

20. **Facilities/Utilities Relocations**. There are 43 known pipelines crossing the project feature areas that will be required to be relocated/modified along with 14 bridges that will also need to be relocated/modified; which includes the relocation/modification of a railroad bridge at Mykawa. The TRC files indicated that of the 43 known pipelines within the project feature areas, 24 are natural gas, 10 are crude oil, 4 are propylene, 3 are ethylene, and 2 are gasoline pipelines. Under 33 USC §701P – Railroad Bridge Alterations at Federal Expense, “on and after July 24, 1946, for authorized flood protection projects which include alterations of railroad bridges the Chief of Engineers is authorized to include at Federal expense the necessary alterations of railroad bridges and approaches in connection therewith” . Coordination with the sponsors has been on-going on this issue and they have requested that they prepare the opinions of compensability. SWG Real Estate has supplied the sponsors with a list of relocations and they will initiate a formal effort on this once the project is closer to authorization.

Clear Creek Conveyance Pipelines:

1. Sta. (319+00), 16” Shell Pipeline (Crude Oil)
2. Sta. (319+13), 14” Enterprise Products (Natural Gas Liquids)
3. Sta. (319+41), 30” Houston Pipeline Co. (Natural Gas)
4. Sta. (380+00), 24” Kinder Morgan Texas (Natural Gas)
5. Sta. (380+00), 30” Kinder Morgan Texas (Natural Gas)
6. Sta. (381+00), 16” San Jacinto Gas Transmission (Natural Gas)
7. Sta. (484+50), 18” Houston Pipeline Co. (Natural Gas)

Mary’s Creek Pipelines:

1. Sta. (98+00), 30” Houston Pipeline Co. LP (Natural Gas)
2. Sta. (98+00), 18” Houston Pipeline Co. LP (Natural Gas)

Turkey Creek Pipelines:

1. Sta. (97+29), 3.5” SEMPIPE, L.P. (Crude Oil)
2. Sta. (93+97), 10.75” Exxon Mobil Corporation (Natural Gas)
3. Sta. (93+39), 8.63” Exxon Mobil Corporation (Natural Gas)

4. Sta. (86+29), 20” Exxon Mobil Corporation (Natural Gas)
5. Sta. (85+20), 6.63” Exxon Mobil Corporation (Natural Gas)
6. Sta. (82+00), 14” Exxon Mobil Corporation (Natural Gas)
7. Sta. (79+60), 8.63” Equistar Chemicals, L.P." (Ethylene)
8. Sta. (79+60), 8.63” Equistar Chemicals, L.P." (Propylene)
9. Sta. (77+90), 6.63” Exxon Mobil Corporation (Natural Gas)
10. Sta. (76+10), 8.63” Exxon Mobil Corporation (Natural Gas)
11. Sta. (76+05), 12.75” Exxon Mobil Corporation (Natural Gas)
12. Sta. (73+30), 6.63” SEMPIPE, L.P. (Crude Oil)
13. Sta. (55+80), 3.5” SEMPIPE, L.P. (Crude Oil)
14. Sta. (55+80), 6.63” SEMPIPE, L.P. (Crude Oil)
15. Sta. (51+13 to 52+06), 14” Exxon Mobil Corporation (Natural Gas)
16. Sta. (51+13 to 52+06), 8.63” Exxon Mobil Corporation (Dilute Propylene)
17. Sta. (51+13 to 52+06), 0” Exxon Mobil Corporation (Chemical Grade Propylene)
18. Sta. (51+13 to 52+06), 14” Exxon Mobil Corporation (Liquefied Petroleum Gas)
19. Sta. (51+13 to 52+06), 6.63” Exxon Mobil Corporation (Gasoline)
20. Sta. (51+13 to 52+06), 0” Exxon Mobil Corporation (Chemical Grade Propylene)
21. Sta. (51+13 to 52+06), 30” Kinder Morgan Tejas Pipeline, L.P. (Natural Gas)
22. Sta. (44+51 to 46+71), 20” El Paso Field Services, L.P. (Natural Gas)
23. Sta. (44+51 to 46+71), 6.63” Equistar Chemicals (Ethylene)
24. Sta. (44+51 to 46+71), 8.63” Equistar Chemicals (Natural Gas Liquids)
25. Sta. (44+51 to 46+71), 12.75” Chevron Pipe Line Company (Ethylene)
26. Sta. (44+51 to 46+71), 30” Enterprise Products Operating L.P. (Natural Gas)
27. Sta. (44+51 to 46+71), 6.63” Teppco Crude Pipeline, L. P. (Natural Gas Liquids)
28. Sta. (27+70), 6.63” Exxon Mobil Corporation, (Natural Gas)
29. Sta. (21+00), 2.38” Exxon Mobil Corporation, (Natural Gas)
30. Sta. (17+65 to 18+10), 8.63” Genesis Pipeline Texas, L.P. (Crude Oil)
31. Sta. (17+65 to 18+10), 12.75” Genesis Pipeline Texas, L.P. (Crude Oil)
32. Sta. (17+65 to 18+10), 12.75” SEMPIPE, L.P. (Crude Oil)
33. Sta. (17+65 to 18+10), 8.63” SEMPIPE, L.P. (Crude Oil)
34. Sta. (10+34), 10.75” SEMPIPE, L.P. (Crude Oil)

Clear Creek Conveyance Bridges:

1. Cullen (Modification)
2. Stone Road (Timber Bridge) (Modification)
3. Mykawa Road (Modification)
4. BN&SF Railroad Bridge (d/s side of Mykawa) (Modification)
5. SH35 (Replace)
6. Bennie Kate (Timber Bridge) (Replace)
7. Country Club Drive (Modification)

Mary’s Creek Bridges:

1. McLean Road (Replace)
2. Veterans Road (Replace)

Mud Gully Conveyance Bridges:

1. Scarsdale (Modify)

Turkey Creek Bridges:

1. Access Road (Replace)
2. Access Road (Well School Rd) (Replace)
3. Beamer Road (Replace)
4. Golf Cart Road (Replace)

21. **HTRW or Other Environmental Contaminants**. The HTRW assessment revealed potential concerns associated with past industrial activity at two facilities and one spill site: Brio Refinery, Dixie Oil Processors, and one spill site at the corner of Scarsdale and Beamer. Costs associated with the cleaning and remediation of contaminated lands will not be credited to the Non-Federal Sponsors.

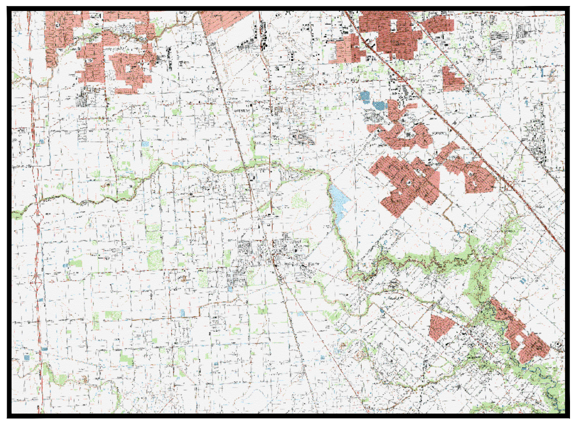
Brio Refinery and Dixie Oil Processors are listed in the regulatory agency database as NPL, CERCLIS, and SSF. Additional research reveals that both facilities were deleted from the NPL list in 2006, but for this evaluation both sites are identified as NPL sites. Prior activity at these facilities impacted groundwater and surface water and sediments of Mud Gully and Clear Creek. However, potential discharge of affected groundwater has been contained through corrective action by the responsible parties and the TCEQ, which included the construction of a soil cap over the residual waste, significantly reducing the potential for direct contact. Subsequently, the concentrations of pollutants in the waters and sediment of Mud Gully and Clear Creek have decreased significantly. Construction of the project would further reduce the potential impact to the sites during major flood events.

The spill site located at the corner of Scarsdale and Beamer is a reported accidental release of 20,000 gallons of unleaded gasoline within the upper portion of Mud Gully in November 1986; its cleanup status is reportedly unknown. The spill apparently occurred on the ground surface and entered into Mud Gully. Due to the extended period of time (26 years) and the biodegradation of gasoline, the lasting impact to the sediment of Mud Gully is limited. However, material to be excavated from this affected segment of Mud Gully may contain detectable levels of COC associated with gasoline. Therefore, sediment characterization will be necessary prior to excavation and placement of excavated material.

22. **Attitudes of the Landowners**. This project has been ongoing for several years now and has been aggressively publicized in the communities along Clear Creek. While most of the citizens of these communities have shown support for the proposed project, some citizens have been apprehensive. Though there has been some apprehension towards this project, it is noted that this will not impede the acquisition process.

23. **Sponsor Notification of Risks**. A letter was transmitted to the HCFCD and Brazoria Drainage District No. 4, on the 30th April 2008, advising them if for any reason, the Project Cooperation Agreement (PCA) never gets signed or if Congress fails to authorize or fund the Project, any land they acquired or money they spent in their effort to acquire land will be at their sole risk. (See both Exhibit "E" and Exhibit "F").

CLEAR CREEK TEXAS PROJECT
REAL ESTATE MAPS 2012



TABLE

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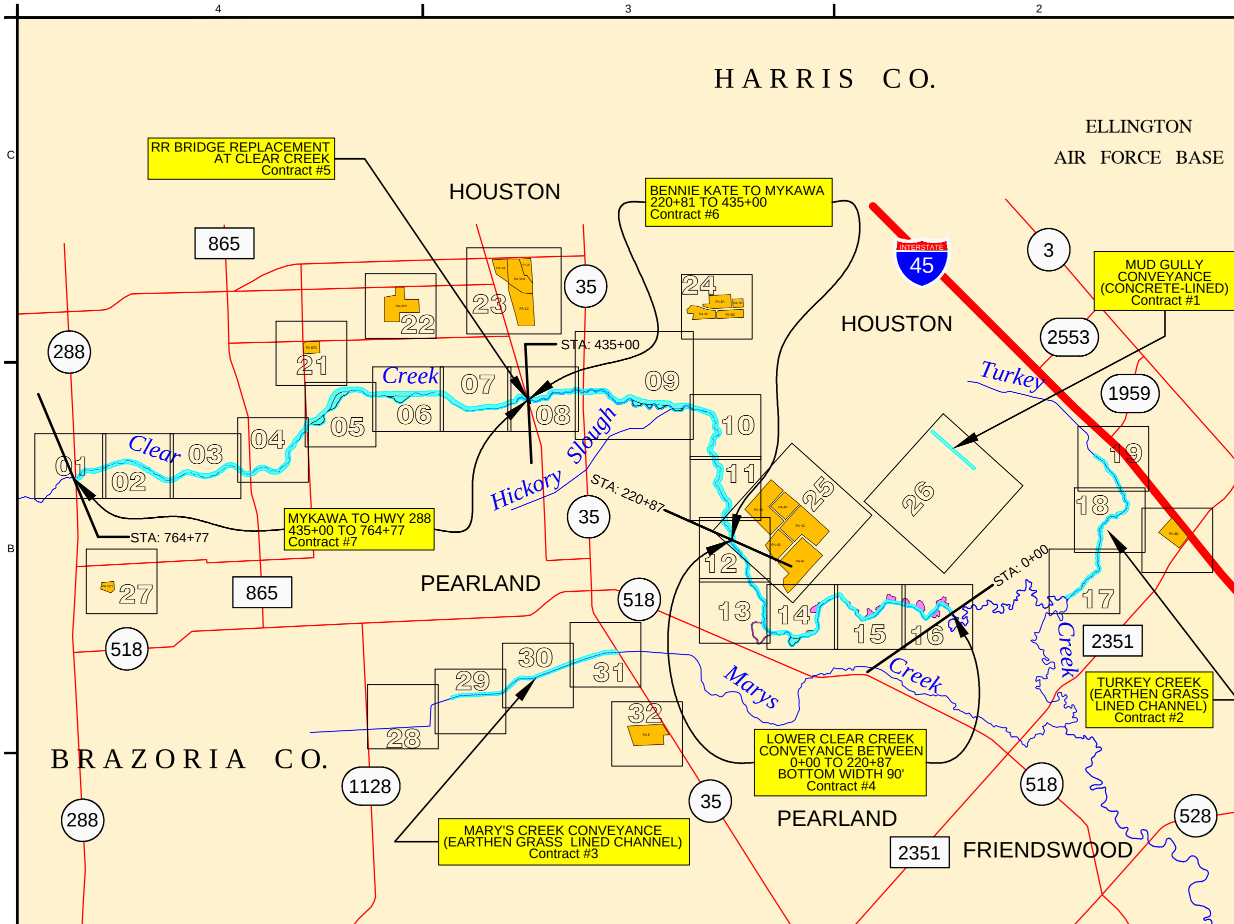
UNITED STATES ARMY CORPS
OF
ENGINEERS
GALVESTON DISTRICT

CLEAR CREEK TEXAS PROJECT REAL ESTATE MAPS 2012



CLEAR CREEK NED PROJECT		COUNTY PARCELS AFFECTED BY CONTRACT		REAL ESTATE MAP SHEET NUMBER	REAL ESTATE REQUIREMENTS																							
Contract Reaches					FEE												CIE				TWAE							
					HABITAT MITIGATION				ENVIRONMENTAL CONVEYANCE FEATURE				RAILROAD EASEMENT				CHANNEL IMPROVEMENT EASEMENT				PLACEMENT AREA				SAND PIT			
					HARRIS		BRAZORIA		HARRIS		BRAZORIA		HARRIS		BRAZORIA		HARRIS		BRAZORIA		HARRIS		BRAZORIA		HARRIS		BRAZORIA	
		HARRIS	BRAZORIA		PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-	PARCELS	AC +/-
Contract 1	[illegible]	[illegible]	0	[illegible]													[illegible]	[illegible]			[illegible]	[illegible]						
Contract 2	[illegible]	[illegible]	0	[illegible]													[illegible]	[illegible]			[illegible]	[illegible]						
Contract 3	[illegible]	[illegible]	[illegible]	[illegible]															[illegible]	[illegible]	[illegible]	[illegible]						
Contract 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
Contract 5	[illegible]	1	0	[illegible]									1	[illegible]														
Contract 6	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
Contract 7	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]							[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
	TOTAL PARCELS PER COUNTY=	247	468	TOTAL=	20	[illegible]	10	[illegible]	12	[illegible]	0	0.00	1	[illegible]	0	0.00	[illegible]	[illegible]	[illegible]	[illegible]	77	[illegible]	0	0.00	15	[illegible]	4	[illegible]
	GRAND TOTAL PARCELS FOR BOTH COUNTIES AFFECTED BY THE PROJECT=	715																										

LEGEND
FEE= FEE SIMPLE TITLE
CIE= CHANNEL IMPROVEMENT EASEMENT
TWAE= TEMPORARY WORK AREA EASEMENT

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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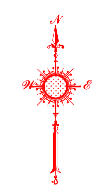
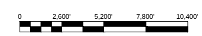




SCALE: 1" = 5,200'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

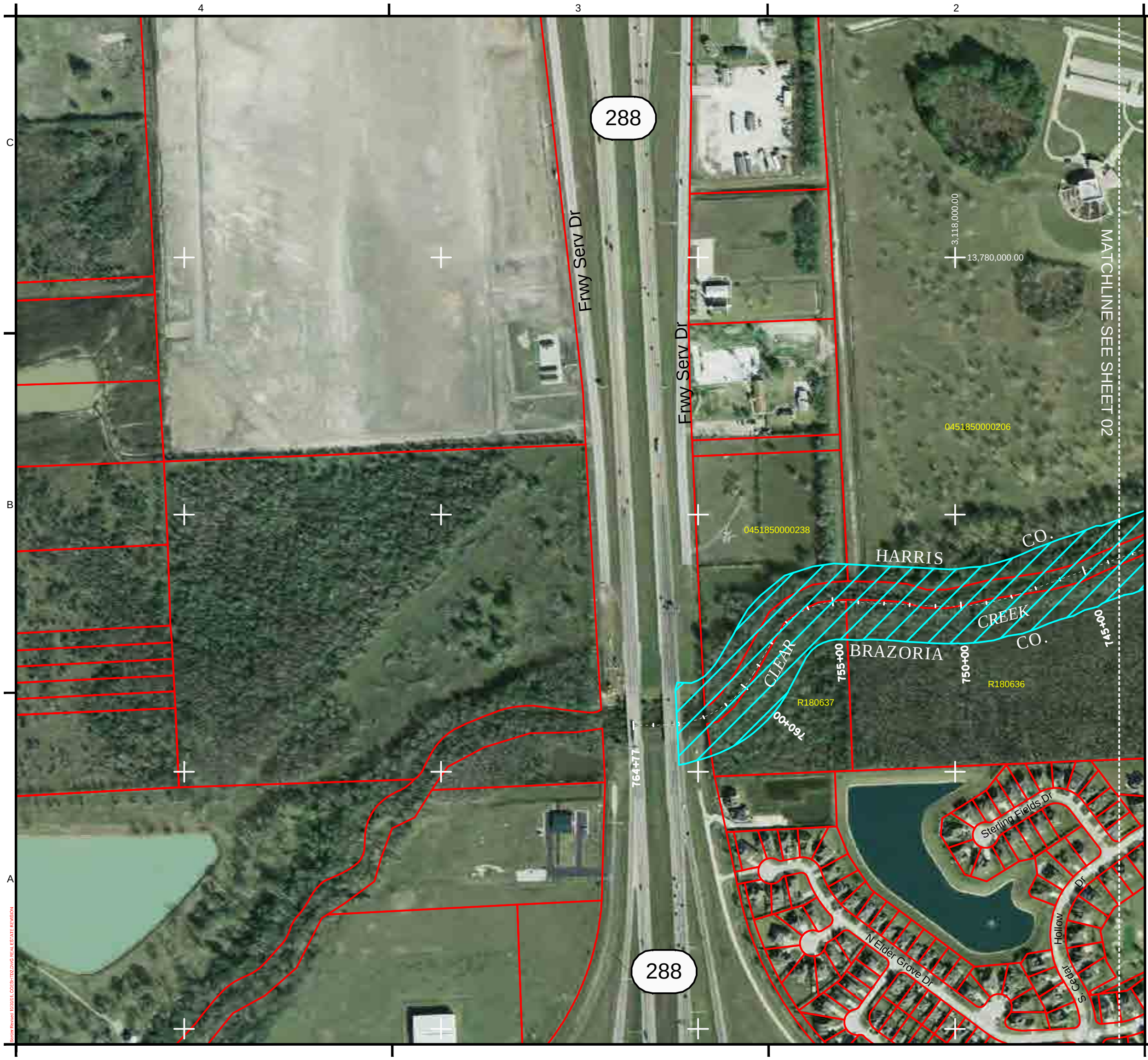
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Reviewed by: B. MURPHY

TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
Index



DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
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- R123456 BRAZORIA CO. TAX ID PARCEL NUMBER
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- PLACEMENT AREAS & SAND PITS (TWAE)
- ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
- RAILROAD EASEMENT (RRE)
- HABITAT MITIGATION (FEE)

0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

DEPARTMENT OF THE ARMY
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GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS
TEXAS

Revised CIE layer and Spreadsheet on 21 Feb 12

Sheet reference number:
1
Sheet 1 of 32

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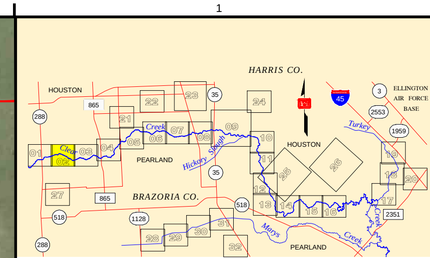

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
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2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
2
Sheet 2 of 32

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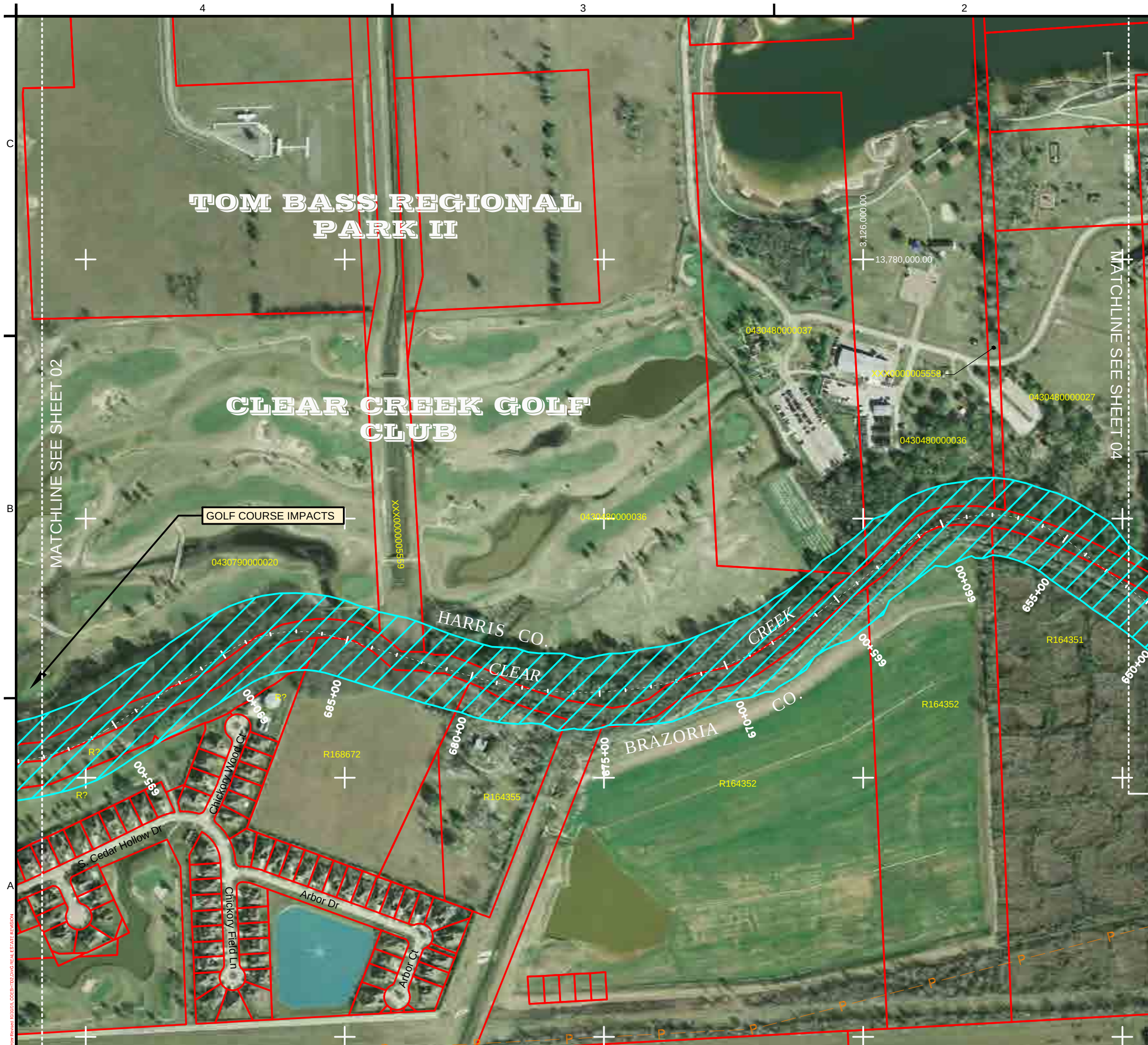

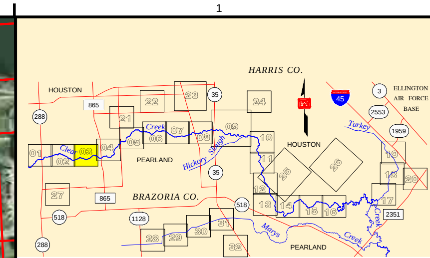

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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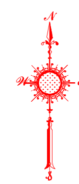

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SCALE: 1" = 300'

CLEAR CREEK TEXAS

REAL ESTATE MAPS

PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 21 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

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2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

TEXAS
HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
3
Sheet 3 of 32

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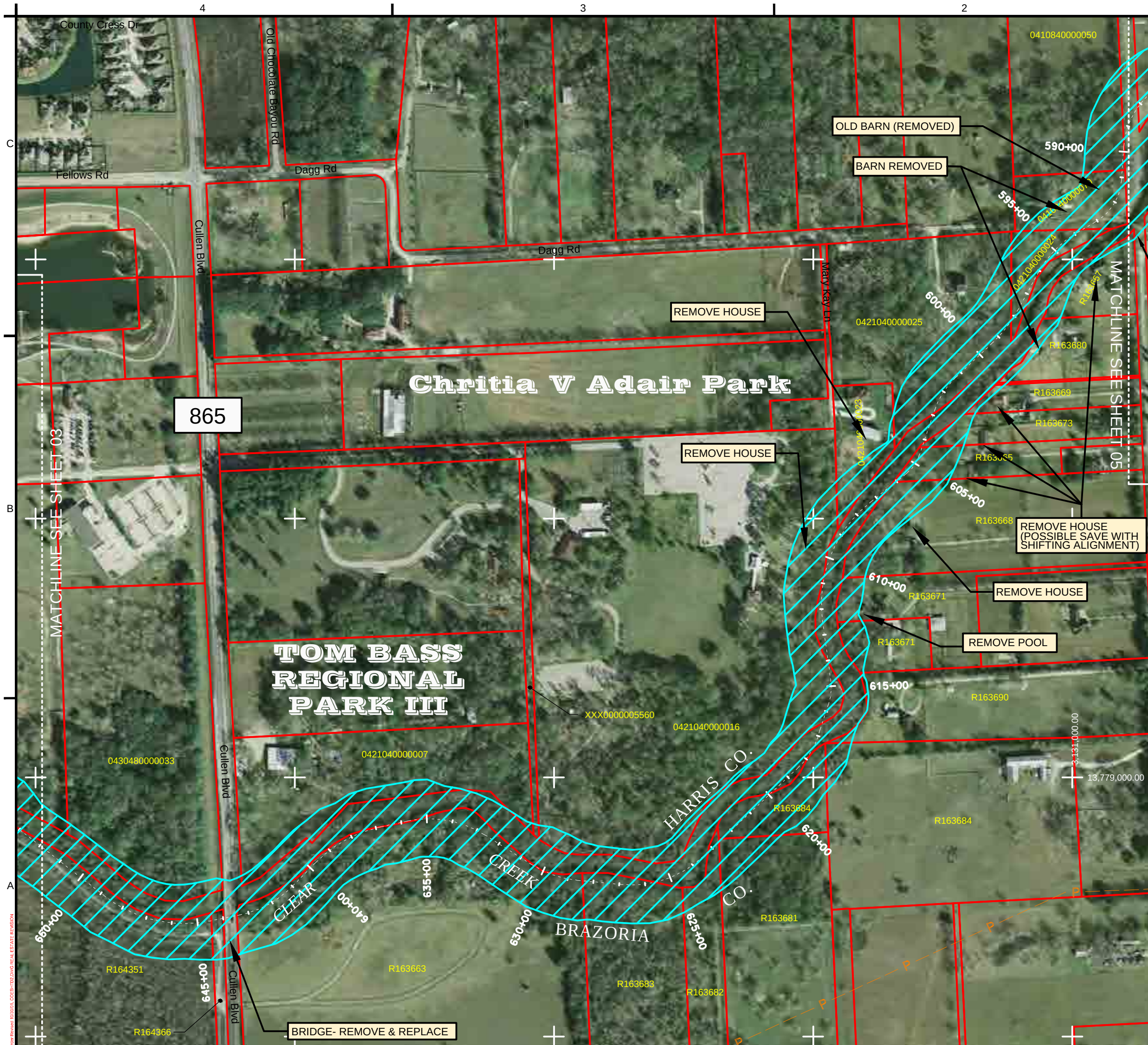

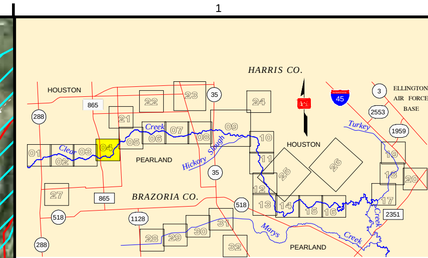

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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	PROPERTY LINE FOR HARRIS & BRAZORIA CO.
0123456789012	HARRIS CO. HCAD PARCEL NUMBER
R123456	BRAZORIA CO. TAX ID PARCEL NUMBER
	CHANNEL IMPROVEMENT EASEMENT (CIE)
	PLACEMENT AREAS & SAND PITS (TWAE)
	ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
	RAILROAD EASEMENT (RRE)
	HABITAT MITIGATION (FEE)

0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Reviewed by: B. MURPHY
Project Manager:

TEXAS
HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
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Sheet 4 of 32

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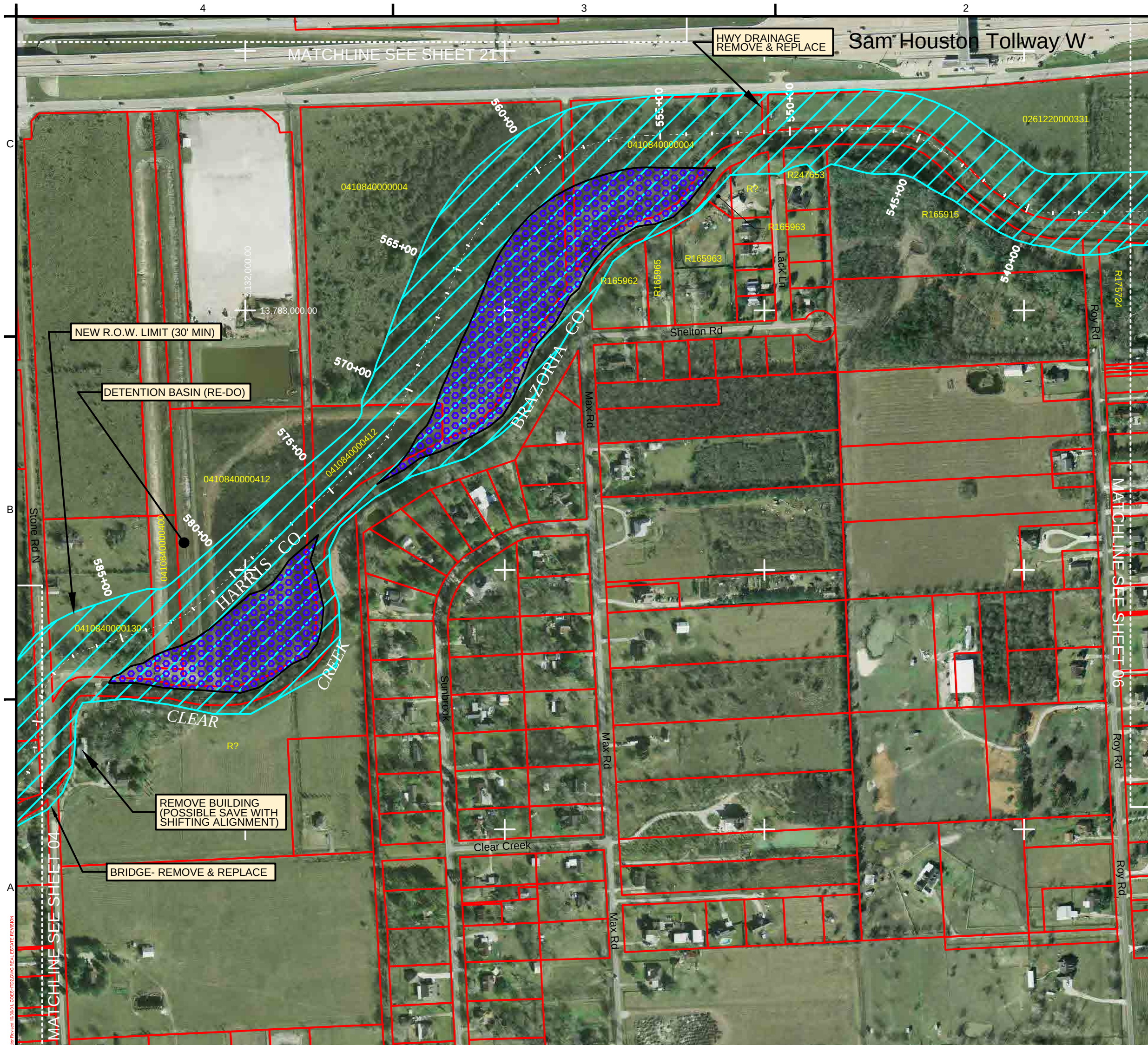

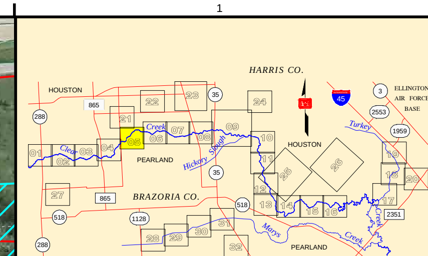

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
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0 150' 300' 450' 600'
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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

DEPARTMENT OF THE ARMY
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HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS
TEXAS

Sheet reference number:
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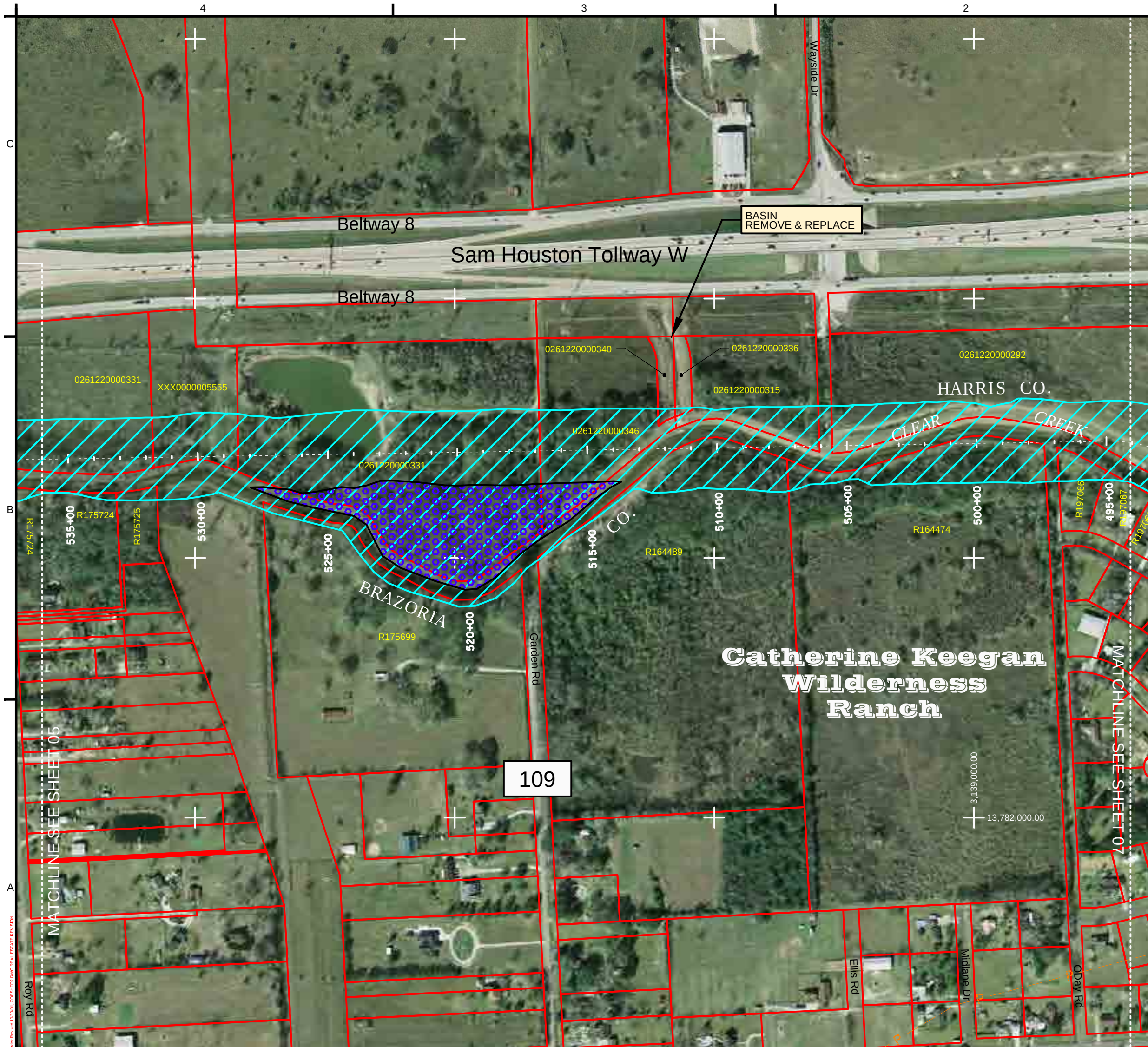
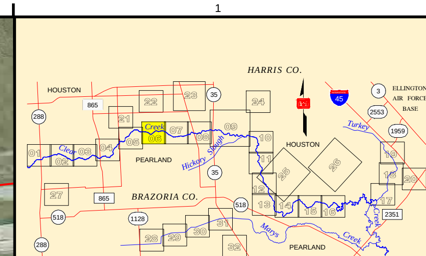
Sheet 5 of 32





DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO | Dwn by: CH | Spec No.: | Reviewed by: B. MURPHY | Project Manager: S. TIRPAK | Date Approved: | Rev. 1 | Assisted by: | Acquisition: | File name: Mstr PDF Clear Creek Map | Plot date: 02/23/12 | Plot scale: 1:1

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
6
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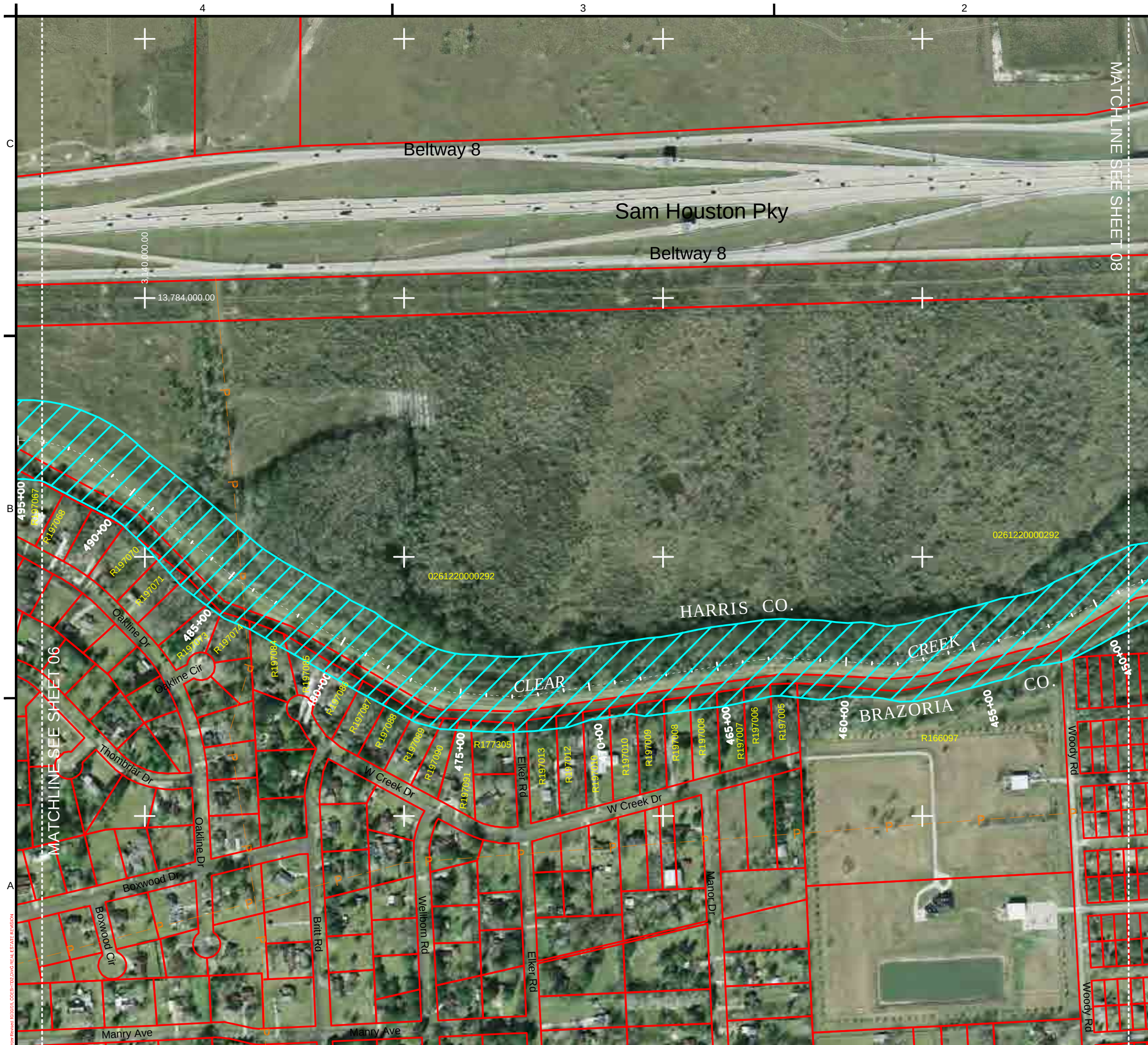

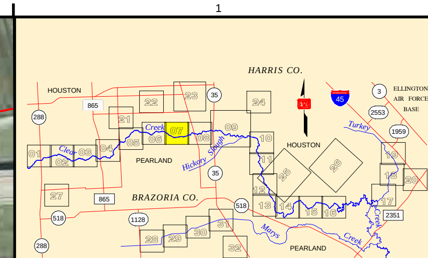

DATUM: NORTH AMERICAN 1983 FEET
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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

Mapping Lead: C. HIDALGO
Drwn by: CH
Reviewed by: B. MURPHY
Project Manager:
Date Approved:
Spec No.:
Assisted by:
Acquisition:
File name: Mstr PDF Clear Creek
Plot date: 02/23/12
Plot scale: 1:1
Rev.: 1

DEPARTMENT OF THE ARMY
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GALVESTON, TEXAS
PREPARED BY:
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2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
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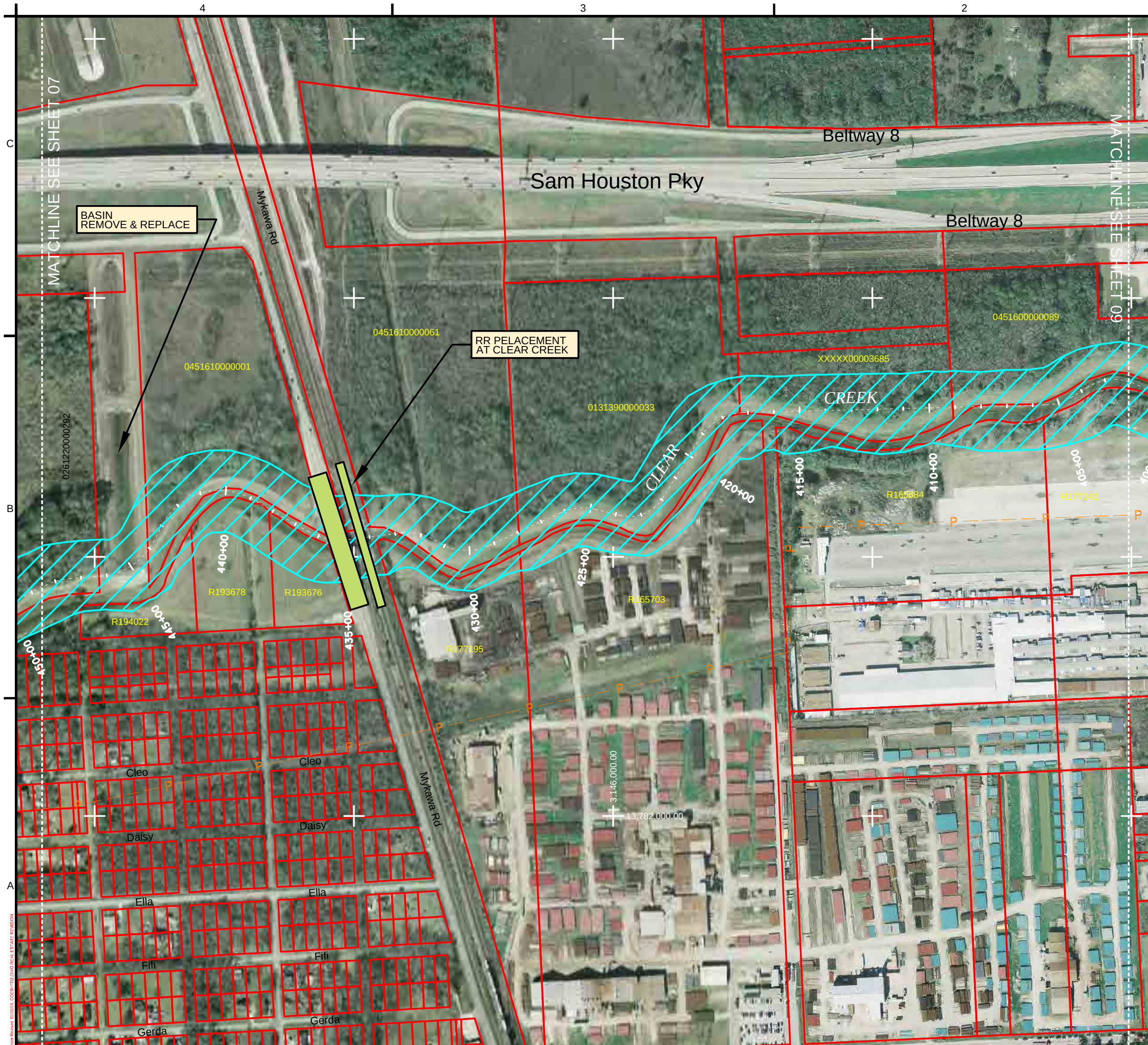

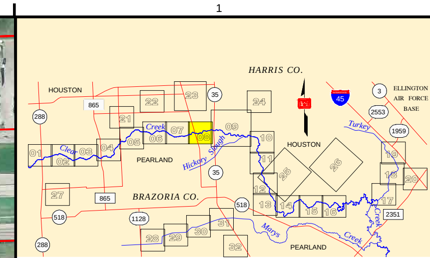

DATUM: NORTH AMERICAN 1983 FEET
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0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 21 Feb 12

Mapping Lead: C. HIDALGO	Date Approved:	Rev. 1
Dwn by: CH	Spec No.:	Assisted by:
Reviewed by: B. MURPHY		Acquisition:
Project Manager: S. TIRPAK		File name: Mstr PDF Clear Creek Map; Plot date: 02/23/12; Plot scale: 1:1

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GALVESTON, TEXAS

PREPARED BY:
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HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
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Sheet 8 of 32

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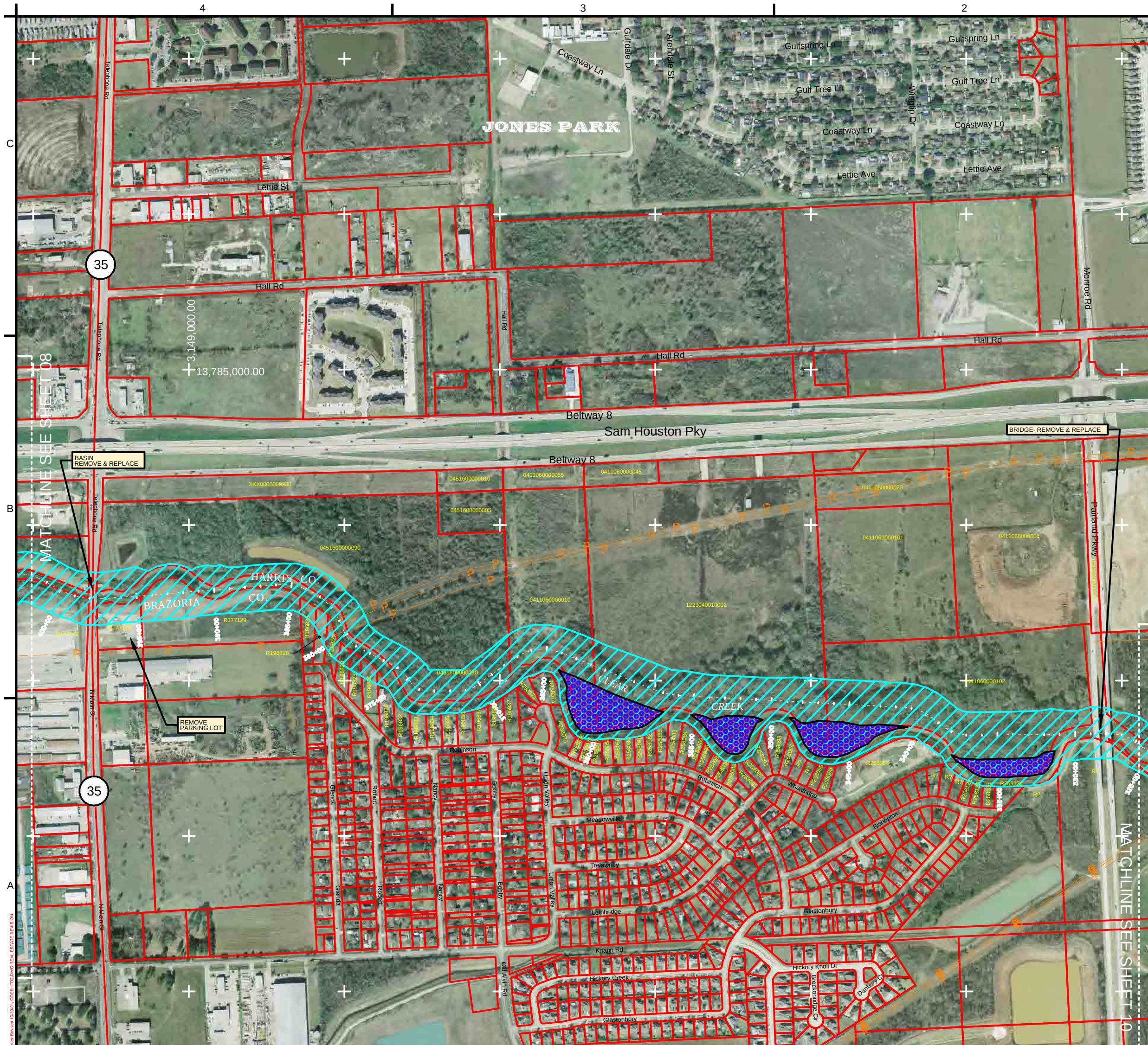

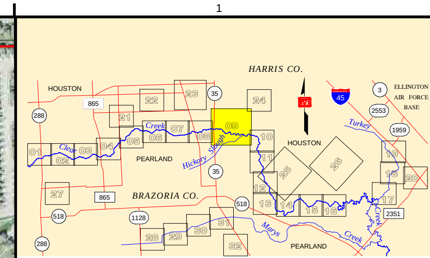

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
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0 250' 500' 750' 1,000'
SCALE: 1" = 500'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised Sheet 09 on 10 May 2010 by updating CIE and Detentions	05/10/10	
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO | Spec No.: | Date Approved: | Rev. 1
Dwn by: CH | Assisted by:
Reviewed by: B. MURPHY | Acquisition:
Project Manager: S. TIRPAK | File name: Mstr PDF Clear Creek Map | Plot date: 02/23/12 | Plot scale: 1:1

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
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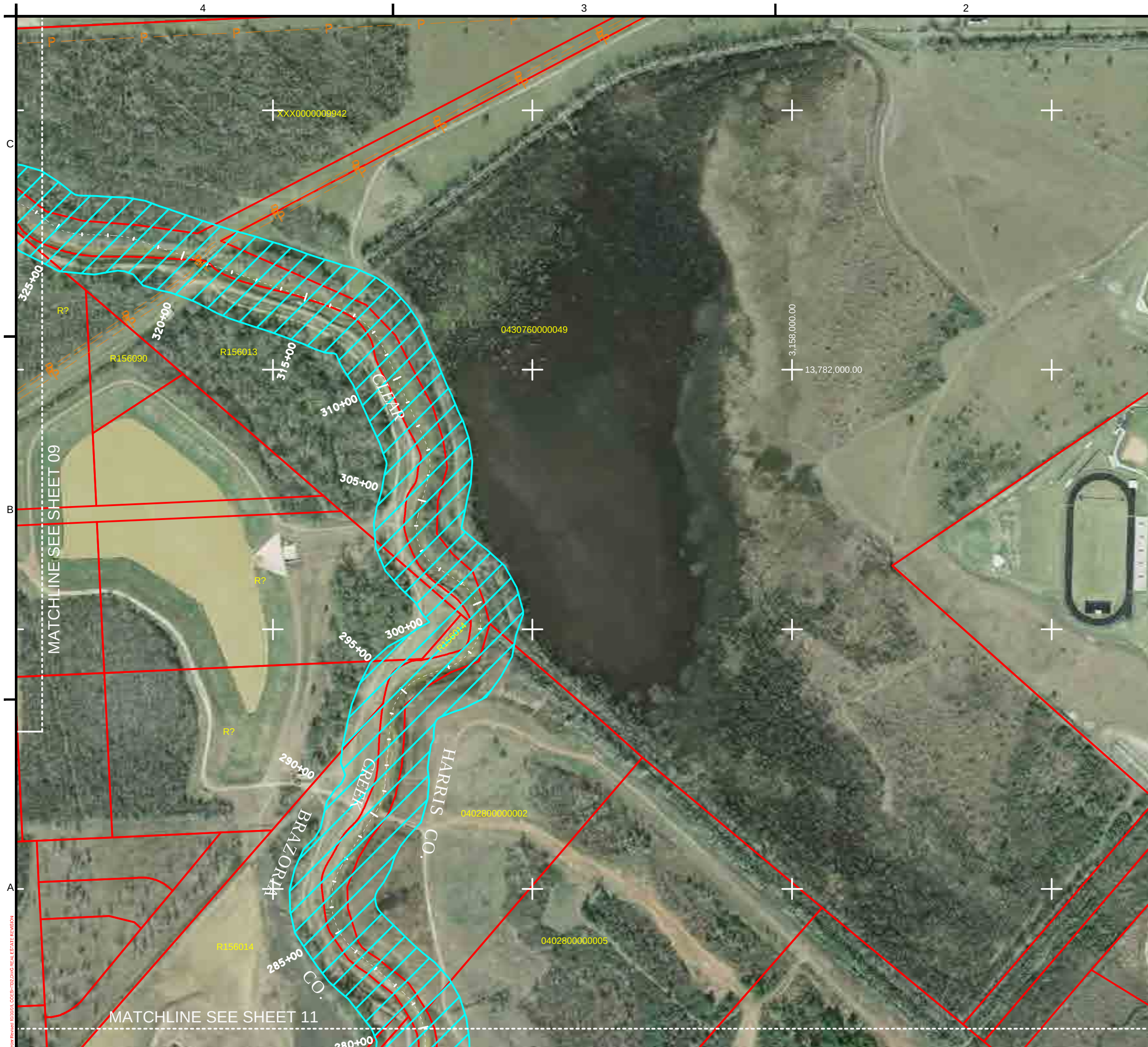

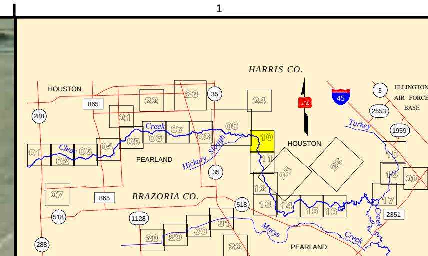

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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- R123456 — BRAZORIA CO. TAX ID PARCEL NUMBER
- CHANNEL IMPROVEMENT EASEMENT (CIE)
- PLACEMENT AREAS & SAND PITS (TWAE)
- ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
- RAILROAD EASEMENT (RRE)
- HABITAT MITIGATION (FEE)

0 250' 500' 750' 1,000'
SCALE: 1" = 500'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

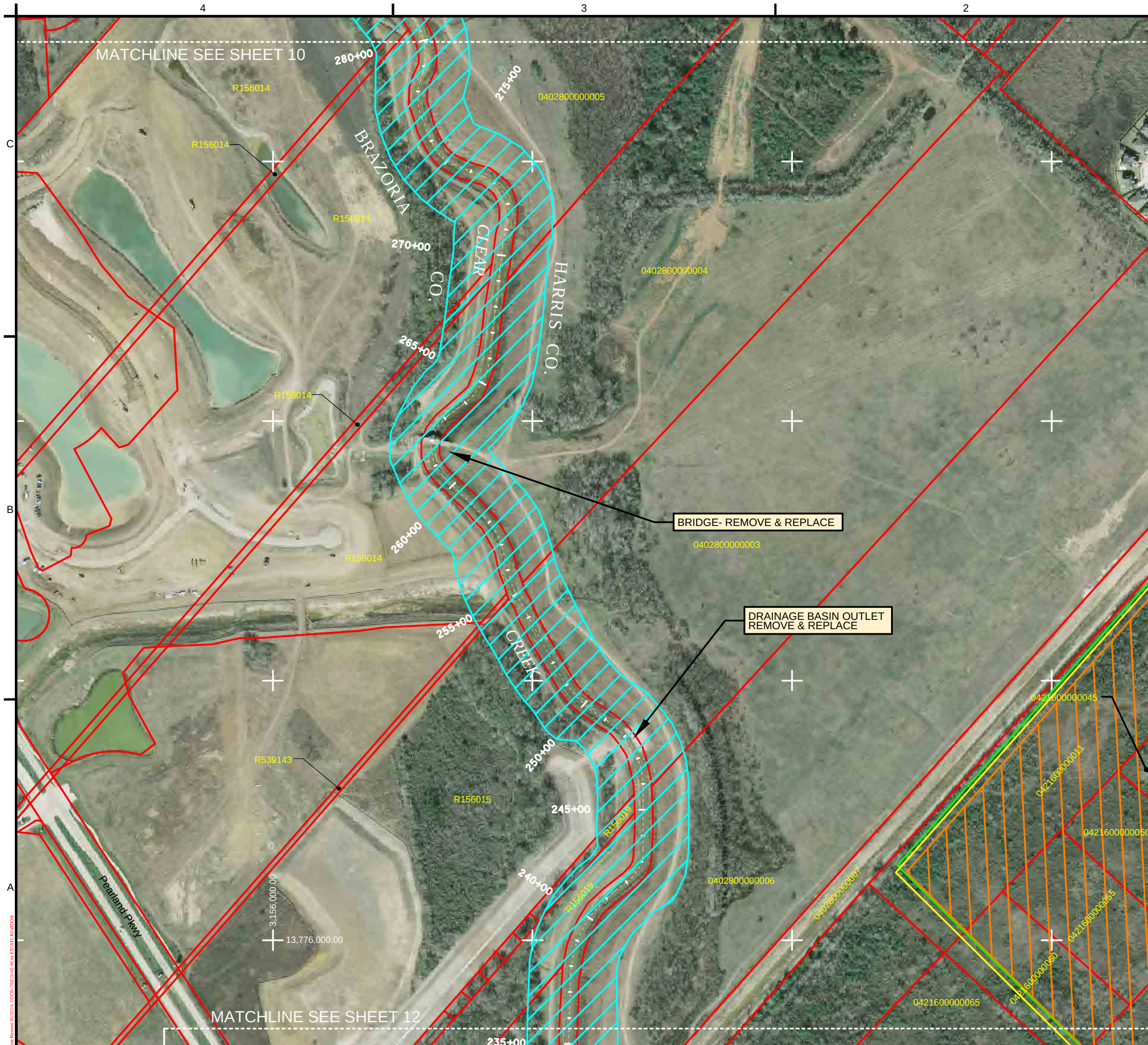
US Army Corps of Engineers
Galveston District

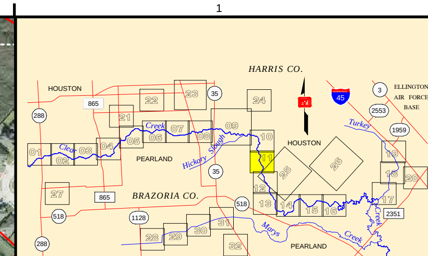
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
10
Sheet 10 of 32





DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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LEGEND

PROPERTY LINE FOR HARRIS & BRAZORIA CO.

0123456789012 HARRIS CO. HCAD PARCEL NUMBER

R123456 BRAZORIA CO. TAX ID PARCEL NUMBER

CHANNEL IMPROVEMENT EASEMENT (CIE)

PLACEMENT AREAS & SAND PITS (TWAE)

ENVIRONMENTAL CONVEYANCE FEATURE (FEE)

RAILROAD EASEMENT (RRE)

HABITAT MITIGATION (FEE)

0 150' 300' 450' 600'

SCALE: 1" = 300'

CLEAR CREEK TEXAS

REAL ESTATE MAPS

PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
1	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Date Approved:
Assisted by:
Rev. 1
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

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GALVESTON, TEXAS

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2000 FORT POINT ROAD
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HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
11
Sheet 11 of 32

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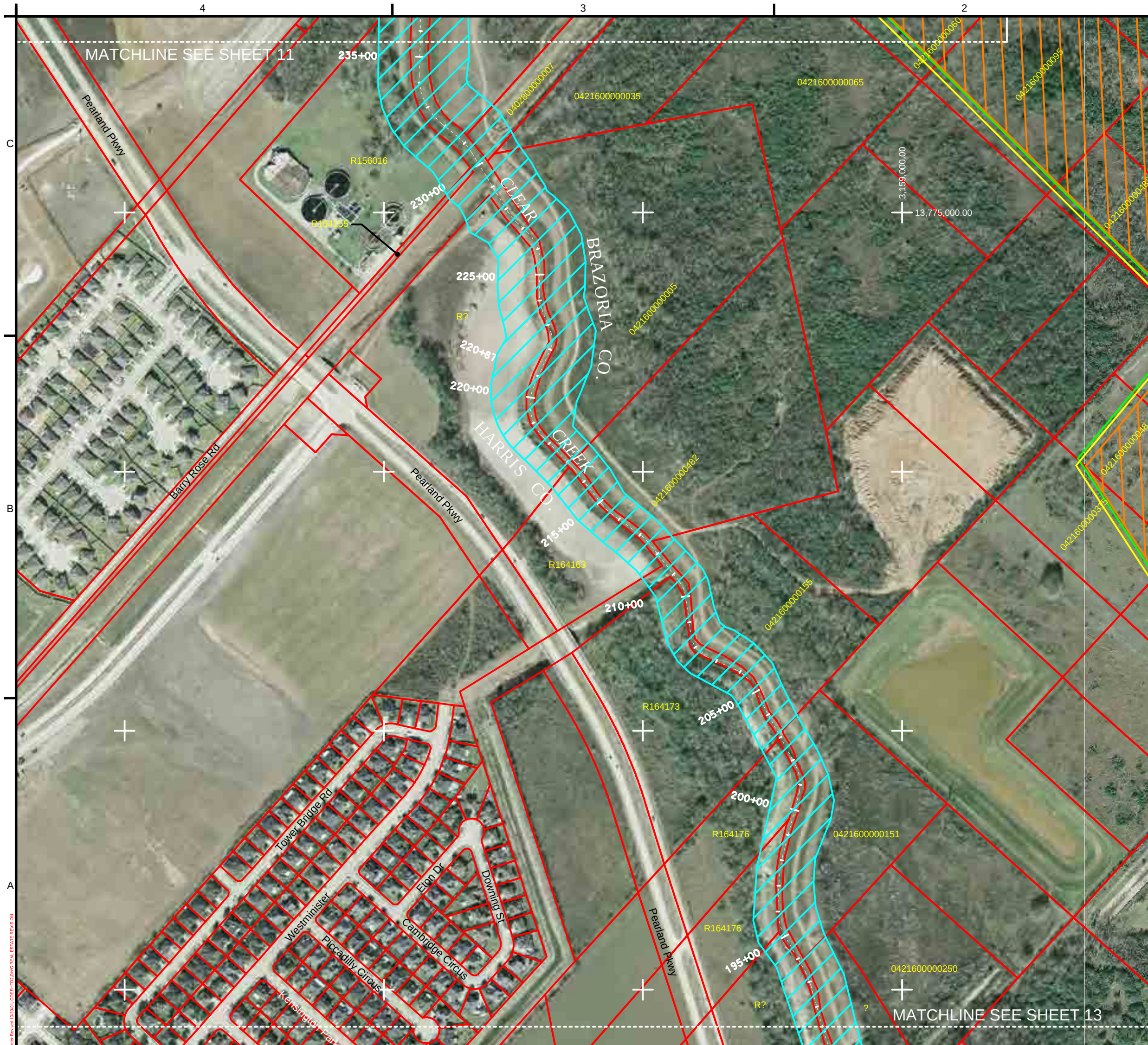

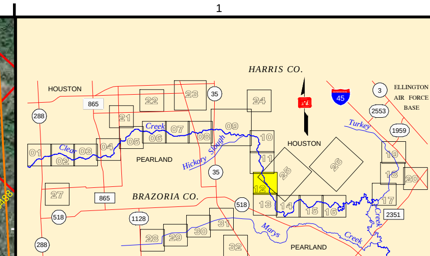

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
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Revised CIE layer and Spreadsheet on 21 Feb 12

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HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
TEXAS
CLEAR CREEK TEXAS

Sheet reference number:
12
Sheet 12 of 32

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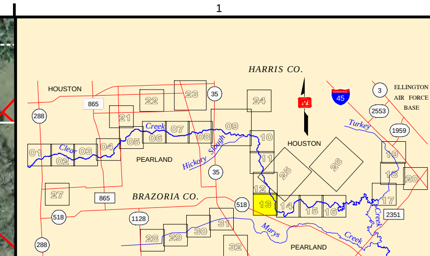

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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CLEAR CREEK TEXAS
REAL ESTATE MAPS

PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12
Symbol | Description | Date | Approved

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Date Approved:
Rev. 1
Assisted by:
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

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HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
13
Sheet 13 of 32

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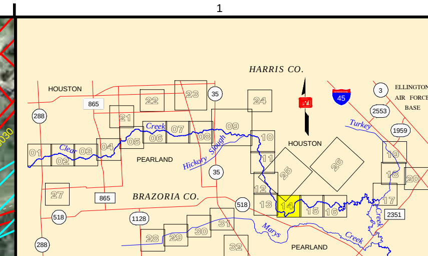

DATUM: NORTH AMERICAN 1983 FEET
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SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CE layer and Spreadsheet on 21 Feb 12

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HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS
TEXAS

Sheet reference number:
14
Sheet 14 of 32

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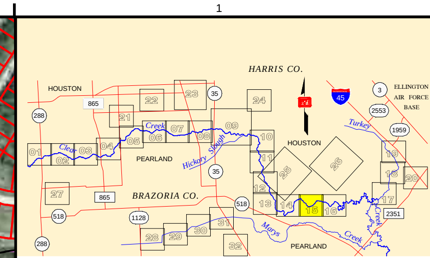

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Reviewed by: B. MURPHY
Project Manager: S. TIRPAK
Date Approved:
Rev. 1
Assisted by:
Acquisition:
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

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GALVESTON, TEXAS

PREPARED BY:
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2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
15
Sheet 15 of 32

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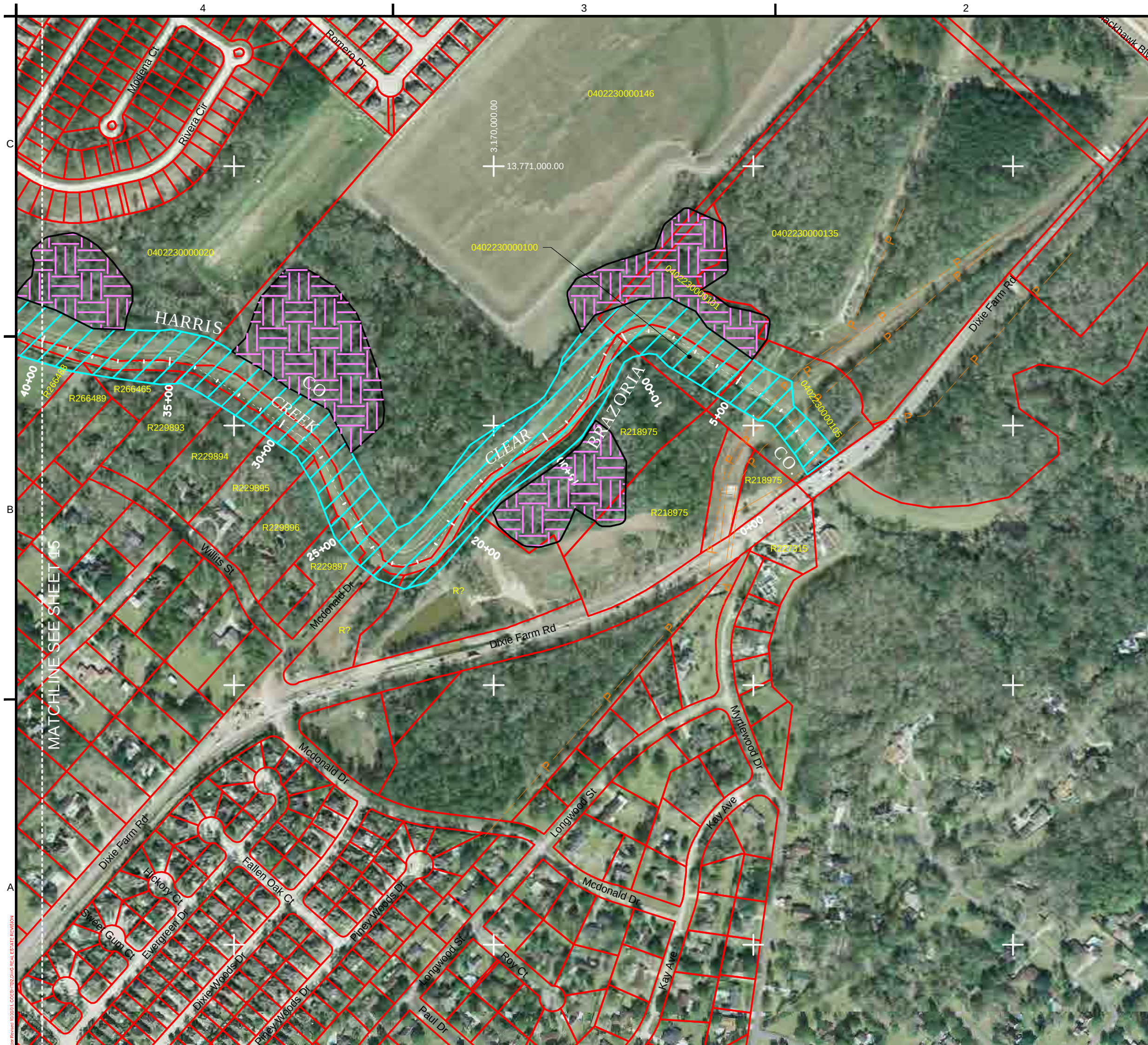

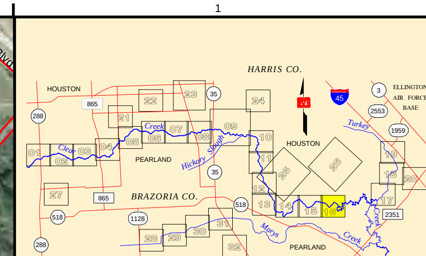

DATUM: NORTH AMERICAN 1983 FEET
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0 150' 300' 450' 600'
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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CE layer and Spreadsheet on 21 Feb 12

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CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
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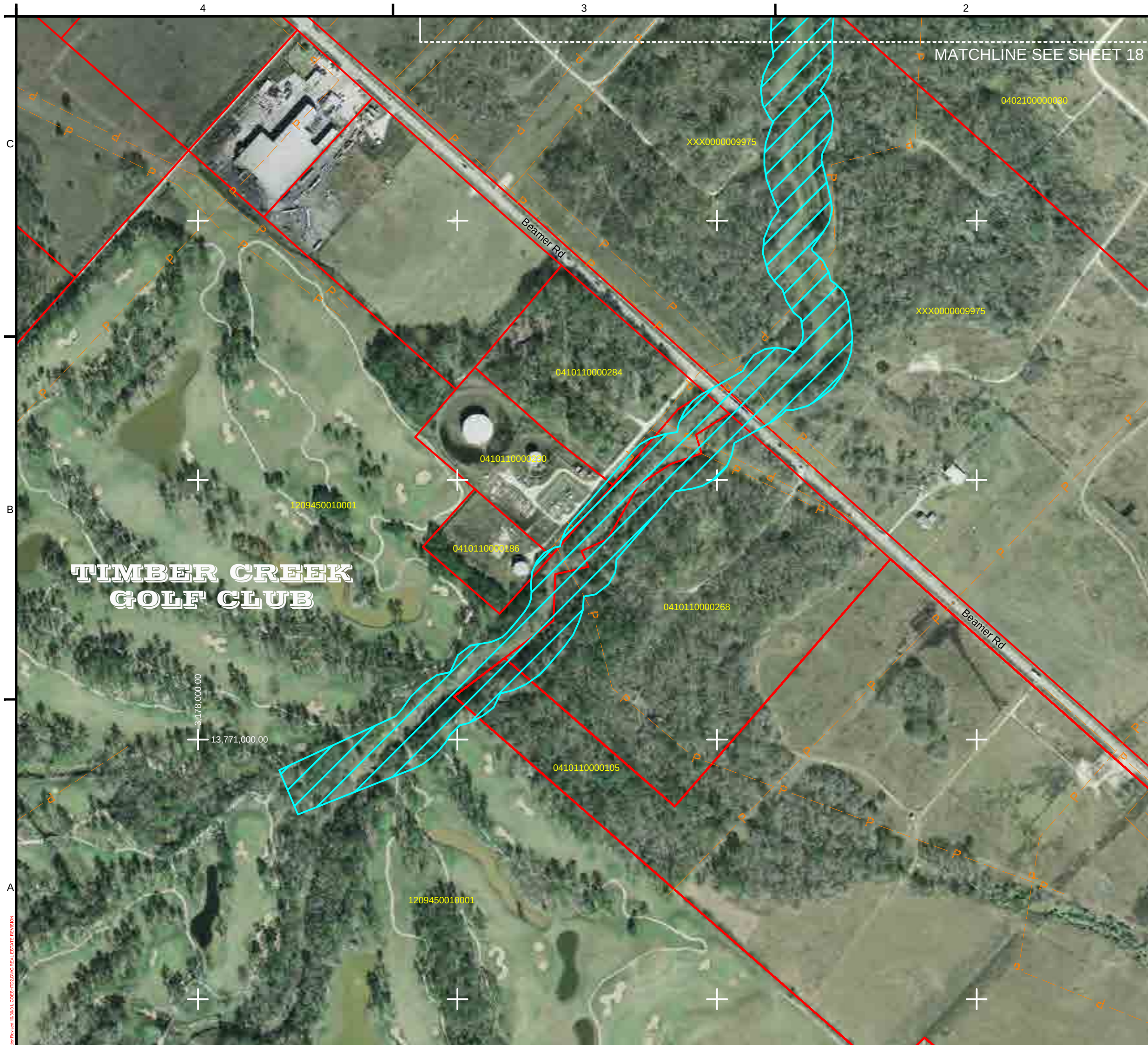
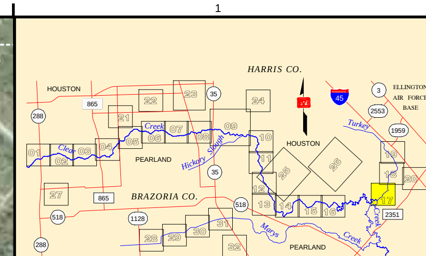
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Reviewed by: B. MURPHY

HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
TEXAS
CLEAR CREEK TEXAS

Sheet reference number:
16
Sheet 16 of 32





DATUM: NORTH AMERICAN 1983 FEET
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ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
RAILROAD EASEMENT (RRE)
HABITAT MITIGATION (FEE)

0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CE layer and Spreadsheet on 21 Feb 12

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HARRIS AND BRAZORIA COUNTIES
TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
17
Sheet 17 of 32

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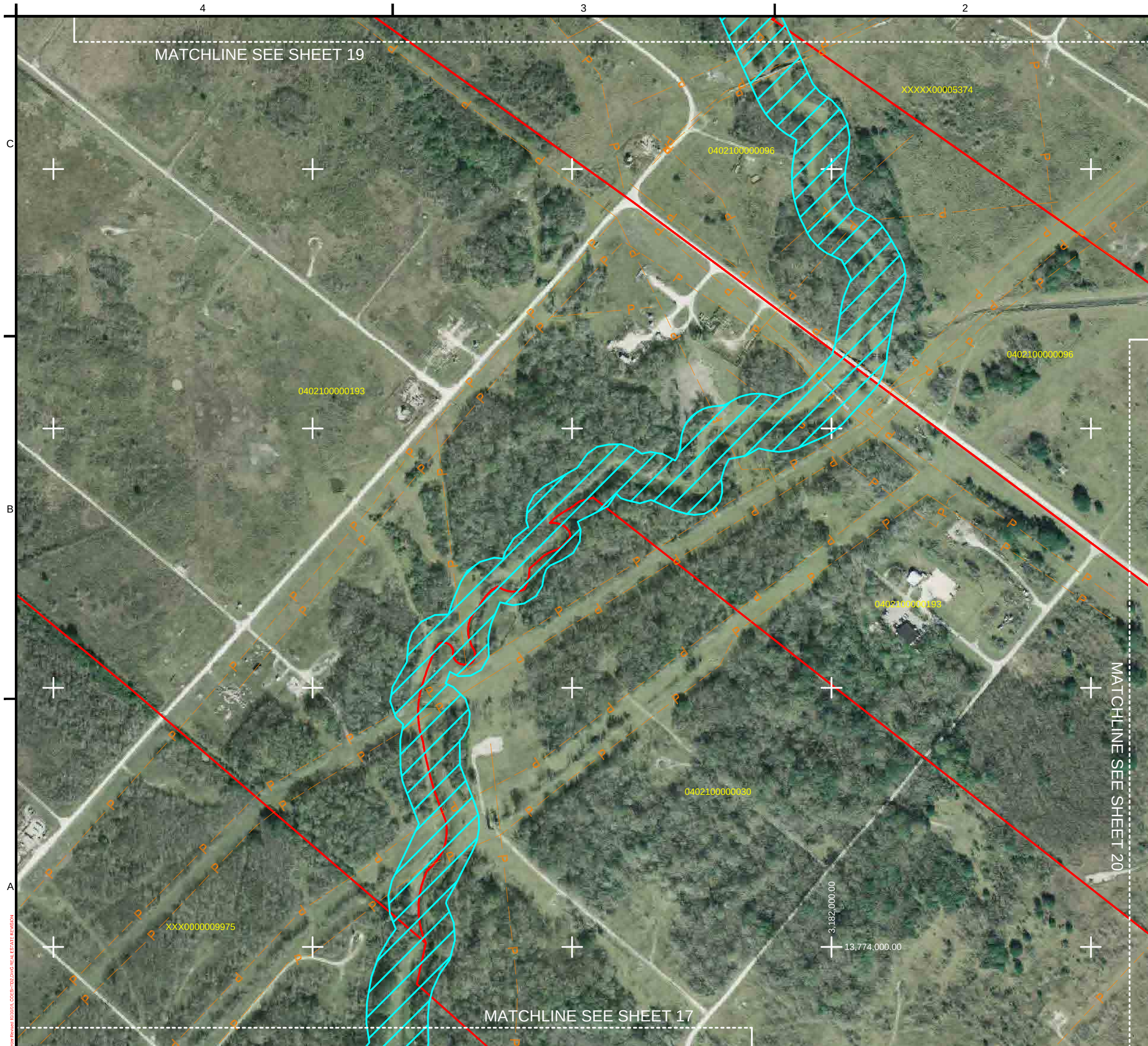

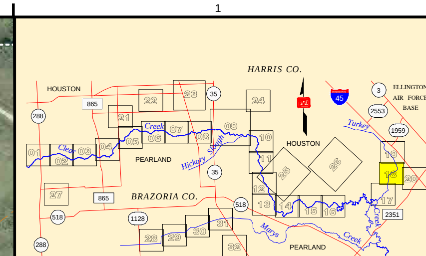

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0 150' 300' 450' 600'

SCALE: 1" = 300'

CLEAR CREEK TEXAS

REAL ESTATE MAPS

PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 21 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dsn by: CH
Reviewed by: B. MURPHY
Project Manager:

HARRIS AND BRAZORIA COUNTIES
TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
18
Sheet 18 of 32

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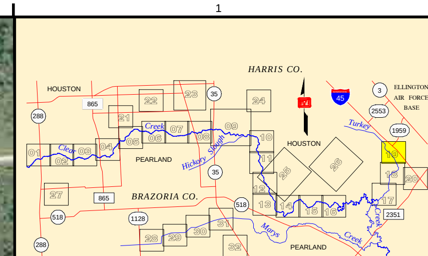

DATUM: NORTH AMERICAN 1983 FEET
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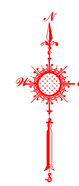

LEGEND

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol | Description | Date | Approved
Revised CIE layer and Spreadsheet on 23 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Date Approved:
Rev. 1
Assisted by:
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
19
Sheet 19 of 32

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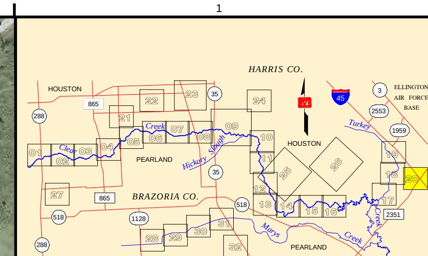

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
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Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
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DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
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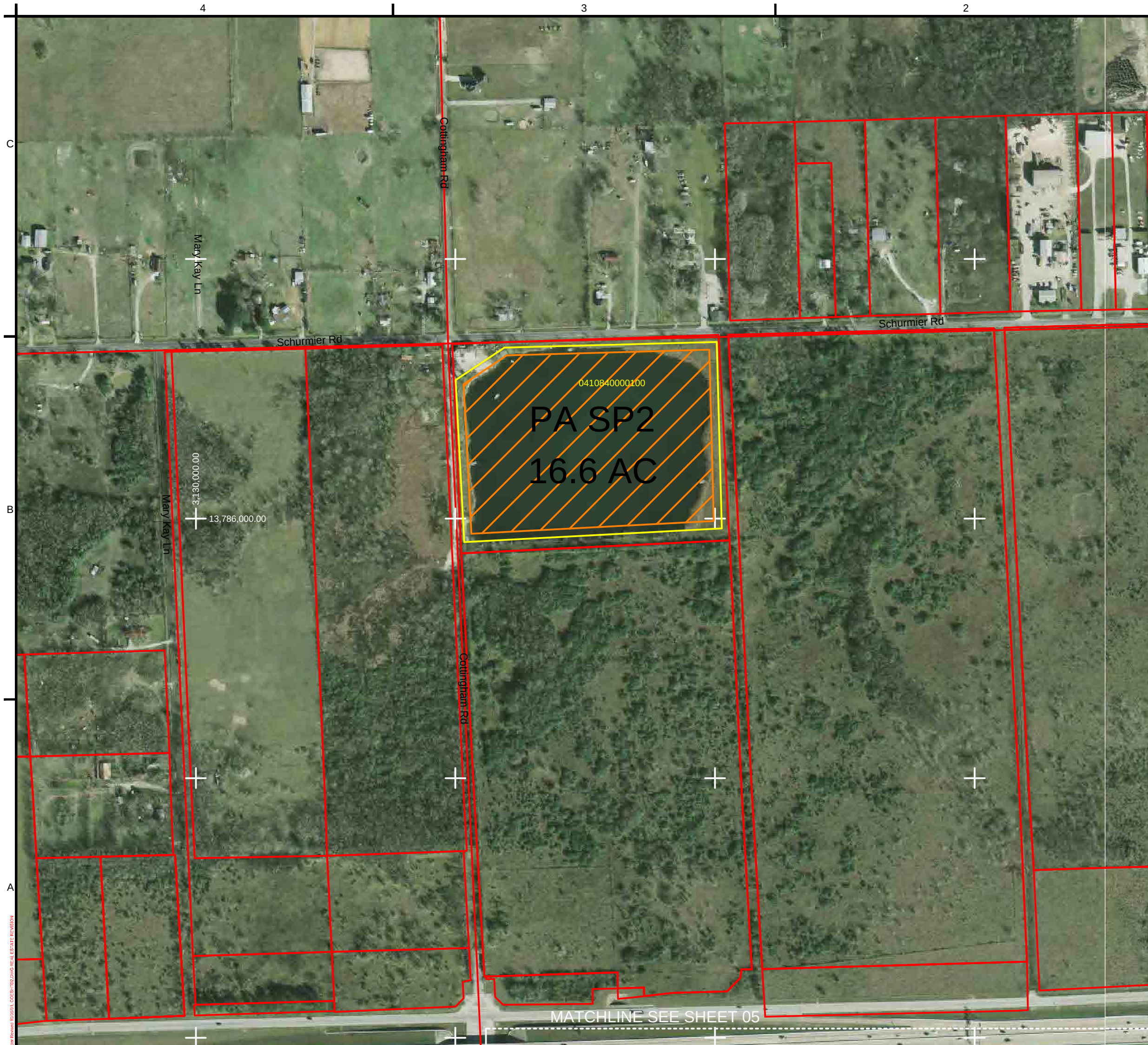
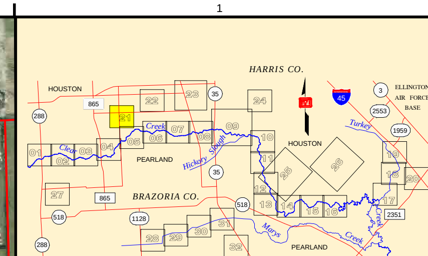
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
20
Sheet 20 of 32





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CLEAR CREEK TEXAS
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PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

Revised CIE layer and Spreadsheet on 23 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Reviewed by: B. MURPHY
Project Manager:

HARRIS AND BRAZORIA COUNTIES
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TEXAS
CLEAR CREEK TEXAS

Sheet reference number:
21
Sheet 21 of 32

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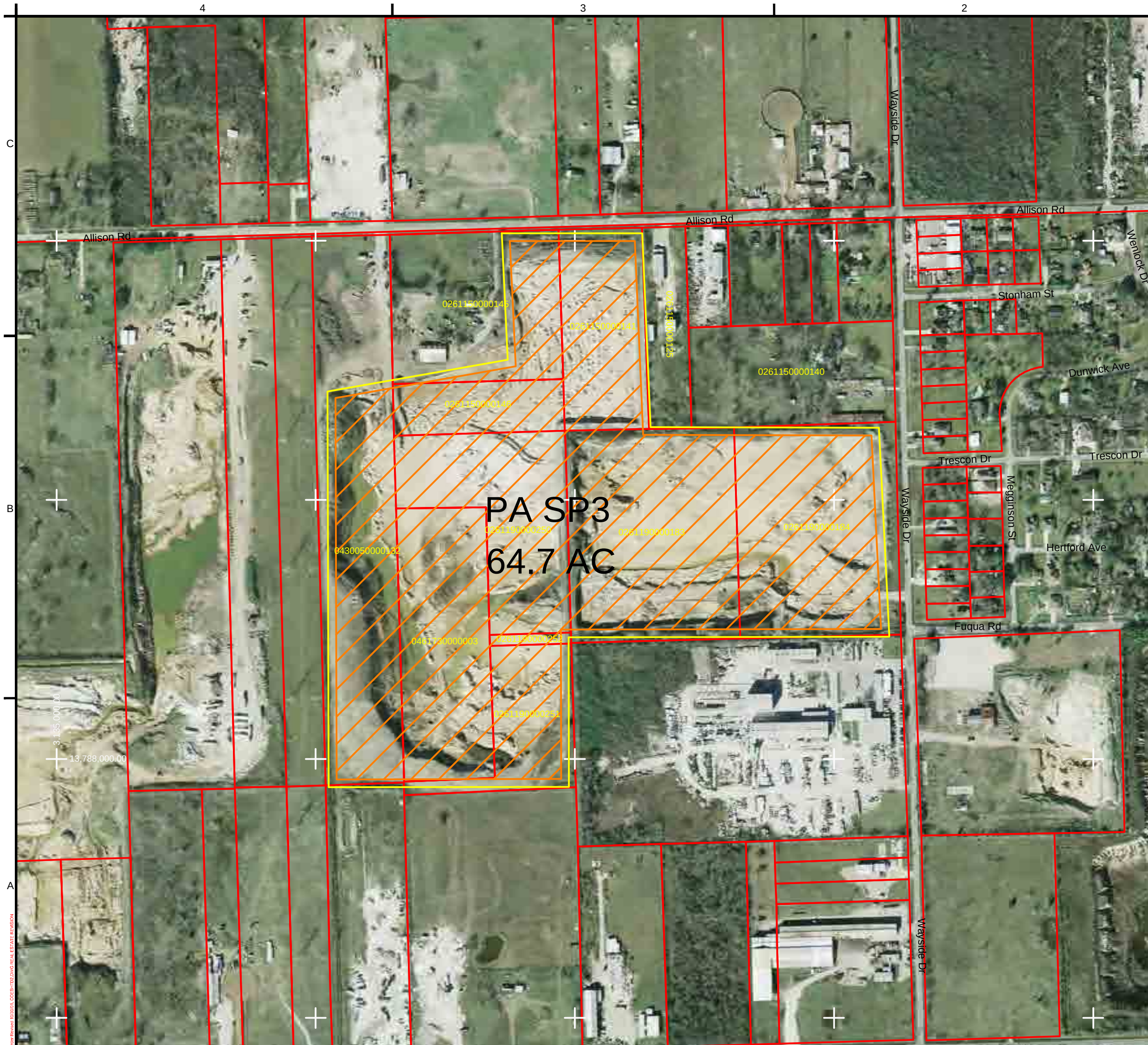

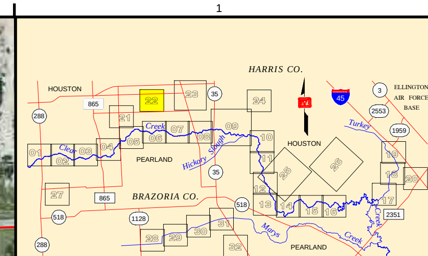

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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LEGEND

- PROPERTY LINE FOR HARRIS & BRAZORIA CO.
- 0123456789012 HARRIS CO. HCAD PARCEL NUMBER
- R123456 BRAZORIA CO. TAX ID PARCEL NUMBER
- CHANNEL IMPROVEMENT EASEMENT (CIE)
- PLACEMENT AREAS & SAND PITS (TWAE)
- ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
- RAILROAD EASEMENT (RRE)
- HABITAT MITIGATION (FEE)

0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Reviewed by: B. MURPHY
Project Manager: S. TIRPAK
Date Approved:
Rev. 1
Assisted by:
Acquisition:
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

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CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
22
Sheet 22 of 32

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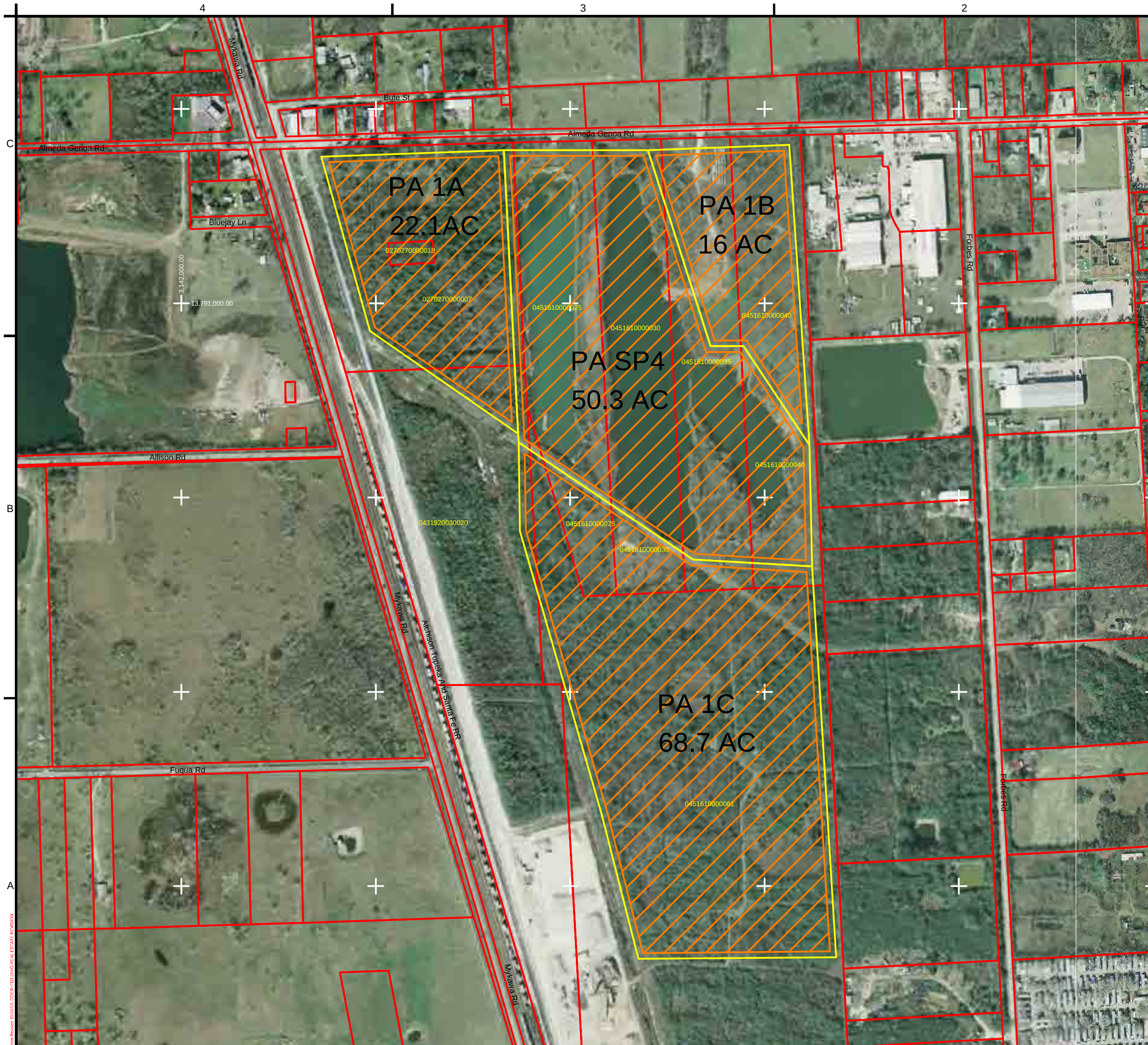

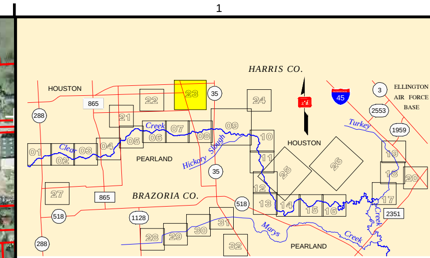

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

DEPARTMENT OF THE ARMY
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GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
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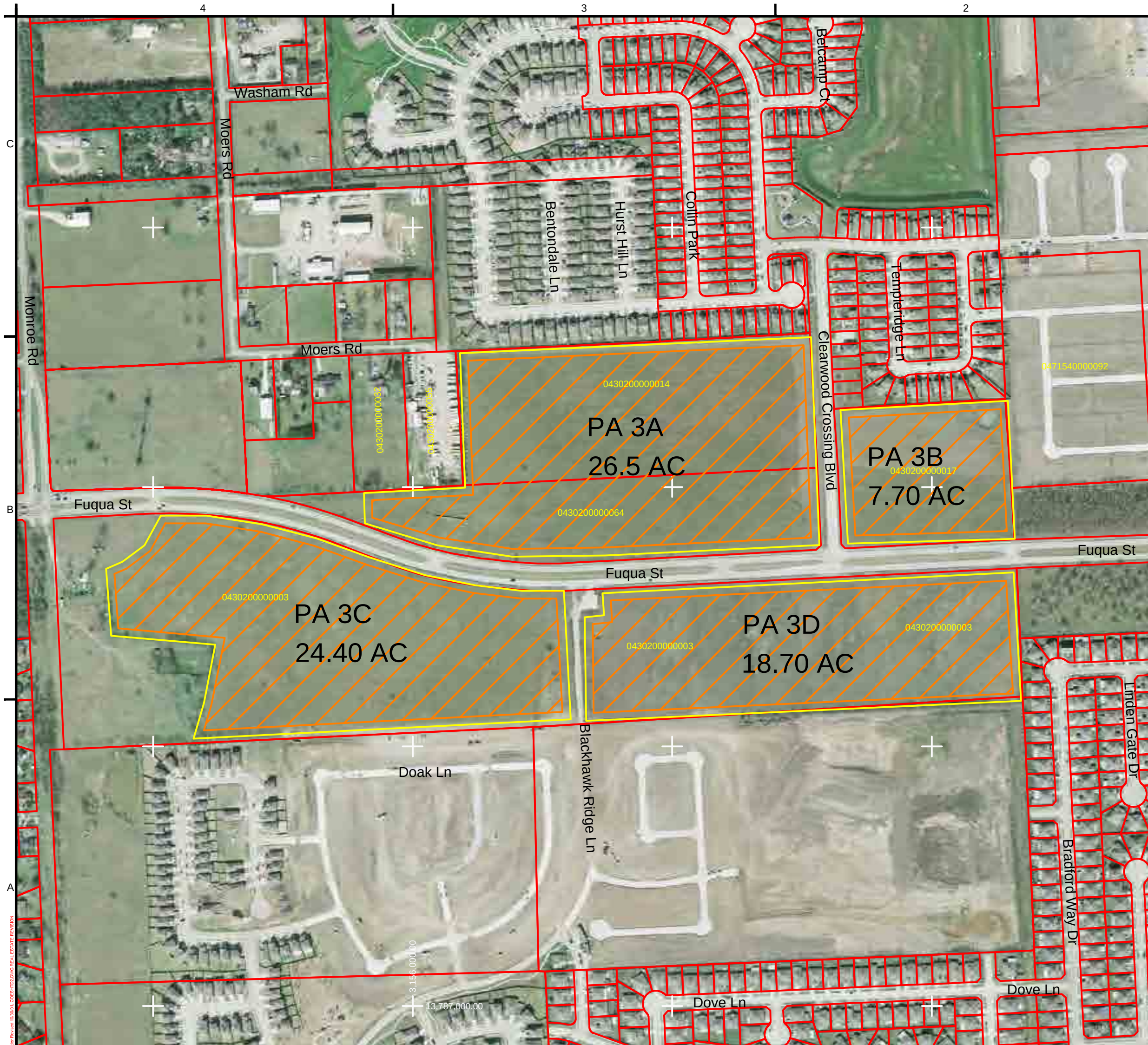
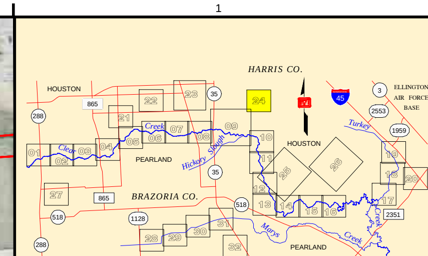
HARRIS AND BRAZORIA COUNTIES
TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
23
Sheet 23 of 32





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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

Symbol | Description | Date | Approved

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CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Reviewed by: B. MURPHY
Project Manager: S. TIRPAK
Date Approved:
Rev. 1
Assisted by:
Acquisition:
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

HARRIS AND BRAZORIA COUNTIES
TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
24
Sheet 24 of 32

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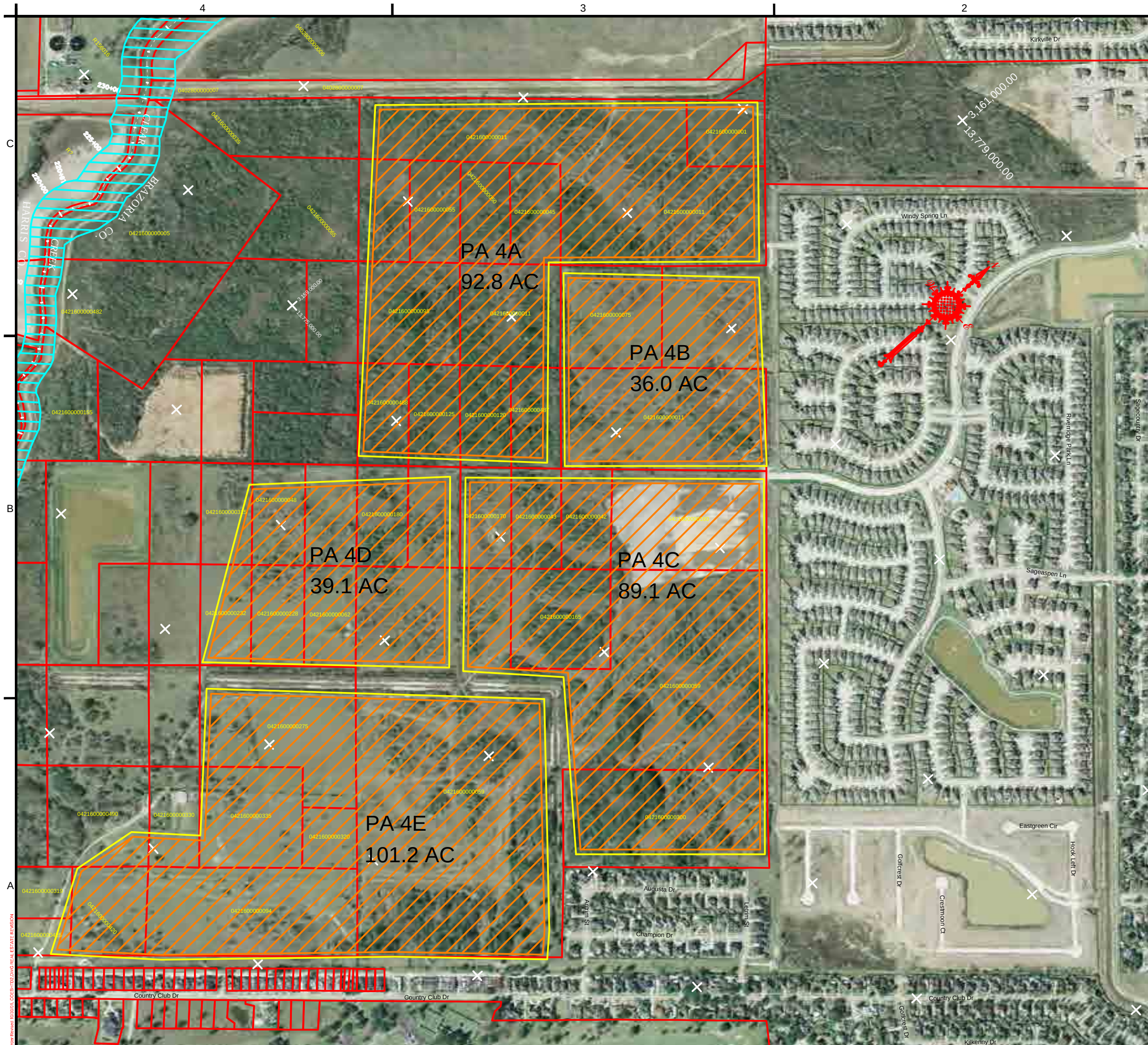

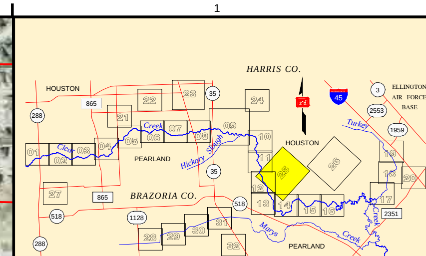

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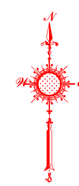

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ENVIRONMENTAL CONVEYANCE FEATURE (FEE)
RAILROAD EASEMENT (RRE)
HABITAT MITIGATION (FEE)

0 250' 500' 750' 1,000'
SCALE: 1" = 500'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Date Approved:
Rev. 1
Assisted by:
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number: 25
Sheet 25 of 32

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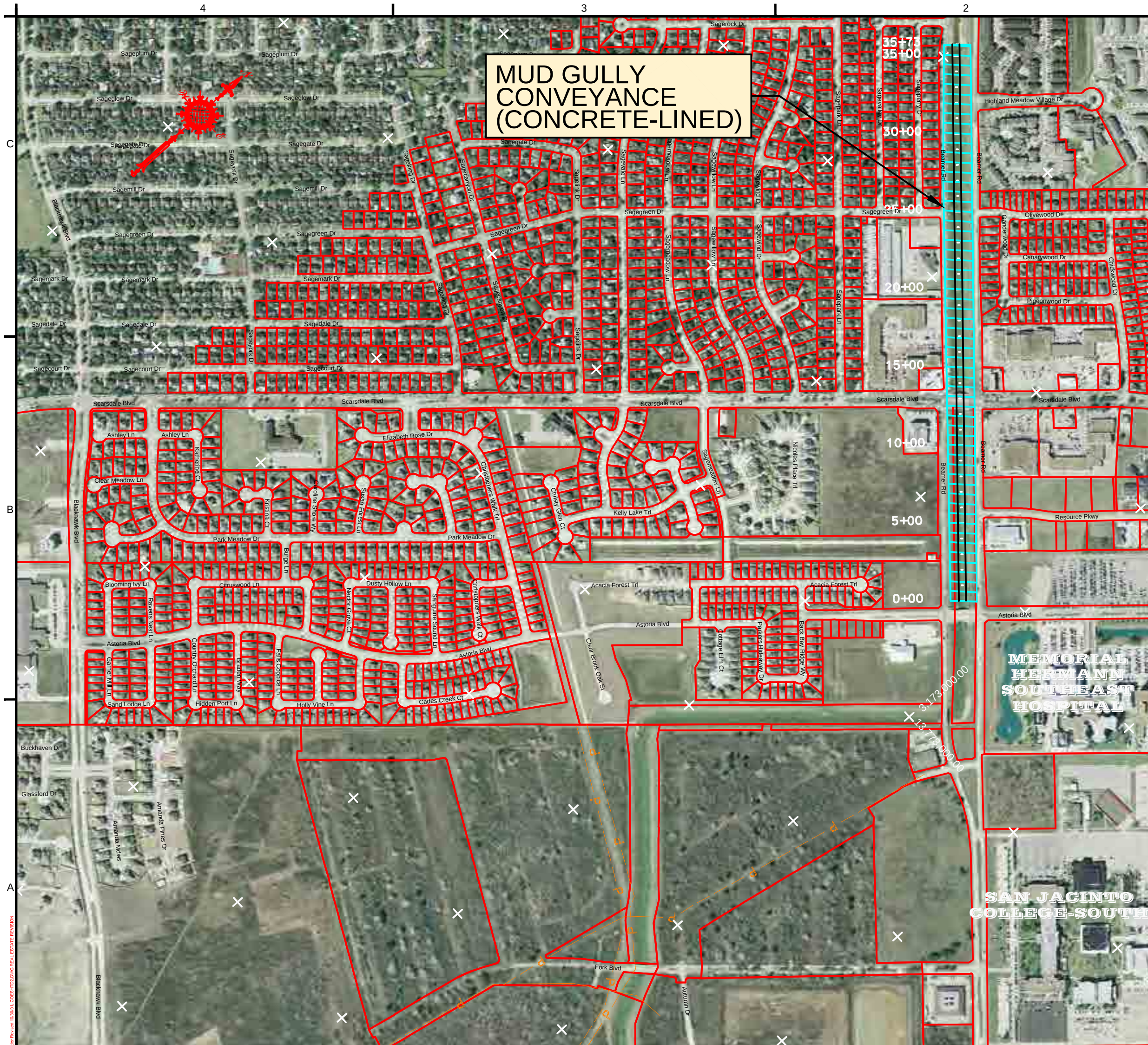

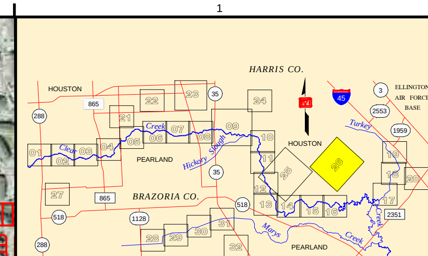

DATUM: NORTH AMERICAN 1983 FEET
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ZONE: SOUTH CENTRAL TEXAS

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
	Revised Sheet 26 on 10 May 2010 by updating CIE and Detentions	05/10/10	
	Revised CIE layer and Spreadsheet on 23 Feb 12		

Mapping Lead: C. HIDALGO
Dwn by: CH
Spec No.:
Date Approved:
Rev. 1
Assisted by:
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

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CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
26
Sheet 26 of 32

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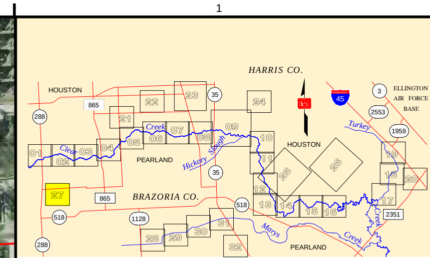

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0 150' 300' 450' 600'
SCALE: 1" = 300'

CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 23 Feb 12

Mapping Lead: C. HIDALGO	Date Approved:	Rev. 1
Dwn by: CH	Spec No.:	Assisted by:
Reviewed by: B. MURPHY		Acquisition:
Project Manager: S. TIRPAK	File name: Mstr PDF Clear Creek Map	Plot date: 02/23/12 Plot scale: 1:1

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CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
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2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
27
Sheet 27 of 32

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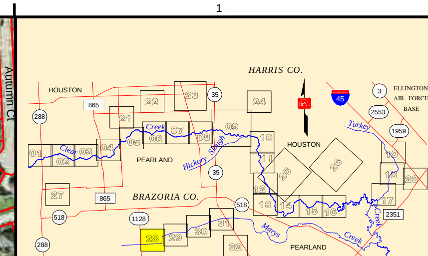

DATUM: NORTH AMERICAN 1983 FEET
PROJECTION: STATE PLANE
ZONE: SOUTH CENTRAL TEXAS

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Revised CIE layer and Spreadsheet on 21 Feb 12

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

Mapping Lead: C. HIDALGO		Date Approved:	Rev. 1
Dwn by: CH	Spec No.:	Assisted by:	
Reviewed by: B. MURPHY		Acquisition:	
Project Manager: S. TIRPAK		File name: Mstr PDF Clear Creek Map; Plot date: 02/23/12; Plot scale: 1:1	

HARRIS AND BRAZORIA COUNTIES — TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
28
Sheet 28 of 32

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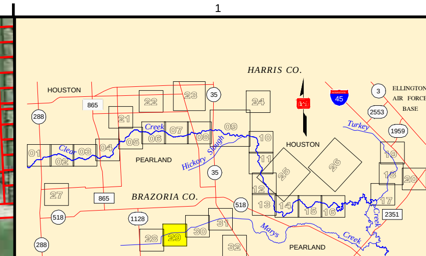

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0 150' 300' 450' 600'

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
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GALVESTON, TEXAS

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GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES
TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
29
Sheet 29 of 32

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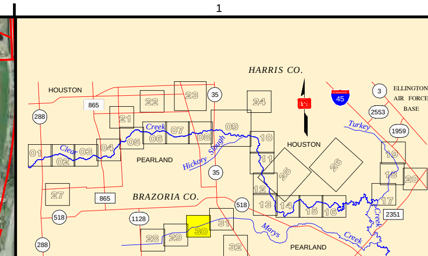

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CLEAR CREEK TEXAS
REAL ESTATE MAPS
PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

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GALVESTON, TEXAS

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HARRIS AND BRAZORIA COUNTIES
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
30
Sheet 30 of 32

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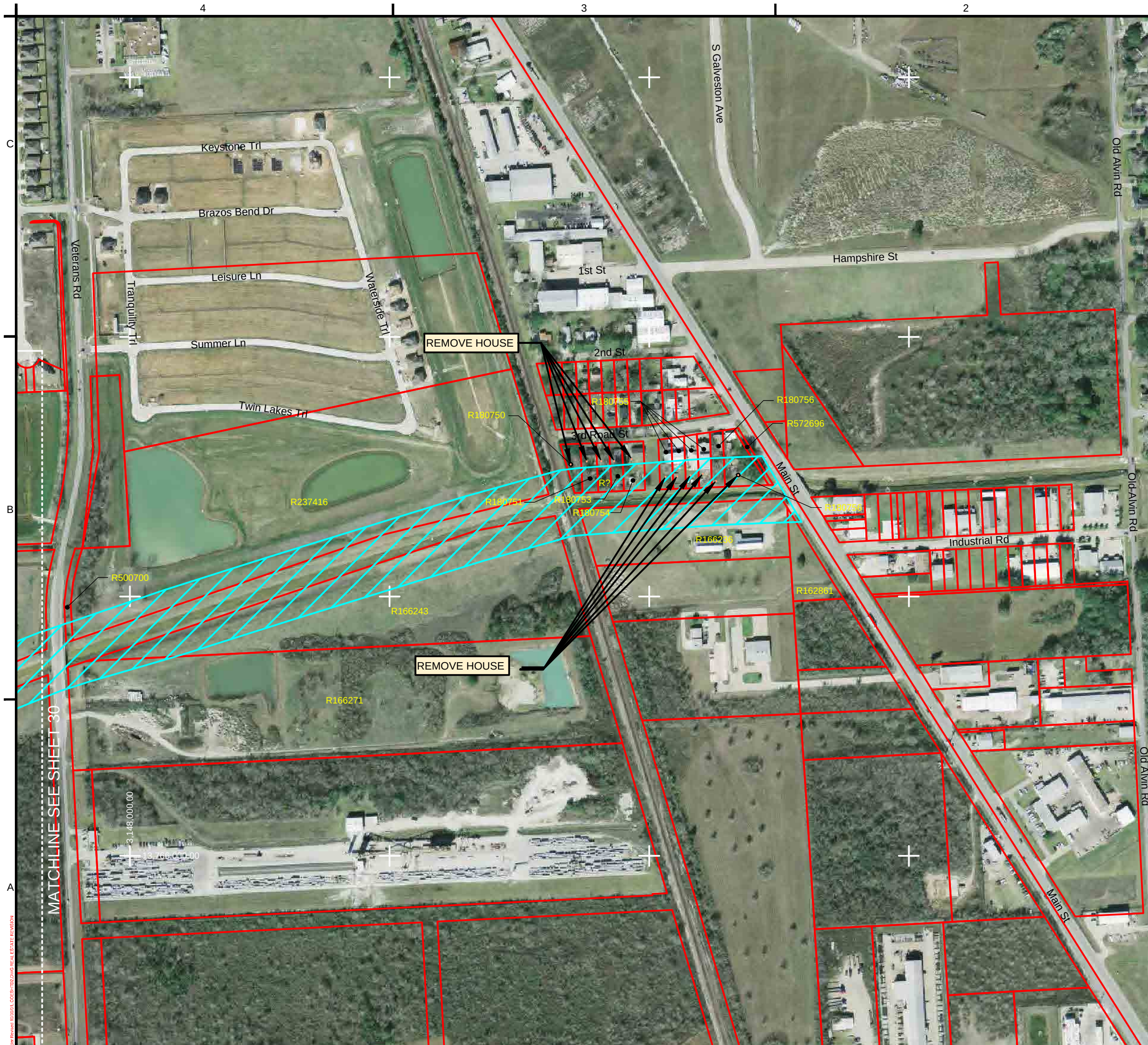

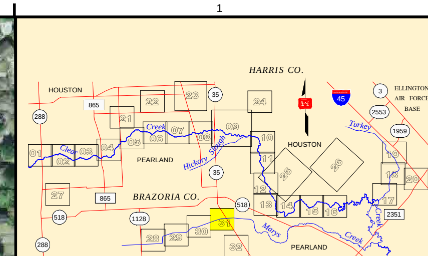

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CLEAR CREEK TEXAS

REAL ESTATE MAPS

PORTION OF HARRIS AND BRAZORIA COUNTY, TEXAS

US Army Corps of Engineers
Galveston District

Symbol	Description	Date	Approved
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Mapping Lead: C. HIDALGO
Dwn by: CH
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Project Manager: S. TIRPAK
Date Approved:
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Acquisition:
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Plot date: 02/23/12
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DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
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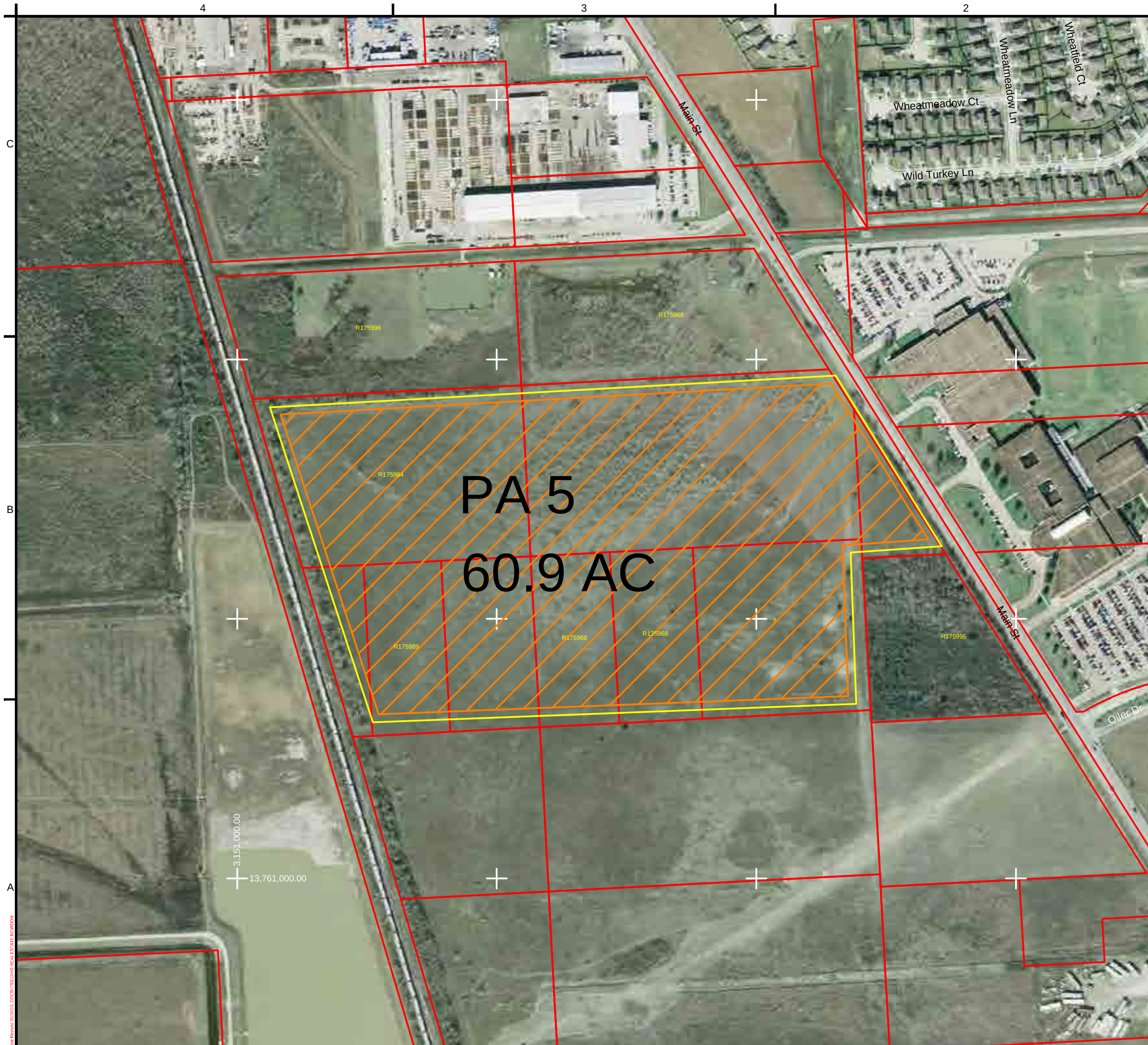
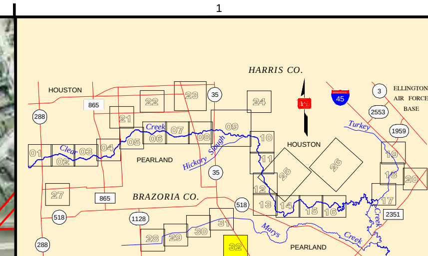
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
31
Sheet 31 of 32





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Spec No.:
Date Approved:
Rev. 1
Assisted by:
Reviewed by: B. MURPHY
Acquisition:
Project Manager: S. TIRPAK
File name: Mstr PDF Clear Creek Map
Plot date: 02/23/12
Plot scale: 1:1

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED BY:
REAL ESTATE DIVISION
CADASTRAL SECTION
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

HARRIS AND BRAZORIA COUNTIES — TEXAS
REAL ESTATE MAPS 2012
CLEAR CREEK TEXAS

Sheet reference number:
32
Sheet 32 of 32

Mstr PDF Clear Creek Map.dwg, 02/23/12, 09:54, M3REXCH3

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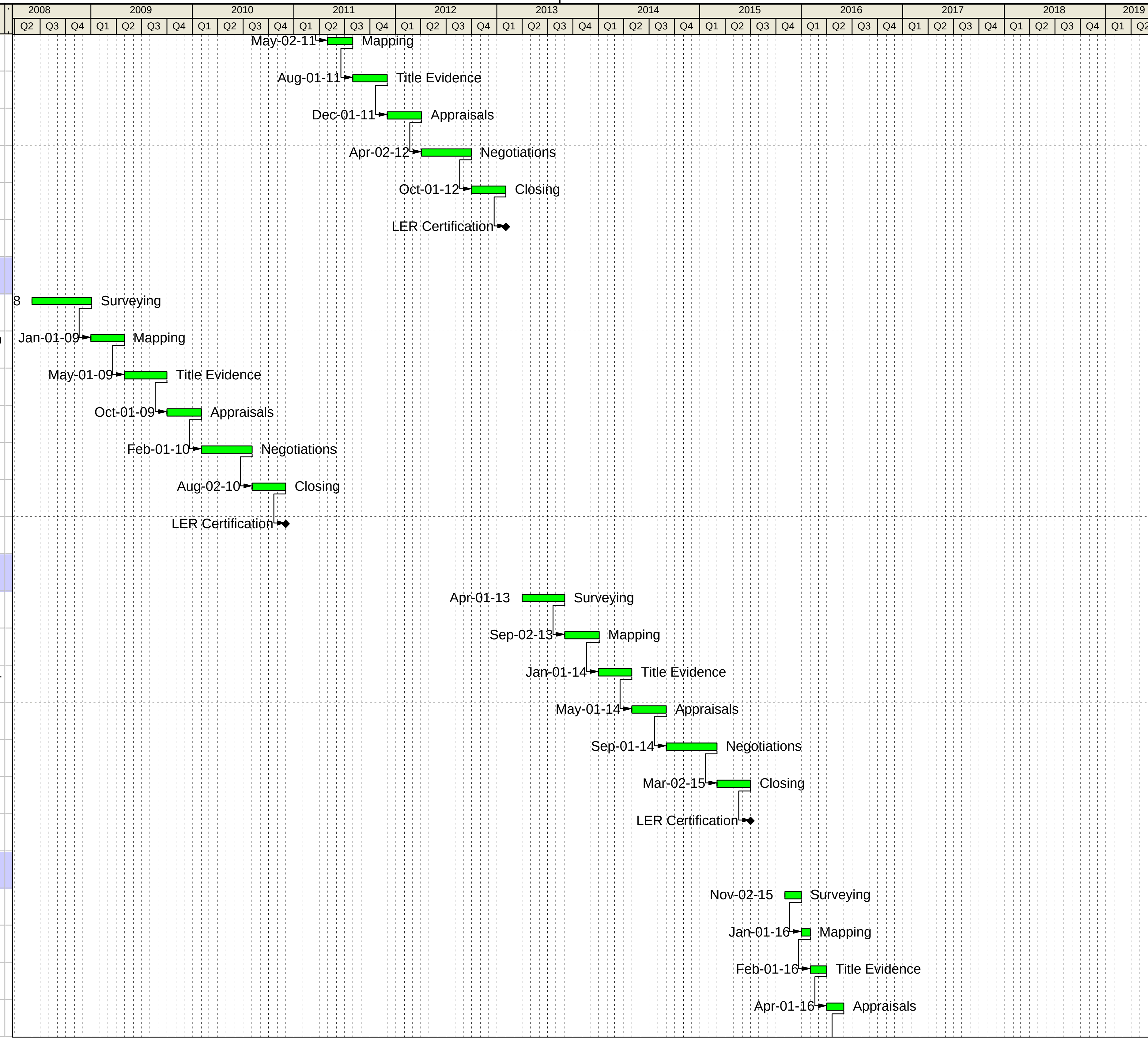
Activity ID	Activity Name	Planned Duration	Start	Finish
RE2008	**Real Estate Acquisition Schedule**	2524d	Jun-02-08	Feb-01-18
RE2008.1	**Mud Gulley Detention (41 Tracts)**	457d	Jan-01-09	Oct-01-10
A1000	Surveying	65d	Jan-01-09	Apr-01-09
A1010	Mapping	66d	Apr-01-09	Jul-01-09
A1020	Title Evidence	89d	Jul-01-09	Nov-02-09
A1030	Appraisals	86d	Nov-02-09	Mar-01-10
A1040	Negotiations	111d	Mar-01-10	Aug-02-10
A1050	Closing	45d	Aug-02-10	Oct-01-10
A1060	LER Certification	0d		Oct-01-10
RE2008.2	**Mud Gulley Conveyance (15 Tracts)**	457d	Dec-02-13	Sep-01-15
A1070	Surveying	66d	Dec-02-13	Mar-03-14
A1080	Mapping	66d	Mar-03-14	Jun-02-14
A1090	Title Evidence	88d	Jun-02-14	Oct-01-14
A1100	Appraisals	89d	Oct-01-14	Feb-02-15
A1110	Negotiations	86d	Feb-02-15	Jun-01-15
A1120	Closing	67d	Jun-01-15	Sep-01-15
A1130	LER Certification	0d		Sep-01-15
RE2008.3	**Clear Creek Offline Detention (61 Tracts)**	262d	Oct-01-09	Oct-01-10
A1140	Surveying	108d	Oct-01-09	Mar-01-10
A1150	Mapping	109d	Nov-02-09	Apr-01-10
A1160	Title Evidence	110d	Dec-01-09	May-03-10
A1170	Appraisals	87d	Jan-01-10	May-03-10
A1180	Negotiations	131d	Mar-01-10	Aug-30-10
A1190	Closing	67d	Jul-01-10	Oct-01-10
A1200	LER Certification	0d		Oct-01-10
RE2008.4	**Turkey Creek Conveyance (45 Tracts)**	545d	Jan-03-11	Feb-01-13
A1210	Surveying	86d	Jan-03-11	May-02-11

◆ Milestone — Progress
Overall Summary — % Complete

Layout: Gilbert Grantt TASK filter: All Activities
Data Date: May-28-08

Activity ID	Activity Name	Planned Duration	Start	Finish
A1220	Mapping	66d	May-02-11	Aug-01-11
A1230	Title Evidence	89d	Aug-01-11	Dec-01-11
A1240	Appraisals	88d	Dec-01-11	Apr-02-12
A1250	Negotiations	131d	Apr-02-12	Oct-01-12
A1260	Closing	90d	Oct-01-12	Feb-01-13
A1270	LER Certification	0d		Feb-01-13
RE2008.5	**Mary's Creek Conveyance (54 Tracts)**	653d	Jun-02-08	Dec-01-10
A1280	Surveying	154d	Jun-02-08	Jan-01-09
A1290	Mapping	87d	Jan-01-09	May-01-09
A1300	Title Evidence	110d	May-01-09	Oct-01-09
A1310	Appraisals	88d	Oct-01-09	Feb-01-10
A1320	Negotiations	131d	Feb-01-10	Aug-02-10
A1330	Closing	88d	Aug-02-10	Dec-01-10
A1340	LER Certification	0d		Dec-01-10
RE2008.6	**Lower Clear Creek Conveyance (62 Tracts)**	588d	Apr-01-13	Jul-01-15
A1350	Surveying	111d	Apr-01-13	Sep-02-13
A1360	Mapping	88d	Sep-02-13	Jan-01-14
A1370	Title Evidence	87d	Jan-01-14	May-01-14
A1380	Appraisals	88d	May-01-14	Sep-01-14
A1390	Negotiations	131d	Sep-01-14	Mar-02-15
A1400	Closing	88d	Mar-02-15	Jul-01-15
A1410	LER Certification	0d		Jul-01-15
RE2008.7	**RR Bridge Replacement at MYKAWA (1 Tra...**	241d	Nov-02-15	Oct-03-16
A1420	Surveying	45d	Nov-02-15	Jan-01-16
A1430	Mapping	22d	Jan-01-16	Feb-01-16
A1440	Title Evidence	45d	Feb-01-16	Apr-01-16
A1450	Appraisals	44d	Apr-01-16	Jun-01-16

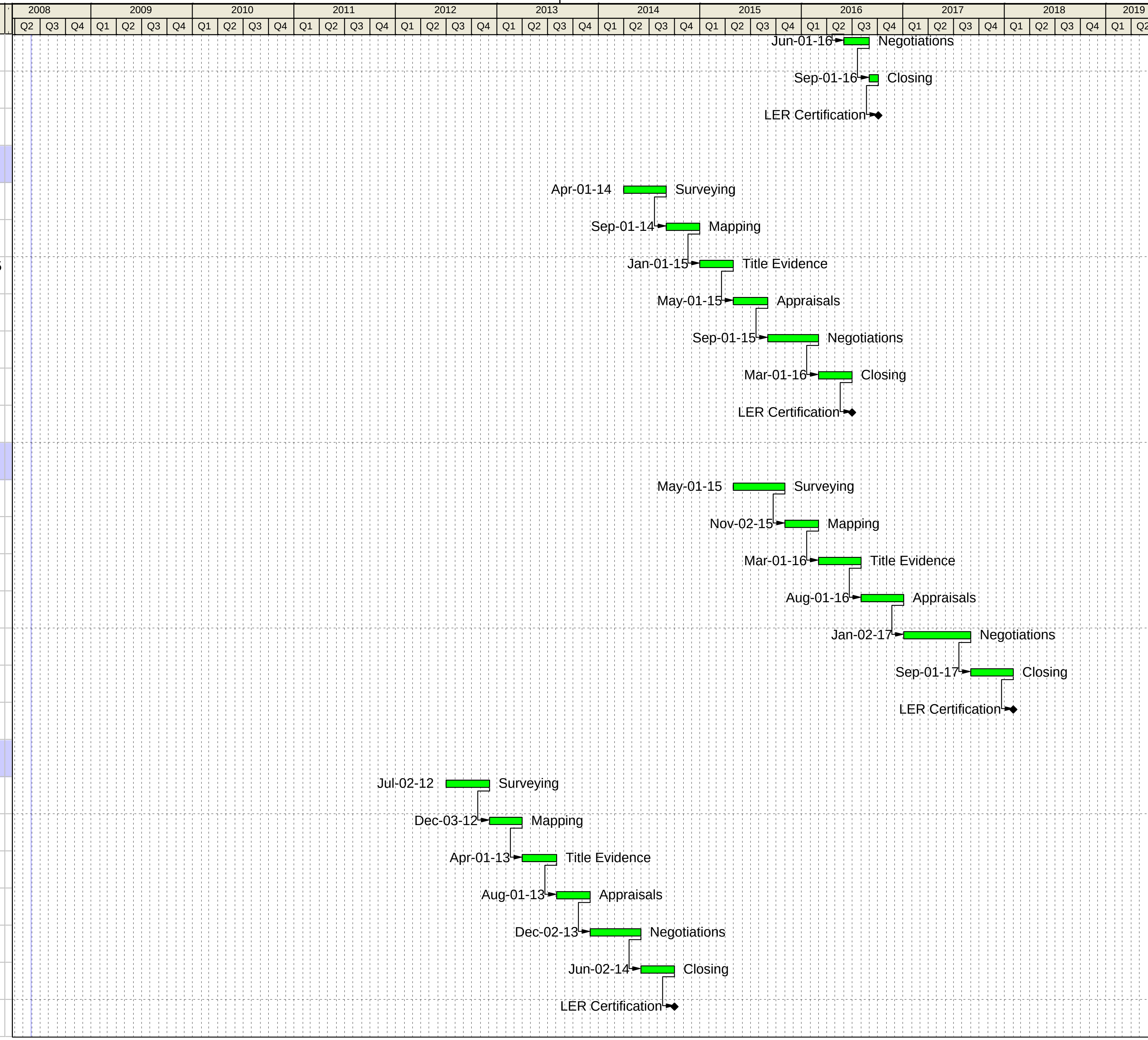


Milestone | Progress
Overall Summary | % Complete

Layout: Gilbert Grantt TASK filter: All Activities

Data Date: May-28-08

Activity ID	Activity Name	Planned Duration	Start	Finish
A1460	Negotiations	67d	Jun-01-16	Sep-01-16
A1470	Closing	23d	Sep-01-16	Oct-03-16
A1480	LER Certification	0d		Oct-03-16
RE2008.8	**MYKAWA To Bennie Kate Upper Clear Cree...**	589d	Apr-01-14	Jul-01-16
A1490	Surveying	110d	Apr-01-14	Sep-01-14
A1500	Mapping	89d	Sep-01-14	Jan-01-15
A1510	Title Evidence	87d	Jan-01-15	May-01-15
A1520	Appraisals	88d	May-01-15	Sep-01-15
A1530	Negotiations	131d	Sep-01-15	Mar-01-16
A1540	Closing	89d	Mar-01-16	Jul-01-16
A1550	LER Certification	0d		Jul-01-16
RE2008.9	**HWY 288 to MYKAWA Upper Clear Creek C...**	720d	May-01-15	Feb-01-18
A1560	Surveying	132d	May-01-15	Nov-02-15
A1570	Mapping	87d	Nov-02-15	Mar-01-16
A1580	Title Evidence	110d	Mar-01-16	Aug-01-16
A1590	Appraisals	111d	Aug-01-16	Jan-02-17
A1600	Negotiations	175d	Jan-02-17	Sep-01-17
A1610	Closing	110d	Sep-01-17	Feb-01-18
A1620	LER Certification	0d		Feb-01-18
RE2008.10	**Mitigation (60 Tracts)**	588d	Jul-02-12	Oct-01-14
A1630	Surveying	111d	Jul-02-12	Dec-03-12
A1640	Mapping	86d	Dec-03-12	Apr-01-13
A1650	Title Evidence	89d	Apr-01-13	Aug-01-13
A1660	Appraisals	88d	Aug-01-13	Dec-02-13
A1670	Negotiations	131d	Dec-02-13	Jun-02-14
A1680	Closing	88d	Jun-02-14	Oct-01-14
A1690	LER Certification	0d		Oct-01-14



Milestone | Progress
Overall Summary | % Complete

Layout: Gilbert Grantt TASK filter: All Activities

Data Date: May-28-08

EXHIBIT "C"

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPABILITY
Brazoria Drainage District #4

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? (yes/no)
b. Does the sponsor have the power of eminent domain for this project? (yes/no)
c. Does the sponsor have "quick-take" authority for this project? (yes/no)
d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? (yes/no)
e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? (yes/no)

II. Human Resources Requirements:

a. How many in-house staff will be available for real estate acquisitions? 0 Qty
b. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? (yes/no)
c. If the answer to II.b. is "yes", has a reasonable plan been developed to provide such training? (yes/no)
d. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? (yes/no)
e. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? (yes/no)
f. Can the sponsor obtain contractor support, if required in a timely fashion? (yes/no)
g. Does the sponsor plan on contracting acquisition support for this project? (yes/no)
h. Will the sponsor likely request USACE assistance in acquiring real estate? (yes/no) (If "yes", provide description)

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? (yes/no)
b. Has the sponsor approved the project/real estate schedule/milestones? (yes/no)

IV. Coordination:

a. Has this assessment been coordinated with the sponsor? (yes/no)
b. Does the sponsor concur with this assessment? (yes/no)

V. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? (yes/no)

b. With regard to this project, the sponsor is anticipated to be: highly capable/fully capable/moderately capable/marginally capable/insufficiently capable. (If sponsor is believed to be "insufficiently capable", provide explanation)

c. Does the sponsor anticipate any changes to the information provided above? (yes/no) (If "yes", provide description)

Prepared by: ______________
Brazoria Drainage District #4

Reviewed by: ______________
Jerry Benavides, Realty Specialist

Reviewed by: ______________
Orlando Rosas, Ch. Real Estate Division

EXHIBIT "D"

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPABILITY
Harris County Flood Control District (HCFCD)

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? (yes/no)
b. Does the sponsor have the power of eminent domain for this project? (yes/no)
c. Does the sponsor have "quick-take" authority for this project? (yes/no)
d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? (yes/no)
e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? (yes/no)

II. Human Resources Requirements:

a. How many in-house staff will be available for real estate acquisitions? 5 Qty
b. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? (yes/no)
c. If the answer to II.b. is "yes", has a reasonable plan been developed to provide such training? (yes/no)
d. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? (yes/no)
e. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? (yes/no)
f. Can the sponsor obtain contractor support, if required in a timely fashion? (yes/no)
g. Does the sponsor plan on contracting acquisition support for this project? (yes/no)
h. Will the sponsor likely request USACE assistance in acquiring real estate? (yes/no) (If "yes", provide description)

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? (yes/no)
b. Has the sponsor approved the project/real estate schedule/milestones? (yes/no)

IV. Coordination:

a. Has this assessment been coordinated with the sponsor? (yes/no)
b. Does the sponsor concur with this assessment? (yes/no)

V. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? (yes/no)

b. With regard to this project, the sponsor is anticipated to be highly capable/fully capable/moderately capable/marginally capable/insufficiently capable. (If sponsor is believed to be "insufficiently capable", provide explanation)

c. Does the sponsor anticipate any changes to the information provided above? (yes/no) (If "yes", provide description)

Prepared by: ______________
Harris County Flood Control District
Thomas P. Faulkner
Assistant Director
Harris County Right of Way Division

Reviewed by: ______________
Jerry Benavides, Realty Specialist

Reviewed by: Orlando Rosas
Orlando Rosas, Ch. Real Estate Division
By
Branch Chief, RE-T

EXHIBIT "E"

April 30, 2008

Real Estate Division

Subject: Proposed Clear Creek Flood Control Project, Harris County, Texas

Mr. Mike Talbot
Harris County Flood Control
District 9900 Northwest Freeway,
Suite 220
Houston, Texas 77092

Dear Mr. Talbot:

It is our understanding, that you may or have begun acquiring rights-of-way in connection with the Clear Creek Project prior to execution of the Project Cooperation Agreement (PCA) with the Federal Government. We appreciate your support for this proposed project but our regulations require us to inform you that **IF FOR ANY REASON, THE PCA NEVER GETS SIGNED OR IF CONGRESS FAILS TO AUTHORIZE OR FUND THE PROJECT, ANY LAND YOU ACQUIRED OR ANY MONEY YOU SPEND IN YOUR EFFORTS TO ACQUIRE LAND WILL BE AT THE SOLE RISK OF THE HARRIS COUNTY FLOOD CONTROL DISTRICT.** Furthermore, for any property that qualifies for Federal participation in the project, your acquisition efforts must be in compliance with all of the provisions of P.L. 91-646, the Federal Relocation Assistance Law.

Please ensure that good records are kept regarding purchase price and real estate administrative expenses such as title evidence, surveys and appraisal fees. This will be necessary for you to receive credit in the event of Federal Authorization. Be advised that regulations dictate that credit will not be given for real estate administrative costs for properties acquired 5 years prior to execution of a PCA.

If you have any questions on any of the above please call Mr. Sal Arcidiacono of my staff at (409)766-3803.

Sincerely,

Orlando Rosas
Chief Real Estate Division

EXHIBIT "F"

April 30, 2008

Real Estate Division

Subject: Proposed Clear Creek Flood Control Project, Brazoria County, Texas

Mr. E.J. "Joe" King
Brazoria County Judge
111 East Locust Street
Angleton, Texas 77515

Dear Judge King:

It is our understanding, that you may or have begun acquiring rights-of-way in connection with the Clear Creek Project prior to execution of the Project Cooperation Agreement (PCA) with the Federal Government. We appreciate your support for this proposed project but our regulations require us to inform you that **IF FOR ANY REASON, THE PCA NEVER GETS SIGNED OR IF CONGRESS FAILS TO AUTHORIZE OR FUND THE PROJECT, ANY LAND YOU ACQUIRED OR ANY MONEY YOU SPEND IN YOUR EFFORTS TO ACQUIRE LAND WILL BE AT THE SOLE RISK OF THE BRAZORIA COUNTY.** Furthermore, for any property that qualifies for Federal participation in the project, your acquisition efforts must be in compliance with all of the provisions of P.L. 91-646, the Federal Relocation Assistance Law.

Please ensure that good records are kept regarding purchase price and real estate administrative expenses such as title evidence, surveys and appraisal fees. This will be necessary for you to receive credit in the event of Federal Authorization. Be advised that regulations dictate that credit will not be given for real estate administrative costs for properties acquired 5 years prior to execution of a PCA.

If you have any questions on any of the above please call Mr. Sal Arcidiacono of my staff at (409)766-3803.

Sincerely,

Orlando Rosas
Chief, Real Estate Division